ASSESSMENT OF FARMERS HANDLING PRACTICES AND EFFECTIVENESS OF DIFFERENT POST HARVEST TECHNOLOGIES OF MAIZE IN KILOSA DISTRICT

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A DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN FOOD QUALITY AND SAFETY ASSURANCE OF THE SOKOINE UNIVERSITY OF AGRICULTURE, MOROGORO, TANZANIA.

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ABSTRACT

Post-harvest management during handling and storage of maize are crucial for ensuring food security. This study was carried out to assess farmers handling practices and effectiveness of different post-harvest technologies of maize in Kilosa district. A household survey on farmers handling practices and post-harvest technologies used by the farmers to store maize was conducted in Mabwerebwere and Ulaya wards of Kilosa district. The study recorded farmers habits on maize handling practices and polypropylene bags were commonly used to store maize. Main causes of post-harvest losses were found to be insects and rodents. However, the study found post-harvest losses occur mainly during shelling and transporting. Also, laboratory experiment was set up for six months to analyze grain quality in maize stored in polypropylene/Hessian bags (PB), multi-layered plastic bags (PICS), metal silo (MS), roof storage with smoke (RS) and roof storage without smoke (R). The parameters analyzed were percentage moisture content (MC), grain damage (GD) loss and mould growth (MG) at 0 day, 90 days and 180 days. The MC (%) was found to increase with the increase in storage time and ranged from 12.20 to 22.66%. The percent grain damaged was found to increase as storage time increase (0.85 to 21.01%). The MG (log CFU/g) was found to increase with the increase in MC and storage time (4.53 to 5.45 log CFU/g). From the study, the grain quality in terms of moisture and mould growth tended to deteriorate with storage period. Multi-layered plastic bags (PICS) and metal silo were much effective for longer period storage of maize without affecting grain quality compared with hessian bags, roof storage with or without smoking. Further studies on the levels of aflatoxins in the maize stored using different storage facilities are recommended.

DECLARATION

I, CONSTANCIA LASWAI HENRY, declare to the Senate of Sokoine University of Agriculture that this research paper is my own original work done within the period of registration and that it has neither been submitted nor being concurrently submitted in any other institution.

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CONSTANCIA LASWAI HENRY (MSc. Candidate) Date

The above declaration is confirmed;

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Dr. RASHID A. SULEIMAN (Supervisor) Date

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This work is dedicated to my beloved daughter Brianna Baraka, fiancée Baraka J. Kitua, parents Profs. Henry S. Laswai and Germana H. Laswai, my sister Emma Laswai and lastly brother Mathias Laswai.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

LIST OF ABBREVIATIONS AND SYMBOLS

ACDI	Agricultural Cooperative Development International
AFPA	*Aspergillus flavus* and *parasiticus* Agar
ANOVA	Analysis of Variance
CFU	Colony Forming Unit
FAO	Food and Agriculture Organization
FAOSTAT	Food and Agriculture Organization Corporate Statistical Database
GD	Grain Damage
GPLP	Grain Post-harvest Loss Prevention
LGB	Larger Grain Borer
MC	Moisture Content
MG	Mould Growth
MS	Metal Silo
Nd	Number of damaged grains
NGO	Non- Governmental Organization
Nu	Number undamaged
PB	Polypropylene Bags
PHL	Post-harvest Loss
PICS	Purdue Improved Crop Storage
R	Roof storage without smoking
RS	Roof storage with Smoking
Spp	Species
SPSS	Statistical Package for Social Sciences
SSA	Sub-Saharan Africa
SUA	Sokoine University of Agriculture
TOSCI	Tanzania Official Seed Certification Institute
UN	United Nations
VOCA	Volunteers in Overseas Cooperative Assistance
WFO	Ward Field Officer

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

Maize is one of the world's most important crops, boosting multibillion-dollar annual revenue (Josh and Michael, 2009). It is a staple food and source of income for millions of resource smallholders in Sub-Saharan Africa (SSA) (Tedele, 2012). Poor post-harvest management of maize grains leads to losses of about 14 to 36 % of harvest, thereby aggravating hunger (Hodges *et al*., 2010). Post-harvest Losses (PHLs) contribute to high food prices by removing part of the supply from the market (Buzby and Hyman, 2012). It is a major constraint to improving food and nutrition security in SSA. Reducing post-harvest losses of grains is an essential component in any strategy to make more food available without increasing the burden on the natural environment (Buzby and Hyman, 2012).

The current PHLs of maize in Tanzania is around 7.5% (Abdoulaye *et al*., 2016). This and PHLs of other cereal grains have a significant impact on the food security and the economy of the smallholder farmers (Jones *et al*., 2015). The PHLs are not only limited to storage, but losses can occur at different levels of the post-production chain (FAO, 2010). However, in Tanzania, the focus has largely been on mitigating storage losses, since most produce, especially grains, are held in storage for some period (FAO, 2010).
According to Aulakh *et al.* (2013), PHLs include the food losses across the food supply chain from harvesting of crop until its consumption. The losses can broadly be categorized as weight loss due to spoilage, quality loss, nutritional loss, seed viability loss and commercial loss (Boxall, 2001). The magnitude of post-harvest losses in the food supply chain varies greatly among different crops, areas and economies (Boxall, 2001).

In developing countries, significant amount of produce is lost in post-harvest operations due to lack of knowledge, inadequate technology and/or poor storage facilities (Tedele, 2012). On the other hand, in developed countries, food losses in the middle stages of the supply chain is relatively low due to availability of advanced technologies and efficient crop handling and storage systems (Bolot *et al*., 2009).

A large portion of food is lost at the end of the supply chain, known as food waste (FAO, 2014). Food waste can be described as food discarded or intentional non-food uses of the food or due to spoilage/expiration of food (FAO, 2014). Post-harvest loss accounts for direct physical losses and quality losses that reduce the economic value of crop, or may make it unsuitable for human consumption (FAO, 2014). In severe cases, these losses can be up to 80% of the total production (Ferris, 2001).

Maize grains are stored between one harvesting season and another ranging between 3 and 12 months, a period in which high post-harvest losses (30-50%) arise, especially those caused by insects (FAOSTAT, 2014). The main aim of the study was to collect information on the practices by farmers in Kilosa district in handling maize and the use of various post-harvest management and storage technologies. Kilosa district was targeted due to its high number of maize growers and popularity of maize as the main staple food and a major source of household income and food security.

1.2 Problem Statement and Justification

Smallholder farmers in rural areas of Tanzania rarely store their crop harvests properly from one season to another due to high post-harvest losses. The main cause of post-harvest losses during maize storage is infestation by insect pests. This has become much of a problem especially to the newly introduced maize varieties that are currently cultivated by most farmers. Grain losses may occur due to poor handling of grains during harvesting, shelling, drying, sorting, grading, storage and transporting. Most of farmers in developing countries including Tanzania lack access to modern technologies for harvesting, processing and storage. Smallholder farmers in developing countries store maize grains for food, seed and for selling when prices increase. Moreover, most of the maize grain harvested in Tanzania is traditionally stored on the farm, where post-harvest pest management is inadequate (Rugumamu, 2004), leading to huge amounts of maize grain losses (Sori and Ayana, 2012).

Moreover, poor storage can lead to growth of spoilage fungi, especially toxigenic which contaminate maize with mycotoxins (Aldred and Magan *et al*., 2004). Hence, post-harvest strategies must be implemented to maintain proper storage conditions, including insect and mould control (Munkvold, 2003). Post-harvest strategies to reduce grain losses include proper storage (hermetic storage), improved drying conditions and application of synthetic insecticides. Others include minimization of the time between harvesting and drying, sanitation, efficient drying to below 14 % moisture content, physical separation of damaged grains and processing, as reported by Suleiman *et al*. (2013).

In addition, most of farmers have little or no knowledge of using these synthetic insecticides. This has resulted in polluting the environment, contaminating maize with poisons which may threaten the health of the end users or farmers harming themselves (Sori and Ayana, 2012). Furthermore, their affordability of the commercial pesticides is uncertain.

Reducing PHLs of maize for smallholder farmers would have positive consequences on poverty alleviation, food security, nutrition status, and household income for the smallholder farmers in developing countries (Shiferaw *et al*., 2011; Affognon *et al*., 2015). Moreover, by introducing simple strategies, such as improved varieties, harvest at the right time, improved storage structures and improved drying efficiency would reduce PHLs considerably (Affognon *et al*., 2015). Limited research interventions have been done on the area of PHLs of maize in Kilosa district and other areas of Tanzania. The aim of this study was to assess effectiveness of different postharvest storage technologies of maize in Kilosa district. The findings obtained from this study will be useful to farmers, extension officers, planners and policy makers in reducing PHLs in maize and improving food security in the rural areas and Tanzania.

1.3 Objectives

1.3.1 General objective

The overall objective of this study was to assess the practices by which farmers handle maize and the effectiveness of different postharvest storage technologies of maize in Kilosa district.

1.3.2 Specific objectives

i. To assess the handling practices and storage technologies of maize in Kilosa district
ii. To assess the causes and extent of losses of maize during handling and storage period.
iii. To evaluate the effect of storage type and period on the quality of maize grain.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Farmers Maize Handling Practices

2.1.1 Harvesting

Harvesting is the single deliberate action to separate the cob from its grown medium. The optimum time of harvesting maize is when the stalks have dried and moisture of grain is about 20-17% (dry basis) (Tilahun, 2007). Harvest maize as soon as it is dry but should not overstay in field, otherwise it will be attacked by weevils (FAO, 1994).

Timing and method (mechanical vs. manual) of harvesting are two critical factors dictating losses during the harvesting operations. A large amount of losses occurs before or during the harvesting operations, if they are not performed at adequate crop maturity and moisture content. Too early harvesting of crop at high moisture content increases the drying cost, make the grains it susceptible to mould growth and insect infestation, and result in a high amount of broken grains and low grinding yields (Khan, 2010).

