Effects of using post-harvest management technologies on household food security in Dodoma Region, Tanzania

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ABSTRACT

In Dodoma Region, Tanzania, the adoption of grain post-harvest management technologies remains low despite their importance for food security. This study, conducted in Kongwa and Chemba Districts between December 2022 and March 2023, analyses effects of using grain post-harvest management technologies and household food security. The specific objectives were to determine household food security status, analyse postharvest management technologies used for maize and sorghum, compare household food security status based on grain post-harvest management technologies used, and determine effects of grain post-harvest technologies and other factors on chances of being food secure. Data were collected from 384 households using a questionnaire, a key informant interview guide, and a guide for focus group discussions. They analysed using IBM SPSS Statistics software to compute descriptive and inferential statistics. Results showed that 52.1% of households were food insecure based on grain consumption, and 43.5% were food insecure based on the Household Food Insecurity Access Scale (HFIAS). Use of improved post-harvest technologies varied across activities, but no significant food security differences were found between users and non-users of improved postharvest technologies. However, food security was significantly different between households whose heads had different levels of education, between households which had different farm sizes, and between smaller and larger households. Binary logistic regression results showed mixed results that household size had significant negative effect on the chances of being food secure, based on amounts of grains consumed but that it had insignificant positive effect on the chances of being food secure, based on HFIAS. Tractor use and group membership had positive significant positive effects on the chances of being food secure, based on amounts of grains consumed. Processing grains and years of schooling had significant positive effects on the chances of being food secure, based on HFIAS. It is concluded that working on the variables that had significant negative effects on the chances of being food secure—household size, age of household head, and land ownership could help increase chances of smallholder farmers being food secure. Such chances could also be increased by keeping up the variables that had significant positive effects on the chances of being food secure—tractor use, being members of farmer groups, improved grain processing means, and education (formal and non-formal). It is recommended to Kongwa and Chemba Districts to promote the use of postharvest technologies analysed and others that are relevant so that more farmers can use them, thereby improving food security. Farming households should join farmer groups, and the agricultural extension service should increase provision of education to farmers on why and how to use the technologies and collaborate with suppliers of the technologies so that they could supply them at more reasonable prices.

Keywords: Grains, Household Food Security, HFIAS, Post-Harvest Management Technologies

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I. INTRODUCTION

Household food security is an important component of well-being, as food is a basic human necessity and a prerequisite for survival, growth, and good health. Hence, being free from hunger is one of the most fundamental human rights that can be satisfied in the context of food security (Food and Agriculture Organization [FAO], 2013). The World Food Summit 1996 defined food security as the ability of all people at all times to have physical and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life (FAO, 2009). The converse of food security is food insecurity, which can be defined as the lack of physical, social, and economic access to adequate food to meet nutritional needs and food preferences necessary to lead active and healthy lives (Campbell, 1991).

Although there has been some progress in food security, improvement has been uneven and insufficient, thus necessitating concerted efforts towards zero hunger. This is to say, the world is far off track to achieving Sustainable Development Goal Number Two (SGD 2): zero hunger. In addition, the level of undernourishment worldwide remained almost unchanged for three consecutive years (2021 - 2023), following a steep increase in food insecurity during the COVID-19 pandemic from December 2019 to the early 2020s (FAO *et al*., 2024). In 2022, about 9.2% of the world's population was facing chronic hunger, equivalent to about 735 million people, which is 122 million people more than in 2019 (United Nations [UN], 2023). An estimated 29.6% of the global population, amounting to 2.4 billion people, were moderately food insecure, that is, they did not have access to adequate food. This number indicates a startling 391 million additional individuals than in 2019.

About Africa, despite having good vast arable land, a 2022 global report indicates that at least one in five Africans slept hungry while an estimated 140 million people faced acute food insecurity (Food Security Information Network, 2022). In Tanzania, like in many other sub-Saharan African countries, food security is not static due to rain-fed dependent agricultural production. In this case, food security status keeps changing from season to season, depending on the amount of rain. For example, the Global Hunger Index 2023 report indicates that from November 2023 to April 2024, about 900,000 individuals, representing 13% of the population of 7.1 million in 21 districts of Mainland Tanzania, were facing significant acute food insecurity (United Republic of Tanzania [URT], 2023a). Specifically, Dodoma Region was ranked number one with a severe prevalence of insufficient food consumption in 2023 (URT, 2023b)

The issue of food insecurity has been lingering on in many sub-Saharan countries, including Tanzania, and several strategies have been initiated to deal with the situation. For instance, in 2015, the United Nations introduced a Sustainable Development Goal (SDG) to respond to persistently high levels of food insecurity in many low and middle-income countries, aiming at eliminating hunger and malnutrition worldwide by 2030 (UN, 2015). Particularly, goal number 2 aims to "end hunger, achieve food security and improved nutrition and promote sustainable agriculture by 20230". Towards meeting that goal, Tanzania works with other development partners such as the World Food Programme (WFP), UN agencies, NGOs, donors and the private sector to improve food security in Tanzania. The national five-year development plan 2021/22-2025/26 emphasizes the improvement of agricultural production by introducing modern crop management systems and increasing storage capacity to eliminate hunger. In addition, in recent years, various grain post-harvest management technologies including hermetic storage bags, metal silos, and airtight containers have been introduced in Dodoma and other regions of Tanzania. These innovations aim to help farmers reduce post-harvest losses, preserve grain quality, and extend storage duration, ultimately contributing to greater food security. Due to the above interventions in Tanzania, food self-sufficiency reached 118% as food crop production continued to increase (URT, 2021).

