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Association between Household Socio-Demographic Factors and Postharvest Management Technologies Use for Grains in Dodoma Region, Tanzania

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Abstract

Purpose: Postharvest management technologies for grains have received inadequate attention as part of food security programmes, and there are has been scant literature detailing their association with socio-demographic factors. This paper assesses the association between socio-demographic factors and postharvest management technologies used for grains in Dodoma Region, Tanzania, focusing on socio-demographic factors of maize and sorghum farmers, postharvest management technologies used for maize and sorghum, and associations between the socio-demographic factors and the technologies.

Methodology: The study employed a cross-sectional research design whereby proportionate stratified random sampling was used to select 384 households from eight villages. Data were collected using a questionnaire, focus group discussions, and key informant interviews. Quantitative data were analyzed using IBM SPSS Statistics software Version 20 whereas thematic analysis was used to analyze qualitative data.

Findings: Results showed that small-scale farming households in Dodoma Region used three main types of postharvest management technologies for grains: Improved technologies which include metal silos, airtight containers, and Purdue Improved Crop Storage Bags (PICS); semi-improved technologies, mostly polypropylene bags; and local technologies, particularly granaries. Chi-square analysis tests showed that household size, household head's sex, age, marital status, and education level were significantly associated with the types of postharvest management technologies used ($p \leq 0.05$).

Unique Contributions to Theory, Practice, and Policy: This study offers a comprehensive understanding of the ways in which household sociodemographic characteristics are associated with adoption of postharvest management technologies. Its contributions include policy ideas for promoting postharvest technologies for grains in Tanzania, based on socio-demographic factors.

Keywords: *Socio-Demographic Factors, Postharvest Management, Technologies, Grains, Household.*

1. Introduction

Grains are important staple food items which are grown locally and processed into various forms for consumption (Raheem *et al*., 2021). Food security in Africa and in other developing countries at large is, therefore, predominantly determined by grains which are available in particular areas. Maintaining the quantity and quality of grain produce is paramount in ensuring sustainable food security. This can be achieved by using appropriate technologies to ensure proper grain management in the postharvest chain (Mwageni *et al*., 2022). However, postharvest management technologies for grains have received inadequate attention as part of food security programs in many developing countries, particularly in sub-Saharan Africa (Ekpa *et al*., 2018), leading to a tremendous loss of food and resources used in production. According to Kalita (2017), grain PHL varies from 20% to 35% across the world in different geographical regions. About one-third of grains produced, amounting to 1.3 billion tons and worth about $1 trillion, are lost globally during postharvest operations every year (Gustavsson *et al*., 2011), while more than 733 million people are hungry at the global level (FAO, 2024 & WHO, 2022). Though the data on grain losses at different levels in Africa are limited (Bisheko & Rejikumar, 2024), the African Postharvest Losses Information System (APHILIS, 2016) reported that the quantity of cereals lost in sub-Saharan Africa (SSA) ranged from 10 to 23% from harvesting to market.

To feed the ever-increasing world population, reduction of food loss is as equally important as increasing production and productivity. Reduction of food loss is also important in achieving SDG 2 (Ending Hunger) and SDG 12 (Ensuring sustainable consumption and production patterns (UNEP, 2015). In this regard, several skills, strategies and equipment are used for postharvest management in developing countries, and in sub-Saharan Africa in particular. For example, the World Food Programme (WFP), with the help of government and non-governmental organizations, works hard in developing countries to enhance postharvest technologies for small-scale farmers, particularly during storage. Improved storage technology such as Purdue Improved Crop Storage Bags (PICS) was reported to reduce up to 98% of food losses irrespective of crop or storage period. These technologies have been reported to be effective in storage as they work without chemicals or pesticides and can easily be used by small-scale farmers in most developing countries (Mutungi et al., 2023). Chemical insecticides such as Actellic Super Dust, on the other hand, have been reported to be used by more than 93% of small-scale farmers and have been effective in controlling insect pests for a few months of grain storage with polypropylene bags (Darfour & Rosentrater, 2022).

The majority of small-scale farmers in developing countries still experience high grain loss up to 30% due to using inadequate storage technology which cannot guarantee protection against major storage pests of staple food crops like maize (Tefera *et al*., 2011). Moreover, pests in stored grains cause not only quantitative loss but also lead to aflatoxin contamination and poisoning (Tefera et al., 2011). Unforeseeable risks in grain storage lead to major grain loss and make small-scale farmers fall into the poverty trap as they have to sell their grains soon after harvesting and buy them back at expensive prices later (Manandhar et al., 2018). Therefore, the inability of farmers to store grains and sell surplus produce at attractive prices impairs households' efforts to ensure food security, fight against poverty, and improve livelihood security. It is within this context that the study on which this article is based examined the main postharvest management technologies for grains used in Kongwa and Chemba Districts in Dodoma Region and their association with socio-demographic characteristics of households.

Three main concepts and one model were applied to this paper. The concepts are household socio-demographic characteristics, postharvest management, and household level use of post-harvest management technologies. The three concepts and the model are explained in this paper. Socio-demographic characteristics refer to a combination of social and demographic factors of an individual or household, including socio-economic status (SES), which is often measured by an individual's educational attainment, occupation, and income *(*Vo et al., 2023). In this study, socio-demographic characteristics included age, sex, marital status, household size, education level, sources of income, and access to credit.