2.1.2 Drying

After harvesting, the greatest enemy of grain is moisture. Wet grains attract insects and mould. Therefore, the grain must be dried as soon as possible after harvesting. Drying is the systematic reduction of crop moisture down to safe levels for storage, usually 12%-15.5% (dry basis) moisture content (Tilahun, 2007). Drying is one of the key post-harvest operations since all down-stream operations depend on it. This is particularly so in some regions where humidity and rainfall remain high at harvesting delaying the harvest and constraining actual drying (FAO, 1994).

Drying permits the escape of moisture from grain to an acceptable level, which can sustain very low metabolism. The enzyme activities and grain tissue respiration are reduced to a very low level, thus inhibiting sprouting/germination (FAO, 2010). During drying, the dry air rapidly takes moisture away from the grain, especially if the air is moving and has got low humidity. Grain can be dried in a crib before shelling and on tarpaulins after it has been shelled. Avoid drying of maize on the ground as the grain that is in contact with the ground will absorb moisture and pick up dirt and insects (Tilahun, 2007).

2.1.3 Shelling

Shelling consists of separating the grains from the cob that holds them. This separation, done by hand or machine, is obtained by shelling, by friction or by shaking the products; the difficulty of the process depending on the varieties grown and on the moisture content and the degree of maturity of the grain (Tilahun, 2007). Shelling operations follow the harvest and whatever pre-drying of the crop is undertaken. These operations may be carried out in the field or on the farm, by hand or with the help of animals or machines. Depending on the influence of agronomic, economic and social factors, shelling is done in different ways (FAO, 1994), shelling by hand, with simple tools, animals or vehicles, with simple machines operated manually and with motorized equipment.

In Tanzania and other developing countries shelling is commonly done by beating maize cobs with stick in a sack or a confined floor space. It is better to use a shelling machine, because beating maize will result in physical damage which makes it vulnerable to pests and moulds contamination. Using a shelling machine is preferred although it will not be afforded by most farmers (FAO, 1994).

2.1.4 Sorting

Sorting is any process of arranging items systematically or grouping items with similar properties. Sorting of maize is mainly for removing discoloured grains, insect damaged grains, husk, shank, foreign material, extraneous vegetable material from maize (FAO, 1994). Sorting is an ideal solutions preferred by processors who demand for the highest standards in producing a safe and quality product, consistently.

2.1.5 Winnowing

Winnowing is an agricultural method developed by ancient cultures for separating grain from chaff (FAO, 1994). It is also used to remove hay and chaff or other pests from stored grain. Moving air can be a very effective way to clean maize grains and get rid of the chaff and other debris. It can also end up blowing away a lot of grains with the chaff. Using the wind to clean grains will work well if there's a significant difference in weight between your harvested seeds and the chaff. Grains are probably the best example the grain seeds are dense, and the chaff is light and easily blown away (FAO, 2010).

2.1.6 Storage

The principal objective in any maize grain storage system is to maintain the stored grains in good condition so as to avoid deterioration both in quantity and quality (FAO, 1994). During storage, the grain must remain dry and clean. Grain storage can be extended for up to 2 years without any significant reduction in quantity and quality. However, most of the farmers sell off their maize grains soon after harvesting due to anticipated losses in storage and later buy food at exorbitant prices. There are improved storage structures that can prolong the storage duration until market prices for grains are favorable (FAO, 1987). Perfect storage hygiene is the basic prerequisite for successful storage (FAO, 2010).

All hygiene measures are very simple, particularly effective and cheap. They can thus be perfectly performed by any farmer with little effort. Storage means the phase of the post-harvest system during which the products are kept in such a way as to guarantee food security other than during periods of agricultural production (FAO, 2010).

2.2 Temporary Storage Technologies

These technologies are quite often associated with the drying of the crop, and are primarily intended to serve this purpose. They assume the function of storage only if the grain is kept in place beyond the drying period. More than three-quarters of the grain in SSA are stored using traditional technologies (Nukenine, 2010).The types of grain and the size determine the design and capacity of storage. While such technologies may work well with small amounts of grain, they are not well suited to large quantities. Although temporary storage technologies are the least desirable, there are circumstances in which they are unavoidable (Nukenine, 2010). Examples of temporary storage include aerial storage, storage on the grounds and others.

2.2.1 Aerial storage

Maize cobs, sorghum or millet panicles are tied in bundles, which are then suspended from tree branches, posts, or tight lines, or inside the house. This precarious method of storage is not suitable for very small or very large quantities and does not provide protection against the weather (if outside), insects, rodents, or thieves (Wambungu *et* *al*., 2009). Little can be done to improve aerial storage except, perhaps, to suggest that the bundles of cereals may be safer if suspended in a well-ventilated part of the house; or above a fireplace where insects may be deterred and the moisture content of the grain may be reduced (FAO,1987).

2.2.2 Storage on the ground or on drying floors

This method can only be provisional since the grain is exposed to all pests, including domestic animals, and the weather (Saxena, 2006). Usually it is resorted to if and only if the producer is compelled to attend to some other tasks, or temporarily lacks means for transporting the cobs to the homestead. The grain is less exposed to risk if it is placed on wattle mats or the like laid on the ground or floor. Drying floors could be improved by making them of concrete; or by stabilising the earth Larger animals are less likely to spoil the grain if such floors are constructed near the house, where they can be better guarded (Nukenine, 2010)

2.2.3 Open timber platforms

Grain is stored on platforms in heaps, in woven baskets or in bags. In humid countries fires may be lit under elevated platforms, to dry the produce and deter insects or other pests (Saxena, 2006). A platform consists essentially of a number of relatively straight poles laid horizontally on a series of upright posts. If the platform is constructed inside a building, it may be raised just 35-40 cm above ground level to facilitate cleaning and inspection (Saxena, 2006). Platforms in the open may be raised at least 1 metre above ground level. They are usually rectangular in shape, but circular or polygonal platforms are common in some countries (Nukenine, 2010).

Open timber platforms may be improved by fitted rodent barriers around the supporting posts (Saxena, 2006). The posts should be driven at least 60 cm into the ground, to withstand pressures caused by wind, uneven loads, or even animals leaning against them (some animals will rub against trees to relieve itches). To protect them against termites, posts should be coated with bitumen or used engine oil, or superficially charred after having the bark removed (Nukenine, 2010). Alternatively, since termites do not attack fresh, healthy wood, green wood which will sprout and grow may be used as poles.

2.3 Long-term Storage Technologies

2.3.1 Storage baskets (cribs) made exclusively of plant materials

In humid countries, where grain cannot be dried adequately prior to storage and needs to be kept well ventilated during the storage period, traditional granaries (cribs) are usually constructed entirely out of locally available plant materials such as timber, reeds, and bamboo (Nukenine, 2010). Under prevailing climatic conditions most plant material rot fairly quickly, and most cribs have to be replaced every two or three years, although bamboo structures may last up to 15 years, with careful maintenance. The upright poles, which support the platforms of traditional storage baskets (cribs) should be at least 80 cm high, and protected against termites as described above. They should also be fitted with rodent barriers in similar fashion (Saxena, 2006). The poles should be as thick as possible to reduce the number needed as well as the amount of metal sheet which has to be purchased for making the rodent barriers.

2.3.2 Plastic bags

Plastic bags are widely used for storage. The product must be dried well because, during storage, further drying is impossible as there is no air circulation. When plastic bags are closed well, air tight storage results, with all its advantages and disadvantages. Plastic bags do not offer much protection against rodents, and they can be pierced by sharp seeds during transport and penetrated by insects. This can be reduced by placing a tightly woven cotton bag inside the plastic bag. Plastic becomes weak or brittle after continued exposure to the sun and therefore no plastic package will last indefinitely. An advantage of transparent plastic is that the product remains visible, which makes control simpler. Although the product may look good from the outside, however, it may have become musty within. Used fertilizer bags cannot be used unless they have been very thoroughly cleaned. They are suitable for storing sowing seed, cereals, pulses, ground nuts, and copra (Tilahun, 2007).

2.3.3 Gallon metal drums

Small drums and water tanks are often available and can be used for storing crops, provided they have been well cleaned. When being used for storage, they should not be placed in full sun light, but protected, preferably under a good roof, and insulated with a layer of straw to prevent large temperature changes (Tilahun, 2007). A tightly closed drum prevents the entry of insects. Grain should be well dried before filling. Drums are suitable for storing cereals, pulses and seeds (Tilahun, 2007).

2.3.4 Solid wall bins

Such grain stores are usually associated with dry climatic conditions, under which it is possible to reduce the moisture content of the harvested grain to a satisfactory level simply by sun-drying (Nukenine, 2010). The base of a solid wall bin may be made of timber, earth or stone. Earth is not recommended because it permits termites and rodents to enter. Unlike the stone made base. Mud or clay silos are usually round or cylindrical in shape, depending on the materials used. Rectangular-shaped bins of this type are less common, because the uneven pressure of the grain inside causes cracking especially at the corners. Clay, which is the basic material, varies in composition from one place to another (FAO, 1987).

2.4 Improved Storage Techniques

2.4.1 Metal silos

Metal silos are suitable for cereals and pulses. A whole range of small metal silo designs exists, with silo capacities up to about 5 tones. Silos can be made with overlapping sheets, bolted or riveted together. The silo has two openings, one for filling at the top and one for emptying at the bottom (Tilahun, 2007). As in the case of metal drums, metal silos should not be placed in full sun light, but sheltered to prevent dramatic temperature changes. Some small silo designs incorporate a ventilation system operated by natural airflow. A rotating fan-like structure is placed on top of the silo and, when the flaps are open, the grain is ventilated by fresh cool air. Metal silos tend to be expensive (Tilahun, 2007).

2.4.2 Purdue Improved Crop Storage (PICS) bags

The Purdue Improved Crop Storage (PICS) bags are simple and cost-effective way of storing grain and seed without using chemicals to control insect pests (Murdock *et al*., 2014). A PICS bag consists of two layers of polyethylene liners and a third layer made from woven polypropylene. When each layer is orderly tied and closed separately, it creates a hermetically sealed environment for storing harvested grain. PICS bags enable farmers to store a variety of legume and cereal crops for more than one year after harvest (Murdock *et al*., 2014). The PICS technology is helping to improve food security and increase income of millions of smallholder farmers in Africa and beyond.

