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Effect of post-harvest loss reduction practices on household food security of cowpea farmers in Niger and Nasarawa States, Nigeria

Tosin Olawoye[1*], Moradeyo Adebanjo Otitoju[2], Olaide Oluwafemi Olawoye[3]
[1]*Department of Agricultural Technology, Federal College of Forest Resource Management, Fugar, Edo State, Nigeria*
[2]*Department of Agricultural Economics, University of Abuja, Abuja, Nigeria*
[3]*International Institute of Tropical Agriculture, Abuja, Nigeria*
[*]Corresponding author: tosinolawoye08@gmail.com

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ABSTRACT
This study evaluated the influence of post-harvest loss reduction procedures (PHLRP) on the food security of cowpea farmers in Niger and Nasarawa States, Nigeria. A multistage sampling procedure was utilized, resulting in the random selection of 216 cowpea producers from six local government areas, with 108 respondents from each chosen state. Descriptive and inferential statistics, including the household food insecurity access scale (HFIAS) and ordered logit models, were employed to assess food security status and evaluate the influence of post-harvest loss reduction methods on food security outcomes. The HFIAS analysis indicated that nearly all cowpea farmers in the study area experienced food insecurity, highlighting the contradiction of food insecurity among households that are primary producers of a vital food crop. Results of the marginal effect showed that the use of pirimiphos-methyl was positive and significantly enhanced the possibility of household food security ($p < 0.01$). In contrast, granary storage ($p < 0.05$) and training access ($p < 0.10$) were significant but reduced the probability of food security among the cowpea farmers. This paper provides empirical information regarding the significance of adaptable PHLRP on enhancing food security for smallholder cowpea farmers, presenting practical policy recommendations for agricultural extension and rural development initiatives in Nigeria. Major constraints faced by the cowpea farmers were the high cost of improved storage materials and high transportation costs. The study recommends making Purdue-improved cowpea bags readily available to reduce post-harvest losses, while encouraging farmers to form cooperatives to share transportation costs.
Keywords: cowpea farmers, food security, post-harvest loss, storage practices

1. Introduction

Post-harvest loss (PHL) refers to the subsequent decline in both the quantity and quality of agricultural food output that transpires between harvest and consumption. Plant crops are susceptible to degradation at various points in time following harvest [1]. Nonetheless, other factors influence the extent and severity of this damage across food supply chains across various crops, locations, and cultural practices. There have been attempts in developing nations to maximize the utilization of produced food; however, a weighty portion of the produce is lost during postharvest procedures because of poor technology, ignorance, and/or poor storage infrastructure [2]. The result of post-harvest losses typically constitutes a squander of resources invested in the production of food crops that remain unconsumed or unutilized for alternative reasons [3]. Postharvest loss has a ripple effect that directly affects the livelihood of farmers. It also harms food security as it results in the shortage of harvested crops that should have contributed to hunger reduction and satisfied the food needs of the final consumer. Individuals are considered to be in a condition of food security when they possess both physical

and financial access to sufficient nutritious food that satisfies their dietary requirements and preferences for an active and healthy lifestyle.

The four pillars of food security- availability, accessibility, usage standards, and stability- ensure that people have access to the key foods they need [4]. One of the most controversial topics at the moment is how to feed the more than seven billion people in the world. This relates to how Nigeria can attain the Sustainable Development Goal (SDG 2) of ending hunger. The food insecurity problem is thus a global happening that efforts must be put in place to ensure people are food secure [5]. In poorer nations, households are more susceptible to food insecurity, which Nigeria is a part of. Therefore, some of these farmers have employed improved technology to reduce postharvest loss, especially for cowpea. Some of these include the use of hermetic storage options such as metallic silos, Purdue Improved Cowpea Storage (PICS) bags, super grain bags, and insecticides-infused woven polypropylene bags designed to prevent pest infestations, among others. These methods are used to reduce cowpea postharvest loss, and studies have indicated that some of these items are popular and reasonably priced [2].

An essential legume crop grown in Nigeria is the cowpea (Vigna unguiculata), they are high in amino acids [6]. The savanna part of the country, which comprises the states of Niger and Nasarawa, produces a large amount of it. For those living in rural and urban areas alike, cowpeas are a cheap and staple protein source that offers remarkable nutritional and nutraceutical qualities as well as additional crop, sustainability, and economic benefits that support food security [7]. Cowpeas are grown by farmers to increase their food security. Prior studies have documented the negative effect of post-harvest losses on food security Ibrahim et al. [8]; Ojo et al. [9], the influence of specific storage technologies such as PICS bags Adomi et al. [10], and practical evidence on the combined outcome of post-harvest loss reduction practices on household welfare [11]. Furthermore, existing reviews confirm that research has been disproportionately concentrated on storage-stage interventions and cereal crops, with legumes such as cowpea and household-level food security outcomes receiving comparatively little attention Stathers et al. [12] Consequently, there remains a gap in the reduction practices of post- harvest losses utilized in Nigeria's Niger and Nasarawa states among cowpea farmers and how it affects their food security in households level, hereafter the reason for this study.