1.1 Statement of the Problem

Despite Tanzania's efforts to increase food production, some regions in Tanzania are still behind the national food security benchmark. Dodoma is one of the regions; it has been reported to have recurrent and chronic food insecurity (Assenga & Kayunze, 2020; Mkonda & He, 2017; Reincke *et al*., 2018). Moreover, post-harvest losses continue to undermine food availability and stability at the household level due to continued use of rudimentary post-harvest technologies, particularly at the storage stage. Although improved post-harvest technologies are now available, their application is still uneven, and their impact on household food security is not fully understood. There is inadequate information regarding how different grain post-harvest management practices affect households' food security conditions across regions. This gap hinders the ability of policymakers, development practitioners, and local stakeholders to design targeted interventions that enhance food security outcomes. Therefore, it is essential to investigate the variation in household food security based on the types and effectiveness of grain post-harvest management technologies used and other factors in Dodoma Region.

1.2 Research Objectives

The specific objectives of this paper were to determine household food security status in terms of amounts of grains consumed per household per year and using the Household Food Insecurity Access Scale (HFIAS), analyse postharvest management technologies used for maize and sorghum, compare household food security status based on grain post-harvest management technologies used, and determine effects of grain post-harvest technologies and other factors on chances of being food secure. Determining the amounts of grains consumed per household per year and using HFIAS is essential because they can provide complementary information on household food security. Therefore, both methods were used to determine food security. Amounts of grains consumed measure what people are eating, while HFIAS reveals how people feel about their access to food. Besides the objectives, the null hypotheses stated below were tested.

1.3 Research Hypotheses

H_{01}: Food security status does not differ significantly between households which use improved grain postharvest technologies and those which use unimproved grain postharvest technologies.

H_{02}: Food security status does not differ significantly between households with and without some factors which are not grain postharvest technologies.

H_{03}: Grain post-harvest technologies do not have significant effects on the chances of being food secure.

H_{04}: Non-grain post-harvest technologies factors do not have significant effects on the chances of being food secure.

II. LITERATURE REVIEW

2.1 Theoretical Review

This paper was guided by the Sustainable Livelihood Theory (SLT), the Diffusion of Innovation Theory (DOI), and the Entitlement to Food Theory. These theories complemented each other in this paper**.**

2.1.1 The Sustainable Livelihood Theory

The theory primarily focuses on how households use many forms of capital—human, natural, financial, social, and physical assets—to achieve sustainable livelihoods and increase resilience. The theory was developed by Robert Chambers and Gordon Conway in 1991, who propounded that a livelihood comprises the capabilities, assets (stores, resources, claims, and access), and activities required for living (Chambers & Gordson, 1991). In this paper, human capital is indicated by household size and hired labour in agricultural production; natural capital is indicated by the amount of land owned; financial capital is indicated by access to credit and cash earnings from agriculture and other income-generating activities; social capital is indicated by group membership; and physical capital is indicated by use of technologies to produce, transport, process/thresh, dry, and store grains harvested. Using better assets and improved technologies is expected to contribute to improving household food security.

2.1.2 Diffusion of Innovations Theory

The theory is useful for studying how innovations, in this case improved grain postharvest management technologies, are accepted and used by households. According to Rogers (1962), the diffusion of agricultural technologies results in increased productivity, ultimately leading to an improved living standard among farming communities. The theory is also applicable to identifying factors that promote or hinder the adoption of improved postharvest management technologies among small-scale farming households. Socio-demographic factors such as gender, age, and education level were considered to have a relationship with the adoption decision.

2.1.3 The Entitlement to Food Theory

The main contention of the entitlement to food theory is: “People do not usually starve because of an insufficient supply of food at the local, national or international level, but because they have insufficient resources, including money ('entitlements') to acquire it” (Sen, 1981). Sen classified entitlements into three categories of endowments, which are (i) all legal resources that can be used to obtain food, including money, land, machinery and animals, but also more abstract resources such as labour power, “know how”, kinship and citizenship; (ii) entitlement mapping which includes terms of trade between endowments and food, goods, and the ratio between money wages and the price of food, or the input-output ratios in farm production; and (iii) entitlement-set, which represents the basket of food, goods, and services that a person can obtain using his/her endowments.

Other scholars (for example, Burchi & De Muro, 2016; Seaman et al., 2014) have also explained the entitlement to food theory, that it explains how households can use various entitlements such as income, assets, and access to markets, rather than solely relying on food availability. Good access to these items helps improve food security through buying food using income from other sources, producing food on own land using agricultural technologies and other inputs, and getting good price from food items produced. Therefore, integrating SLT, DOI and the entitlement to food theory provided a comprehensive framework for understanding the relationship between grain postharvest management technologies and household food security in Dodoma Region. Every theory offers a distinct viewpoint that complements each other, assisting in the analysis of complex relationships between food security and technology adoption.

2.2 Empirical Review

Several studies have investigated the relationship between the use of improved grain postharvest technologies and household food security (Kotu et al., 2019, 2023; Lawrence, 2022; Mutungi et al., 2023; W. Tesfaye & Tirivayi, 2018). For instance, according to Kotu et al. (2019), improved storage technologies, such as PICS bags or Polypropylene (PP) bags plus Actellic Super, are useful in addressing food security and income objectives among poor rural households. In addition, Kotu et al. (2019) found that mechanized shelling, drying tarpaulins, and airtight storage reduced postharvest losses in Tanzania's maize-based systems, and impacts on households' food security and welfare. Tesfaye & Tirivayi (2018) found that the use of improved storage technologies enhanced food and nutrition security and could play a key role in alleviating the challenges of feeding a growing population.

On the same note, storage is an important stage in ensuring the quantity and quality of stored grains, hence food security. Therefore, improved storage technologies have been reported by several scholars to be effective in reducing storage losses (Baoua et al., 2014; Chigoverah & Mvumi, 2016; Mwageni et al., 2022; Williams et al., 2017). Accordingly, William et al (2017) encourage small-scale farmers to use improved storage technologies, specifically PICs bags as they have been found to be effective at reducing postharvest losses. Chigoverah and Mvumi (2016) found that storing grains in hermetic bags could be an effective pesticide-free alternative to synthetic pesticides in reducing grain storage losses under smallholder farming conditions, even where pest infestations occur.