2.5 Factors Affecting Quality of the Stored Grain

Without proper management the grain can rapidly deteriorate, becoming a worthless mass (Devereau *et al*., 2002). Grain spoilage is usually the result of several different handling and management operations and decisions. The main factors affecting the quality of maize grain during storage include moisture contents, temperature, mould and fungi, insect pests, birds, and rodents.

2.5.1 Grain moisture content

It is essential that all grains should have moisture content that is below their safe moisture content before they enter the store. The moisture content below which micro-organisms cannot grow is referred to as the safe moisture content (Tilahun, 2007). Table 1 lists the safe moisture content levels for cereals valid for temperatures up to 27ºC (Tilahun, 2007). The safe moisture content have direct relationship with storage time; the lower the moisture contents the longer the storage time (Galati *et al*., 2011). Moisture levels above safe moisture content can be tolerated if only short times are required. If grain moisture content is too high, even the best aeration equipment and monitoring management will not keep the grain from spoiling (Galati *et al*., 2011). All micro-organisms (including moulds) and insects require moisture to survive and multiply. Higher moisture contents speed up the rates of multiplication of fungi particularly *Aspergillus spp*., which produce dangerous toxins (aflatoxins), and make the grain unfit for human consumption (Galati *et al*., 2011). Safe moisture levels for storage have been recommended (Table 1).

Table 1: Safe moisture content for different crops stored below 27˚C

Produce	**Safe moisture content (% dry weight)**
Maize	13
Wheat	13
Millet	13
Sorghum	13
Paddy	14
Rice	13

Source; (Tilahun, 2007).

Furthermore, if the moisture content of a stored product is too low, microorganisms will be unable to grow provided that the moisture in the store is also kept low (Gonzales *et al*., 2009). Moisture should therefore be prevented from entering the store. The sitting and ventilation of the store are important (Weinberg *et al*., 2008) because condensation of moisture can cause storage problems like mould growth (Weinberg *et al*., 2008). In addition, moisture migration is more of a problem in a peaked storage because the moisture is concentrated in a smaller volume of grain (Weinberg *et al*., 2008). Moisture movement problems can be prevented or minimized by keeping grain mass temperatures equalized and within the average range of outside air temperature (Weinberg *et al*., 2008).

2.5.2 Grain temperature

Direct temperature control of small stores is not usually a technical or economic possibility (Devereau *et al*., 2002). So, other measures, particularly reducing the moisture content of the stored produce are necessary (Gonzales *et al*., 2009). The temperature within a store is affected by sun, the cooling effect of radiation from the store, outside air temperatures, heat generated by the respiration of both the grain in the store and any insects present (Gonzales *et al*., 2009). With a few exceptions, microorganisms thrive in environments with temperature between 10 and 60°C (Galati *et al*., 2011). As temperature increases, grain will lose moisture to the surrounding air, thereby increasing the relative humidity (RH) (Devereau *et al*., 2002). It has been observed that in most cereal grains, every 10 °C rise in temperature causes an increase of about 3 % in relative humidity (ACDI/VOCA, 2003).

Moreover, the changing temperature and relative humidity not only promote mould growth, but also cause considerable nutrient losses of grain (Shah *et al*., 2002). It has been reported by Rehman *et al*. (2002) that, after six months of maize storage at 45°C and 12 % RH, results showed significant decreases in protein soluble sugars, up to 20.4 %.

2.5.3 Insects

Many species of insects are found in stored products. Insects are the major causes of post-harvest grain losses. They penetrate the kernels and feeding on the surfaces and the endosperm (Fekadu, 2007). They remove selectively the nutritious part of the food and encourage the development of bacteria and increase the moisture content of the food. Insect infestation will eventually lead to other storage problems (Sori and Ayana, 2012). They give off moisture which can cause grain moisture contents to increase enough to create a mould problem.

Generally, smallholder farmers store maize for three main purposes: as food used until next season; as seed and for selling when prices are high. However, storage pest damage significant portions of their stored maize (Rugumamu, 2004). The most serious insect pests that cause severe economic damage to maize in the storage are the maize weevils (*Sitophilus zeamais)*, and the larger grain borer (LGB) (*Prostephanus truncatus)* (Suleiman *et al*., 2015). Others important storage insect pests include the Angoumois grain moth (*Sitotroga cerealella*), the lesser grain weevil (*Sitophilus oryzae*) (Gitonga *et al.*, 2015). Most of the maize grain harvested in Tanzania is traditionally stored on the farm where post-harvest pest management is inadequate (Rugumamu, 2004).

Mould activity will in turn raise temperatures and result in an increased rate of insect reproduction. Greater numbers of insects create more moisture and the cycle is repeated at an ever increasing rate (Sori and Ayana, 2012). Insects also cause quality deterioration through their excreta as they consume. Insects are generally not a problem in grain stored for less than 10 months or a year if the grain is at its safe moisture and low temperature of storage; controlling insects with insecticides, including fumigants, rather than using preventative methods that incur great cost (Sori and Ayana, 2012). Chemical grain treatment may be justified if persistent infestations cannot be controlled by drying and/or cooling.

2.5.4 Fungi

One of the most serious safety problems in the tropical countries and throughout the world is the contamination of maize grain with fungi (Kaaya and Kyamuhangire, 2006). Fungal species can develop both in storage and field. Toxigenic fungi invading maize are divided into two distinct groups, field fungi and storage fungi (Pitt, 2000). There are several key fungal species associated with stored grains, including *Fusarium* spp., *Penicillium* spp., *Rhizopus* spp., *Aspergillus* spp and *Tilletia* spp (Williams and MacDonald, 1983; Barney *et al*., 1995).

Storage moulds invade maize grain and cause rot, kernel discoloration, loss of viability, vivipary, mycotoxin contamination, and subsequent seedling blights (Williams and McDonald, 1983). According to Sone (2001), broken maize and foreign materials promote development of storage moulds, because fungi more easily contaminate broken kernels than intact kernels. Infection of maize grain by storage fungi results in discoloration, dry matter loss, chemical and nutritional changes and overall reduction of maize grain quality (Chuck-Hernández *et al*., 2012).

Maize grain is generally harvested with moisture content of around 18 to 20 % (dry basis) and then dried (Alborch *et al*., 2011). According to Reed *et al*. (2007) the higher the initial moisture contents the greater the infection of maize kernels. If inadequately dried, the conditions are favourable for fungi to grow, which can result in a significant decrease in grain quality and quantity (Marín *et al*., 1998).

Mycotoxins are a chronic problem for maize grown in warm, humid, tropical and sub-tropical regions (Kaaya and Kyamuhangire, 2006). Mycotoxins are secondary metabolites that are produced by the moulds that may be present in the stored maize grains (Weinberg *et al*., 2008). According to Pitt (2000), the most important mycotoxins that frequently occur in cereal grains are aflatoxins, ochratoxins, fumonisins, trichothecenes, and zearalenone. The two most common and toxic mycotoxin compounds encountered on maize in tropical and subtropical regions are aflatoxins and fumonisins (Krska, 2008).

Moulds infections can result in mycotoxin contamination in all stages from growing, harvesting, storage to processing (Chulze, 2010). Aflatoxin is predominantly a problem in cereal grains, particularly in maize (Krska, 2008). It is produced by three main species of fungi, *Aspergillus flavus*, *A. parasiticus*, and *A. nomius*. They generate four significant aflatoxins: B_1, B_2, G_1, and G_2 and they can produce toxin during storage, transportation, and during processing (Krska, 2008). These fungi can be found everywhere such as in soil, in plant and animal remains, milk, and in grains and seeds such as peanuts and maize and can tolerate and resist a wide range of conditions (Pitt, 2000).

Fumonisins are another group of chemically related mycotoxins, the most common and most toxic called fumonisin B_1 (FB_1), with FB_2 and FB_3 common in lower concentrations. Many *Fusarium* sp. are associated with ear rot and stalk rot in maize.

The most common species in maize is *Fusarium verticillioides* (previously called *F. moniliforme*), which is presumed to be the main source of fumonisins. However, *F. proliferatum*, *F. subglutinans*, *F. thapsinum* and *F. nygamai* have also been isolated from ear-rotted maize, and are on record as capable of producing fumonisins. Mycotoxins produced by *Fusarium moniliforme* and closely related species, growing on maize and other grains are serious problems throughout the world (Pitt, 2000).

Furthermore, *fumonisins*, are widespread in tropical and subtropical regions (Afolabi *et al*., 2006), cause symptom less infections throughout the plant and in maize grain, and it is presence mostly ignored because it does not cause visible damage to the plant (Fandohan *et al*., 2003). The U.N Food and Agricultural organization (FAO) estimated that about 25 % of the world food crops are contaminated with to mycotoxin such as *fumonisins* (Fareid, 2011). *Fusarium* is considered field fungi as it invades over 50 % of maize grains before harvest (Fandohan *et al*., 2003). It is regarded as most prevalent fungi associated with maize, and can cause asymptomatic infection (Scott, 1993).

2.5.5 Rodents

Three species of rodents are major pest of stored products: *Rattus rattus* (Black rat), *Rattus norvegieus* (Brown rat), *Mus musculus* (House mouse). Rodents consume cereal crops and damage sacks and building structures (Fekadu, 2007). They contaminate much great portion of the grain with their urine and droppings than they consume. Poisoning and preventing their access to stored commodities can control them. Biological control also applied to stop rat damages. Generally, rats transmit diseases (typhus, rabies, trichomaisis) (Fekadu, 2007). Regardless of storage period this grain pest can invade the stored grain and affect the quantity and its quality.

The most destructive rodent pests in Tanzania and other SSA countries is the multi mammate shamba rat, *Mastomys natalensis* (Makundi *et al*. 1991; Leirs *et al*., 1996). The main characteristics of *M. natalensis* are an enormous breeding capacity and ability to coexist both as field and house rats (Sluydts *et al*., 2009; Brooks and Fielder, 2013). This makes huge challenges to control and remains a chronic problem for many countries in sub-Saharan Africa (Odhiambo *et al*., 2005).