The primary aim of this paper is to ascertain how post-harvest loss reduction strategies affect the food security of cowpea farming households in Niger and Nasarawa States, Nigeria, although the specific objectives were to describe the socio-economic characteristics of the cowpea farmers, determine the outcome of reduction practices of post-harvest loss on the food security status of the households producing cowpea, and identify the constraints militating against reduction of post-harvest loss among cowpea producing households in the study area. The study holds significance as it will stimulate additional investigation into post-harvest loss reduction strategies while considering the impact on household food security. It would also serve as a reservoir of information or reference materials for national and international agricultural-related agencies.

2. Methods

This research was conducted in Niger and Nasarawa States, both located in Nigeria. Niger State, which was established in April 1976, has Minna as its administrative capital. Geographically, the state lies between longitudes 3°30′E and 7°20′E, and around latitude 8°22′N. It occupies a vast land area of approximately 76,363 square kilometres and had an estimated population of about 5.56 million in 2016, growing annually at a rate of 3.4% [13]. Administratively, the state is divided into twenty-five Local Government Areas. Climatically, the region experiences annual rainfall ranging from 120 mm to 200 mm, with mean temperatures between 29°C and 32°C [14]. The hottest months typically fall between March and June, while cooler temperatures are observed from December to January. These climatic conditions contribute to the predominance of floodplain soils, which vary in composition across locations.

Nasarawa State, created on October 1, 1996, has its capital in Lafia. It is situated within the Guinea Savannah ecological zone, around latitude 9°N and between longitudes 7°E and 10°E. The state shares boundaries with Benue State to the south, Kogi State to the west, the Federal Capital Territory (Abuja) to the northwest, Kaduna and Plateau States to the northeast, and Taraba State to the southeast. Covering approximately 27,117 square kilometres, Nasarawa State has an estimated population of about 2.52 million [13]. It consists of thirteen Local Government Areas, with agriculture serving as the primary livelihood for the majority of residents. In addition, the state is endowed with mineral resources, including bauxite and salt deposits. The climate is characterized by distinct wet and dry seasons, with an average annual rainfall of approximately 131.73 mm. A multistage

sampling procedure was adopted for the selection of respondents. At the first stage, three Local Government Areas noted for cowpea production were purposively selected from each state. In Niger State, Bosso, Wushishi, and Bida were selected, while Karu, Keffi, and Kokona were chosen from Nasarawa State. The second stage involved the random selection of eighteen villages, with three villages drawn from each of the selected Local Government Areas. In the final stage, a total of 216 households were selected using a snowball sampling technique, with twelve households obtained from each village. Data for the study were sourced primarily through field surveys, using Computer-Assisted Personal Interviewing (CAPI) facilitated by the Kobo Toolbox platform.

2.1. Model specification

Both descriptive and inferential statistical techniques were employed to address the study objectives. Household food security status was determined using the Household Food Insecurity Access Scale (HFIAS), while the influence of post-harvest loss reduction strategies on household food security was analysed using an ordered logit regression model. The HFIAS framework evaluates key dimensions such as anxiety about food availability, food quality and preferences, as well as economic access to food [15]. This tool was developed by the Food and Nutrition Technical Assistance III (FANTA) in 2007 in collaboration with its partners and is structured as a standardised questionnaire designed to capture household experiences of food insecurity. The instrument consists of a set of occurrence questions asked over a 30-day recall period (four weeks), requiring binary responses (0 = No, 1 = Yes). For each affirmative response, a follow-up question assesses the frequency of occurrence, categorised as rarely (1–2 times), sometimes (3–10 times), or often (more than 10 times) within the recall period [16]. To improve efficiency and avoid redundancy, skip patterns are incorporated, ensuring that frequency questions are not asked when the initial response is negative. The HFIAS generates four key indicators: the Household Food Insecurity Access Scale Score (HFIAS score), Household Food Insecurity Access Prevalence (HFIAP), Household Food Insecurity Access-related Conditions, and Household Food Insecurity Access-related Domains. Among these, the HFIAP indicator was adopted in this study because it directly categorises households according to the severity of food insecurity. The HFIAP classifies households into four distinct categories: food secure, mildly food insecure, moderately food insecure, and severely food insecure. Progression across these categories reflects increasing severity, based on the frequency and intensity of food insecurity conditions experienced by households.