Different scholars have defined postharvest management differently. According to Hasanuzzaman (2014), postharvest management technology is an interdisciplinary science and technology applied to agricultural produce after harvesting for its conservation, processing, packaging, distribution, marketing and utilization to meet food and nutritional requirements of the people in relation to their needs. The major aim of postharvest management is to prevent deterioration of produce and thus ensure good quality at its final stage (Tibagonzeka et al., 2018). Another definition was given by Hasanuzzaman (2014), who defined post-harvest management technology as a process which incorporates all treatments that occur from the time of harvest until when the foodstuff reaches the final consumer.

The definition of postharvest management technology for this paper is skills, techniques and equipment used in the postharvest value chain to ensure the quality and safety of agricultural products for household food security and livelihood. The main aim of postharvest management technology is to prevent food loss which is among the major contributors to food insecurity in developing countries (Santeramo, 2021).

Previous related studies have shown empirical linkages between socio-demographic factors and technology choice. For example, a study by Mwageni et al. (2022) on adoption of improved storage technology for reduction of postharvest losses among smallholder cereal crop farmers in Mvomero District, Tanzania, showed that socio-demographic characteristics such as education level, income level, knowledge, and age of respondents had great contributions to the adoption of improved cereal crop storage technologies. Other linkages have been reported by Benimana et al. (2021) that membership in a farmer group, access to credit, the quantity of maize produced, access to training, and selling maize soon after it dries are the major factors influencing the decisions of smallholder farmers to use alternative maize storage technologies.

Another study by Kadilikansimba et al. (2023) revealed that only farming experience and information-seeking behavior significantly and positively influenced the adoption of improved practices. In addition, a study by Mutungi et al. (2023) revealed that different demographic characteristics had different impacts on different postharvest chains. For example, access to credit and off-farm income were unique determinants of airtight grain storage, while group membership increased the probability of adopting tarpaulins for drying grains and airtight bags for grain storage (Mutungi et al., 2023).

Scanty literature is, however, available reporting on the association between socio-demographic features and postharvest management technologies in Dodoma Region. Also, there is inadequate research that informs policymakers, development partners and extension services on how socio-demographic factors interact with the use of postharvest management technologies in Dodoma Region. This paper aimed, therefore, to examine the association between socio-demographic factors and postharvest management technologies for grains in Dodoma Region. The results from this paper have potential to inform interventions by policymakers and agricultural extension officers to promote better postharvest practices and ultimately improve food security and reduce poverty at the household level. The conceptual framework of this paper is presented in Fig. 1.

Conceptual Framework

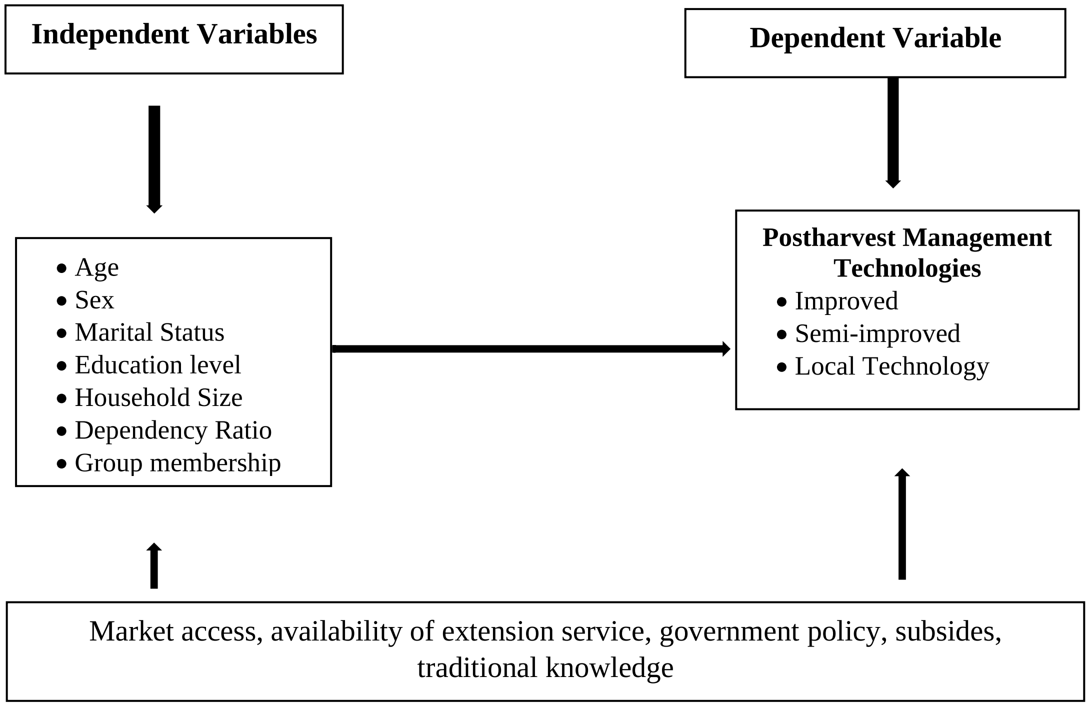

Figure 1: Conceptual framework about association between household socio-demographic factors and grain postharvest management technologies use

The conceptual framework describes how sociodemographic characteristics such as age, sex, marital status, education level, and household size are associated with the use of postharvest management technology for grains. For example, with regard to age, older farmers may be more willing to adopt improved technology than younger farmers due to their long-time farming experience. Higher education increases the likelihood that people will have access to information about improved postharvest management technologies and may decide to use them. Moreover, decision-making and access to resources are influenced by interactions between men and women, with women facing barriers to using and gaining access to improved postharvest technologies. Moreover, larger households may have more individuals to assist with manual labor; hence, they have higher chances to use improved technology than smaller households. In connection to this, government policy, the market, subsidies, extension services, and traditional knowledge; all act as intermediate factors between socio-demographic variables and use of postharvest management technology.

