TRADITIONAL STORAGE PRACTICES ON THE QUALITY OF MAIZE

A CASE STUDY IN THE SHAI OSUDOKU DISTRICT IN THE GREATER ACCRA REGION.

BY

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THIS THESIS IS SUBMITED TO THE UNIVERSITY OF GHANA, DEPARTMENT OF CROP SCIENCE IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF MASTER OF PHILOSOPHY IN CROP SCIENCE (POSTHARVEST TECHNOLOGY) DEGREE.

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DECLARATION

This is to certify that this thesis is the result of research undertaken by Kodwo Aggrey towards the award of the Master of Philosophy Degree in Crop Science (Post Harvest Technology) in the Department of Crop Science, University of Ghana.

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ABSTRACT

Maize (corn) is one of the most crucial and strategic cereal crops in Africa. Production occurs in all ten regions of Ghana. Despite significant improvement in food storage methods, many communities in Ghana still use traditional storage practices and structures for keeping food and seed. This has led to short falls in maize supply due to high losses and poor quality. Thus the need to determine the effect of traditional practices and storage structures on the quality of maize stored. The objective of the research was to study the traditional storage practices on the quality of maize in Shai-Osudoku District in the Greater Accra Region of Ghana. Field observations, survey and laboratory experiments were the research methods used to collect information on the farmers storage practices, structures used and the perceptions of farmers towards quality. Weight loss, grain discolouration, germination rate, moisture content, insect and foreign matter counts were the quality attributes measured in the laboratory. The results indicated that most of the storage practices undertaken by the farmers did not protect the maize quality produced but rather promoted their destruction. The storage structures identified were inefficient in protecting the grains stored from fire, pest attacks, theft, harsh environmental conditions and finally they are not durable. Maize taken from Agomeda community (Hermetic and Sack storage structures) were observed to have the highest quality as a results of high efficient storage practices and structures undertaken by the farmers to preserve the high variety of maize they cultivate. Maize farmers should partner with other stakeholders to be trained on good storage practices and structure management of maize grains. Further work should be conducted to ascertain the effect these practices and structures have on the chemical quality attributes of the maize grains stored.

DEDICATION

This work is dedicated to my spiritual fathers in the Lord, sisters and brothers, and C. T. C. members especially Salosy cell members. To my dearest wife, Cynthia Elinam Aggrey, and children, I say "Thank you" for you patience, love, support and prayers that inspire me in all my endeavours.

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Table of Contents

LIST OF FIGURES

LIST OF PLATES

LIST OF TABLES

CHAPTER ONE

1.0 INTRODUCTION

Maize (*Zea mays*) is one of the world's important cereal crops which is grown throughout West Africa. The major producing countries in the region are Benin, Burkina Faso, Cameroon, Cote d'Ivoire, Ghana, Mali, Nigeria, Senegal, Togo and Democratic Republic of Congo (CIMMYT, 1990). It is an important commodity in West Africa sub-regional trade, particularly between Ghana, Burkina Faso, Mali, Togo and Niger through mainly informal trading (Bdizakin *et al*., 2014). Maize has recently surpassed cassava as Africa's most important food crop in terms of calories consumed (Webb and Highly, 2000) and also doubles as a main source of income for the producers in the maize surplus regions.

In Ghana, maize is the largest staple crop and is the mainstay of the diet of the majority of Ghanaians, because it is the base for several traditional food preparations (such as banku, kenkey, tuozafi) (Morris *et al.,* 1999). It is cultivated in all the 10 regions of the country with the Eastern Region being the largest producer. In terms of production, maize ranks third only after roots and tubers and plantain (MOFA, 2013). Maize is also a politically sensitive crop; a popular food "kenkey" prepared from it was once sent to the Parliament of Ghana where the size of a ball was used as a measure of the state of the economy (Sienso and Asuming-Brempong, 2013). Additionally, it represents the second largest commodity crop in the country after cocoa (ISSER, 2012). Maize is also associated with household food security such that a low-income household is considered food insecure if it has no maize stock in store, regardless of other foods the household has at its disposal (Tweneboah, 2000). It accounts for 50-60% of the total cereal production in Ghana (Egyir, 2003; ISSER, 2012). The total average annual production in Ghana between 2007 and 2012 was 1.5 million MT (MoFA, 2013), which indicates that maize supply in Ghana has steadily been increasing over the period. It is estimated that Ghana is about 99% self-sufficient in domestic maize production (Nyanteng and Asuming-Bempong, 2003), therefore proper storage practices should be done in order to reduce postharvest losses to major storage insect pests which have been identified as an important constraint to food security. Several improved maize varieties available in Ghana including Abeleehe, Aburotia, Dobidi, Dorke, Kawanzie, Kwadaso Local, Obatanpa, Okomasa and Mama (Adesina Zinnah, 1993: Manga, 2010).

