UDS International Journal of Development [UDSIJD] ISSN: 2026-5336
Volume 10 No. 2, 2023
https://www.udsijd.org

FARMERS' CHOICE OF POSTHARVEST MANAGEMENT PRACTICES: DETERMINANTS AND FOOD SECURITY IMPLICATIONS IN THE TOLON DISTRICT OF GHANA

[1]Abubakar, S. A., [2]Alhassan, H., [3]*Dagunga, G.

[1]*Faculty of Agricultural, Food and Consumer Sciences, University for Development Studies, Tamale, Ghana*
[2]*School of Economics, University for Development Studies, Tamale, Ghana*
[3]*Department of Applied Economics, University for Development Studies, Tamale, Ghana*

**Corresponding Author:* *dagungagilbert@gmail.com*

Abstract

Postharvest losses remain a key threat to the efforts by developing countries to achieving the zero hunger global agenda. Farmers in many areas have employed mechanisms aimed at managing postharvest losses. This study, therefore, sought to analyze rice farmers' choice of postharvest management practices and its implication on household food security in Tolon district, Ghana. The results revealed that, the various postharvest management practices among rice farmers were chemical application, heat control method, and cleaning and sorting method. Estimation results from the multivariate probit model indicated that, FBO membership, household size, access to credits, farm size and farmer awareness of postharvest loss influence farmers' choice of postharvest management practices. Likewise, the ordered probit results showed that farmers who employ heat control in managing postharvest losses were more likely to be at the acceptable level of food consumption. The effect of heat control was found to be more effective when combined with other postharvest management practices like chemical control and cleaning/sorting. The outcome of the study suggests the need to encourage the use of heat control postharvest management strategies which may go a long way to help in the achievement of the zero-hunger global agenda. This should be used in combination with chemical control and cleaning/sorting.

Keywords: Rice farmers; Postharvest losses; Food Security; Multivariate Probit; Ordered Probit model

Introduction

Food crops such as legumes, tubers, and cereals are the major sources of food in Ghana (FAO, 2016). Policymakers are therefore often mostly concerned about the production and marketing of these to ensure availability for all. If food security is to be achieved in Ghana as is required by the second sustainable development goal, maintaining a sufficient level of marketable food surplus in terms of quality and fair price is very critical. Public policies, however, have focused more on the production and consumption aspects.

Rice is one of the world's most cultivated crops (Minh et al., 2019). It is an important component of diets consumed in many developing countries, and also a staple food in many African countries (Saba & Ibrahim, 2018). Much emphasis has been placed on promoting cereal grain production through improved technology which has resulted in some increase in productivity (Gabriel & Hundie, 2006). In the case of Ghana, rice yield has increased by 48% from 2.7mt/ha to 4.0mt/ha between the periods of 2016 and 2017 respectively (Asare, 2019). This success could be attributed to programmes by the government over the years such as the Food and Agricultural Sector Policy (FASDEP I & II), the Youth in Agriculture (YIA) programme as well as the efforts of development partners like Alliance for Green Revolution Africa (AGRA) among others. Currently there are different varieties of rice produced by Ghanaian farmers such as AGRA rice and jasmine rice. The successes are indications that the government is on the right path towards the transformation and modernization of agriculture (Asare, 2019).

One of the greatest global issues today is how to achieve food security for an increasing global population while ensuring sustainable growth in the long term. As estimated by the FAO (2018), by 2050, about 70% increase in the production of food will be needed in order to feed the world's growing projected population of nine billion. By definition, a household is said to be food secured "when all people, at all times, have physical and economic access to sufficient, safe, and nutritious food to meet their dietary needs and food preferences for an active and healthy life" (FAO, 2003). Additional trends such as rising urban populations, lifestyle changes and rising middle-class diet patterns in emerging economies along with climate change put significant pressure on the planet's resources: decreasing freshwater resources and biodiversity and loss of fertile land (Kiaya, 2014). These raise an alarm on the need to engage in varied innovations to produce more food especially in developing countries like Ghana. This also suggests that measures must be put in place to reduce the food waste or loss at all aspects of the food value chain including postharvest losses.

While studies such as Godfray et al. (2010) has opined that many nations have concentrated in past years on increasing crop production, land utilization and population management as their strategies to cope with the rising food demand, Postharvest loss (PHL) remains a serious threat to this global target of increasing food production by 70% by 2050. Ironically, less than 5% of research funding has been assigned in previous years to this concern (Kumar and Kalita, 2017). About 30% of the food produced is wasted in postharvest activities worldwide each year, an amount that could be used to feed a significant population (Kumar and Kalita, 2017). In Ghana about 11.9% of all rice produced ends up not consumed due to postharvest losses (AHPLIS, 2021)

The term 'post-harvest' refers to all activities that are carried out after the harvesting of produce. It embraces all the stages after harvests such as cleaning, grading, transportation, storage, processing, packaging, and marketing (Kalita, 2017). Due to the often-greater loss of output during the period of transport and storage, management practices are implemented to reduce these losses. Postharvest loss can be defined as the loss from the harvest stage to the consumption stage that results entirely from the consumer's qualitative loss and quantitative loss (Abiad & Meho, 2018). Quantitative loss can be characterized as the dietary loss resulting from weight loss, crop spillage, and pest attack. Qualitative loss is the loss of food that results from nutrient deficiency, excessive change in taste and texture (Taiwo and Bart-Plange, 2016). Recent studies demonstrated that approximately $680 billion and $310 billion worth of food is lost and wasted in developed and developing countries respectively. The same study revealed that averagely about 30% of cereals are lost yearly (Sawicka, 2019).

Though there are other crop losses throughout the production chain from pre-harvest, harvest and post-harvest stages, it has been estimated that pre-harvest and post-harvest food losses are higher in Africa than the global average; the effect of these losses on livelihoods are often negative and severe, especially on the rural folks and poor urban dwellers. Undeniably, the economy of Ghana is highly depended on agriculture, with about 60% of the population being farmers (FAO, 2018). Ghana, like many other Sub-Saharan African (SSA) countries, is bedeviled with varying degrees of postharvest losses (Tanye, 2016). The quantum of food that is unavailable for people because of postharvest losses is huge enough to provoke attention (Tanye, 2016). This raises many questions as to what should be done and where do we start from? What is the potential of postharvest management options in reducing these losses? Ansah et al. (2017) asserted that, farmers postharvest management practices are effective in improving their welfare through increase in household income in northern Ghana.