2. Materials and Methods

The geographical area for this study is Dodoma Region in Central Tanzania, particularly in two districts, namely Kongwa and Chemba. The region has a semi-arid climate, a unimodal rainfall pattern, an average of 350 to 1000 mm per annum, and the rainy season normally extends from December to April (Borhara et al., 2020). The major economic activity is crop production, which is dominated by subsistence farming. The major crops grown for food and cash include maize, bulrush millet, sorghum, groundnuts, cassava, sunflower, beans and horticultural crops. Livestock keeping; mainly local cattle, sheep and goats, and poultry; is also done by many people in the area. The region was purposively selected due to its favorable nature of grain production despite its semi-arid nature. Maize is the most important staple food in Tanzania and flourishes well in Dodoma Region in agricultural seasons with good rains (URT, 2007). Also, due to relocation of the capital city of Tanzania from Dar es Salaam to Dodoma in 2016, the population of Dodoma has been rising, leading to higher needs for staple food supply. Additionally, the region frequently suffers from food insecurity due to drought conditions as a result of inadequate and erratic rains (URT, 2019). The information generated by studying the two districts from different geographical locations will inform relevant stakeholders in addressing regional challenges about grain postharvest management to improve grain storage, reduce losses, and enhance food security in similar agrarian contexts.

A cross-sectional research design was used to assess socio-demographic characteristics and use of post-harvest management technologies by small scale farmers in the study districts. The design is appropriate for descriptive purposes as well as for determining relationships and effects between and among variables (Kothari, 2004). In addition, it facilitates determining correlations and differences among variables. In addition, the design was appropriate because the study was intended to provide a snapshot of the linkages among households' socio-demographic characteristics and the use of postharvest management technologies.

The sample size for the study was 384 households, which was calculated based on Cochran**'s (**1977) formula. Cochran developed the formula for calculating a representative sample size when the population is infinite as follows: $\boldsymbol{n_0} = \frac{z^2pq}{e^2}$ 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, $n_0 = \frac{z^2pq}{e^2}$ = $(1.96^2*0.5*0.5)/(0.05*0.05) \approx 384$.

The sampling unit was a household. The 384 households were selected in four wards, two from each of the two districts. In each of the wards, two villages were selected to make a total of 8 villages. The wards and the villages were selected randomly using a scientific calculator whereby, first, all the wards in the two districts and all the villages in the wards were assigned serial numbers, and then the Ran # key of a scientific calculator was pressed repeatedly, every time choosing a ward or a village whose serial number corresponded with the random number that was generated using the scientific calculator.

In addition, proportionate stratified sampling was used at the district and ward levels to select more and fewer households in districts and wards with more and fewer households, respectively. This was done to avoid underrepresentation of wards and villages with more households and to avoid overrepresentation of wards and villages with fewer households. Proportionate stratified sampling of households was done by first listing male-headed households (MHHs) and female-headed households (FHHs) separately with assistance of village leaders. Then, in each village, random numbers were generated for MHHs and FHHs in MS Excel using the RAND() command. MHHs and FHHs whose serial numbers corresponded with the random numbers that were generated were selected.

Primary data were collected using a questionnaire whose copies were administered to household heads. The heads of households were requested to provide all necessary information pertaining to agricultural production and the types of food postharvest management technologies they used for both maize and sorghum**.** Moreover, key informant interviews were held with four Ward Extension Officers (WEOs) as they were considered to have in-depth knowledge on postharvest management technologies. In addition, four focus group discussions were conducted in the four wards (one FGD per ward) with eight to ten participants in each case. The FGD participants were a mixture of older and younger farmers, the youth and women together.

Qualitative and quantitative methods were employed to analyze the primary data that were collected. Qualitative data were analysed by being summarized by their themes, and comparing and contrasting arguments given by participants in different focus groups and by different key informants. Quantitative data were analysed using the IBM SPSS 20 Statistics software to compute descriptive statistics, particularly frequencies, percentages, means, minimum and maximum values, and standard deviations of individual variables. Moreover, inferential analysis was done by running chi-square tests to determine associations between socio-demographic characteristics of households and postharvest management technologies used for grain handling.

3. Results and Discussion

3.1 Households' Socio-Demographic Characteristics

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The main socio-demographic characteristics of the household heads that were analysed were the household head's age, sex, marital status, household size and education level. Socio-demographic characteristics are important as they provide information on the relationship between farmers' socio-demographic factors and uses of grain postharvest management technologies in the context of the study on which this paper is based. The findings in Table 1 show the distribution of the respondents by their socio-demographic characteristics.