The household food insecurity categories are defined as follows:

1. HFIA Category 1 (Food Secure): A household is considered food secure if concerns about food are either absent or occur very infrequently ((Q1 = 0) or (Q1 = 1 with Q1a = 1)).
2. HFIA Category 2 (Mildly Food Insecure): A household falls into this category if it occasionally experiences worry about food availability ((Q1 = 1, Q1a = 2 or 3)), or is unable to consume preferred foods ((Q2 = 1, Q2a = 1, 2, or 3)), or consumes a limited variety of foods ((Q3 = 1, Q3a = 1)), or rarely eats desirable foods ((Q4 = 1, Q4a = 1)).
3. HFIA Category 3 (Moderately Food Insecure): This category includes households that frequently or occasionally consume a limited variety of foods ((Q3 = 1, Q3a = 2 or 3) or (Q4 = 1, Q4a = 2 or 3)), and/or begin to reduce meal size or frequency on occasion ((Q5 = 1, Q5a = 1 or 2) or (Q6 = 1, Q6a = 1 or 2)), without experiencing the most severe food insecurity conditions (Q7–Q9).
4. HFIA Category 4 (Severely Food Insecure): Households are classified as severely food insecure if they frequently reduce meal size or number ((Q5 = 1, Q5a = 3) or (Q6 = 1, Q6a = 3)), and/or experience extreme conditions such as having no food, going to bed hungry, or spending an entire day without eating, even if these occur infrequently ((Q7 = 1, Q7a = 1, 2, or 3), (Q8 = 1, Q8a = 1, 2, or 3), (Q9 = 1, Q9a = 1, 2, or 3)).

In this framework, Q1–Q9 represent the core occurrence questions, while Q1a–Q9a capture the frequency of these conditions within the 30-day recall period. The prevalence of household food insecurity was computed as the proportion of households within each category. Specifically, the percentage of severely food-insecure households was calculated as:

$$\frac{\text{Number of households classified as severely food insecure}}{\text{Total number of surveyed farming households}} \text{ x } 100 \quad (1)$$

2.2. Ordered logit model

The Ordered Logit model was utilized in order to ascertain the influence of post-harvest loss reduction strategies on consumer food security. Since each explanatory variable is assumed to have the same influence

on each cumulative logit, an ordered logit model regression is also known as a proportional-odds model. To quantify changes in the likelihood of food insecurity outcomes in relation to a change in the explanatory factors, logit coefficients are expressed as predicted probabilities of Y = 1 or marginal effects.

A category that suggests a rise in the variable increases the possibility of belonging to that group; on the other hand, a negative estimate decreases the probability of belonging to that group. An observed ordinal variable called Y in the ordered logit model is a function of another variable called y* that is not measured. Different threshold points exist for the latent variable y*.

Following Greene [17] and Long [18], Equation (2) specifies:

$$y\iota * = x\iota' \alpha + \varepsilon\iota \tag{2}$$

Explicitly, the model is stated thus:

$$y_\iota* = \alpha_o + \alpha_1X_1 + \alpha_2X_2 + \alpha_3X_3 + \alpha_4X_4 + \alpha_5X_5 + \alpha_6X_6 + \alpha_7X_7 + \alpha_8X_8 + \alpha_9X_9 + \alpha_{10}X_{10} + \alpha_{11}X_{11} + \mu \tag{3}$$

where μ is a random error term that has a standard normal distribution, α is a vector of parameters to be estimated, $\dot{x}$ is a vector of regressors describing farming household ι, and $\dot{y}$* is the latent variable of the food insecurity (access) categories of cowpea farming household ι.

$$Y_i = \begin{cases} 1\ if \text{ if } y\iota * \leq \mu\iota \text{ (food secure)} \\ 2 \text{ if } \mu\iota \leq y\iota * \leq \mu2 \text{ (mildly food insecure)} \\ 3 \text{ if } \mu2 \leq y\iota * \leq \mu3 \text{(moderately food insecure)} \\ 4 \text{ if } y\iota * > \mu3 \text{ (severely insecure)} \end{cases} \tag{4}$$

The regressor variables that were used include: X_1 = The use of Purdue Improved Cowpea Bags (PICS) represented as a dummy variable (1 = used, 0 = otherwise); X_2 = Fumigation of storage measured as a dummy variable (1 = yes, 0 = no); X_3 = Engagement in drying practices, specified as a dummy variable (1 = yes, 0 = no); X_4 = The use of tarpaulin for drying, captured as a dummy variable (1 = yes, 0 = no); X_5 = Super grain bags, represented as a dummy variable (1 = yes, 0 = no); X_6 = Storage in granaries, measured as a dummy variable (1 = yes, 0 = no); X_7 = The use of aluminium phosphate for storage protection, specified as a dummy variable (1 = yes, 0 = no); X_8 = The use of wood ash for storage, captured as a dummy variable (1 = yes, 0 = no); X_9 = The application of pirimiphos-methyl for storage, represented as a dummy variable (1 = yes, 0 = no); X_{10} = Access to Training on post-harvest management practices, measured as a dummy variable (1 = yes, 0 = no); X_{11} = Educational attainment, measured in years of formal schooling.