In the Tolon district, rice farmers resort to varying postharvest management practices, some of which seek to reduce the moisture content of the grains to avoid spoilage while others seek to prevent pests' attacks. One of these postharvest management practices is heat control. Heat control involves the drying of the grains to reduce the moisture content from it so that it could be stored for a long time without undergoing deterioration. Also, heating regulates the temperature in the stores to avoid spoilage. Kumar and Kalita (2017) revealed that inadequate drying can result in mold growth and significantly high losses during storage and milling. Another technique employed is sorting and cleaning. This practice is carried after threshing and milling. The milled rice is cleaned to ensure that it is safe for storage and consumption. Rice husk and stones are removed from the grains to produce quality and clean rice which reduces the chances of it being rejected by consumers. Hence rejection by consumers or the market constitutes a loss since it is contrary to the ethics of responsible production. If not totally rejected, there is value loss which affects the price of the commodity thereby constituting a postharvest loss (Kumar and Kalita, 2017). Finally, different chemicals are used to spray the storage rooms of the harvested rice to prevent insects and disease infestation.

Hence given the adverse effects of postharvest losses as outlined above and the postharvest management practices employed by farm households in the study area, it is not yet revealed as to what factors inform their decisions to choose a particular postharvest management practice and how that affects their food security situation which this study seeks to achieve.

Materials and Methods

Study area and sampling technique

The study was conducted in the Tolon district. The district of Tolon stretches from latitudes 9 ° 15 to 10 ° 0 02 'North and Longitudes 0 ° 53and 1 ° 25 to the South. It shares its boundaries with Kumbungu to the north, North Gonja to the west, Central Gonja to the south and Sagnarigu to the east. The district is characterized by a single rainy season which starts at the end of April with little rainfall, climbs to its height in July-August and declines sharply and ends in October-November. Between November to March, the dry season begins with daytime temperatures ranging between 33° C to 39° C, while mean night temperatures range from 20° C to 26° C (GSS, 2014). The annual mean rainfall varies from 950 mm-1,200 mm. About 87.3 % of the households in the district engage in agriculture, forestry and fishery for their livelihood (GSS, 2014). The soil is generally of the sandy loam type except in the low lands where alluvial deposits are found. The main crops grown in the district are rice, maize, groundnuts, soybeans and sweet potatoes. The presence of the Savanah Agricultural Research Institute (SARI) and AVNASH rice processing factory within the district makes rice production an essential economic activity for most farmers. This study thus focused on rice farmers since a reduction in postharvest losses have the potential to generate extra income to farmers as well as food for consumption.

A multi-stage sampling was employed to sample 207 farmers used for this study. The Tolon district was purposively selected in the first stage because majority of farmers in the district engaged in rice production with a significant proportion said to be moderately food insecure (WFP, 2012). In the second stage, a simple random sampling was employed to select nine communities out of which 23 rice farmers were further selected randomly which gave a sample size of 207. The total number of rice farming households in the district has been reported to be about eight thousand one hundred and ten (8110) households. The Yamane formula was used in the sample size selection (Yamane, 1967).

$$\text{Sample size} = n = \frac{N}{1+N(\alpha)^2}$$

Where N = total number of households (8,110), n = sample size, α = confidence level (93%, 0.07)

$$n = \frac{8110}{1+8110(0.07)^2} = 199 \approx 200$$

However, 207 farm households were selected and interviewed.

Multivariate Probit Regression Model

A multivariate probit model was employed to analyze the factors affecting the choice of postharvest management techniques [1] by farmers. In managing post-harvest losses during storage, farmers may use various combinations of post-harvest management techniques to help reduce their losses (Ansah et al., 2018). The multivariate probit is an enhancement of the probit model which is used to jointly estimate various correlated binary outcomes (Temesgen, et al., 2017). The multivariate probit model is expressed as;

$$y_{im} = \beta_{im}x_{im} + \varepsilon_{im} \qquad (1)$$

where y_{im} (m= 1... k) represents the dependent variable of postharvest management techniques selected by the ith farmer (i = 1… n). The dependent variables are polychotomous variable indicating that storage is done using the appropriate technique for post-harvest management. The techniques of post-harvest management were grouped into three groups: chemical application, heat control, cleaning and sorting. A farmer may employ one or more post-harvest management techniques. x_{im} is a $1 \times k$ independent variables defined in Table 1 which affects the decision for a given postharvest management technique and β_{im} is a $k \times 1$ vector of unknown parameters to be estimated. ε_{im} , $m = 1,2, \dots m$ are the error terms distributed as multivariate normal, each has a mean of zero, and a variance- covariance matrix V, where V has values of 1 on the lead diagonal and correlations.

The above equation is an m-equation system seen in the following equations:

$$y_{1i}^* = \beta_1' x_{1i} + \varepsilon_{1i} \qquad (2)$$

$$y_{2i}^* = \beta_2' x_{2i} + \varepsilon_{2i} \qquad (3)$$

$$y_{3i}^* = \beta_3' x_{3i} + \varepsilon_{3i} \qquad (4)$$

The latent dependent variables are observed through the decision to accept them or not (y_{ki}) such that:

$$y_{im} = \begin{cases} 1 \; if \; y_{ki}^* > 0 & k = 1,2,3 \\ 0 & otherwise \end{cases}$$

There are six combined odds that lead to the six potential combinations of implementing and not implementing each of the three strategies of post-harvest management. The probability that the ith farmer will select all three postharvest management techniques is given as:

$$\Pr(\, y_{1i} = 1 \quad y_{2i} = 1 \quad y_{3i} = 1) \qquad (5)$$

[1] The study used postharvest management practices and postharvest management techniques interchangeably

$$\Pr(\varepsilon_{1i} \le \beta_1' x_{1i}, \quad \varepsilon_{2i} \le \beta_2' x_{2i} \quad \varepsilon_{3i} \le \beta_3' x_{3i}) \quad (6)$$

$$\Pr(\varepsilon_{3i} \le \beta_3' x_{3i}, \quad \varepsilon_{2i} \le \beta_2' x_{2i} \quad \varepsilon_{1i} \le \beta_1' x_{1i}) \quad (7)$$

$$\Pr(\varepsilon_{2i} \le \beta_2' x_{2i}, \quad \varepsilon_{1i} \le \beta_1' x_{1i} \quad \varepsilon_{3i} \le \beta_3' x_{3i}) \quad (8)$$