On the other hand, non-grain postharvest management technologies; such as household head age, household size, sex of the household head, size of the farm, and group membership; have also great contribution to household food security as reported by various scholars (Akello & Mwesigwa, 2023; Bokusheva et al., 2012; Drammeh et al., 2019; Khanam et al., 2020; Kumba, 2015; Niles et al., 2021; Owach et al., 2017; Rashid et al., 2024). According to Drammeh et al. (2019), household head characteristics have a different impact on food security. Moreover, with regard to household size, larger families are more likely to face food insecurity and place additional strain on food consumption than smaller ones. Also, age of household head was another factor reported by Drammeh et al. (2019) to affect food security; an increase in household head's age reduces food production and has an adverse effect on household food security. With regard to group membership, Niles et al. (2021) reported household group memebership to be associated with more than 10% reduction in average months of food insecurity, an effect moderated by community social network type.

2.3 Conceptual Framework

The conceptual framework in Figure 1 shows relationships between using improved postharvest management technologies and food security. Households which use improved postharvest management technologies could benefit from increase in grain quantity due to loss reduction, better grain quality, and increased income which in turn improve household food security.

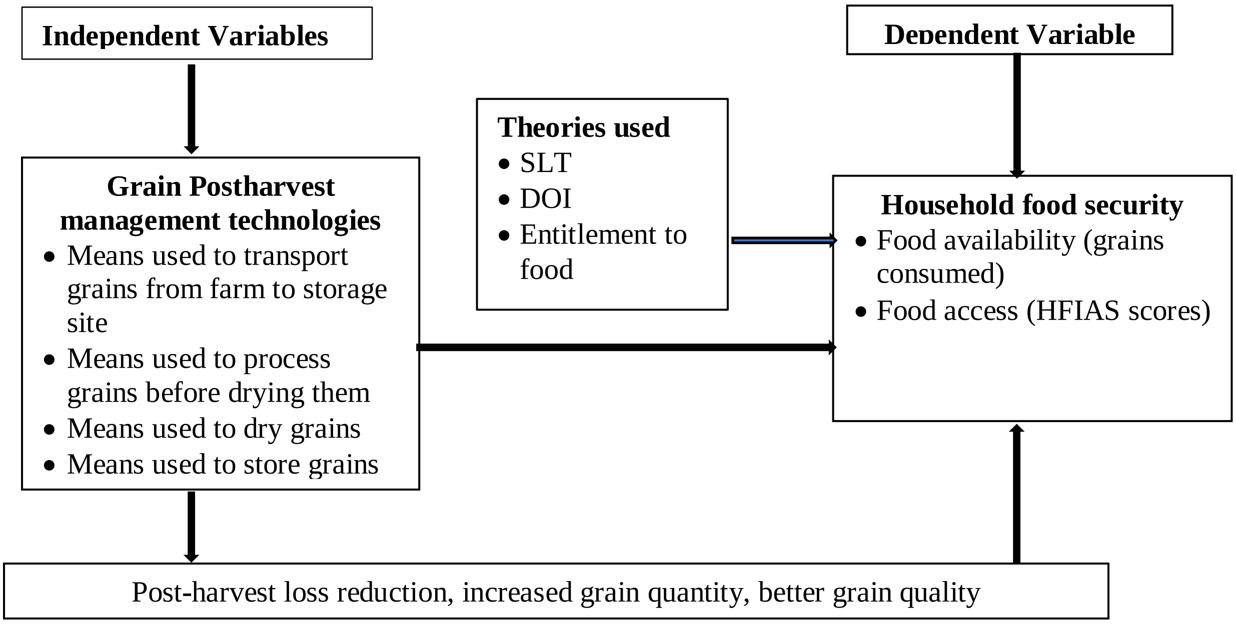

Figure 1
Conceptual framework for the study on which this paper is based

III. METHODOLOGY

A cross-sectional research design was used to collect primary data in Dodoma Region, Tanzania, from December 2022 to March 2023 for a PhD study, covering the 2021/22 agricultural season, i.e. July 2021 to June 2022. The region is located in the central part of Tanzania between latitudes 3° 82 and 6° 57' South of the equator and between longitudes 36° 26' and 35° 26' East of the Greenwich Meridian. The region has six districts: Bahi, Chamwino, Chemba, Kondoa, Kongwa, and Mpwapwa. The region has a surface area of 41,311 km^2 and its headquarters are in

Dodoma City. The region shares borders with four regions: Manyara, Iringa, Singida, and Morogoro. The population of the region was reported to be 3,085,625 in 2022 (URT, 2022). The region is primarily semi-arid and hence characterised by irregular and unimodal rainfall, which normally falls from November or December to April or May. Agriculture is the major means of livelihood, with both cash and food crops being grown in the area. The main food crops grown are maize, sorghum, millet, rice, pulses, cassava and potatoes, while the main cash crops grown are grapes, mangoes, baobab trees, and oil seeds (sunflower, groundnuts, and simsim).