3. Results and Discussion

3.1. Socio- economic characteristics of the cowpea farming households in the study area

The socio-economic attributes of cowpea farming households examined in this study include variables such as age (measured in years), gender, marital status, educational attainment, level of participation in cowpea production, primary and secondary occupations, literacy status, and frequency of cowpea consumption. A summary of these characteristics for households in Nasarawa and Niger States is presented in Tables 1 and 2. The findings reported in Table 1 indicate that the average age of household heads across the two states is approximately 44 years. However, when disaggregated, the mean age of cowpea farmers differs between the states, standing at 39 years in Nasarawa State and 50 years in Niger State. Suggesting that respondents predominantly fall within their economically productive years, which is generally linked to increased agricultural output and enhanced food accessibility. The prevalence of older farmers in Nasarawa State (51-60 years) may hinder labor efficiency and diminish agricultural productivity, thereby restricting household food availability. This finding is consistent with the findings of Alabi [19] that older farmer populations are linked to lower productivity, lower technology adoption, and higher food-security vulnerability. The gender distribution, characterized by male predominance in both Nasarawa (96%) and Niger (54%), indicates that access to productive resources like land and capital may be skewed in favor of male-headed families. However, female participation in agriculture markedly enhances household dietary diversity and nutritional outcomes through improved resource allocation for food consumption [20]. The high proportion of married respondents, as presented in Table 1 in both states, 90% in Nasarawa and 89% in Niger, suggests the availability of family labor, which can boost agricultural production and food access. However, larger household sizes associated

with marriage may increase consumption pressure, thereby diluting per capita food availability, particularly in resource-constrained settings [21]. Non-formal education is most common in Nasarawa state at 33%, while secondary education is most common in Niger state at 53%. Education augments farmers' capacity to embrace advanced technology, obtain market information, and make informed dietary decisions. Thus, households in Niger State with relatively higher educational levels are more likely to obtain improved food security outcomes. This aligns with studies that education strengthens both agricultural output and household food consumption trends [1]. In Nasarawa State, the majority of farming family heads (99%) work primarily as farmers, with the remaining 32% being agro-processors. Farmers make up the majority of household heads in Niger State (54%). Although agriculture increases food availability via self-production, over-reliance on farming exposes households to output shocks, potentially undermining food security. In contrast, the existence of agro-processing enterprises in Nasarawa State indicates a degree of economic diversification, which can enhance resilience and stabilize household food consumption [22]. The majority of respondents in the states of Nasarawa and Niger were engaged in full-time cowpea farming, accounting for 100% and 58% of the responses, respectively, as shown in Table 1.

In the states of Nasarawa and Niger, respectively, 86% and 94% of the heads of household were literate. This may indicate a positive influence on food security through improved decision-making and adoption of better farming and nutrition practices. Data from households showed that 91% of people in Nasarawa State and 52% of people in Niger State ate cowpeas two to three times a week. This indicates moderate protein intake and potential gaps in dietary adequacy compared with populations reporting daily legume consumption [23].

Table 1. Summary of respondents by their socio-economic features

Variables	Nasarawa state		Niger state		Total	
	Frequency	Percentage (%)	Frequency	Percentage (%)	Frequency	Percentage (%)
Age of Household head						
20-30			18	16.7	18	8
31-40	10	9.3	46	42.6	56	26
41-50	45	41.7	35	32.4	80	37
51-60	48	44.4	9	8.3	57	26
> 60	5	4.6			5	2
Total	108	100	108	100	216	100
Sex of household head						
Male	104	96.3	58	53.7	162	75
Female	4	3.7	50	46.3	54	25
Total	108	100	108	100	216	100
Marital status						
Married	97	89.8	96	88.9	193	89
Never married	2	1.9	11	10.2	13	6
Divorced	4	3.7	1	0.9	5	2
Widow/widower	5	4.6			5	2
Total	108	100	108	100	216	100
Educational attainment						
Primary	17	15.7	14	13	31	14
Secondary	21	19.4	57	52.8	78	36
Tertiary	18	16.7	28	25.9	46	21
Adult Education	16	14.8	2	1.9	18	8
Non-formal	36	33.3	7	6.5	43	20
Total	108	100	108	100	216	100