The multivariate probit model which has three variables $y_1 \ldots\ldots y_{3,}$ are formulated such that;

$$y_i^* = 1 \; if \; \beta_i x' + \varepsilon_i > 0 \quad \text{and}$$

$$y_i = 0 \; if \; \beta_i x' + \varepsilon_i \le 0 \quad i = 1, 2,3$$

$$p_i = \Phi(y^*) = \Phi(\beta_0 + \beta_1 x_{i,1} + \beta_2 x_{i,2} + \beta_3 x_{i,3} + \beta_4 x_{i,4} + b\beta_k x_{ik})$$

where x is a vector of the independent variables; $\beta_1, \beta_2, \beta_3, \beta_4, \ldots. and \; \beta_n$ are conformable parameter vectors and $\varepsilon_1, \varepsilon_2, \varepsilon_3, \varepsilon_4, and \; \varepsilon_n$ are random errors distributed as a normal multivariate distribution with zero mean, unitary variance and an n × n correlation matrix.

The variables listed in Table 1 were used as the independent variables and were selected based on previous empirical studies (Ansah et al., 2017). The age of the farm household head is expected to have positive effect on postharvest management as, the older a farmer gets, he/she gains more knowledge about how to minimize his or her output after harvest (Taiwo and Bart-Plange, 2016). The sex of the household head is very relevant for managing postharvest losses. It reveals the main decision maker of the household, whether a man or woman. This could be positive and negative depending on how resourced the household head is. Education is projected to positively influence postharvest management practices. This is because it is assumed that once a farmer is educated, he or she should have a fair idea as to how to manage losses after harvest to its minimum as compared to a farmer who has no form of education (Mukarumbwa et al., 2017). The perceived quantity lost within the production season is expected to have a negative effect on postharvest management. This is because, farmers who perceive they lost more may attribute the losses to poor postharvest loss management practices. Membership of a farmer-based organization (FBO) is projected to have a beneficial impact on postharvest management activities. This is because if farmers belong to an FBO, they are assumed to learn more about how to manage their output after harvest in order to prevent them from wasting (Anaba, 2018). Household expenditure was included in the model. This is expressed as a measure of welfare (Ehiakpor et al., 2019) and is expected to have a positive effect on the practice of postharvest management. Credit is expected to have a beneficial impact on post-harvest management practices. This is because when farmers have access to credit, they can afford modern and reliable storage facilities to help reduce or avoid losses after harvesting. It must also be recognized that, not all forms of credits are used to manage post-harvest losses. Some credits may be used to purchase inputs for production which may require repayment after harvest. Depending on the time for repayment it could be further used to manage postharvest losses or farmers may have to sell in a hurry which can have a negative effect on post-harvest loss management. Households with larger farm sizes are expected to have more resources for managing post-harvest losses as compared to their counterparts since land is seen as a valuable resource for wealthy northern households. Meanwhile, households that are aware of post-harvest management practices are more likely to practice it as compared to those that are not. Household size is also expected to have a positive effect on postharvest management practices because larger household size represent availability of labour to help with the management of the produce during storage (Mukarumbwa et. al., 2017). For the variable years in farming, it is assumed that, when a farmer has been into farming for so many years, he or she gets a lot of experience in managing his or her output in order to minimize or prevent postharvest losses as compared to someone who has not been into farming for so many years (Mukarumbwa et al., 2017). The variable marital status is expected to have a positive effect on postharvest management practices. When one is married, he or she has a lot of responsibilities such as taking care of children's school fees, feeding the family and paying bills. Therefore, they try their best to minimize the losses of their produce after harvest as much as they can in order to fulfil their responsibilities as compared to farmers that are single and have fewer responsibilities (Kikulwe et. al., 2018).

Ordered Probit Regression Model

An ordered probit regression model was used to examine how post-harvest management activities impact on the food security status of farm households. The food security status of households was calculated using the Food Consumption Score (FCS). There are several indicators for measuring food security such as the household dietary diversity score, the household hunger scale, and coping strategy (Leroy et al., 2015). The Food Consumption Score (FCS) which was developed by the World Food Program has been used by many organizations and researchers because of its ability to capture the quantity and quality of household food consumption for which reason it has been adopted for this study (Marivoet et al., 2019). Following WFP (2008), Leroy et al. (2015), Ngema et al. (2018) and Atara et al. (2019), the mathematical formula for calculating FCS is expressed as equation (9):

$$FCS = a_{staple}x_{staple} + a_{pulse}x_{pulse} + a_{veg}x_{veg} + a_{fruit}x_{fruit} + a_{animal}x_{animal} + a_{sugar}x_{sugar} + a_{dairy}x_{dairy} + a_{oil}x_{oil} \quad (9)$$

where, X_i = number of days in the past 7 days for which each food category was consumed. The cumulative duration of the number of the frequencies of the various foodstuffs belonging to the same food group shall be seven (7) days.

a_i = weight of each food group

The dependent variable, food security was measured as an ordered variable but not a binary outcome. This is because calculating food security as a binary response discards critical household information that happens to have indices ranging from lowest to highest food security (Nkegbe et al., 2017). Since the measure of food security is ordinal, the most appropriate models are ordered logit or ordered probit. An ordered logit model assumes the error term is logistically distributed while an ordered probit model assumes the error term is distributed as normal. The logistic and normal distribution, however, yield similar results, and so the ordered probit model was employed in this study. The ordered probit model is built almost the same on a latent regression as the binomial logit model (Kunitou, 2017), where the utility of a choice consists of a deterministic component $(\beta' x_i)$ and an error term (e_i), which is autonomous from and follows predetermined distribution of deterministic components. The model of the ordered probit is given as;

$$y_i^* = \beta' x_i + \varepsilon_i \quad i = 1,2,3 \ldots..n \qquad (10)$$

where, x_i is a vector of explanatory variables which affect the probability of the f farm households being food secure, β' is a vector of parameters to be determined, ε_i is a random error term that assumes normal distribution. The relation between the variables observed and the latent is written as a vector of non-observable parameters of the threshold (or break point).;

This is calculated using the relation;

$$y_i = j \; if \; \mu_{j-1} < y_i^* i \leq \mu_j \quad j0,1,2,3 \ldots.j \quad (11)$$

Where $\mu_{-1} = -\infty$, $\mu_0 = 0$, $\mu_J = \infty$ and $\mu_{-1} < \mu_0 < \mu_1 < \cdots < \mu_J$.