There are several ways by which rodents may signal their presence. The most easily noticed are damage and burrows (Leslie and Summerell, 2006). In stores footprints may be noted in dusty places and, of course, rodents will leave their droppings scattered about. Often the species can be identified by the size and shape of droppings. Less obvious are the 'smears' found in places regularly visited by rats. They are caused by rats brushing their bodies against objects or when they slide around rafters and corners. Smears are indicators of heavy usage and infestation, and good places for laying down tracking powders (Leslie and Summerell, 2006).

However, these signs are normally apparent only after a substantial population has become well established, when the point in time for economical control has already passed. This can be done by searching for foot prints in fine sand or tracking powder placed at strategic points. Areas around and outside the store should also be checked frequently for the presence of rodents (Leslie and Summerell, 2006).

2.5.6 Metabolic activities

Cereal grains are living materials and their normal chemical reactions produce heat and chemical reactions byproducts (Fekadu, 2007). Heat is also generated by insects, mites and microorganisms, which if presented in large numbers may lead to a significant rise in temperature of stored products. Under aerobic conditions the complete combustion of a typical carbohydrate can be represented by the following equation:

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O + 677.2\text{kcal}$$

There are two types of losses during metabolic processes: The loss due to grain being converted by microorganism to carbon dioxide and water and the other loss that occurs when the grain (entirely or as individual kernels) is rejected.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study Area

The study was conducted in Kilosa district, Morogoro, Tanzania. Kilosa district is located between latitudes 5º55‟ and 7º53‟ S and longitudes 36º30‟ and 37º30‟ E. It is situated at an altitude of 495 meters above sea level. Kilosa is characterized as a semi-arid and dry area in Eastern Tanzania, with a long history of food shortage and post-harvest losses (Kamala *et al*., 2016). The main economic activity is agriculture and maize is one of the major food and cash crops grown.

3.2 Nature of the Study

The study involved household survey using a structured questionnaire (Appendix 1). In addition, samples of maize were collected at intervals of three months, that is, at 0, 90 and 180 days and taken to laboratory for determination of quality attributes.

3.3 Research Design and Sampling

A cross-sectional survey was used in collecting field data in Kilosa district, whereby two wards, Mabwerebwere and Ulaya were selected. This selection was based on the extent of participating in agricultural activities that is crop farming and livestock keeping. Two villages were selected in each ward, that were Kibaoni M and Muungano villages in Mabwerebwere ward and Kibaoni U and Nyameni villages in Ulaya ward. A simple random sampling was used to select a total of 50 farmers from each ward, making a total of 100 respondents. This sample size was considered to be sufficient as per Bailey (1994) that is if subdivided, the smallest sub-sample should be at least 25 respondents. The target populations for this study were the farmers in a district where

Grain Post-Harvest Loss Prevention (GPLP) project was being implemented. The present study included both project members and non-members.

A longitudinal study was used to collect laboratory samples for determination of the quality of maize grain stored in different types of storage structures for six months. Maize samples were collected at an interval of three months (90 days), 0 day, 90 and 180 days of storage period and taken to laboratory for subsequent analyses. About 600 g of maize sample from each farmer were purchased and collected from 48 farmers using different types of storage structures. The samples were kept in air tight plastic bags and taken to the laboratory for subsequent analyses.

3.4 Household Survey

Household survey was conducted using a pretested structured questionnaire (Appendix 1) administered to 100 farming households. The collected information included the maize handling practices performed by farmers, knowledge and perception of farmers on postharvest management and storage technologies of maize. Direct observations were made on the type of the storage structures that farmers use, pesticides and status of the rooms used as store for maize.

3.5 Preparation and Analysis of maize samples

Approximate 50 g from each sample was ground using grinding machine to fine particles and sub-divided to obtain a representative sample for analysis. Laboratory analyses were conducted in two laboratories, located at the department of Food Technology, Nutrition and Consumer Sciences at Sokoine University of Agriculture (SUA), and the Tanzania Official Seed Certification Institute (TOSCI), both in

Morogoro. The sample analyses included the quality attributes of the stored grains, such as moisture content, grain losses due to damage, isolation and identification of moulds.

3.5.1 Moisture content

The moisture content of maize samples was determined using dry oven method as described by the International Seed Testing Association (2017) method no 9.1. About 5 g of each sample were weighed in pre-dried and pre-weighed in crucibles, and then placed into an oven set at 130^0 C for 4 hours to dry. Thereafter, the weight of crucible and dried samples were recorded. The weight of dry matter was obtained as the difference between the weight of dried sample and that of the crucible. The difference obtained was expressed as percentage dry matter with respect to the original amount of the sample taken;

$$\% \text{ Dry matter} = \frac{C-B}{A} \times 10 \quad \ldots\ldots (1)$$

Where;

A = Weight of fresh sample (g)

B = Weight of dry crucible (g)

C = Weight of crucible and dry sample (g)

(C-B) = Weight of dry sample (g)

3.5.2 Grain damage losses

The percentage grain damage was determined using the equation described by Boxall (1986) as cited by Tadele *et al.* (2011).

$$\text{Percentage grain damage (D)} = (N_d / (N_u + N_d)) \times 100 \quad \ldots\ldots (2)$$

Where;

N_d=Number of damaged grains

N_u =Number of undamaged grains

The number of damaged maize grains was obtained by taking 0.5 kg of maize sample and counting all the grains that were damaged by *S. zeamais*. The same sample procedure was conducted for undamaged grain.

3.5.3 Isolation and Identification of Moulds

3.5.3.1 Sample preparation

Exactly 1 g of the ground sample in Section 3.5 was mixed with 5 mls of 0.1% peptone water, which was prepared by dissolving 0.1 g of peptone powder in 100 mls of distilled sterilized water.

3.5.3.2 Media preparation

About 22.75 g of *Aspergillus flavus* and *Aspergillus parasiticus* agar (AFPA) was suspended in 500 ml of distilled water and heated to dissolve completely. The mixture was autoclaved at 121°C for 15 minutes. Thereafter 1 ml out of 50 mg/ml of sterilized chloramphenicol solution was added in the mixture and cooled under room temperature to 50°C.

3.5.3.3 Isolation and counting of moulds

The mixture was then poured into petri-dishes followed by inoculation of samples in 3 dilution levels that is 10^{-1}, 10^{-2} and 10^{-3}. The samples were then incubated in 28^{o} C for 3 days, during which the samples with *Aspergillus flavus* and *Aspergillus parasiticus* produced orange-yellow colonies. The colonies were counted and colony forming unit (CFU) was calculated according to Janeth *et al*. (2003) as;

$$CFU = \frac{\text{Number of colony x Dilution factor}}{\text{Volume plated (ml)}} \qquad (3)$$

3.6 Data Analysis

The data from the survey were entered and processed using Excel sheets and Statistical Package for Social Sciences (SPSS) software version 20 IBM. Descriptive statistics, such as frequencies and percentages were computed. The data generated from laboratory analyses were subjected to one-way analysis of variance (ANOVA) to determine the significant differences between means, using Statistical Package for Social Sciences (SPSS) software version 20 IBM. The Turkey post hoc and homogeneinty tests were calculated to separate the mean significance between the storage types. Results were expressed as means ± standard deviation.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Characteristics of the Respondents

The demographic information and other social characteristics of the respondents are presented in Table 2. The majority of respondents in all villages had more than 40 years, implying that most of the farmers who are cultivating maize are those with higher age than young individuals. The youths are much involved in motorcycle business and livestock keeping (FAO, 1985).

Table 2: Percent responses on demographic information, education levels of respondents and GPLP membership in different villages

Demographic and education information	Village			
	Mabwerebwere ward		Ulaya ward	
	Kibaoni(M)	Muungano	Kibaoni (U)	Nyameni
Age (years)				
18-25	0	0	3.7	11.1
26-40	34.6	55.0	51.9	37
Over 40	65.4	45.0	44.4	51.9
Gender				
Male	42.3	80.0	42.3	55.6
Female	57.7	20.0	57.7	44.4
Education level				
None	11.5	5.0	3.7	7.4
Primary school	76.9	90.0	77.8	88.9
Secondary school	11.5	5.0	18.5	0
College	0	0	0	3.7
GPLP Membership				
Members	50.0	60	50	44.4
Not members	50.0	40	50	55.6

The population of male respondents (80 %) in Muungano village was higher compared to the other villages. This trend was due to the fact that the interview took place during the farming season, when most women were involved in farming. Note that farms in this village are located far distant from their homestead. Majority of respondents in all villages (above 76%) had attended primary school education (FAO, 1985). However, only Nyameni village had about 3.7% of the respondents who had attended college. Most of the respondents had primary education and mostly engaged in farming and livestock keeping (FAO, 1985). About 50% of the interviewees from the four villages were members of Grain Post-harvest Loss Prevention Project (GPLP) and others were not members because they were not aware of the project and others were not around when GPLP went to visit. Others thought that their farms were more important than the meeting itself.

4.2 Maize Handling Practices and Storage Technologies

The percent responses of the maize handling practices by the farmers in the study area are presented in Table 3.

Table 3: Percentage responses on the maize handling practices in the different villages

Maize Handling Practice		Village			
		Mabwerebwere ward		Ulaya ward	
		Kibaoni(M)	Muungano	Kibaoni(U)	Nyameni
Harvesting	Manual	92.3	100	92.6	100
	Machine	7.7	0.0	3.7	0.0
	Others	0.0	0.0	3.7	0.0
Drying	In the field	53.8	65	70.4	66.7
	Direct sun drying	42.3	35	29.6	25.9
	Others	3.8	0	0	3.7
Drying (days)	Less than 7	53.8	55.0	40.7	44.4
	7-14	11.5	5.0	3.7	0.0
	Over 14	34.6	40.0	55.6	55.6
Shelling	Hand shelling	50.0	15.5	18.5	37.0
	Hand driven machines	3.8	5.0	55.6	44.4
	Motorized equipments	19.2	50.0	3.7	0.0
	Hand and hand driven machines	26.9	15.0	14.8	18.5
	Hand, hand driven machines and motorized equipments	0.0	5.0	3.7	0.0
	Hand driven machines and motorized equipments	0.0	10.0	0.0	0.0
	Others	0.0	0.0	3.7	0.0
Sorting criteria	Colour	3.8	5.0	3.7	0.0
	Size	26.9	0.0	11.1	3.7
	Damaged	34.6	0.0	44.4	29.6
	Size and damaged	3.8	10.0	3.7	22.2
	Colour and damaged	3.8	0.0	3.7	0.0
	Colour and size	7.7	0.0	0.0	0.0
	None	19.2	85.0	29.6	44.4
	Others	0.0	0.0	3.7	0.0

4.2.1 Harvesting

Table 3 shows the farmers handling practices in maize during harvesting were by most respondents (about 92%) harvested maize manually while a few (about 3%) used machines. The quality control of maize starts with harvesting, whereby optimum stage of harvesting maize is when the stalks have dried, and moisture of grain is about 20-17% (dry basis) (Weinberg *et al*., 2008). Harvesting of maize should be done as soon as it is dry but not overstay in the field since it may be attacked by weevils. The respondents revealed that maize grains were checked by beating the maize kernel to ensure that they are dry and others by putting the maize grains together with salt in an empty soft drink bottle, the bottle is shaken well. When the salt remains in the bottle it means that the maize grains were not dried properly. During harvesting the respondents used tarpaulin so as to ensure that the maize grains are clean and to avoid losses on the ground while transporting them from the farm to the field.