Table 1. Continued

Variables	Nasarawa state		Niger state		Total	
	Frequency	Percentage (%)	Frequency	Percentage (%)	Frequency	Percentage (%)
Primary occupation						
Farming	107	99.1	58	53.7	165	76
Gathering			3	2.8	3	1
Trading			15	13.9	15	7
Civil Service			18	16.7	18	8
Artisan	1	0.9	11	10.2	12	6
Others			3	2.8	3	1
Total	108	100	108	100.1	216	100
Secondary occupation						
Farming	23	21.3	45	41.7	68	31
Trading	2	1.9	29	26.9	31	14
Civil Service	14	13	2	1.9	16	7
Artisan			16	14.8	16	7
Agro-processing	34	31.5	15	13.9	49	23
Others	35	32.5	1	0.9	6	3
Total	108	100.2	108	100.1	216	100
Involvement in Cowpea Farming						
Full-time	108	100	63	58.3	171	79
Part-time			45	41.7	45	21
Total	108	100	108	100	216	100
Household below 18 years (Dependants)						
1-9	104	96.3	101	93.5	205	95
10-18	4	3.7	7	6.5	11	5
Total	108	100	108	100	216	100
Household above 60 years (Dependants)						
1-5	104	96.3	101	93.5	205	95
6-10	4	3.7	7	6.5	11	5
Total	108	100	108	100	216	100
Literacy						
1-6	93	86.1	102	94.4	195	90
7-13	15	13.9	6	5.6	21	10
Total	108	100	108	100	216	100
Cowpea consumption						
Daily			17	15.7	17	8
Once a week	4	3.7	20	18.5	24	11
2-3 times per week	98	90.7	56	51.9	154	71
Others	6	5.6	15	13.9	21	10
Total	108	100	108	100	216	100

3.2. Food security status of cowpea farming households

Household food security status among cowpea farming households in Niger and Nasarawa States was determined using the nine-item HFIAS questionnaire designed under the Food and Nutrition Technical Assistance III (FANTA) programme. Table 2 provides data on the incidence of hunger. In addition, the frequency and percentages are shown in the table in parentheses next to the number of respondents who responded to each question.

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Table 2. Pattern of food insecurity experiences among cowpea farming households

Incidence Question (N = 216)	**No** Frequency (%)	**Yes** Frequency (%)
1. Were you perturbed that your household would not have sufficient food?	88(40.7)	128(59.3)
2. Due to shortage of resources, were you or any other household member unable to eat the meals you preferred?	83(38.4)	133(61.6)
3. Did a dearth of resources force you or any other household member to eat a confined choice of food?	82(38.0)	134(62.0)
4. Were you forced to consume meals you truly didn't want to eat because you didn't have the means to eat anything else?	84(38.9)	132(61.1)
5. Was there so little food in your household that you had to eat a smaller meal than you felt you needed?	125(57.9)	91(42.1)
6. Was there an insufficient amount of food for any other household member, causing them to skip meals during the day?	148(68.5)	68(31.5)
7. Has there ever been a time when your family lacked access to food due to a lack of resources?	176(81.5)	40(18.5)
8. Did you or any household member not have enough food to go to bed at night?	214(99.1)	2(0.9)
9. Was there so little food that your household member went a whole day and night without eating anything?	215(99.5)	1(0.5)

*Percentage in parenthesis

Results from Table 3 and Figure 1 show that, out of the 216 cowpea farming households surveyed, 35.19% were classified as food secure, while 20.37%, 25.93%, and 18.52% fell into the mildly, moderately, and severely food insecure categories, respectively. These findings align with the study by Otekunrin et al. [15], which applied the Household Food Insecurity Access Scale (HFIAS) to assess food security among farming households in rural Oyo State, Nigeria, and reported a high prevalence of food insecurity, with 87.2% of households affected. However, the results contrast with those of Ogunniyi et al. [24], who found that approximately 76.8% of maize-producing households were food secure. The high prevalence of food insecurity among cowpea farmers in the study area may be a result of structural constraints within the farming system, such as a high dependence on rain-fed agriculture, which exposes households to climatic variability, leading to unstable production and inconsistent food availability. This is compounded by the predominance of smallholder farming, where limited access to inputs, credit, and improved technologies restricts productivity and income, thereby weakening food access [25]. Additionally, for instance, lower educational attainment and older farmers in some households (especially in Nasarawa State) may limit the adoption of improved farming practices, nutritional practices, and productivity and adaptive capacity, thereby affecting both food availability and utilization, further contributing to food insecurity.