The probabilities are given as;

$$prob[Y_i = j] = prob[\mu_{j-1} < y_i^* \leq \mu_j]$$

$$= prob[\mu_{j-1} - x_i'\beta < e_i \leq \mu_j - x_i'\beta]$$

$$= \emptyset(\mu_i - x_i'\beta) - \emptyset(\mu_{j-1} - x_i'\beta) \quad (12)$$

As asserted by Nkegbe et al. (2017), since there is no positive conditional mean function and the marginal effects in ordered probability models are not straightforward, the influence of a change in the explanatory variables on cell probabilities is generally considered. These are expressed as follows:

$$\frac{\partial Prob[cellj]}{\partial xi} = [\varphi(\mu j - 1 \, - x'i\beta) - \varphi(\mu j \, - x'i\beta)] \times \beta \quad (13)$$

The normal density function is φ (·). In the light of the previous discussion the empirical model of this study is specified as:

$$FCSij = \beta 0 + \beta_1 HHage_i + \beta_2 Male\_dum_i + \beta_3 HHsize_i + \beta_4 Education_i + \beta_5 HHQloss_i + \beta_6 FBOi + \beta_7 HHexp_i + \beta_8 Credit_i + \beta_9 Fsize_i + \beta_{10} PHLaware_i + \beta_{11} CleanSorti + \beta_{12} Chemical_i + \beta_{13} Heatcont_i + \mathcal{E}_i \quad (14)$$

where FCS as previously defined, subscript *i* represents a household and *j* represents the ordered classification of household food security (poor food consumption, borderline food consumption and acceptable food consumption). The various post-harvest management practices (Cleaning/sorting, chemical control and hear control) are assumed to be exogenous. This is because, the household decision to engage in any of these practices does not necessary depend on their food security status.

Table 1: Description and Measurement of Variables

Variable	Description	Measurement
HHage	Age of household head	Number of years
HHsex	Sex of the household head	Dummy; 1 = if male; 0 = otherwise
HHsize	Household size	Number of people eating from the same pot
Education	Education of head of household	Number of years in formal education
Qloss	Quantity loss	Kilograms
FBO	Member of Farmer-Based Organization	Dummy; 1 = if yes; 0 = otherwise
HHexp	Total household monthly expenditure	Ghana cedis
Credit	Access to credit	Dummy; 1= if yes; 0 = otherwise
Fsize	Farm size	Acres
HHsize	Household size	Number of people in a household
PHLaware	Awareness of post-harvest loss	Dummy; 1 =if yes; 0 = otherwise
CleanSort	Cleaning/ Sorting management	Dummy; 1 =if yes; 0 = otherwise
Chemical	Chemical application	Dummy; 1 =if yes; 0 = otherwise
Heatcont	Heat control	Dummy; 1 =if yes; 0 = otherwise

Source: Field Survey, 2020

Results

Socio-Demographic Characteristics of Respondents

The study first presented the farm-specific and institutional factors postulated to have an influence on farmers' choice of postharvest management practice. Results from Table 2 reveal that most of the household heads in the study area were males (88.89%). About 77.67% of the respondents were married while 3.40% were divorced. About 61.84% of the respondents had no formal education with as low as 2.09% of the respondents having tertiary education. Further, 10.14% and 20.29% of the respondents had completed Junior high school and Senior high school respectively. Only 4.83% of the respondents had access to credit and 95.17% had no access to any form of credit from the results analyzed. It was also realized that 46.83% of the farmers that belong to FBOs usually discuss issues concerning rice marketing, rice varieties and fertilizer, pesticides, and weedicides application. Only a few of the farmers discuss issues relating to rice postharvest loss.

The result also shows that 96.62% of the respondents were aware of postharvest loss while 3.38% of the respondents were not aware of it.

Table 2: Summary Statistics of Selected Variables

Variables	Frequency	Percentage (%)
Farmer-specific and sociodemographic factors		
Sex of the household head		
Male	184	88.89
Female	23	11.11
Total	207	100.00
Marital status		
Married	160	77.67
Single	39	18.93
Divorced	7	3.40
Total	207	100.00
Educational status		
No formal education	128	61.84
Primary	4	1.93
Junior High	21	10.14
Senior High	42	20.29
Tertiary	6	2.90
Other	6	2.90
Total	207	100.00
Institutional factors		
Access to credit		
Yes	10	4.83
No	197	95.17
Total	207	100.00
FBO membership		
Yes	97	46.86

No	110	53.14
Total	207	100.00
Awareness of postharvest loss		
Yes	200	96.62
No	7	3.38
Total	207	100.00

Source: Field Survey, 2020

Postharvest management practices among farmers in the Tolon district

Farmers were asked on three postharvest management techniques namely, heat control, chemical application and cleaning/sorting. The result is presented in Table 3. Most of the farmers practised chemical application as compared to heat control and cleaning/sorting. As high as 81.16% indicated that, they use chemicals in order to avoid losses after harvest while 58.34 % and 18.36% employed heat control and cleaning/sorting respectively.

Table 3: Postharvest management techniques during storage

Variable	*Number of farmers*	*Frequency*		*Percentage %*	
PHLMP		***Yes***	***No***	***Yes***	***No***
Heat control	207	121	86	58.45	41.55
Chemical application	207	168	39	81.16	18.84
Cleaning and sorting	207	38	169	18.36	81.64

Source: Field Survey, 2020

Factors Influencing Famers Choice of Postharvest Management Techniques

The study first sought to identify the factors influencing farmers' choice of postharvest management techniques in the study area. Using the multivariate probit model for the estimation, the results are presented in Table 5. The Log-likelihood value was found to be -283.955 while that of the Wald chi-square (24) was 51.740 indicating that the estimates of the multivariate probit model are different from zero and thus justifies the discussion of the results. Both farmer-specific and institutional factors were found to significantly influence farmers' choice of a given postharvest management technique as shown in Table 4.