4.2.2 Drying

Majority of respondents (64%) said that drying of maize takes place in the field while 33% said drying is done after harvesting (Table 3), for a period which depends on weather conditions. When it is sunny, it takes less than 7 days for maize to dry and when it is not sunny, it takes more than 14 days for maize to dry in the field (Table 3). After harvesting, the greatest enemy of maize grain is moisture content. If the grains are moist they may attract insects and mould. Therefore, the grain must be dried as soon as possible after harvesting ready for storage. Safe moisture levels for storage range between from 12-15.5% dry basis (Tilahun, 2007). Furthermore, studies conducted by Hell and Mutegi (2011) recommended that harvested commodities should be dried as quickly as possible to safe moisture levels of 10–13% dry basis for grains..

4.2.3 Shelling

Shelling is another handling practice used by farmers, where the grains are removed from the cobs. Farmers in Kibaoni (U), Kibaoni (M) and Nyameni villages shelled maize using hand and hand driven machines, such as sticks but for Muungano village, 50 percent of respondents commonly used motorized equipment because majority were the members of GPLP and were given education on maize shelling. Beating maize cobs with a stick in a sack or confined floor space was found common by respondents in all villages. The disadvantage of beating maize is that the grain may become physically damaged, making it vulnerable to pests and moulds such as *Sitophilus zeamais* and *Aspergillus flavus* (Sauer andTuite, 1997). It is better if motorized machines (maize sheller) are used (FAO, 1994). However, respondents reported that motorized machines are costly since it is charged per sack of maize cobs shelled.

4.2.4 Sorting

Respondents from Kibaoni (U) and Kibaoni (M) villages usually sort their maize grains prior to storage (Figure 1). Sorting was based on the grain size, whereby the large grains are considered of high quality and kept as seed stock and the small grains are for food consumption.

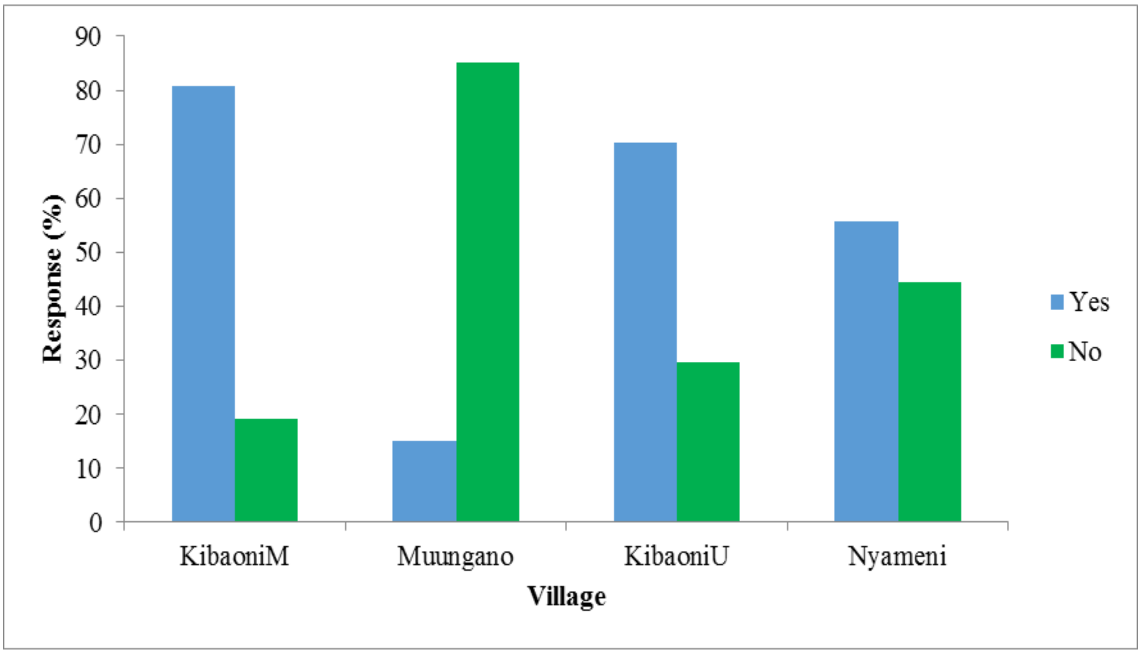

Figure 1: Percent responses on maize sorting in different villages

The respondents said that maize was sorted by removing grains that were damaged by insects and moulds. Majority of the respondents in Muungano and Nyameni villages said that they do not sort maize because the maize husks when mixed with pesticides are useful in the prevention of insect infestations in stored maize.

4.2.5 Winnowing

Figure 2 indicates that majority of respondents in all villages except those from Muungano village winnowed maize prior to storage.

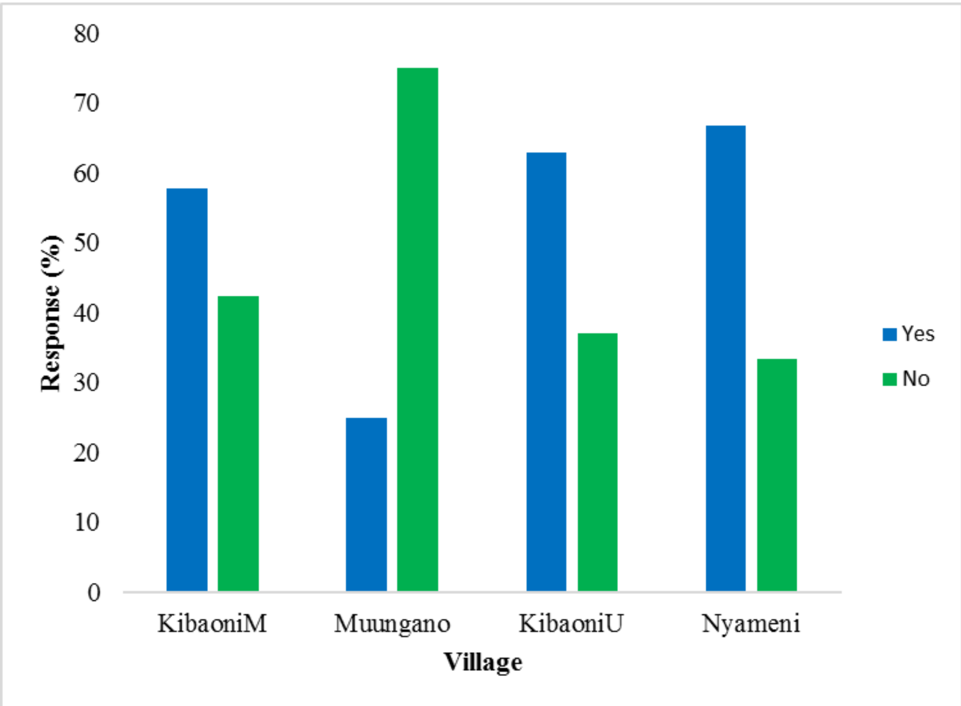

Figure 2: Percent of responses who perform winnowing of maize in the different villages

Respondents in Muungano said that they do not do winnowing for the purpose of reducing insects and pests infestation, especially when maize is stored in hessian bags. They perceive that the dust reduces the air space available to the insects and where pesticide is applied, it binds to the dust and increase the effectiveness (Anonymous, 2002).

4.2.6 Storage

The types of storage facilities observed to be used in the different villages include solid wall bins, sack storage, metal silo, roof storage with smoking and roof storage without smoking (Figure 3).

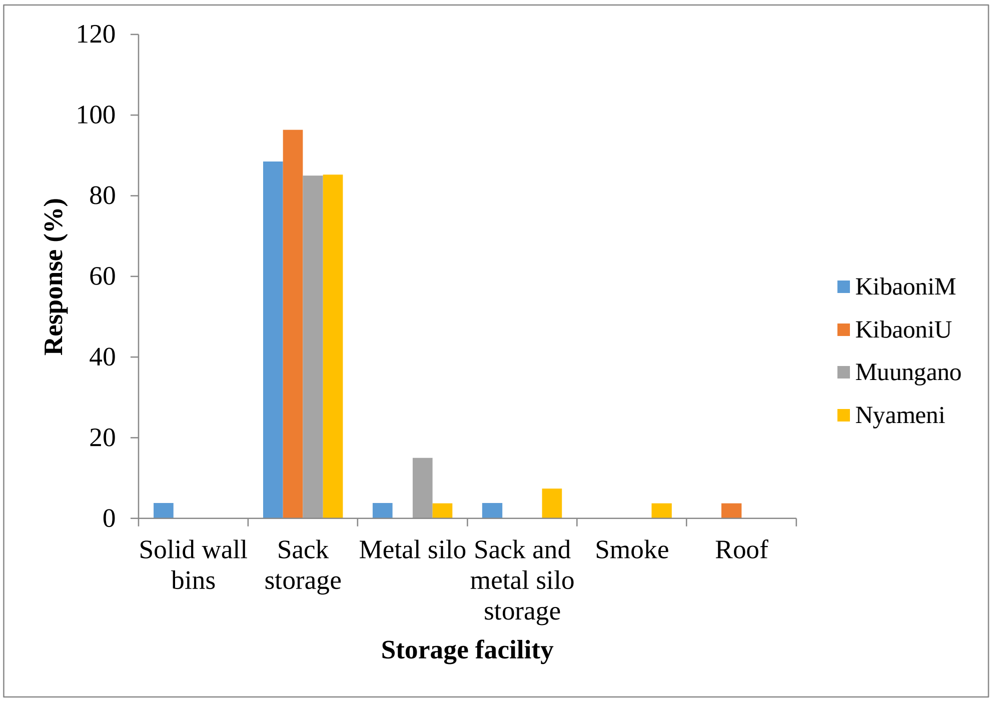

Figure 3: Percent responses on the type of storage facility of maize in the different villages