3.1.1 Sex of household head

The findings in Table 1 indicate that 79.9% of the households surveyed were male-headed households while female-headed households were 20.1%. These per cents are different from the corresponding national level ones, which are 72.1% and 27.9% for male- and female-headed households, respectively (URT, 2023). Despite sex differences in farming activities, male- and female-headed households were engaged in farming activities and used postharvest management technologies to prevent grain loss. According to Obi-Egbedi et al. (2022), farming encompasses predominant livelihood activities in rural areas; this enhances heads of households ensuring food availability to their families by engaging themselves in farming activities and proper management of crops to prevent postharvest losses. Literature also recommends that family members should ensure proper management of grains after harvesting to prevent loss and to enhance food security (Lelea et al., 2022).

Table1: Socio-demographic factors of maize and sorghum farmers interviewed (n = 384)

Variables	**Categories**	**Kongwa District**		**Chemba District**		**All**	
		n	**%**	**n**	**%**	**n**	**%**
Sex	Male	165	43.0	142	37.0	307	79.9
	Female	54	14.1	23	6.0	77	20.1
Age	Below 25	6	1.6	0	0.0	6	1.6
	25-34	14	3.6	39	10.2	53	13.8
	35-44	47	12.2	39	10.2	86	22.4
	45-53	59	15.4	37	9.6	96	25.0
	54-65	48	12.5	32	8.3	80	20.8
	Above 65	45	11.7	18	4.7	63	16.4
Marital status	Married	151	39.3	128	33.3	279	72.7
	Single	4	1.0	4	1.0	8	2.1
	Separated	19	4.9	12	3.1	31	8.1
	Widow/widower	30	7.8	8	2.1	38	9.9
	Cohabiting	15	3.9	13	3.4	28	7.3
Households size	Smaller (0 to 4)	136	82.5	132	60.3	268	69.8
	Larger (5≤)	29	17.5	87	39.7	116	30.2
Education level	Informal education	33	8.6	1	0.3	34	8.9
	Primary education	184	47.9	138	35.9	322	83.9
	Secondary education	1	0.3	16	4.2	17	4.4
	Tertiary education	1	0.3	10	2.6	11	2.9

During a focus group discussion, it was agreed that both male and female heads of households invested their valuable time in the grain post-harvest chain from harvest to storage. Male household heads tended to have more responsibilities than female household heads in grains storage. Nevertheless, even in male-headed households, women did more activities than men in the postharvest management chain as reported by participants in an FGD as follows:

> "*Men do parts of manual physical work which are considered difficult for women to do, like bringing crop products from the farm to home and ensuring the products are properly stored. Activities like winnowing, sieving, and bagging are mainly done by women" (FGD Kongwa, March, 2023).*

The above quotation means that, in the research area, both men and women participate in the post-harvest management chain from harvest to consumption.

3.1.2 Age of household head

In the study area, the minimum age for the head of household was 25 years while the maximum age was above 65. The average ages for male and female household heads were 65.3 and 67.5, respectively, signifying that females live longer than males as also supported by literature (Baum et al., 2021). With regard to farming activities, older persons above 35 years had higher experience in farming than ones aged up to 35 years. Older people also dominated farming activities by 70%, compared to 30% of younger persons. This finding is supported by other researchers that over 80% of smallholder farmers are older people of more than 60 years (Lindsjö et al., 2021). Many studies done in most parts of sub-Saharan Africa (SSA) reported low interest of young generation in farming activities (Mthi et al., 2021; Njeru, 2017; Trevor & Kwenye, 2018). Several reasons have been highlighted as to why there is low interest of youth's participation in farming activities. The reasons include various misconceptions associated with the industry, information gap, unawareness of opportunities in agriculture, uncompetitive wages, and high physical demands (Magagula & Tsvakirai, 2020). Also, rural-urban migration has been mentioned as among factors for low young generation's involvement in agricultural activities (Ochieng & Ochieng, 2020). Thus, as the findings in Table 1 show, a higher proportion of the respondents who were engaged in small-scale farming activities were of ages ranging between 45-53 (15.4%) in Kongwa District, while in Chemba District two categories 25-34 and 35-44 had the same per cent of 10.2%. The category with the lowest proportion of respondents who were engaged in small-scale farming activities was that of people with the age range below 25.

3.1.3 Marital status of household heads

Five groups were analysed concerning marital status: married, single, separated, widowed, and cohabiting. The results indicated that 72.7% of the household heads were married while the rest had various marital statuses as presented in Table 1. Married household heads dominated farming activities. It is so in many African countries, and it is supported by other scholars, for example Oladimeji et al. (2015 and Owitti (2015).

3.1.4 Level of education

The level of education was another socio-demographic characteristic that was analysed. The distribution of the respondents according to their levels of education is shown in Table 1. The average number of years for which household heads had gone to school was 8.7 while the minimum and maximum years were zero and 19, respectively. More than four-fifths (83.8%) of the household heads interviewed had completed primary education while 8.9% had no formal education. Thus, the literacy level in the form of farmers' ability to read and write in the national language, Kiswahili, was relatively high in the study area. Literacy level is an important tool for deciding about agricultural investment. Research by Mutungi et al. (2023) supports this finding by asserting that education increases technology use through better ability to interpret technical knowledge and allocate resources, particularly money, to acquire technology.