A sample of 384 households was determined by being calculated based on Cochran's (1977) formula, which is $\boldsymbol{n_0} = \frac{z^2pq}{e^2}$, where: $\boldsymbol{n_0}$ is the sample size; z is the selected critical value at the 95% confidence level, which is 1.96; p is the estimated proportion of an attribute that is present in the population, normally 0.5; q = 1-p, i.e. 0.5; and e is the desired level of precision, normally 0.05. Therefore, $\boldsymbol{n_0} = \frac{z^2pq}{e^2}$ = (1.962*0.5*0.5)/(0.05*0.05) ≈ 384. Proportionate stratified sampling was used to select households that participated in the study. Different numbers of wards and villages were selected to avoid underrepresentation of wards and villages with more households as well as avoiding overrepresentation of wards and villages with fewer households. Stratification of the respondent households was also based on wards, villages, and male and female household headship. This was done by first listing wards, villages, and male-headed households (MHHs) and female-headed households (FHHs) separately with the assistance of local leaders. Then, in each village, random numbers were generated for MHHs and FHHs in MS Excel using the Rand() command (http://tibasicdev.wikidot.com/68k:rand). The households whose serial numbers corresponded with the random ones that were generated were selected. The research was a mixed-methods study whereby data were collected through a structured questionnaire, key informant interviews (KIIs), and focus group discussions (FGDs) for triangulation of data collection methods. The tools were in English but, since the researcher and research assistants had good knowledge of both English and Kiswahili, Kiswahili was used to administer the tools. The information that was collected using the three types of tools was about main postharvest management technologies used for grains and household food security status, in line with the specific objectives of the study.

Food security was measured in two different ways: food availability and food access. Food availability was measured in terms of kilogrammes of maize consumed from own harvests and from purchasing per capita per year. Maize was used because it is the most important staple food in the research area. Food access was measured in terms of vulnerability to inadequate access to food, using the Household Food Insecurity Access Scale (HFIAS), emulating (Coates *et al*., 2007). The HFIAS was developed between 2001 and 2006 by the USAID-funded Food and Nutrition Technical Assistant Project (FANTA) employing a set of general questions called household food insecurity access scale questions. The questions can accurately distinguish food secure from food insecure households. Using the HFIAS, household representatives are asked to respond positively or negatively to nine questions each of which is about an undesirable incident of access to food in the previous four weeks. For each question with an Yes answer, the respondents are asked to specify the frequency of occurrence of the incident and are required to respond either Rarely (once or twice in the past four weeks = 1 point), Sometimes (three to ten times in the past four weeks = 2 points), or Often (more than ten times in the past four weeks = 3 points). Therefore, the maximum possible score on the scale is 27 points, if one answers Yes and Often to all the questions, fewer points meaning higher food security. Households whose representatives answer No and those who answer Yes and Rarely are regarded to be food secure.

The questions on the HFIAS address three main key domains: Anxiety and uncertainty about food supply for instance worrying about not having enough food, insufficient quality food like eating monotonous or less preferred food items, and insufficient quantity such as reducing meal sizes or skipping meals. Therefore, the HFIAS tool is primarily used to evaluate how well households can economically access food, their food preferences, concerns about food supply, and the amount of food available. All age groups were considered in the HFIAS analysis. HFIAS has four indicators of household food insecurity, namely, household food insecurity access-related conditions, household food insecurity access-related domains (HFIAD), household food insecurity access prevalence (HFIAP), and household food insecurity access score.

The data were analysed using IBM SPSS Statistics software whereby frequencies, percents and descriptive statistics of individual variables were computed. The descriptive statistics included measures of central tendency (means and medians) and measures of dispersion (minimum and maximum values, range values, and standard deviations). The frequencies and percents included statistics about households that used various postharvest management technologies for maize and sorghum. Moreover, for the third specific objective of this paper, inferential analysis was done using Mann-Whitney U test to compare food security status (amounts of grains consumed per capita per year and points scored on the HFIAS scale that were proxy indicators of food security). Mann–Whitney U test is a non-parametric test which is used when the test variable is not normally distributed; it is equivalent to an independent samples t-test in parametric analysis when the test variable is normally distributed. Both Mann–Whitney U and independent samples t-tests are used for with and without comparisons. In this paper, the grouping variables were improved and unimproved means of grain transportation, processing, drying, and storage. The test variable was food security status, which was indicated by grains consumed per capita per year and points scored over 27 on the

Household Food Insecurity Access Scale (HFIAS), both of which were skewed to the right as indicated by normal distribution curves that were computed to check the normality. The right tails of the curves were longer than the left ones. Due to the skewness, the Mann-Whitney U test was used instead of the independent samples t-test.

For the fourth specific objective, binary logistic regression was used to determine the effects of grain post-harvest technologies and non-grain post-harvest technologies factors on the chances of households being food secure. The outcome variable was food security, and the predictor variables were grain post-harvest technologies and non-grain post-harvest technologies factors. Both the outcome and predictor variables are defined in Table 1.

Table 1

Variables Included in the Binary Logistic Regression Model

Variables	Definitions	Measurement
Outcome variable		
Food security	Food availability (grains consumed per capita per year)	Food insecure = 0, Food secure 1
	Food access (Scores on the HFIAS scale)	Food insecure = 0, Food secure 1
Predictor variables		
Transport means	Transporting grains from farm to storage site	Unimproved = 0, Improved = 1
Processing means	Shelling grains before drying them	Unimproved = 0, Improved = 1
Drying means	Drying grains	Unimproved = 0, Improved = 1
Storing means	Storing grains	Unimproved = 0, Improved = 1
Sex	Being male or female biologically	Female = 0, Male = 1
Age	Years since the household head was born	Actual years, continuous
Household size	All members in the household	Actual years, continuous
Land ownership	Whether they owned land	Didn't own = 0, Owned = 1
Tractor use	Whether used a tractor or a hand hoe	Hand hoe = 0, Tractor = 1
Types of seeds used	Whether used improved or local seeds	Local = 0, Improved = 1
Fertiliser use	Whether any kind of fertilizer was used	Didn't use = 0, Used = 1
Group membership	Whether they were farmer groups members	Non-member = 0, Member = 1

Each of the two indicators of food security was regressed on the same predictor variables to determine which of them had negative or positive and significant or insignificant effects on the chances of being food secure. The binary logistic regression equation was specified in accordance with Agresti and Finlay (2009), as follows:

$$P\ (y) = \frac{e^{\alpha + \beta 1x1 + \ldots \beta kxk}}{1 + e^{\alpha + \beta 1x1 + \ldots \beta kxk}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where:

$P\ (y)$ = the probability of the success alternative occurring, in this case being food secure,

e = the base of the natural logarithm (approximately 2.718),

α = the intercept of the equation,

β_1 to β_k = coefficients of the predictor variables listed in Table 1, and

x_1 to x_k = the predictor variables listed in Table 1.