Table 4: Percentage responses on the types of storage bags used in the different villages

Type of storage bag	Village			
	Mabwerebwere ward		Ulaya ward	
	Kibaoni (M)	Muungano	Kibaoni (U)	Nyameni
Polypropylene/ Hessian bag	61.5	60.0	85.2	88.9
Sisal- woven bag	3.8	0.0	3.7	0
Plastic bag	7.7	5.0	0	0
Multi-layered plastic bags(PICS)	26.9	25.0	3.7	0
Polypropylene and PICS	0	0	3.7	0
None	0	10.0	3.7	11.1

Polypropylene (Hessian) bag (Plate 1(a)) was the most common storage method (60%) in all the four villages surveyed as similarly reported by several other workers (Opit *et al.,* 2015). One of the limitations of using polypropylene woven sacks is that they can be easily destroyed by pests and are not airtight thus grains are prone to fungal and aflatoxin contamination (Hell *et al.,* 2000; Udoh *et al.,* 2000). Another storage material used in the study area is the Purdue Improved Crop Storage (PICS, Plate 1(d)) by 26.9%, 25% and 3.7% of respondents in Kibaoni(U), Muungano and Kibaoni(M) villages, respectively (Table 4). Most of the interviewees said that PICS technology was costfully; a similar finding was reported in a study by Hell and Mutegi (2011) and this remain to be a major constraint for adoption by small-scale farmers. Other respondents indicated that PICS bags are easily destroyed by pests, hence they hesitate to use them. Others said they were not aware of PICS bags at the time of harvest. The use of PICS for storing grains is gaining popularity in the study area because of advantages over traditional storage facilities, supporting the observation made by Hell *et al*., 2010 and Murdock *et al*., 2003. Other storage facilities found in the two wards were roof storage, roof storage with smoke and sisal bags as shown in plates 1(e), 1(f) and 1(b), respectively.

(a)

(b)


JINSI YA KUTUMIA NA KUTUNZA SILO
Chakula Bora, Afya Bora

(c)


Purdue Improved

(d)

(e) (f)

Plate 1: Different types of storage facilities found in the study area

Figure 4 shows that majority of respondents from the different villages store maize in a store, together with other stuffs, such as clothes and bicycles as seen in Plate 2(b). This may make the produce prone to infestation by pests and mould growth. It is well known that poor post-harvest storage management may lead into significant dry matter losses and accumulation of post-harvest mycotoxins (Magan *et al*., 2010). The respondents from Kibaoni (M), however, indicated that special stores for cereal crops such as maize, rice and pigeon peas are normally used as seen in Plate 2(a).

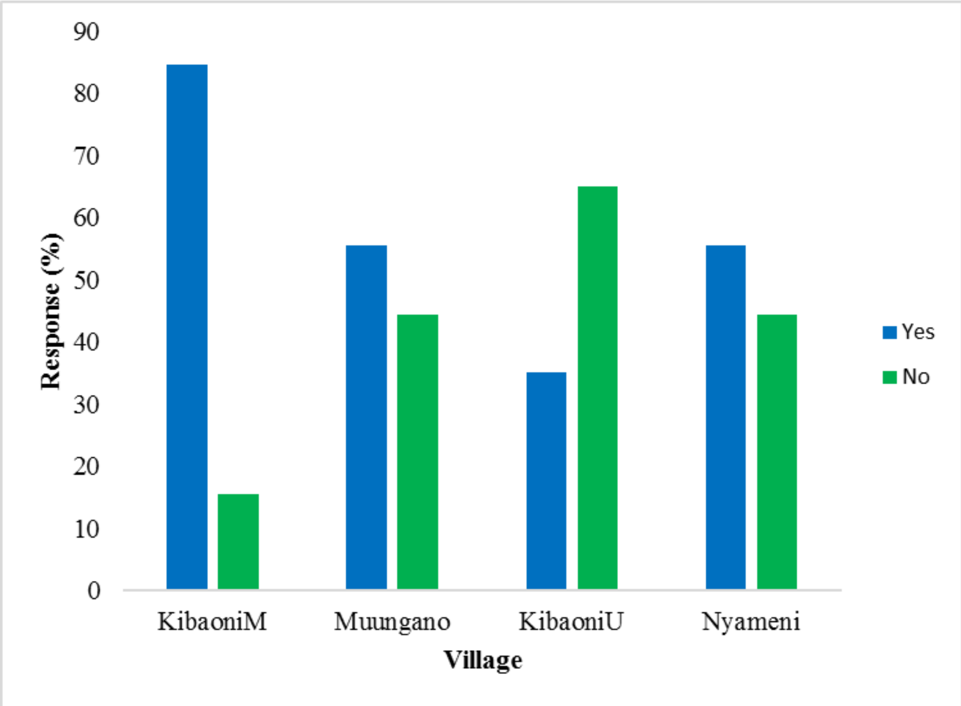

Figure 4; Percent responses on Maize storage in a store

-

(a)

(b)

Plate 2: Examples of stores for storing maize grain in the study area

4.3 Causes of Post-harvest Losses of maize

The main causes of post-harvest losses of maize are shown in Table 5. The results show that insects (Plate 3a) and rodents (Plate 3b) were the major causes of post-harvest losses of maize in all the four villages.

Table 5: Percent responses on the main causes of post-harvest losses of maize in the study area

Main causes	Village			
	Mabwerebwere ward		Ulaya ward	
	Kibaoni(M)	Muungano	Kibaoni(U)	Nyameni
Insect attack	23.1	25.0	55.6	33.3
Rodents	34.6	40.0	22.2	18.5
Mould growth	0	10.0	0	18.5
Others	23.1	0	14.8	22.2
Insect and rodents	0	5.0	3.7	7.4
None	19.2	20.0	3.7	0

Insects damage was the leading cause (56%) in Kibaoni (U). It was observed that the maize weevils, *Sitophilus zeamais* (Plate 3a), was the major insect pest in all the four villages, as similarly commented by Mendalis *et al*. (2007) that grain storage losses due to insect pests have been a serious problem, threatening the livelihood of small-scale farmers. In protecting maize from insect damage, the respondents normally apply different types of pesticides in their produce, especially those who store maize in polypropylene/hessian bags. The common pesticide used were synthetic pesticides (Plate 4a &b), also reported by Suleiman *et al*. (2013). Only few respondents indicated using natural pesticides such as use of cow dung.

Damage by rodents was mostly in Muungano (40%) followed by Kibaoni M, (35%) villages. The observed rodent species that commonly consume maize and damage the sacks and building structures was *Mus musculus* (House mouse, Plate 3b). They contaminate the grains with urine and faecal droppings. Mould growth on maize grain was observed in the villages of Nyameni (18.5%) and Muungano (10.0%) as indicated in Table 5. The respondents revealed that heavy rainfall during the harvesting season might have caused mould growth and much post-harvest loss as similarly reported by Hodges (2012).

(a) (b)

Plate 3: Maize weevils (*Sitophilus zeamais)”a”* and House mouse (*Mus musculus)”b”*

(a) (b)

Plate 4: Typical pesticides used by respondents in stored maize

The major post-harvest losses of maize occur during shelling and transporting maize from the field to homestead (Figure 5). This is due to the fact that most farmers lack access to modern methods of harvesting, transporting and storage. It was also reported that losses occur during harvesting because of lack of use of proper means for harvesting and collecting the produce on the ground as also reported by Sori and Ayana (2012). Also, during shelling, the use of hand, such as beating using sticks was reported to lead into broken maize (Hodges, 2012). Cracking and breaking of kernels normally happen during harvesting and shelling, although insect and rodent feeding may also be responsible for breaks in the pericarp (Sauer and Tuite, 1997).

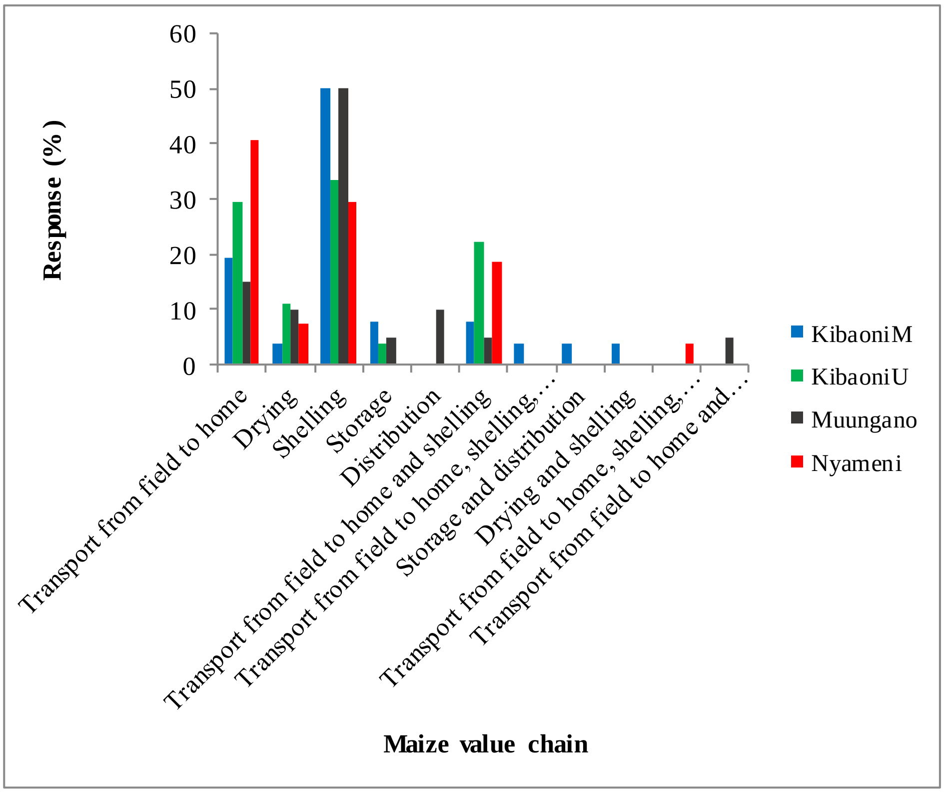

Figure 5: Percent responses on the stages of occurrence of major losses at post-harvest maize value chain in the different villages

4.4 Mycotoxins Awareness by Respondents

The result show insufficient awareness of mycotoxins in humans and animals (Figure 6). The respondents were aware of the fungal growth in maize if not properly dried before storage, but they were unaware of mycotoxins. During consumption, sorting was done to remove the damaged grains only.