Table 3. HFIA prevalence of cowpea farming households

HFIA categories	Frequency	Percentage (%)
Food secure	76	35.19
Mildly food insecure	44	20.37
Moderately food insecure	56	25.93
Severely food insecure	40	18.52
Total	216	100.00

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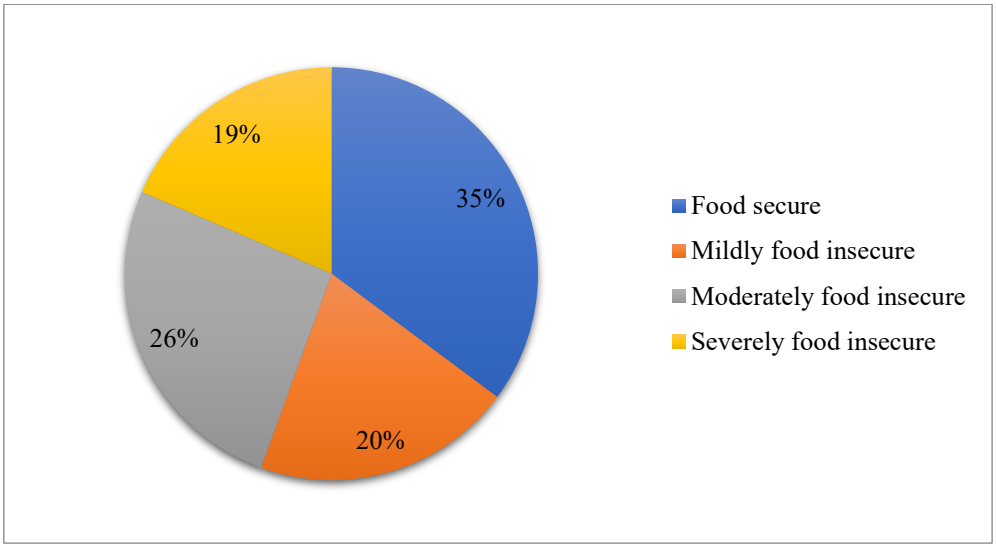

Figure 1. The household food insecurity access categories

3.3. Effect of post-harvest loss reduction strategies on household food security of cowpea farming households in the study area

Using ordered logistic regression, Table 4 provides information on how post-harvest loss reduction techniques affect the food security status of cowpea farming households. Household food security was categorized into four levels: food secure (1), mildly food insecure (2), moderately food insecure (3), and severely food insecure (4). The marginal effects derived from the model provide insights into how changes in the explanatory variables alter the probability of households falling into each food security category. The chance of food insecurity is moved between the four categories by the explanatory variables, which are explained by the marginal effects. Storage in granaries, usage of pirimiphos-methyl, and availability of training were the important variables; the statistical significance of the coefficients and the marginal effects are detailed below. The stronger explanatory power of the model is indicated by the Wald chi2 value of 210.02. The log probability of occurrence was -279, and the probability chi2 was likewise noteworthy at ($p<0.01$). The marginal effect finding indicated that granary storage was significant at ($p<0.05$). According to the results, a unit increase in granary storage lowers the odds that cowpea farming households will be food secure by 0.29, but raises the risk that they will be moderately or severely food insecure by 0.12 and 0.110, respectively. This counterintuitive finding may suggest that, rather than mitigating losses, traditional storage systems may exacerbate them. This may also reflect an adoption gap where farmers who rely on granaries have not transitioned to hermetic or chemical storage, meaning their participation in cowpea farming has not translated to food security gains. This aligns with the post-harvest loss framework, which emphasizes that inadequate storage technologies significantly reduce effective food availability at the household level [26], [27]. Empirically, recent studies show that traditional granary systems are associated with substantial quantitative and qualitative losses, sometimes reaching up to 50%, due to pest infestation, moisture, and structural weaknesses [28]. In contrast, the utilization of pirimiphos-methyl had a significant coefficient at ($p<0.01$). According to the results, using more pirimiphos-methyl enhances the likelihood that a cowpea home will have food security by almost 3.80 times, while using less of it decreases the risk that a household will have moderate or severe food insecurity by 1.25 and 2.07. Pirimiphos-methyl, an organophosphate insecticide, is effective against a broad spectrum of storage pests. Studies confirm that this chemical storage treatment effectively suppresses pest-induced grain deterioration, preserves the quantity and nutritional quality of stored cowpea, thereby directly strengthening household food availability [29]. Unexpectedly, access to training on post-harvest loss management was found to be statistically significant ($p < 0.10$). The marginal effects indicate that a unit increase in access to training reduces the likelihood of a household being food secure by 0.13, while increasing the probability of being severely food insecure by 0.09. This outcome suggests a disconnect between the acquisition of knowledge and its practical application, supporting the argument by Hörner et al. [30] that access to information does not necessarily translate into effective adoption of improved practices. Training alone does not guarantee improved outcomes unless it is accompanied by access to resources, effective delivery mechanisms, and behavioral change. Thus, the result does not necessarily imply that training is ineffective per se, but rather that its impact is conditional on quality, accessibility, and the enabling environment for adoption [31].