IV. FINDINGS & DISCUSSION

4.1 Household Food Security Status Based on Amounts of Grains Consumed

Grains were used to determine food security because the amount consumed per capita per year for a household to be considered food secure is well established as 135 kg (Mtaki & Snyder, 2023). In Tanzania, maize consumption ranges from 52 to 328 g per person per day (Ranum & Pe, 2014). Among the respondents, during the agricultural season 2021/22, which the research covered, 372 (98.2%) produced maize; 35 (9.2%) produced sorghum; and 6 (1.6%) produced bulrush millet. Accordingly, the main type of grain the respondents consumed was maize, as also supported by literature, which states that maize is the main staple food in Tanzania and provides about 80% of dietary calories and 8 to 11% of utilizable protein to the population (Mtaki & Snyder, 2023). Also, maize is among the priority crops in Tanzania, important for ending hunger and achieving food security (URT, 2016).

The amounts of maize obtained from own harvests and bought for consumption were added up because normally farmers in the research area sell some maize from the amounts harvested and later in the same agricultural season buy maize for home consumption (Abass *et al*., 2014; Mather *et al*., 2013). Based on that method, the average amount of maize consumed was 189.8 kg per capita per year, while the minimum and maximum amounts were 13.3 kg and 940.0 kg, respectively. More than half of the respondents (200 = 52.1%) consumed at least 135 kg per capita per year, but 184 = 47.9% of the respondents consumed less than that amount. Based on those amounts of grains consumed, 52.1% of the households were food secure, while 47.9% were food insecure.

4.2 Household Food Security Status Based on Household Food Insecurity Access Scale

Using HFIAS classification, food secure households were those whose household members had not been worried that they would not have enough food and where they had rarely been worried about the same in the previous four weeks (Coates et al., 2007). Based on this classification, 217 (56.5%) and 167 (43.5%) of the households surveyed were food secure and food insecure, respectively. More households were food secure in Kongwa District (60.7%) compared to Chemba District (50.9%), but there was no significant association between district of residence and being food secure (Chi-square = 3.694, p = 0.055, Phi = 0.098). Also, there was no significant association between other socio-demographic variables and food security status, based on the HFIAS scale, as seen in Table 2. The Phi-statistic measures the strength of association and is interpreted as follows: Lowest to 0.10 means low strength of association; 0.11 to 0.30 means moderate strength of association, and more than 0.3 means high strength of association (Balakrishnan *et al*., 2015).

Table 2

Association between Some Socio-Demographic Variables and Food Security Based on Points Scored on the HFIAS

Explanatory variable		**Food security Status***		**Chi-square**	**Sig. (2-sided)**	Phi
		Food secure (%)	**Food insecure (%)**			
District	Kongwa (219)	60.7	39.3	3.694	0.055	0.098
	Chemba (165)	50.9	49.1			
Household headship	Male (307)	55.0	45.0	1.331	0.249	0.059
	Female (77)	62.3	37.7			
Household head's age	Younger (< 36 years)	56.8	43.2	0.002	0.962	0.002
	Older (35 > 35 years)	56.5	43.5			
Household size	Smaller (1 to 4) members	58.2	41.8	1.041	0.307	0.052
	Larger (5 and more members)	52.6	47.4			
Group membership	Member	50.9	49.1	3.601	0.058	0.097
	Non-member	60.6	39.4			

*No to 1 and Yes Rarely to 1a items of the scale

4.2 Postharvest Management Technologies Used for Maize and Sorghum

The postharvest management technologies analysed in this paper for maize and sorghum were means used to transport harvests from farm to storage site, means used to process grains before drying them, means used to dry the grains, and means used to store grains as summarized in Table 3.

Table 3

Households that used various Postharvest Technologies

Technologies used	**Kongwa**				**Chemba**				**All**			
	Improved*		**Unimproved****		**Improved**		**Unimproved**		**Improved**		**Unimproved**	
	n	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**
Transporting grains from farm to storage site	49	22.9	165	77.1	51	32.1	108	67.9	100	26.8	273	73.2
Processing grains before drying them	145	68.4	67	31.6	116	72.5	44	27.5	269	70.1	115	29.9
Drying grains	5	2.4	207	97.6	2	1.3	158	98.8	7	1.9	365	98.1
Store grains	89	42.0	123	58.0	103	64.4	57	35.6	192	51.6	180	48.4

* and ** as defined in the text below

With regard to means used to transport crop harvests from farm to storage sites, those who used donkeys, oxen, or bicycles were regarded to be using unimproved technologies, and those who used tricycles, motorcycles, and power tillers were regarded to be using improved technologies. The results showed that 100 (26.8%) households' used improved means for transporting crop products from their farms to storage sites, while 273 (73.2%) used unimproved methods. With regard to processing grains, particularly maize, before drying it, those who shelled maize from their cobs by hand or by putting the cobs in bags and hitting them with sticks were considered to be using unimproved technologies, while those who used shelling machines were considered to be using improved technology. The results indicated that 269 (70.1%) of the households used improved technology in processing their produce, while 115 (29.9%) used unimproved technology.

With regard to drying grains, those who dried grains by spreading them on the ground, getting them aerated in the farm or leaving them on farm to dry were regarded to be using unimproved technologies, while those who dried grains on tarpaulins were regarded to be using improved technology. The results indicated that only 7 (1.9%) used improved technology for drying grains, whereas 365 (98.1%) used unimproved methods. With regard to grain storage, those who used granaries or polypropylene bags were regarded to be using unimproved technologies, while those who used airtight containers (jerry canes and drums), Purdue improved crop storage bags (PICS) and improved silo were regarded as using improved technologies. The results showed that 192 (51.6%) of the households used improved technologies, whereas 180 (48.4%) used unimproved technologies.