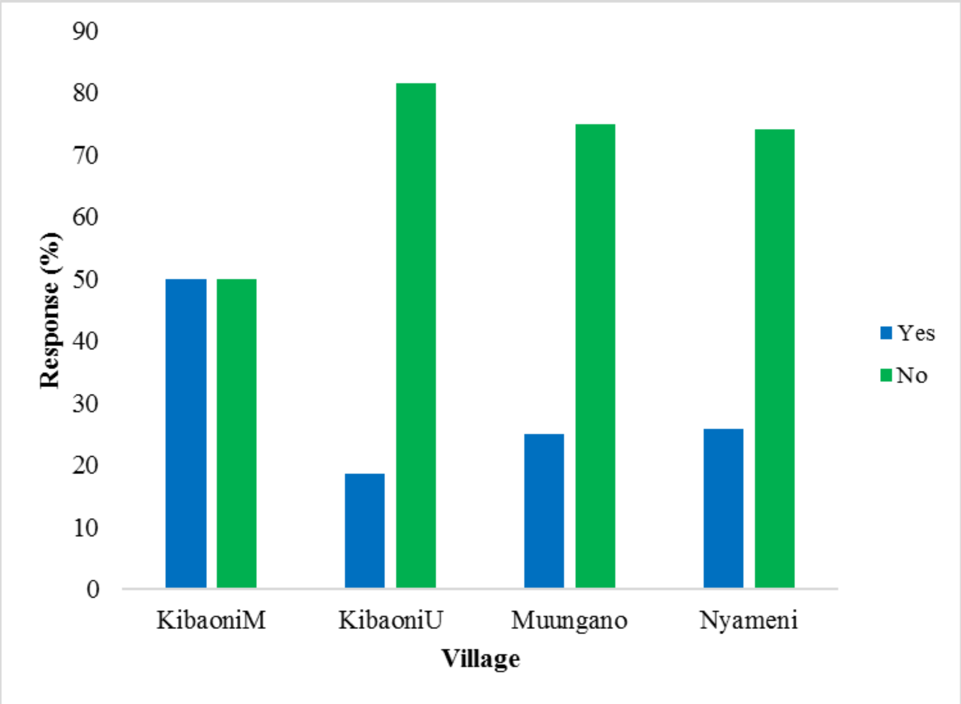

Figure 6: Percent responses on the awareness of effects of mycotoxins in human and animals

Mycotoxins occur more frequently in areas with hot and humid climate, favourable for the growth of moulds; they can also be found in temperate zones (CAST, 2003). Exposure to mycotoxins is mostly by ingestion, but also occurs by the dermal and inhalation routes. The diseases caused by exposure to mycotoxins are known as mycotoxicoses. Mycotoxicoses in humans or animals are characterized as food or feed related, non-contagious, non-transferable, non-infectious, and non-traceable to microorganisms other than fungi. Mycotoxins have various acute and chronic effects on humans and animals (Dinis *et al*., 2007). Human food can be contaminated with Mycotoxins at various stages in the food chain (Bennett and Klich, 2003); wide range of commodities can be contaminated with mycotoxins both at pre- and post-harvest stages (CAST, 2003).

4.5 Effects of Storage Type and Time of Storage on the quality of maize grain

4.5.1 Moisture content of maize

The mean values of moisture contents in the different silos were significantly (P>0.05) at day 0 (Table 6). The mean values were within the recommended safe moisture levels for grains of 10–13% dry matter given by Hell and Mutegi (2011). This implies that farmers were keen to perform proper procedure of drying the maize grains before storing.

Table 6: Mean values of moisture content (%) of maize stored in different facility and storage time

Storage facility	Storage Time (Days)		
	0	90	180
Polypropylene Bag	13.04 ± 0.49^{a}	15.38 ± 1.49^{ab}	16.73 ± 2.86^{ab}
Multi-layered plastic bags(PICS)	13.13 ± 0.52^{a}	13.88 ± 0.95^{ab}	14.04 ± 0.60^{a}
Metal Silo	12.20 ± 1.38^{a}	12.96 ± 1.30^{a}	12.93 ± 1.20^{a}
Roof storage with smoking	12.83 ± 0.05^{a}	18.90 ± 0.19^{c}	22.66 ± 0.57^{c}
Roof Storage without smoking	12.27 ± 0.15^{a}	16.45 ± 1.71^{b}	20.91 ± 0.85^{b}

Values are expressed as means ± SD. Mean values with different superscripts in a column are significantly different (p<0.05).

The percentage moisture contents of the grains in the different storage facilities increased with storage time increase (Table 6). This trend could be due to the increase in the growth of insects which resulted in the increased moisture during respiration of both insects and grains. Frequent opening and improper closing of the metal silo and PICS bags could also add moisture from the atmosphere. For the grains stored in roof, the grains were left exposed which led to the increase in moisture content from the air. The mean value of moisture content in the metal silo for the whole study period was more or less constant and was within the safe moisture for stored maize below 27^{o}C, which is 13% dry weight as recommended by Tilahun (2007). The other storage types recorded much higher moisture contents than the recommended level as from day 90 to day 180.

Based on the experimental measured results in Table 6 and their evaluation, it can be stated that, extraneous moisture levels have significant impact on the conditions of maize grain storage. The higher the moisture content, the more susceptible the maize grain to mould and insect deteriorations (Suleiman *et al*., 2013).

4.5.2 Maize grain damage

Table 7: Mean values of percentage maize grain damage by S. zeamais.

Storage	**Storage Time (Day)**		
	0	90	180
Polypropylene Bag	10.35 ± 9.21^{ab}	15.73 ± 11.21^{ab}	21.01 ± 10.72^{b}
Multi-layered plastic bags(PICS)	2.32 ± 1.62^{a}	4.47 ± 3.87^{a}	6.13 ± 4.78^{a}
Metal Silo	0.85 ± 0.55^{a}	3.48 ± 1.44^{a}	4.33 ± 1.60^{a}
Roof storage with smoking	17.10 ± 0.00^{b}	18.00 ± 0.00^{b}	19.89 ± 0.00^{b}
Roof Storage without smoking	11.81± 0.00^{ab}	17.32 ±0.00^{b}	19.81 ± 0.00^{b}

Values are expressed as means ± SD. Mean values with different superscripts in a column, are significantly different ($p<0.05$).

The percentage grain damage varied from 0 day to 180 days, whereby in metal silo there was slight increase in grain damage from 0.85% to 4.33% due to less air entrapment during opening and closing. In Polypropylene bag there was rapid increase in grain damage from 10.35% to 21.01% due to presence of maize weevils and also the storage time whereby the pesticides applied were no longer effective to the insects hence grain damage. Solution to reduce the grain damage is to use resistant varieties as reported by Suleiman *et al*., (2015). Another strategy to such problem is to use weevil resistant varieties like flint corn. There was significant differences (p>0.05) in the values recorded (Table 7) among the five types of storage analyzed.

Loss of about 18% was reported in other African countries by Kerstin *et al*. (2010) for maize grain stored in polypropylene sacks for a period of six months storage. Per household, average actual loss was reported to be about 12% of the average total grain produce (Abebe and Bekele, 2006). Farmers are managing insect pests of importance such as weevils using chemicals, botanicals, sanitation, and mechanical tools. Bauoa *et al*. (2012) demonstrated that PICS bags protect maize against insect pests during field trials with no loss of quality over 6 months.

Serious damage is done by *Sitophilus zeamais* during maize storage (Table 7 and Plate 3a). These results are in agreement to those reported by Fikremariam *et al*. (2009). Maize damaged by weevils causes food loss, increased poverty and lower nutritional values of grain, increased malnutrition, reduced weight and market values as reported by Keba and Sori (2013). Given that most farmers stored grain and seed together, *S. zeamais* obvious reduced the germination percentage and hence maize production as also earmarked by Pingali and Pandey (2001).

4.5.3 Mould growth

The number of colonies (Plate 5) recorded varied at day 0 ranged from 4.53 log CFU/ml in roof storage to 5.42 log CFU/ml in roof storage with smoking, at 90 days ranged from 4.00 log CFU/ml in roof storage without smoking to 5.42 log CFU/ml in roof storage with smoking and at 180 days ranged from 5.04 log CFU/ml in roof storage without smoking to 5.45 log CFU/ml in roof storage with smoking, with statistical significant differences (p>0.05) in the values recorded among the five types of storage analyzed (Table 8).

Table 8: Mean effects of the type of storage and storage time on mould growth of maize grain (log CFU/g)

Storage	Storage Time (Days)		
	0	90	180
Polypropylene Bag	5.09 ± 108.45[ab]	5.01 ± 83.32[a]	5.04 ± 83.70[a]
Multi-layered plastic bags(PICS)	4.77 ± 76.22[a]	4.23 ± 14.32[a]	4.31 ± 13.72[a]
Metal Silo	5.06 ± 96.96[ab]	4.89 ± 77.56[a]	4.93 ± 81.18[a]
Smoking	5.42 ± 29.69[b]	5.42 ± 19.09[b]	5.45 ± 10.60[b]
Roof Storage	4.53 ± 12.72[a]	4.00 ± 5.65[ab]	5.04 ± 4.24[a]

Values are expressed as means ± SD. Mean values with different superscripts in a column are significantly different (p<0.05).