The crop is a major staple food for a large proportion of the population, in addition to being an important animal feed. In Ghana, human consumption of maize is the greatest in the Southern parts of the country because it is used to prepare a wide variety of local maize meals including “kenkey”, “banku”, “tuozafi” and “akple” (Amankwa, 2009). The importance of maize is centred on the large quantity of carbohydrates, proteins, vitamins and fats, contained in the kernels. Therefore, making it compare favourably as an energy source with root and tuber crops (Asiedu *et al.*, 2002; Agona *et al.*, 2008). Maize is eaten on cobs, which are either cooked or roasted. Maize flour is also used in making porridge for breakfast in many homes in urban areas while the maize itself is used in the manufacture of feeds for livestock. Maize is also a good source of starch and oil. Chaudhary (1993) reported that maize grain contains about 72% starch, 10% protein, 4.8% oil, 5.8% fiber, 3.0% sugar and 1.7% ash. It is a source of raw material for industry, where it is mainly used for the praparation of corn starch, corn oil, dextrose, corn syrup, flake cosmestics wax, alcohol and tanning material for leather industries. In Africa it is mainly produced by small holders using low level of technology hand tools and little or no purchased inputs.

Thus yields are low and the production process aims at providing subsistence requirements with very little surplus for sale (Agona *et al.*, 2008).

Depite the nutritional and economic importance of maize, it is estimated that Africa suffers from 20-30% postharvest losses valued at 4 billion dollars annually (SDC, 2011). Infestation by insect pests accounts for between 20 to 50% of post-harvest losses in maize (Anankware *et al.*, 2012). Losses have been defined as any change in the ability, edibility, wholesomeness or quality of food that prevents it from being consumed by people (Harries and Linblad, 1976). According to the authors food losses may be direct or indirect. Direct loss is the disappearance of food by spillage, or consumption by insects, rodents and birds whilst indirect loss is the lowering of quality to the point where people refuse to eat it. In addition three periods of time have been identified. These are pre-harvest, harvest and post harvest, during which food may be lost. Each stage has its own characteristic problems and means of overcoming these problems. Post-harvest losses occur between the completion of harvest and the moment of human consumption. Losses in storage may be as a result of weight loss due to respiration, cracking of grains due to over drying, misapplication of synthetic insecticides, rodents and insects infestation and damage, and contamination with mycotoxins caused by moulds and bacteria and dead parts of insects (Boxall, 2001). Storage structures vary considerably and are unable to prevent insect infestation. Storage losses are typically patchy and can be a big threat to food security and household incomes particularly when losses are severe (Belmain and Stevenson, 2001). Adetunji (2007) outlined various traditional storage structures. These include farmhouses, cribs, barns, platforms, warehouses, silos, pens, yards, sheds, deep litter houses, palm front woven baskets, hutches and cages. Storage practices in developing countries cannot guarantee protection against major storage pests of staple food crops like maize. The lack of suitable storage structures for grain storage and absence of storage management technologies often force the smallholders to sell their produce immediately after harvest (SDC, 2011).