The above postharvest management used has implications for food security; therefore, the use of improved technologies in the postharvest chain is important for enhancing household food security. This is attributed to the fact that improved postharvest management technologies in transportation, processing, drying, and storage could help reduce food loss, which could, in turn, enhance food security. Several scholars have also reported on the advantages of using improved postharvest management technologies for food security. For example, Jarman *et al.* (2023) found that improved technologies; such as better storage facilities, packaging, and transportation methods; significantly reduced spoilage and waste during the postharvest period. This is advantageous as it leads to a reduction of food losses, enhances food quality and safety, increases economic value, and promotes sustainable agriculture, generally contributing to sustainable agriculture (Jarman *et al*., 2023). Using improved technologies is also important for increasing food accessibility by enhancing availability and improving household income, both of which are important dimensions of food security (Alais & Magoti, 2023; Geoffrey *et al*., 2025).

4.3 Differences in Food Security by Use of Improved Grain Postharvest Technologies

As explained in the methodology, differences in food status (amounts of grains consumed per capita per year and points scored on the HFIAS scale that were the proxy indicators food security) were determined using Mann–Whitney U test. The results are presented in Table 4.

Table 4

Differences in Food Security by use of Improved Grain Postharvest Technologies

Technologies used and other factors	**n**	**Grains consumed per capita per year**				**n**	**Overall points scored over 27 on the HFIAS scale**			
		Mann-Witney U test statistic (U)	**Standardized test statistic (z)**	**p-value**	**Effect size = $\frac{z}{\sqrt{n}}$**		**Mann-Witney U test statistic (U)**	**Standardized test statistic (z)**	**p-value**	**Effect size = $\frac{z}{\sqrt{n}}$**
Means used to transport crop harvests	363	13,472.5	0.745	0.457	0.04	367	12,906.5	-0.306	0.760	-0.02
Means used to process grains	372	14,133.5	-0.371	0.711	0.02	377	15,836.5	0.793	0.428	0.04
Means used to dry grains	372	1,077.5	-0.7310	0.478	0.04	377	1,506.5	0.742	0.458	0.04
Methods to store grains	372	16,581.5	-0.674	0.500	0.03	377	16,902.0	-0.804	0.421	0.04
Sex of household head	372	10,920.500	-0.392	0.695	-0.02	377	11,339.5	-0.116	0.907	-0.10
Owning smaller or larger farmland	369	21,287.5***	4.182	0.000	0.22	374	18,247.5	0.762	0.446	0.04
Use of hand hoe or tractor	372	8,762.0	-1.097	0.273	-0.06	377	9,806.5	-0.264	0.917	-0.01
Household size (Smaller vs larger)	307	2,060.0***	-7.359	0.000	-0.42	313	6,113.0	-0.611	0.541	-0.03
Which kind of seeds did you plant	369	11,063.5	0.181	0.856	0.01	374	11,376.0	0.332	0.740	0.02
Used fertilizers (Yes vs No)	371	13,484.500	1.532	0.126	0.08	376	12,291.500	-0.316	0.752	-0.02

*Medians were significantly different at the 5% level; ***Medians were significantly different at the 0.1% level.

The results in the table 4 indicate that food security status based on grains consumed per capita per year and on overall points scored on the HFIAS scale did not differ significantly by any grain postharvest management technology used, which is indicated by all the p-values being greater than 0.05. Therefore, the null hypothesis that "food security status does not differ significantly between households which use improved grain postharvest technologies and those which use unimproved grain postharvest technologies" was accepted**.** However, opposite results were expected. The plausible explanation for the unexpected results is the presence of other factors such as household head's sex, age, and years of schooling; household size; land ownership; tractor or hand hoe use; types of seeds used; fertiliser use; and farmer group membership. Other factors which might be more associated with food security than postharvest technology factors are household income, climatic conditions, access to the market, and health conditions of the household head. Another explanation is that few households used the improved postharvest technologies studied.

According to these results, it is not automatic that once households use improved postharvest management technologies they become more food secure than those that do not use them, albeit their use of those technologies can reduce postharvest losses. The effect size values are interpreted as follows: < 0.3 is a small effect size; 0.3 and above is a medium effect size; and 0.5 and above is a large effect size (Funder & Ozer, 2019). The effect size values show the magnitudes of the effects of the explanatory variables on the response variable (food security status in this paper).

Several reasons for not using improved postharvest management technologies were captured during focus group discussions. One of the reasons was high cost of acquiring improved postharvest management technologies. Another reason was lack of training which would give the farmers knowledge and information about the advantages of postharvest management technologies. Technical challenges on using the technologies was also another challenge as to why the farmers had little knowledge about how to use them. Various scholars also support this by arguing that there is low adoption and use of improved postharvest management technologies due to several reasons such as inadequate awareness by many farmers on the benefits of such technologies or lack of the skills to use them effectively. Also, limited access to extension services which provide information and training is a barrier to adoption of new technologies (Mutungi *et al*., 2023; Mwageni *et al*., 2022).

Unlike the differences in food security based on postharvest technologies used that were not significantly different, there were significant differences in food security between smaller and larger households. The results in Table 4 show that the difference in food security based on grains consumed per capita per year by household size was significant with a negative effect size (U = 2,060.0, p = 0.000, r = -0.42). The negative effect size in this case means that the bigger the household size the lower food security was. Another grouping variable by which there were significant differences in food security was size of farmland owned (U = 21,287.5, p = 0.000, r = 0.22). The positive effect size in this case means that the bigger the farmland size the higher food security was. Other scholars, including Akello & Mwesigwa (2023), Assenga & Kayunze (2020), and Mutisya *et al*. (2016), have reported similar findings on the association between socio-demographic variables and household food security. Smaller households were more food secure than larger households, regardless of larger households having more sources of labour for agricultural activities. This is attributed to the fact that larger households have more mouths to feed; so, the total food requirement increases, and they may not have enough land for production. Thus; limited land, income, or food may be spread thinly across more people.