3.1.6 Household size

Household size was another socio-demographic factor which was analysed concerning the use of postharvest management technologies in Kongwa and Chemba Districts. Table 1 gives a summary of household sizes in both districts. The minimum and maximum household sizes were 1 and 9, respectively. In addition, 82.5% of households surveyed in Kongwa District and 60.3% in Chemba District had 1 to 4 people, categorized as small household sizes in this study. Moreover, 17.5% of households in Kongwa District and 39.7% in Chemba District had 5 and more household members, categorized as larger household sizes in this study. Several scholars have reported that household size is a good source of farm labour in most rural areas of Africa, which ultimately determines the size of farm cultivated and food security status (Ameh et al. 2017; Lowder et al., 2016; Haq et al., 2022). This is because most of the household members take part in agricultural production activities. On the other hand, if the members of the household cannot work hard to meet household food requirements they may be a source of household food insecurity as the mouths to feed are many. A study by Massawe (2016) in Kishapu and Mvomero Districts, Tanzania, reported the presence of food insecurity in households with bigger household sizes as they were not able to meet household food needs during the pre-harvest season.

3.2 Postharvest Technologies Used for Maize and Sorghum Handling

Postharvest management technologies used in the postharvest chain are important in reducing food loss thus improving household food security status. Several definitions have been used to define postharvest losses (PHL), sometimes used interchangeably with food waste (Chaboud & Daviron, 2017; Fabi et al., 2021). This study adopted the definition by Bendinelli et al. (2020) who define PHL as an unintentional decrease in the quantity of food produced for human consumption at all stages of the food supply chain (FSC) regardless of the cause or destination (Bendinelli et al., 2020). In this study, the postharvest chain incorporated harvest, transport, drying and storage. At each stage, the respondents were asked to identify types of technology used and strategies used in the management of their farm produce to prevent losses.

3.2.1 Harvest and transportation of maize and sorghum

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Harvest is the first stage of postharvest management chain whereby crop products are harvested after achieving a good maturity stage for the good quality of the grains for storage (Afzal et al., 2020). According to (FAO, 2018), the term "harvest" refers to a crucial point in the agricultural cycle when the seasonal produce becomes ready for consumption, storage, or sale. This stage has a direct impact on the availability dimension of food security.

The respondents were asked to state the means they used to harvest their crop products after attaining a good maturity stage. All the small-scale farmers involved in the study (100.0%) harvested their crop products manually using machetes, knives and other rudimentary tools. Further, they stated that maize was left on the farm to dry after maturity before being harvested while sorghum was harvested just after maturity and further dried by being spread on the soil or on tarpaulins. At this stage, food loss was mainly due to maize grains dropping down from maize cobs left in the field and grain damage during harvest. After harvesting, grains were transported to the homestead for storage using various means of transport including on household members' heads, by oxen and donkeys pulled carts, bicycles, motorcycles, tricycles, power tillers, tractors or motor vehicles. The means used to transport crop harvests from farm to storage sites are summarised in Table 2.

Table 2: Means used to transport crop harvests from farm to storage site (n = 384)

Means of transport used	**Kongwa District**				**Chemba District**				**Both Districts**			
	Yes		**No**		**Yes**		**No**		**Yes**		**No**	
	n	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**
Head	17	7.9	197	92.1	14	8.8	146	91.3	31	8.3	343	91.7
Donkeys	15	7.0	199	93.0	15	9.4	145	90.6	30	8.0	344	92.0
Oxen	157	73.4	57	26.6	104	65.4	55	36.4	261	70.0	112	30.0
Bicycles	15	7.0	199	93.0	21	13.1	139	86.9	36	9.4	338	88.0
Tricycles	20	9.3	194	90.7	25	15.6	135	84.4	45	11.7	329	88.0
Motorcycles	28	13.1	186	86.9	28	82.5	132	82.5	56	15.0	318	85.0
Power tillers	8	3.7	206	96.3	20	12.5	140	87.5	28	7.5	346	92.5

As shown in Table 2, the major means of grain transportation was by traction animal-driven carts, mainly oxen: 73.4% and 65.4% in Kongwa and Chemba Districts, respectively. The transportation methods used had also some implications for food loss as some grains spilled off on the way during transportation; hence much care was needed during the transportation. This finding is also supported by Kiaya (2014), that great care should be taken when transporting fully mature crop products to prevent any detached grains from falling off before reaching storage or threshing sites. It was elaborated, during a focus group discussion, as follows:

> *"Using power tillers to transport grain produce is a quick means as it saves time in comparison with transporting such produce using donkeys or on head, but some produce can spill off on the way due to wind or shudder" (FGD Chemba, 2023).*

From the previous quote, the reason for grains falling off on the way due to wind or shudder is applicable to other means of transport such as transport by donkey-driven carts, tricycles and motor vehicles.

3.2.2 Primary processing

Generally, grain primary processing encompasses the activities designed to clean, sort and remove inedible fractions from the grains (Papageorgiou & Skendi, 2018). These include pounding, threshing, drying, winnowing, cleaning, packaging or bagging, and any other related activities necessary for ensuring grain quality before storage (Sharma et al., 2023). However, this paper investigated in detail drying and storage which are the most critical stages in grain losses as detailed below.