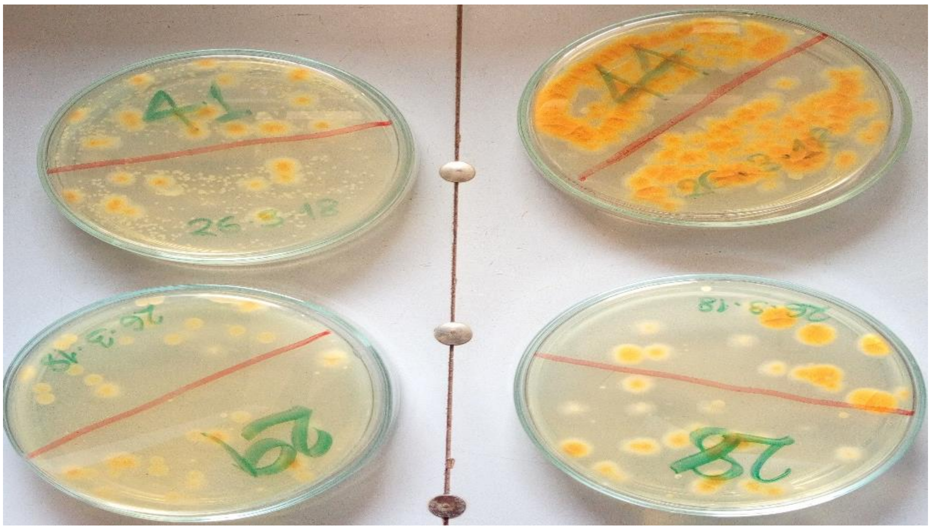

Plate 5: The developed colonies of *Aspergillus flavus* and *Aspergillus parasiticus* species

In general, mould count (CFUs) increased with increased moisture content of the grain and storage time for all the storage types. The percentage moisture content was shown to be relatively high in polypropylene bags, roof storage with or without smoke, thus increased mould growth in these storage facilities. These results are in agreement with that report by Weinberg *et al*. (2008) that when the moisture content of maize grain above 13% dry matter and temperature above 25^{o}C, is a conducive environment for mould growth. Microbial growth tends to be at minimum in stored grains when the moisture of corn is equal or less than 13% dry matter. As the moisture increases mould grows faster (Weinberg *et al*., 2008). The increased mould growth in metal silo and multi-layered plastic bags (PICS) storage was likely due to air leakage or reintroduced ambient air.

Aflatoxin-producing moulds are often present in an environment with other microorganisms which can influence aflatoxin production. Storage pests such as the *Sitophillus zeamais* (Motschulsky) contribute to the production of aflatoxins (Lamboni and Hell, 2009) by disseminating spores of *A. flavus* in the field and stored products. The optimum grain moisture for Aspergillus growth and aflatoxin development ranges from 13-20% (dry basis), with a relative humidity of 62–99% of the surrounding air (Sumner and Lee, 2012).

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

From the study results it can be concluded that the respondents had insufficient knowledge on the post-harvest handling of maize and commonly used storage facility were the polypropylene (Hessian) bags. However, multi-layered plastic bags (PICS) and metal silo have been promoted.

Post- harvest losses throughout the maize value chain usually occur during maize shelling and transporting from the field to the homestead and storing. The main causes of maize losses during storage included insects (*Sitophilus zeamais*) and rodents (*Mus musculus*).

Grain quality interms of moisture and mould growth tended to deteriorate with storage period. Also, interms of grain damage by insects tended to increase with the increase in storage period. Multi-layered plastic bags (PICS) and metal silo were found to be much effective for longer period storage of maize without affecting grain quality compared with hessian bags, roof storage with or without smoking.

5.2 Recommendation

Further study could be done in assessing grain damage of maize grain that is stored in the field. In laboratory the conditions are somehow controlled therefore getting the real picture on what is going on in the field might not be easily seen and also during transportation from field to the laboratory the number of live insects may increase and cause more damage outside the storage Proper monitoring of temperature of the surrounding, temperature inside the storage, moisture content of the grain before storing and relative humidity of the surrounding atmosphere of the storage should be done so as to maintain the highest quality of stored grain. The lower the moisture content and temperature the longer the storage time without mould and insect infestation.

Maize should be properly dried to moisture contents below 14% (dry basis) immediately after harvest and stored in a sealed, airtight container or structure, to reduce oxygen concentration, which will limit the presence of insects. Proper winnowing, sorting or separating foreign materials and broken corn kernels produced during harvesting from clean maize should be done so as to reduce development of grains pests and mould.

Assessment of storage time should be considered immediately after harvest so as to get the real picture of what happens from the beginning to the end of storage time. Further study is recommended to assess levels of aflatoxin in maize. Further research should be undertaken on other issues that could not be covered in this study, such as comparing the storage structures and farmer’s handling practices of maize. Regular checks should be conducted to the farmers to ensure adherence to safety and hygiene requirements of the storage facilities.

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APPENDICES

Appendix 1: Questionnaire on farmers handling practices and post-harvest technologies.

My name is **Henry, Constancia L.** student from Sokoine University of Agriculture (SUA). I am currently doing my research on assessment of farmers handling practices and effectiveness of different post-harvest technologies of maize in Kilosa district as a requirement for the completion of Msc. Food Quality and Safety Assurance degree programme. The purpose of this interview is to collect information on the farmers handling and storage technologies. You will be interviewed on your maize handling and post-harvest storage technologies. The interview will be recorded in a questionnaire. No one else but the interviewer will be present unless you would like someone else to be there. The information recorded will be confidential and no one else except the researcher (s) will be able to access. Please feel free to participate and if you have any question regarding the research please ask to the interviewer and he /she will explain to you.

A. Socio-demographic information

1. Respondent's Serial No ………………………….
2. Sex
   a) Male
   b) Female
3. District…………… Division………………… Ward…………………..
   Village/Street ……………..
4. What is your age? ………………………………………………

5. Marital status
    a) Single
    b) Married
    c) Divorced
    d) Separated
    e) Widow/widower
6. What is your education level?
    a) Primary school
    b) Secondary school
    c) College
    d) University
    e) Not gone to school

B. General information about the farmer

7. Do you have any knowledge about maize handling practices?
    a) Yes
    b) No
8. Do you know any factor that cause maize post-harvest losses?
    a) No
    b) Yes
9. If yes is it due to
    a) Insects attack
    b) Rodents
    c) Birds
    d) Mould growth
    e) Moisture

10. Are you a member in Grain Post-harvest Loss Prevention Project?

    a) Yes

    b) No (Why) ……………..

11. If yes (9) what have you benefited from the project ……………?

12. Where is your farm located at ………………..?

    a) Around the house

    b) Few Kilometres (km) away from the house

    c) Very far from the house

    d) In another village

13. How many acres do you use for maize cultivation …………….?

    a) 0.5 – 1 acre

    b) 2-5 acres

    c) More than 5 acres

14. How many times do you cultivate maize per year……………..?

    a) Once

    b) Twice

    c) Others (mention) ……………

15. How much do you harvest per season …………….?

    a) Very small

    b) Moderate

    c) Very much

    d) None

16. Do you sell the maize that you cultivate?

    a) Yes (Reason) …………………………..

    b) No (Reason)…………………………….

17. How much do you sell the maize per Kilogram (Kg)………………..?

18. How much loss do you incur per season of harvesting………………?

    a) Very small
    b) Moderate
    c) Very much
    d) None

C. Maize handling practices

19. In which ways do you use for harvesting maize?

a) Hand
b) Machine
c) Any other mention ……………………

20. Which method do you use for drying maize?

a) Standing-crop drying in the field
b) Drying in piles
c) Drying in cribs
d) Any other method, mention ……………………………

21. What is the duration of drying the maize?

a) 7 days
b) 14 days
c) 21 days
d) 1 Month
e) More than a month ……………..

22. Which method do you use for threshing maize?

    a) Hand threshing
    b) Threshing with animals or vehicles
    c) Threshing with hand-driven machines
    d) Threshing or shelling with motorized equipment
    e) Any other method, mention………

23. Before threshing do you separate rotten maize from the good ones?

    a) Yes
    b) No (Why)…………………

24. Do you do winnowing of the maize?

    a) Yes
    b) No (Why) ……………………….

D. Maize storage (circle the appropriate answer)

25. What type of storage do you use among the following? (You can circle more than one if applicable)

    a) Solid wall bins
    b) Sack storage
    c) Storage baskets
    d) Metal silos

26. If sack storage is used what type of storage bag?

    a) Polypropylene
    b) Sisal-woven bag
    c) Plastic bag
    d) Purdue improved crop storage (PICS)

27. In what form do you prefer in storage of maize?

a) Husked maize

b) De-husked maize cobs

c) Shelled grains

28. Do you always store maize in a store?

a) No why………………………………….

b) Yes Why………………………………..

29. Do other cereals being stored together with maize?

a) No

b) Yes

30. If Yes (13) list them……………………………………………….................

E. Condition of building/ store

31. For how long have you been using your store?

a) Less than a year

b) 1 year

c) 5 years

d) More than 5 years

32. Does the store roof have leakages?

a)Yes

b) No

32. How often do you do cleanliness of your storage structure?

a)Once a month

b) Once every 3 months

c)Once every 6 months

d) Once per year

e)Whenever necessary

f) Never done

F. Storage time state of maize grains (circle more than one response if applicable)

34. For how long the grains are stored?

a) 1 month

b) 2-5 months

c) 6 months

d) More than 6 months

35. What drying process is adopted prior to storage (a) Mats (b) roof (c) floor (d) smoke

36. Any sorting before storage? (a) Yes (b) No

37. What criteria do you use when sorting? (a) Colour (b) Size (c) Shape (d) insect infested

(e) Physical damaged (f) mould

38. Do you apply pesticides on the grains prior storage? (a) Yes (b) No

39. If the answer above is Yes, name the type of pesticide used…………

THANK YOU AND GOOD LUCK.