Table 4: Multivariate Probit regression of factors influencing Farmers Choice of Postharvest Management Techniques

Variables	**Postharvest management Techniques**		
	Heat control Coefficient (Std. Err.)	Cleaning/sorting Coefficient (Std. Err.)	Chemical Coefficient (Std. Err.)
Sex of household head	0.186	0.118	0.542*
	(0.303)	(0.334)	(0.316)
Age of household head	0.019**	-0.024**	0.025**
	(0.009)	(0.011)	(0.011)

Years of education	-0.004	0.018	-0.011
	(0.017)	(0.019)	(0.019)
Household size	-0.020**	-0.003	-0.021*
	(0.010)	(0.012)	(0.011)
Farm size	0.052	0.091**	0.001
	(0.042)	(0.040)	(0.044)
Access to credit	0.504	1.035***	0.055
	(0.348)	(0.329)	(0.387)
FBO	0.347*	0.137	-0.289
	(0.187)	(0.221)	(0.221)
Awareness of post-harvest loss	0.571	3.865	1.416***
	(0.519)	(101.670)	(0.522)
Constant	-1.236**	-4.574	-1.222*
	(0.628)	(101.671)	(0.653)
Number of observations	207		
Wald chi-square (24)	51.740***		
Log likelihood	-283.955		

*Standard errors are in the brackets. ***, **, * represents significance level at 1%,5% and 10% respectively.*

Correlation Among the Different Post-Harvest Loss Management Techniques.

Additionally, multivariate probit model further establishes the correlation between the various postharvest management practices. The results in Table 5 show a strong and statistically positive correlation between heat control and chemical application as well as for cleaning/sorting. There was an insignificant weak correlation between chemical application and cleaning/sorting.

Table 5: Coefficients of correlation of the different management techniques from the evaluation of Multivariate Probit regression.

	Heat control	Cleaning/sorting	Chemical
Heat control	1		
Cleaning/sorting	0.524*** (0.160)	1	
Chemical	0.878*** (0.175)	0.201 (0.160)	1

*Standard errors are in the brackets. ***, **, * represents significance level at 1%,5% and 10% respectively.*

Likelihood ratio test chi2 (3) = 42.833 Prob>chi2= 0.0000

Household Food Security Situation among rice farmers

On farm households' food security status, the results showed that 6.28% of the respondents were within poor food consumption levels (FCS<21). About 56.04% of the respondents were on the borderline of food consumption (21.5≤FCS<35) while 37.68% of the respondents were on the acceptable food consumption level (FCS ≥35).

The Effect of Postharvest Management Techniques on Farm Households' Food Security Status.

The ordered probit model was used to analyze the effects of postharvest management techniques on households' food security status. Household food consumption score was used as a food security indicator. The level of farmers' food consumption was then categorized and ordered into three groups: poor food consumption, borderline food consumption, and acceptable food consumption. The results on the effects of postharvest management techniques on food security are presented in Table 6. Both the coefficients and the marginal effects of the ordered probit are reported.

Table 6: Ordered probit regression results of the effects of postharvest loss on food security

Variable	*Estimates*		*Marginal effects*					
	Coefficient	***SE***	***FCS=1***	***SE***	***FCS=2***	***SE***	***FCS=3***	***SE***
Age of the household head	-0.0049	0.0081	0.0005	0.0008	0.0014	0.0023	-0.0019	0.0031
Sex of household head	-0.2806	0.2902	0.0262	0.0277	0.0805	0.0838	-0.1067	0.1104
Household size	0.0309***	0.0107	-0.0028**	0.0012	-0.0088***	0.0032	0.0118***	0.0041
Years of education	-0.0155	0.0163	0.0016	0.0016	0.0044	0.0047	-0.0059	0.0062
Quantity loss	-0.0097*	0.0051	0.0009*	0.0005	0.0028*	0.0015	-0.0037*	0.0019
FBO	0.0438	0.1815	-0.0041	0.0170	-0.0125	0.0521	0.0167	0.0690
Total household expenditure	-0.0002	0.0001	1.9532	0.0000	0.0001	0.0002	0.0000	0.0000
Access to credit	0.2605	0.4083	-0.0243	0.0386	-0.0747	0.1174	0.0991	0.1553
Farm size	0.0115	0.0138	-0.0011	0.0013	-0.0033	0.0040	0.0043	0.0059
Cleaning/sorting management	-0.4219*	0.2447	0.0394	0.0242	-0.1210*	0.0719	0.1604*	0.0931
Chemical application	-0.068	0.2605	0.0063	0.0244	0.0194	0.0747	-0.0257	0.0991
Heat control	0.4631**	0.2071	0.0433**	0.0212	-0.1327**	0.0618	0.1761*	0.0787
Chemical*Heat control	0.0345***	0.0098	-0.0312**	0.0120	0.00243	0.00231	0.0121**	0.0056
Heat control*Cleaning/sorting	0.4545**	0.2311	-0.0045	0.0320	0.0390*	0. 0211	0.0028	0.0011
Cleaning/sorting*Chemical control	0.5430	0.6123	0.0005	0.0071	0.0117	0.0138	0.0030	0.0160

Number of obs =207   LR chi2(12) =29.41   Prob > chi2 = 0.0034   Pseudo R2 = 0.0855   Log likelihood = -157.3167

*FCS 1=poor food consumption, FCS 2=borderline food consumption, FCS 3= acceptable food consumption. ***, **, * represents significance level at 1%,5% and 10% respectively*