3.2.2.1 Drying

Drying of grains is an important stage before storage to ensure good quality and quantity of stored grains. According to Bradford et al. (2020), grain dryness is a vital factor for ensuring the quality of stored grains. They add that insufficiently dried grains are easily attacked by insects and mycotoxins (Bradford et al., 2020). Open sun drying is a common method used to dry grains in many countries of sub-Saharan Africa and in some other developing countries *(*Qu et al., 2021). This is done by either leaving crop products in the field till they reach the full-dry stage or by spreading them in thin layers on the soil or by spreading them on tarpaulins or on any other material designed for drying grains. In this study, the respondents were asked to state whether they dried their produce after harvesting, methods they used for drying and for how long for full drying. The details are presented in Table 3 where four methods are reported, namely spreading grains on the ground (71.4%), aeration of grains on farm (19.5%), leaving grains on farm to dry (88.0%), and spreading grains on tarpaulins (1.8%). The maximum number of days taken for grains to dry was reported to be seven whereas the minimum was reported to be three days.

Table 3: Drying methods used for maize and sorghum (n = 384)

Means used to dry grains	**Yes**		**No**	
	n	**%**	**n**	**%**
Spreading grains on the ground	274	71.4	110	28.6
Aeration of grains on the farm	75	19.5	309	80.5
Leaving grains on a farm to dry	338	88.0	46	12.0
Spreading grains on tarpaulins	7	1.8	377	98.2

3.2.2.2 Bagging and storage

Bagging and storage are the final stages of primary processing whereby grains are bagged and stored in specified places for further use, either consumption or sale. Bagging and storage are crucial stages for ensuring the quality of grains for consumption. The facilities should be favourable in preventing grain loss brought about by moisture and pests like rodents, insects, termites and microorganisms. In Kongwa and Chemba Districts, bagging is done manually, and all semi-improved, improved and traditional facilities were reported to be used for storage as

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summarized in Table 4. Semi-improved facilities, in this study, refer to woven bags (polypropylene) used to store grains but unable to maintain grain quality for more than six months without the application of chemicals. Improved storage technologies can maintain grain quality for a year or more without the application of chemicals. They include hermetic bags, metal silos, and air-tight containers such as plastic drums and jerry cans. The results indicate that the majority of small-scale farmers still relied on semi-improved storage technologies which hardly guarantee long-term grain storage. The reasons for not using improved technologies were reported by the respondents to be high costs of the technologies, compared to the costs of semi-improved technologies. During a focus group discussion, about using semi-improved technologies due to their low cost, the discussants agreed as follows:

> "*The price of 10 semi-improved bags is equal to that of one hermetic bag. So, we better buy semi-improved bags which we can change after a few months rather than hermetic bags which are expensive"* (FGD, 2023, Kongwa)

Table.4: Means for storing maize and sorghum

	Maize				**Sorghum**			
Storage means used	**Yes**		**No**		**Yes**		**No**	
	n	**%**	**n**	**%**	**n**	**%**	**n**	**%**
Granary	66	17.2	318	82.8	56	14.6	328	85.4
Polypropylene bags	314	81.8	70	18.2	308	80.2	76	19.8
Airtight containers (jerry canes and drums)	112	29.2	272	70.8	114	29.7	270	70.3
Purdue improved crop storage bags (PICS)	183	47.7	201	52.3	183	47.7	201	52.3
Improved silo	83	21.6	301	78.4	89	23.2	295	76.8

3.3 Association between Socio-Demographic Characteristics and Use of Postharvest Management Technologies for Maize

In order to determine associations between socio-demographic factors and the use of postharvest management technologies, the two groups of variables were cross-tabulated including commands for generating chi-square and p-values. The results are presented in Table 5 and discussed thereafter.

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Table 5: Associations between socio-demographic factors and maize drying technologies

Socio-demographic factors		Maize drying technologies used: Spreading on the ground Yes (%)	No (%)	Aeration on the farm Yes (%)	No (%)	Leaving on the farm to dry Yes (%)	No (%)	Tarpaulins Yes (%)	No (%)
Sex	Male	68.7	31.3	19.5	80.5	87.3	12.7	2.3	97.7
	Female	81.8	18.2	19.5	80.5	90.9	9.1	0.0	100.0
	Chi-square	5.159*		0.000		0.762		4.725	
	Sig. (2-sided)	0.023		0.990		0.383		0.094	
Age	Below 25	100.0	0.0	16.7	83.3	83.3	16.7	0.0	100.0
	25-34	60.4	39.6	17.0	83.0	92.5	7.5	1.9	98.1
	35-44	52.3	47.7	24.4	75.6	91.9	8.1	2.3	97.7
	45-53	83.3	16.7	10.4	89.6	88.5	11.5	2.1	97.9
	54-65	77.5	22.5	22.5	77.5	83.8	16.2	2.5	97.5
	Above 65	77.8	22.2	25.4	74.6	84.1	15.9	0.0	100.0
	Chi-square	30.257***		8.460		4.629		45.509***	
	Sig. (2-sided)	0.000		0.133		0.463		0.000	
Marital status	Married	68.1	31.9	17.9	82.1	88.5	11.5	2.2	97.8
	Single	75.0	25.0	0.0	100.0	100.0	0.0	0.0	100.0
	Separated	77.4	22.6	16.1	83.9	96.8	3.2	0.0	100.0
	Widowed	81.6	18.4	26.3	73.7	86.8	13.2	0.0	100.0
	Cohabiting	82.1	17.9	35.7	64.3	71.4	28.6	3.6	96.4
	Chi-square	5.593		8.409		10.771*		6.070	
	p	0.232		0.078		0.029		0.639	
House hold size	Smaller (1 - 4)	74.3	25.7	21.3	78.7	86.9	13.1	1.5	98.5
	Larger (5≤)	64.7	35.3	15.5	84.5	90.5	9.5	2.6	97.4
	Chi-square	3.649		1.704		0.982		17.094***	
	Sig. (2-sided)	0.056		0.192		0.322		0.000	
Education level	Informal education	76.5	23.5	32.4	67.6	85.3	14.7	5.9	94.1
	Primary education	70.8	29.2	18.9	81.1	87.9	12.1	1.6	98.4
	Secondary education	64.7	35.3	11.8	88.2	88.2	11.8	0.0	100.0
	Tertiary education	81.8	18.2	9.1	90.9	100.0	0.0	0.0	100.0
	Chi-square	1.439		5.042		1.743		20.915**	
	Sig. (2-sided)	0.696		0.169		0.627		0.002	