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Table 4. The marginal effects of post-harvest loss reduction measures on household food security status of cowpea farming households

Explanatory variables	parameter	Coefficient	Food Secure	Mildly Food Insecure	Moderately Food Insecure	Severely Food Insecure
			dy/dx	dy/dx	dy/dx	dy/dx
The use of PICS bags (X_1)	α_1	-0.047	0.009	0.001	-0.003	-0.006
		(0.259)	(0.054)	(0.004)	(0.022)	(0.036)
Fumigation of storage (X_2)	α_2	-0.511	0.107	0.008	-0.043	-0.072
		(0.313)	(0.064)	(0.008)	(0.025)	(0.045)
Drying (X_3)	α_3	-0.271	0.057	0.004	-0.023	-0.038
		(0.528)	(0.109)	(0.009)	(0.044)	(0.075)
Tarpaulin for drying (X_4)	α_4	-0.170	0.036	0.003	-0.014	-0.024
		(0.251)	(0.052)	(0.005)	(0.021)	(0.036)
Super grain bags (X_5)	α_5	-0.236	0.049	0.004	-0.019	-0.033
		(0.254)	(0.053)	(0.005)	(0.021)	(0.036)
Storage in granaries (X_6)	α_6	1.411**	-0.294**	-0.023	0.119**	0.198***
		(0.599)	(0.124)	(0.016)	(0.058)	(0.073)
Aluminum phosphate (X_7)	α_7	-0.121	0.025	0.002	-0.010	-0.017
		(0.798)	(0.167)	(0.013)	(0.068)	(0.111)
The use of ashes(X_8)	α_8	-0.406	0.085	0.007	-0.034	-0.057
		(0.629)	(0.131)	(0.011)	(0.053)	(0.087)
Pirimiphos-methyl (X_9)	α_9	-14.788***	3.085***	0.235	-1.249***	-2.070***
		(1.180)	(0.244)	(0.182)	(0.214)	(0.263)
Access to Training (X_{10})	α_{10}	0.614*	-0.128*	-0.009	0.052	0.086*
		(0.372)	(0.077)	(0.009)	(0.031)	(0.051)
Educational level (X_{11})	α_{11}	-0.013	0.003	0.000	-0.001	-0.002
		(0.024)	(0.005)	(0.000)	(0.002)	(0.003)
Diagnostic statistics:						
Wald $chi^2(11)$ = 210.02						
Prob > chi^2 = 0.0000						
Log pseudo likelihood = −279						
Number of observations	216					

*** Significance at 1% level; ** significance at 5% level; * significance at 10% level. Figures in parentheses are robust standard errors;

3.4. Constraints militating against post-harvest loss among cowpea farming households in the study area

The limitations that cowpea farming households in the research area have in reducing post-harvest loss are listed in Table 5. The respondents in the research area cite high transportation costs, long travel times to the market, increased storage material costs, and limited loan availability as their main obstacles.

The high cost of improved storage materials was attested by the cowpea farming households to be a very critical challenge, with 62%, 35% of them confirming it to be critical, and 2% to be less critical. This finding reflects the inability of cowpea farming households to afford improved hermetic storage technologies such as Purdue Improved Cowpea Storage (PICS) bags, making the cowpea farmers rely on structurally deficient traditional granaries that are susceptible to rodent infestation, leakages, and weather damage. This cost barrier,