Discussions

From the descriptive statistics in Table 2, most households were headed by males. About 88.89% of the household heads were males while 11.11% were females. This result was expected because in Ghana, men are mostly seen as the head of the household (Dagunga et al., 2020). Women only become the head of the household when the man or husband is deceased or travels. Also, the relatively high percentage of married people among respondents (77.67%) could be associated to the fact that marriage is seen as an important aspect of life in Dagbon communities that brings respect and honour to couples and their families. Majority (61.84%) of the respondents had no formal education. Even though the Ghana Statistical Service [GSS] (2014) reported an average marital rate of 44.3% for households in northern region, the rate in this current study suggests a relatively higher rate. Even though the district has institutions including the University for Development Studies, the study suggests that most of the indigenes themselves probably do not attend. This could also be tied to the priority for hunting and desire to engage in businesses by households in the area. The low (4.83%) accessibility to credit by farmers was associated to the fact that most of the farmers are poorly resourced and thus cannot provide collateral to access credit. Also, the low accessibility to credit could be because most of the farmers (53.14%) do not belong to any farm-based organization (FBO's) that can help them to access credit and discuss issues related to postharvest management. Almost all farmers were aware of postharvest losses. About 96.62% of the respondents were aware of postharvest loss while 3.38% of the respondents were not aware of it. The high awareness is expected to influence their choice of postharvest management techniques in order to minimize the loss or waste.

The main postharvest management techniques practised by farm households in the Tolon district included chemical control, heat control and cleaning/sorting. From Table 3, the results show that about 58.45% of farmers used heat control as a rice postharvest management technique. This indicates that more than half of the farmers used heat as part of their postharvest management techniques. Controlling the moisture of paddy during storage is essential because it determines the final quality of the rice. The quantity of moisture in paddy is usually controlled by the amount of heat it is subjected to. Concerning rice materials, heat treatment is also used to dehydrate harvested rice through drying. The traditional heated air at low temperatures is usually used to avoid potential cracking (Weinberger, 2009). Farmers in the study area usually dry their rice using the sun. About 81.16% of the farmers also indicate they use chemical control as a postharvest loss management technique to avoid insect attack. This was the most common method indicated by the farmers as it has the highest percentage. While the high application of chemicals can be a source of postharvest loss, it is also essential in controlling postharvest losses (Anaba, 2018). This means that farmers need only know that chemical applications can control postharvest losses, they also need to know how and when to apply it to avoid its side effect. The chemicals are used to prevent pests, insects, and rodents' attacks to help reduce post-harvest losses. Also, about 18.36% of the farmers indicated that they use cleaning and sorting as a postharvest management technique. Winnowing is the cleaning process most widely used in developing countries (Kumar and Kalita, 2017). Generally cleaning is performed to distinguish whole grain from broken grains and other foreign materials. This prevents insect attacks and reduces losses from post-harvest. The low percentage of cleaning and sorting could emanate from the fact that winnowing is mostly done after milling in order to separate the husk from the grains. In the study area, not too many farmers process their grains further. Many store the paddy rice while others further mill it for storage.

With regards to the determinants of postharvest losses as presented in Table 4, the sex of the household head was found to have a positive and significant influence on only chemical control. This means that male headed households are more likely to use chemicals as a postharvest management technique than female headed households. This result meets the a priori expectation because men in northern Ghana have more access and control of most resources in society, including farm inputs. As heads of the household, they are also exposed to workshops or programmes aimed at ensuring food security. The age of the household head was also found to have a positive and statistically significant effect on farmers decision to practice both heat control and chemical application but negative for cleaning/sorting. This means that as farmers age increase, they become more likely to use heat control and chemical application as post-harvest management techniques than younger farmers. However, for cleaning and sorting, younger farmers are more likely to use it as a postharvest management technique than older farmers. This implies that as the age of a farmer increases, their chances of using heat control and chemical application increases, however their chances of using cleaning/sorting as a postharvest management technique reduces. This makes sense because cleaning/sorting is labour intensive and requires a lot of time and energy as opposed to heat control and chemical application. Older farmers do not have that energy to use for cleaning/sorting and hence use more of heat control and chemical application than the cleaning/sorting. This result is consistent with that of Ahmed and Anang (2019) who also reported a positive relationship between the age of farmers and the adoption of farm technology. Household size has a negative relationship with heat control and chemical application but not statistically significant with cleaning/sorting. This means that as the farmer's household size increases, the probability of using heat control or chemical application as a postharvest management technique decreases. This result does not meet expectations because households with more people are expected to have more labour for collaborative effort towards food security through reduced post-harvest losses. The results however make economic sense because, larger household size does not necessarily imply more labour since most of them could be dependents (Infants and aged). Also, decision making in the household is more central to the head than the number of people in the household and hence the result is not counterintuitive. This result in this study is consistent with that of Ahmed and Anang (2019) who reported a negative association between technology adoption and household size. Farm size has a positive relationship with cleaning/sorting and heat control but not significant with chemical application. It means farmers with a large farm size are more likely to use cleaning/sorting than those with small-farm size. It does not meet our expectation as cleaning/sorting is labour intensive and can be difficult to implement with a large farm scale. However, the result still makes sense because commercialized farmers have enough resources to buy equipment which makes cleaning/sorting easy. Access to credit also has a positive relation with cleaning/sorting and it is significant at 1%. This implies that farmers who have access to credit are more likely to use cleaning/sorting than farmers who do not have access to credit. This is because access to credit can enable a farmer to purchase machines and tools that may help in cleaning and sorting. Anaba (2018) noted that limited access to credit leads to high postharvest loss among tomato farmers in the Upper East region of Ghana due to poor postharvest management. Again, FBO membership also has a positive relationship with heat control and it is significant at 10%. This implies that farmers who belong to FBOs are more likely to use heat control than farmers who do not belong to any FBO. Through FBOs, farmers can set up facilities for heat control as a postharvest management technique. This is in line with Anaba (2018) who indicated that through FBOs farmers can set up processing and other facilities to better manage postharvest losses. Awareness of postharvest management has a positive relationship with chemical application and it is significant at 1%. This means that farmers who are aware of postharvest management techniques are more likely to use chemical application as a postharvest management technique than farmers who are not aware of it. This makes sense because farmers can follow only the technologies they know about or have learned about (Kariuki, 2019). Awareness also makes farmers prepare well for its application including securing all the necessary materials.