*Association significant at 5%; **Association significant at 1%; ***Association significant at 0.1%

Drying is the most important stage that precedes storage in the grain postharvest chain to ensure the quality of grain products before storage. Drying reduces grain losses during storage and is one of the most important postharvest operations (Purohit et a*l*., 2006). The results in Table 5 show that drying maize by spreading it on the ground was significantly associated with female household headship (X^2 = 5.159, p = 0.023) and that drying maize on tarpaulins was more associated with male household headship, although the association was not significant 4.725, p = 0.094). This implies that women have less opportunity to access improved technologies than their male counterparts. The cost incurred in the purchase or hire of the tarpaulins impairs women from accessing the technology. This is due to the inherited nature of women's low access to productive resources as supported by other scholars, including Achandi et al. (2018), Anaglo (2014), and Butt et al. (2010).

On the other hand, drying maize by spreading it on the ground and by spreading it on tarpaulins were significantly associated with the age of household head (household heads aged below 25 years leading in drying maize by spreading it on the ground (X^2 = 30.257, p = 0.000), and those aged 35 to 65 years were leading in drying maize on tarpaulins (X^2 = 45.509, p = 0.000). The plausible reason is that, at a younger age household heads are at the beginning of agricultural investment; hence their access to resources is limited, and they may be reluctant to invest due to the cost incurred. In addition, inadequate experience may contribute to reluctance among young farmers to invest in improved technology. This is contrary among people with advanced age who relatively easily decide to use improved technology due to their higher experience in agricultural activities as farmers gain more experience with increasing age. This argument is supported by other scholars (Mukarumbwa et al., 2017; Ramírez & Shultz, 2000), who confirmed that age and experience have positive influence on adoption of technologies.

Moreover, there was a significant association between household size and drying maize on tarpaulins (X^2 = 17.094, p = 0.000). The results in Table 6 show that larger households led by drying maize on tarpaulins as compared to smaller households. This signifies the presence of shared value and resources among households with five or more members. Also, larger households need more grain reserves for their food than smaller households; hence they may decide to use tarpaulins to maintain the safety of their grain products. This will also enable them to improve household food security for their members as supported by Manda et al. (2024) and Mutungi et al. (2023).

Education was another significant variable associated with drying maize using tarpaulins (X^2 = 20.915, p = 0.002). The ability to read and write enables farmers to gain more information on postharvest management; hence there is an increase of tarpaulin use as the literacy level of household heads increases. This finding is also supported by other scholars (Maonga et al., 2013; Twilumba et al., 2020; Benimana et al., 2021). On the other hand, it is contrary to the findings by Berem (2007) who propounded that household heads' education level had no relationship with the likelihood of one investing in postharvest technologies use.

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Table.6: Associations between socio-demographic factors and maize storage technologies