therefore, perpetuates a cycle in which storage practice does not translate into food security improvement because the quality of available storage infrastructure remains inadequate. These limitations are consistent with research by Abimbola [32], who discovered that farmers may be forced to sell their produce straight from the farm due to high storage material costs. Also, 74% of the cowpea farming households agreed that high transportation costs were a serious constraint, 67% agreed it was critical, and 4% agreed it was less critical. Far distances to the market were a very serious problem, with 65%, 32% confirmed it was critical, and 2% agreed it was a less serious problem. These factors are likely to limit the timely sale or storage of produce, indirectly reducing efficiency. Recent studies show that poor market access and high transport costs increase post-harvest losses and reduce income stability, which in turn limits the adoption of loss-reducing technologies. This finding aligns with Oyegbile and Oyesola [33], who reported that high transport costs and weak agro-logistics drive post-harvest losses and reduce household food security. In the same vein, Inadequate access to credit was confirmed by the cowpea farming households to be very critical at 55%, 38% of them confirmed it to be critical, and 7% to be less critical. Limited financing not only limits the purchase of improved storage technologies and pesticides but also reduces households' ability to invest in transport and other inputs necessary for effective post-harvest management. Empirical evidence highlights that credit access is a key determinant of smallholder adoption of post-harvest technologies, reinforcing the link between financial inclusion and food security [34]. Other constraints faced by the cowpea farming households are no linkage to the market after harvesting, which was agreed to be very critical at 25%, critical at 72%, and less critical at 3%. This reflects a structural gap in the post-harvest value chain that limits farmers' ability to convert stored cowpea into income, indirectly weakening their capacity to achieve food security through market participation.

Table 5. Results on the constraints militating against post-harvest loss reduction among cowpea farming households in the study area

Constraints	Very critical	Critical	Less critical	Not critical	Mean value
High cost of improved storage materials	134 (62.0)	77 (35.6)	4 (1.9)	1 (0.5)	3.6
No available improved storage material	34 (15.7)	160 (74.1)	22 (2.8)	0.00	3.1
No linkage to the market after harvesting	54 (25.0)	156 (72.2)	6 (2.8)	0.00	3.2
Far distances to the market	141 (65.3)	70 (32.4)	5 (2.3)	0.00	3.6
Inadequate Training on post-harvest loss reduction practices of cowpea farming	68 (31.5)	145 (67.1)	3 (1.4)	0.00	3.3
High Transportation cost	160 (74.1)	52 (67.1)	4 (4.1)	0.00	3.7
Inadequate access to credit	118 (54.6)	83 (38.4)	15 (6.9)	0.00	3.5
Inadequate technical know-how in storage techniques	42 (19.4)	163 (75.5)	11 (5.1)	0.00	3.1
Lack of Agricultural extension and advisory training on post-harvest loss handling	38 (17.6)	154 (71.3)	23 (10.6)	1 (0.5)	3.1

Figures in parentheses are percentages

The inadequate training on post-harvest loss reduction practices of cowpea farming was attested by the cowpea farming households to be very critical at 32%, critical at 67%, and less critical at 1%. This finding provides an important contextual grounding for the unexpected regression result in which access to training was negatively associated with food security outcomes. The argument that training exposure alone does not guarantee behavioral change or technology adoption is supported by the widespread perception of training inadequacy among respondents, which implies that current training programs may suffer from quality deficiencies, poor targeting, or a failure to address the particular post-harvest challenges of cowpea farming households. The inadequate training on post-harvest loss reduction practices of cowpea farming agrees with the results of Ovharhe et al. [1], who concluded that it was a serious problem that affected the post-harvest loss of farm

produce. Again, the inadequate technical know-how in storage techniques was confirmed to be very critical at 19%, critical at 76%, and less critical at 5%. This further reinforces that knowledge gaps at the farm level remain significant despite the availability of improved post-harvest technologies.

Lack of agricultural extension and advisory training on post-harvest loss handling was agreed to be a very critical constraint by the cowpea farming households at 18%; they agreed that it was critical at 71% and less critical at 11%. Lack of agricultural extension and advisory training on post-harvest loss handling was a critical problem for the respondents, and it aligns with Dauda et al. [35], who suggest that one of the problems with the usage of improved cowpea technologies was the lack of sound extension services. Agricultural extension and advisory trainings assist in creating awareness and guidance on the use of available improved technologies, and if these trainings are efficient It may serve as a bridge to help farmers adopt new technologies that will increase their production efficiency and lower post-harvest losses.

4. Conclusion and Recommendation

According to the study's findings, this study shows that although cowpea farmers are largely within a productive age and moderately literate, a majority still experience food insecurity. The findings underscore an effective post-harvest loss reduction practice, rather than mere participation in cowpea farming, is critical to improving food security. Notably, improved practices like the use of pirimiphos-methyl enhance food security, while traditional storage methods worsen it. The study contributes empirically by demonstrating that technology effectiveness and adoption conditions determine food security outcomes. Therefore, to address these issues, this study recommends that policies should promote affordable, improved storage technologies and strengthen access to credit schemes. Extension services must be restructured to focus on practical, adoption-driven training approaches. Investments in rural infrastructure and market linkages are essential to reduce costs and improve farmers' income stability. Tackling these constraints will reduce post-harvest losses and boost household food security, ensuring more food for the family and household welfare, and increasing income for the family.

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