In addition, the household may struggle to meet other necessities such as health, education, and shelter, as not all members may be able to contribute equally to labour or income; that is the household may be overburdened by their dependent members, such as the elderly, children, and the sick. Other scholars (Akello & Mwesigwa, 2023; Rashid *et al*., 2024) had the same findings that larger households are more food insecure than smaller ones. Therefore, the second null hypothesis that "Food security status does not differ significantly between households with and without some factors which are not grain postharvest technologies" was rejected**.**

4.4 Effects of Postharvest Technologies Use and Other Factors on Food Security

As pointed out just under Table 1, using binary logistic, each of the two indicators of food security was regressed on the same predictor variables to determine which of the predictor variables had positive or otherwise and significant or otherwise effects on chances of being food secure. The results were as showed in Table 5.

The diagnostic test results in Table 5 are mixed. The overall Wald statistic (0.609) that was not significant (p = 0.435) means that the overall model was not well predicting the outcome as the p-value was not significant, while the one that was 7.560 (p = 0. 006) shows that the model well predicted the outcome as it was significant. The chi-square values for the Omnibus Tests of Model Coefficients that were significant in both cases (p = 0.000 and p = 0.010) mean that the overall model well predicted the outcome. The Hosmer and Lemeshow Test chi-square values that were not significant (p = 0.761 and p = 0.904) mean that the predictors well predicted the outcome variable. For the Hosmer and Lemeshow test results, a large chi-square statistic as well as a small p-value < 0.05 suggests poor fit, while a small chi-square statistic as well as a large p-value > 0.05 indicates a good fit. The -2 Log likelihood (-2LL) values that were much higher than 0 (298.641 and 476.188) mean that the model was not well fitting the likelihood that was determined. The -2LL is a measure of how well the estimated model fits the likelihood. It ranges from 0 to +infinity, is normally negative, and values closer to zero indicate a better fitting model. For the variables in the equation based on kilograms of grains consumed, the Cox & Snell R Square that was 0. 437 and theNagelkerke R Square that was 0.584 mean that the predictor variables entered in the model were able to predict about 43.7% (i.e. 0.437 x 100) to 58.4% (i.e. 0.584 x 100) of the variance of the outcome variable. For the variables in the equation based on the HFIAS scale, the Cox & Snell R Square that was 0.072 and the Nagelkerke R Square that was 0.097 mean that the predictor variables entered in the model were able to predict about 7.2% to 9.7% of the variance of the outcome variable.

Table 5

Effects of Postharvest Technologies use and other Factors on Food Security

Variables in the Equation	**Variables in the equation based on kg of grains consumed**				**Variables in the equation based on the HFIAS scale**			
	B	**Wald**	**Sig.**	**Exp(B)**	**B**	**Wald**	**Sig.**	**Exp(B)**
Transport means (1)	-0.276	0.671	0.413	0.759	0.116	0.212	0.645	1.123
Processing means (1)	-0.299	0.872	0.350	0.742	0.601	5.707	0.017	1.823
Drying means (1)	-0.257	0.054	0.816	0.773	1.011	1.339	0.247	2.749
Storing means (1)	0.526	1.953	0.162	1.692	0.385	1.684	0.194	1.470
Sex (1)	-0.048	0.017	0.897	0.953	0.448	2.470	0.116	1.565
Age	0.008	0.358	0.550	1.008	-0.021	4.294	0.038	0.979
Years of schooling	-0.057	1.044	0.307	0.944	0.118	7.157	0.007	1.126
Household size	-1.255	89.616	0.000	0.285	0.017	0.091	0.763	1.017
Land ownership (1)	0.207	0.402	0.526	1.230	-0.493	4.172	0.041	0.611
Tractor use (1)	0.880	5.003	0.025	2.412	-0.154	0.289	0.591	0.857
Types of seeds used (1)	-0.174	0.214	0.644	0.840	0.117	0.169	0.681	1.124
Fertiliser use (1)	0.036	0.011	0.918	1.036	0.002	0.000	0.993	1.002
Group membership (1)	0.524	2.744	0.098	1.689	-0.551	5.653	0.017	0.577
Constant	4.219	17.383	0.000	67.992	0.305	0.172	0.679	1.357
Diagnostic test results	Outcome variable: Food secure = 1, Food insecure = 0 Overall Wald statistic = 0.609 (p = 0.435) Omnibus Tests of Model Coefficients chi-square = 212.291 (p = 0.000) Hosmer and Lemeshow Test chi-square = 4.970 (p = 0.761) -2 Log likelihood = 298.641 Cox & Snell R Square = 0.437 Nagelkerke R Square = 0.584				Outcome variable: Food secure = 1, Food insecure = 0 Overall Wald statistic = 7.560 (p = 0. 006) Omnibus Tests of Model Coefficients chi-square = 27.716 (p = 0.010) Hosmer and Lemeshow Test chi-square = 3.436 (p = 0.904) -2 Log likelihood = 476.188 Cox & Snell R Square = 0.072 Nagelkerke R Square = 0.097			

In Table 5, the variables with negative B-values had negative effects on the chances of being food secure, but only one of them, household size, had a significant effect (B = -1.255, p = 0.000) at the 0.1% level on the chances of being food secure, based on amounts of grains consumed. Based on HFIAS, three variables had significant negative effects on the chances of being food secure at the 5% level: age of household head (B = -0.021, p = 0.038), land ownership (B = -0.493, p = 0.041), and group membership (B = -0.551, p = 0.017). The findings imply that, as age of the household head increases, the chances of being food secure decreases. Older farmers' physical limitations that may limit their mobility and capacity to work long hours or carry out demanding chores related to grain production, harvesting, and processing are the reasons for this. Older farmers may also experience fixed income and restricted access to resources. Other scholars (Mutero et al., 2016; Touch et al., 2024) also reported similar findings that older farmers, especially in Africa, face several challenges that affect their agricultural production, hence leading to food insecurity.