Socio-demographic factors		Grain storage technologies used									
		Granary		**Polypropylene bags**		**Airtight containers**		**PICS§**		**Metal silos**	
		Yes (%)	**No (%)**	**Yes (%)**	**No (%)**	**Yes (%)**	**No (%)**	**Yes (%)**	**No (%)**	**Yes (%)**	**No (%)**
Sex	Male	16.9	83.1	80.1	19.9	30.6	69.4	51.1	48.9	23.8	76.2
	Female	18.2	81.8	80.5	19.5	26.0	74.0	33.8	66.2	20.8	79.2
	Chi-square	0.067		0.006		0.636		7.449**		0.311	
	Sig. (2-sided)	0.796		0.939		0.425		0.006		0.577	
Age	Below 25	33.3	66.7	100.0	0.0	0.0	100.0	100.0	0.0	0.0	100.0
	25-34	39.6	60.4	90.6	9.4	52.8	47.2	84.9	15.1	58.5	41.5
	35-44	0.0	100.0	82.6	17.4	60.5	39.5	89.5	10.5	39.5	60.5
	45-53	8.3	91.7	78.1	21.9	22.9	77.1	42.7	57.3	12.5	87.5
	54-65	27.5	72.5	82.5	17.5	2.5	97.5	5.0	95.0	2.5	97.5
	Above 65	20.6	79.4	66.7	33.3	15.9	84.1	15.9	84.1	15.9	84.1
	Chi-square	49.481***		13.166*		91.355***		181.343***		79.098***	
	Sig. (2-sided)	0.000		0.022		0.000		0.000		0.000	
Marital status	Married	17.6	82.4	80.3	19.7	31.5	68.5	51.3	48.7	23.3	76.7
	Single	25.0	75.0	87.5	12.5	50.0	50.0	62.5	37.5	37.5	62.5
	Separated	19.4	80.6	77.4	22.6	29.0	71.0	48.4	51.6	22.6	77.4
	Widowed	15.8	84.2	81.6	18.4	15.8	84.2	21.1	78.9	15.8	84.2
	Cohabiting	10.7	89.3	78.6	21.4	25.0	75.0	42.9	57.1	28.6	71.4
	Chi-square	1.349		0.513		5.858		13.201**		2.553	
	Sig. (2-sided)	0.853		0.972		0.210		0.010		0.635	
Household size	Smaller	19.4	80.6	79.1	20.9	28.7	71.3	48.5	51.5	23.1	76.9
	Larger	12.1	87.9	82.8	17.2	31.9	68.1	45.7	54.3	23.3	76.7
	Chi-square	3.059		0.681		0.389		0.258		0.001	
	Sig. (2-sided)	0.080		0.409		0.533		0.612		0.976	
Education level	Informal education	5.9	94.1	91.2	8.8	20.6	79.4	32.4	67.6	17.6	82.4
	Primary education	17.4	82.6	79.5	20.5	30.1	69.9	49.4	50.6	22.4	77.6
	Secondary education	29.4	70.6	76.5	23.5	29.4	70.6	35.3	64.7	29.4	70.6
	Tertiary education	27.3	72.7	72.7	27.3	45.5	54.5	63.6	36.4	54.5	45.5
	Chi-square	5.633		3.215		2.689		5.743		7.155	
	Sig. (2-sided)	0.131		0.360		0.442		0.125		0.067	

§Means Purdue improved crop storage bags

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*Association significant at 5%; **Association significant at 1%; ***Association significant at 0.1%

The results in Table 6 show a significant association between sex of household head and storing grains using improved technology, particularly PICS, male-headed households leading in using them (Chi-square = 7.449, p = 0.006). This implies that male-headed households had better chances of accessing agricultural resources and information than female-headed households and hence were more likely to adopt modern agricultural post-harvest management technologies. This is attributed to the fact that men control many productive resources such as land, capital and other valuable assets. In addition, in most cases, men make decisions on agricultural investment and may have an upper hand in making decisions on the use of improved postharvest management technologies. This is supported by other scholars, for example Abunga et al. (2012) in their study of adopting modern agricultural production technologies by farm households in Ghana. However, other scholars reported an insignificant association between sex of household and use of modern agricultural technologies, for example studies by Doss & Morris (2000) and Overfield & Fleming (2001), but other studies have reported a negative association between sex of household head and use of agricultural technologies. For example, Asfaw et al. (2012) in their study on the impact of modern agricultural technologies on smallholder welfare in Tanzania and Ethiopia reported that if the household head was male, the chances of adoption of wheat technology packages decreased.

The results also show that there were significant associations between age and all the means used for storing maize ($p \leq 0.05$). Household heads aged 25 to 44 were leading in storing maize using improved technologies, including airtight containers, Purdue-improved crop storage bags, and metal silos. The implication of this is that almost all households used some kind of improved postharvest management technologies for grains but younger households used improved technologies more than older ones. This implies that younger farmers are more eager to practice modern technologies in their agricultural investment than older people (Yokamo, 2020). However, there are conflicting ideas reported by different scholars. Some other scholars reported age to have a negative association with the farmers' technology use, while others confirmed age to have a positive influence on the use of improved technologies (Mignouna et al., 2011). They propounded that older farmers are assumed to have gained knowledge and experience over time and are better able to evaluate technology information than younger farmers. Contrary to this allegation, other scholars reported age to have a negative association with the use of improved agricultural technologies. The implication is that when farmers grow older there is an increase in risk aversion and decreased interest in long-term investment in the farm, while young farmers are typically less risk-averse and are more willing to try new technologies (Abunga et al., 2012).

4.0 Conclusions and Recommendations

The findings which showed that very few of the households' surveyed used improved means to transport grains harvested, dry grains, and store grains, imply that grain postharvest losses would persist if more households did not use improved postharvest technologies for grains. The findings which showed that household heads' sex, age, marital status, level of education, and marital status were significantly associated with using modern technologies to dry and store grains, imply that promotion of these technologies based on these socio-demographic factors would give promising results.

Based on the above conclusions, it is recommended that the Ministry of Agriculture, NGOs, and other development partners should promote the use of postharvest technologies for grains in Dodoma Region based on socio-demographic factors, particularly household head's sex, age, level of education, and marital status. Also, the government should invest in training farmers, provision of subsidies, and financial support to use improved postharvest management technologies to enhance their accessibility and sustainable use. Moreover, the government should ensure the availability of postharvest technologies that are affordable, easy to use, and culturally acceptable to small-scale farming households, particularly in Dodoma Region.

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