Table 5 further presents results on the correlation among the three postharvest management practices in the study area. The results show a strong positive correlation between heat control and chemical control which was significant at 1%. This implies that farmers who employ heat control are more likely to also practice chemical control. Also, a moderate positive correlation exists between heat control and cleaning or sorting. The correlation between chemical control and cleaning/sorting was weak and insignificant though positive. The positive significant correlation between heat control and chemical control as well as cleaning/sorting could imply that, combining heat control could be effective when first cleaned and sprayed with appropriate chemicals.

Finally, the results on the effect of postharvest management techniques on household food security show that different postharvest management practices significantly influence household food security. From the study results, heat control was found to have a positive and significant influence on household food security. This means that farmers who practice heat control are more likely to be food secured (i.e., belong to an acceptable level of food consumption) than farmers who do not practice heat control. The marginal effects indicate that farmers who practice heat control are 4.34% less likely to be in the poor food consumption category and 17.6% more likely to be in the acceptable food consumption category, holding all other variables constant. Cleaning/sorting and chemical application both have negative coefficients but chemical application did not have a significant effect on food security. The marginal effect showed that households that employed cleaning/sorting as a postharvest management technique were about 16.04% more likely to be at the acceptable level of food consumption and 12.1% less likely to be at the borderline of food consumption. We further examined the combined effect of these three postharvest management techniques on household food security. The results showed that, chemical control together with heat control had a positive and statistically significant effect on household food security. The marginal analysis showed that, households that combines both chemical and heat method were 3.12% less likely to be at the poor food consumption category but 1.2% more likely to be at the acceptable level of food consumption. Also, heat control when combined with cleaning/sorting had a positive and significant effect on household food security. Households that combine these were found to be 3.9% likely to be at the borderline of food consumption.

Other socioeconomic factors were also found to influence household food security in the study area. The coefficient of the quantity of postharvest loss during storage, measured in kilograms is negative and statistically significant at 10%. This means that an increase in the quantity of postharvest loss, during storage, by one kilogram decreases the likelihood of a farmer consuming an acceptable level of food in the household. The marginal effects also show an increase in the quantity of postharvest loss, during storage, by one kilogram increases the likelihood of a farmer being in the poor food consumption category by 0.09% and decreases the likelihood of a farmer being in the acceptable food consumption category by 0.37%, holding all other factors constant. This result meets the a priori expectation because as the quantity of loss increases, it decreases the quantity of food available in stock. This will in turn have a negative implication on the farmer's food security status. This finding is in line with Tanye (2016) who also observed a negative effect of postharvest loss on food availability and worsening food security. The results also show that household size has a positive effect on food security and it is significant at 1%. This means that households with fewer members are less likely to be food secured than households with many members. The marginal effects indicate that an increase in the number of household size by one person decreases the likelihood of the farmer being in the poor food consumption category by 0.289% and increases the likelihood of the farmer being in the acceptable food consumption by 1.176%, ceteris paribus. This result does not meet a priori expectation because large household size means many mouths to feeds. This exerts pressure on the availability of food for everyone at all times. However, the result still makes sense because a large household size also means a large pool of human resources. This available human resource has the potential of working to provide food for all the people in the household.

Conclusion and Recommendations

The main purpose of the study was to analyze farmers' choice of postharvest management techniques and its implication on household food security in Ghana. A cross-sectional data collected from 207 rice farmers in the Tolon district were used. The multivariate probit model was employed to examine the factors that influence farmers' choice of postharvest management techniques while the ordered probit regression model was used to analyze how postharvest management practices influence households' food security. Based on the study, the postharvest management techniques used by the rice farmers include chemical application, heat control method, and cleaning and sorting methods. Results from the multivariate probit model revealed that FBO membership, household size, access to credits, farm size and farmer awareness of postharvest loss influence farmers choice of postharvest losses in the Tolon district. The ordered probit results show that the use of heat control in managing postharvest losses enhances farm households' food security situation. Specifically, farmers who practice heat control are 4.34% less likely to be in the poor food consumption category and 17.6% more likely to be in the acceptable food consumption category. Also, farmers who practised cleaning/sorting were less likely to be food secured as compared to those who do not practise them. Chemical control alone was not proven to be effective in contributing to household food security but when combined with heat control, the combined effect was significant in improving the household food security situation. Also, the combined effect of heat control and cleaning/sorting had a significant influence on household food security.

The study thus recommended that, government and development partners should encourage and promote the use of heat control as well as combine it with chemical method or cleaning/sorting to help reduce rice postharvest losses and waste in Ghana. This will go a long way to help in the achievement of the zero-hunger global agenda. Male farmers, lesser households and farmers belonging to FBOs should be given priority in such a pursuit.

Funding

Not applicable

Conflict of interest

The authors declare that they have no conflicts of interest.

Availability of data and materials

The data is available upon request

ORCID

Alhassan Hamdiyah (https://orcid.org/0000-0002-5524-9482)

Gilbert Dagunga (https://orcid.org/0000-0001-6835-6546)

References

Abiad, M. G., & Meho, L. I. (2018). Food loss and food waste research in the Arab world: A systematic review. *Food security*, *10*(2), 311-322.

Ahmed, H., & Anang, B. T. (2019). Does farmer group membership enhance technology adoption? Empirical evidence from Tolon district of Ghana. *Review of Agricultural and Applied Economics (RAAE)*, *22*(1340-2019-3700), 26-32.

AHPLIS (2021) Postharvest losses, https://www.aphlis.net/en/page/20/data-tables#/datatables?tab=dry_weight_losses&metric=prc&crop=6&country=279 Accessed on 14th February, 2021

Anaba, G. A. V. I. N. U. S. (2018). *Assessment of Postharvest*

Losses along the Fresh Tomato Value Chain in the Upper East Region of Ghana (Doctoral dissertation, University of Ghana).

Ansah, I. G. K., Ehwi, J., & Donkoh, S. A. (2018). Effect of postharvest management practices on welfare of farmers and traders in Tamale metropolis and Zabzugu District, Ghana. *Cogent Food & Agriculture*, *4*(1). https://doi.org/10.1080/23311932.2018.1475916

Ansah, I. G. K., Tetteh, B. K., & Donkoh, S. A. (2017). Determinants and income effect of yam postharvest loss management: Evidence from the Zabzugu District of Northern Ghana. *Food Security*, *9*(3), 611-620.