With respect to land ownership, most small-scale farmers own small farmland pieces; hence, as the size of land owned by small-scale farmers decreases, the likelihood of being food secure also decreases. This means that smaller land possession leads to lower production, income, and capacity to handle economic shocks, coupled with unfavorable climate change. This finding has also been reported by other scholars including Assefa & Abide (2023), Mebratu (2018), and Ruslan & Prasetyo (2023). The above results with respect to group membership imply that if a household failed to be a member of a group, the likelihood of being food secure decreased and vice versa. Therefore, households belonging to certain community groups such as Village Community Banks (VICOBA), Savings and Credit Cooperative Societies (SACCOS), and farmers groups were, on average, less food secure compared to those which did not belong to such groups; this is supported by Kehinde et al. (2021) and Niles et al. (2021). Group membership had a significant positive effect at the 10% level on the chances of being food secure (B = 0.524, p = 0.098), based on grains consumed. This is attributed to benefits acquired by one being a member of a certain group, such as collective bargaining and access to resources, knowledge and skills sharing, social safety net and mutual support, and easy access to information and resources (Seydou Z., *et a*l 2021; T. Tesfaye & Nayak, 2022).

The variables with positive B-values had positive effects on the chances of being food secure. Using tractors, unlike using hand hoes, had a significant positive effect at the 5% level on the chances of being food secure in terms of grains consumed (B = 0.880, p = 0.0250). This implies that households that used tractors had higher chances of being food security than those which used hand hoes. Contrary to hand hoeing, farmers could use tractors to till and prepare greater land areas considerably more quickly, resulting in more food available. This has also been reported by other scholars (Aryal et al., 2021; Liao et al., 2022; Westhuizen, 2024).

Moreover, based on HFIAS, processing grains using improved means (B = 0.601, p = 0.017) and years of schooling (B = 0.118, p = 0.007) had significant positive effects at the 5% and 1% levels, respectively, on the chances of being food secure. This implies that the use of improved postharvest management technologies in processing led to a reduction of grain losses, making more food available to households in terms of quality and quantity. In the case of education, the positive significant influence was attributed to the fact that better education improves farmers' ability to make informed decisions concerning improved agricultural practices and techniques, such as adopting improved farming practices.

The results of testing the hypothesis that 'Grain post-harvest technologies do not have significant effects on chances of being food secure' and the one that "Non-grain post-harvest technologies factors do not have significant effects on chances of being food secure" are mixed, as seen in Table 5. The possible reasons for these results may be due to different rates of adoption of postharvest management technologies in transporting, processing, drying, and storage. Also, the application of different variables of postharvest technologies and sociodemographic variables might have complicated the results.

4.5 Relevance of the Theories Applied to this Paper

The three theories applied to this study; the Sustainable Livelihood Theory (SLT), the Diffusion of Innovation Theory (DOI), and the Entitlement to Food theory; are relevant in the research area. The applicability of the Sustainable Livelihood Theory was indicated by social capital in terms of being a member to a farmer group having a positive and significant effect on the chances of being food secure, based on amounts of grains consumed. The applicability was also indicated by natural capital (size of land owned) having a positive effect on the chances of being food secure, based on amounts of grains consumed. The applicability was applicable in terms of human capital (in terms of household size), as it had a positive effect on the chances of being food secure, based on HFIAS.

The applicability of the Diffusion of Innovation Theory was shown by the binary logistic regression findings, which showed a significant positive effect of years of schooling on the chances of being food secure, based on HFIAS. Farmers with different levels of education are expected to have different levels of adoption of postharvest management technologies and use them to improve food security. The applicability of the Entitlement to Food Theory was confirmed by the binary logistic regression results, which showed a positive significant effect of using tractors on the chances of being food secure, based on amounts of grains consumed; a positive effect of using improved seeds on the chances of being food secure, based on HFIAS; and use of fertiliser having positive effects on food security, based on both grains consumed and HFIAS.

V. CONCLUSION & RECOMMENDATIONS

5.1 Conclusion

Post-harvest losses continue to undermine food availability and access at the household level due to the continued use of rudimentary post-harvest technologies, particularly at the storage stage. Although improved post-harvest technologies are now available, their application is still low, and this undermines efforts to improve food security in Dodoma Region, Tanzania. Working on the variables that had significant negative effects on the chances of being food secure—household size, age of household head, and land ownership—could help increase the chances of smallholder farmers being food secure. Such chances could also be increased by keeping up the variables that had significant positive effects on the chances of being food secure: Tractor use, being members of farmer groups, improved grain processing means, and schooling (formal and non-formal education).

5.2 Recommendations

From the findings and the above conclusions, the following recommendations are worth considering. Local Government Authorities in Dodoma Region; in collaboration with other development partners, including NGOs and FBOs; should promote improved grain post-harvest technologies to increase their adoption. This promotion should also include the use of tractors, improved seeds, and organic and inorganic fertilizers. Agricultural extension services should educate farmers on the benefits and usage of these technologies while collaborating with suppliers to make them available at reasonable costs. Small-scale farming households are encouraged to join farmer groups and actively participate in educational sessions to reduce grain post-harvest losses and improve food security. Since farmland size is linked to food security, farmers should use recommended inputs (mechanized farming, improved seeds, and fertilizers) to maximize yields. The Government should intervene and regulate contracts between landlords and tenants to prevent exploitation so that farmers can get maximum benefits from the land they own or hire.

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