Asare, N. K. O. (2019). Farmers access to farm credit and its influence on cereal productivity in Ghana (Doctoral dissertation, University of Education, Winneba).

Atara, A., Tolossa, D., & Denu, B. (2019). Assessment of food security situation of the rural households: the case of Boricha Woreda of Sidama Zone, Ethiopia. *GeoJournal*, 1-17.

Ehiakpor, D. S., Danso-Abbeam, G., Dagunga, G., & Ayambila, S. N. (2019). Impact of Zai technology on farmers' welfare: Evidence from northern Ghana. *Technology in Society*, *59*, 101189.

Food and Agricultural Organization [FAO](2018). WFP and WHO: The State of Food Security and Nutrition in the World 2018. *Building climate resilience for food security and nutrition*, *200*.

Food and Agricultural Organization of the United Nations [FAO] (2016). Minimum dietary diversity for women: a guide for measurement. *Rome*

Gabriel, A. H., & Hundie, B. (2006). Farmers' post-harvest grain management choices under liquidity constraints and impending risks: Implications for achieving food security objectives in Ethiopia, Paper presented at the International Association of Agricultural ecnomists on 12-18th August, 2006, Queensland,Australia Doi: 10.22004/ag.econ.25716

Godfray, H. C. J., Beddington, J. R., Crute, I. R., Haddad, L., Lawrence, D., Muir, J. F.,Pretty, S. M., Sandy, M.T& Toulmin, C. (2010). Food security: the challenge of feeding 9 billion people. *science*, *327*(5967), 812-818.

GSS. (2014). *Population and Housing Census. District Analytical Report - Tolon District*

Ibrahim, H. I., Saba, S. S., & Ojoko, E. A. (2018). Postharvest loss in rice production: Evidence from a rural community in *northern Nigeria. Fudma Journal of Sciences, 2(1), 17-22.*

Kariuki, L. W. (2019). Effects of Adoption of Technology on Performance of Deposit Taking Sacco's: A Case of K-Unity Sacco, Kiambu County (Doctoral dissertation, United States International University-Africa)

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

Kikulwe, E. M., Okurut, S., Ajambo, S., Nowakunda, K., Stoian, D., & Naziri, D. (2018). Postharvest losses and their determinants: A challenge to creating a sustainable cooking banana value chain in Uganda. *Sustainability*, *10*(7), 2381.

Kumar, D., & Kalita, P. (2017). Reducing postharvest losses during storage of grain crops to strengthen food security in developing countries. *Food security*, *6*(1), 8.

Kunitou, J. (2017). Consumers' Preferences and Willingness to Pay for Certified Vegetables in Ouagadougou, Burkina Faso. *http://udsspace.uds.edu.gh/handle/123456789/1212*

Leroy, J. L., Ruel, M., Frongillo, E. A., Harris, J., & Ballard, T. J. (2015). Measuring the food access dimension of food security: a critical review and mapping of indicators. *Food and nutrition bulletin*, *36*(2), 167-195.

Marivoet, W., Becquey, E., & Van Campenhout, B. (2019). How well does the Food Consumption Score capture diet quantity, quality and adequacy across regions in the Democratic Republic of the Congo (DRC)?. *Food Security*, *11*(5), 1029-1049.

Minh, H. V. T., Avtar, R., Mohan, G., Misra, P., & Kurasaki, M. (2019). Monitoring and mapping of rice cropping pattern in flooding area in the Vietnamese Mekong Delta using Sentinel-1A data: a case of an Giang Province. *ISPRS International Journal of Geo-Information*, *8*(5), 211.

Mukarumbwa, P., Mushunje, A., Taruvinga, A., Akinyemi, B., & Ngarava, S. (2017). Factors influencing number of post-harvest practices adopted by smallholder vegetable farmers in Mashonaland East Province of Zimbabwe. *International Journal of Development and Sustainability*, *6*(11), 1774-1790.

Ngema, P. Z., Sibanda, M., & Musemwa, L. (2018). Household food security status and its determinants in Maphumulo local municipality, South Africa. *Sustainability*, *10*(9), 3307.

Nkegbe, P. K., Abu, B. M., & Issahaku, H. (2017). Food security in the Savannah Accelerated Development Authority Zone of Ghana: an ordered probit with household hunger scale approach. *Agriculture & Food Security*, *6*(1), 35.

Quaye, W. (2008). Food security situation in northern Ghana, coping strategies and related constraints. *African journal of agricultural research*, *3*(5), 334-342.

Sawicka B (2019). Postharvest losses of agricultural produce. In *Zero hunger. Encyclopedia of the UN Sustainable Development Goals*. Available at: https://.doi:10.1007/978-3-319-69626-3_40-1

Taiwo, A., & Bart-Plange, A. (2016). Factors responsible for post-harvest losses and their effects on rice producing farmers: A case study of Afife and Aveyime rice projects in the Volta region of Ghana. *International Research Journal of Engineering and Technology (IRJET) e-ISSN*, 2395-0056.

Tanye, R. (2016). The effects of yam postharvest losses on food security in the kintampo municipality of the Brong Ahafo Region of Ghana (Doctoral dissertation) http://udsspace.uds.edu.gh/handle/123456789/879

Temesgen, F., Emana, B., Mitiku, F., & Gobana, E. (2017). Application of multivariate probit on determinants of sesame farmers market outlet choices in Gimbi District, Ethiopia. *African Journal of Agricultural Research*, *12*(38), 2830-2835.

Weinberger, K. (2009). *Postharvest Training for Supply Chain Actors in Cambodia, Laos, and Vietnam* (Vol. 9, No. 717). AVRDC-WorldVegetableCenter.

WFP. (2008). “Food Consumption Analysis, Calculation and Use of the Food Consumption Score in Food Security Analysis.” Rome: World Food Programme, Vulnerability Analysis and Mapping Branch (ODAV).

WFP. (2012). Comprehensive Food Security & Vulnerability Analysis GHANA 2012 Focus on Northern Ghana. (May)

Yamane, T. (1967). *Statistics ; An Introductory Analysis*. *2nd Edition*. http://www.sidalc.net/cgibin/wxis.exe/?IsisScript=bac.xis&method=post&formato=2&cantidad=1&expresion=mfn=033304