Since storage does not improve quality it suffices to say that the handling or storage practice of the farmer does affect the final quality of the produce. Some of the handling practices include harvesting, dehusking, shelling, drying, bagging and storage. Storage practices in developing countries cannot guarantee protection against major storage pests of staple food crops like maize, leading to 20-30% grain losses, particularly due to post-harvest insect pests and grain pathogens (Tefera *et al.,* 2010). The effectiveness or otherwise of these handling practices contribute greatly to the final quality of grain before they get to storage. The reduction of grain losses, especially those caused by insects, microorganisms, rodents and birds can increase the available food provisions (Badawi, 2001). According to Sisman and Ergin (2011), storage is done to maintain quality of harvested product not to improve it. The aim of storage is to preserve properties of products and freshness until marketing or consumption. But most maize produced are stored in structures which do not maintain the quality of it. Different traditional methods of storing maize are been practised by most farmers. A survey by Nyanteng (1972) and Addo *et al.,* (2002) indicated that these traditional storage methods dominate in all the ten regions of Ghana. Quality is an important determinant of crop retail prices (Kohl & Uhl, 1998). This is affected by both the handling pratices and the storage structures used by the farmers. Storage of poorly dried maize and the use of traditional storage structures by farmers have long been suspected to increase Fusarium incidence and fumonisin production during storage (Atukwase *et al.,* 2012). The storage practices employed by smallholder farmers contribute greatly to poor quality of maize stored in traditional storage structures. This is because these practices are not properly performed on time. Though, (Karthikeyan *et al*., 2008), reported that traditional storage practice have two advantages over scientific knowledge namely, it has little or no cost and readily available. There is increasing demand for high-quality and safe food, free of chemical and physical contaminants and pathogens (Weinberg *et al.*, 2007). Environmental conditions, traditional farming methods and improper grain drying and storage practices facilitate quality reduction and insect infestation (Kerstin *et al.*, 2010). Effective handling practices and storage are crucial to improve agricultural incomes and food security for small scale farmers. Stored maize is attacked and damaged by several pests that lead to quality deterioration forcing farmers to sell at reduced prices and below the production cost (Sori *et al.*, 2012). Consumers of maize will pay less for maize of poor quality.

Despite significant improvement in food storage methods, many communities in Ghana still use traditional storage methods for food and seed. This has led to short falls in maize supply which has been attributed to improper traditional methods of storage and handling practices (Armah and Asante, 2003). This is because traditional storage structures coupled with improper handling practices provide limited protection against fungal growth, insect and rodent damage, especially in areas where climate is warm and humid. Although traditional storage structures are inexpensive to construct and maintain, traditional storage systems are not able to hold commodities, keep out moisture, control enzymatic activity and microbial growth and keep out rodents, insects and thieves. The quality of grains during storage is affected by entomological, microbiological and environmental factors resulting in physio-chemical and organoleptic changes that lead to significant product qualitative and quantitative losses (Iconomou *et al.*, 2006). In view of the fact that maize is a major crop in Ghana, it is important for farmers in the country to adopt and employ appropriate storage practices to store in order to reduce storage losses, insect infestation, discolouration and rodent damage to ensure that the maize they produce is of premium quality for consumption. The quality of maize grains produced by the farmers increases their income and also reduces food insecurity in the country. Unlike perishable crops, maize can be stored for a long period of time although; preservative quality during long term storage is a problem in many parts of the world as quality reduces with time of storage. Tefera *et al.,* (2011) commented that traditional storage practice in developing countries cannot guarantee protection against major storage pests of staple food crop like maize leading to 20-30% grain losses, particularly due to postharvest insect pests and grain pathogens. Proper storage of food grains is necessary to prevent spoilage, increase keeping quality and for monetary reasons. Any traditional storage practices employed or adopted by farmers could have dire effect on the quality of maize stored. Good storage practice minimises risk throughout the supply chain and safeguards food safety for consumers (HGCA, 2011). This study therefore seeks to identify the various traditional storage practices used by the maize farmers in Shai Osudoku District in Greater Accra Region. Findings from the research would help farmers to use appropriate storage practices to store high quality maize under good hygienic practices and sanitation. It would also help reduce storage losses and insect infestations.

The broad objective of the research is to determine the traditional storage practices on the quality of maize in the Shai Osudoku District. The specific objectives are

1) To identify the various maize storage practices of the farmers from harvesting to storage.
2) To identify the types of storage structures being used by farmers.
3) To determine the effectiveness of the storage structures in relation to:

i) Insect infestation

ii) Grain losses over a specific period

iii) Germination losses

iv) Discolouration

v) Presence of foreign contaminants

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Maize production in the world and Africa

Maize (*Zea mays L.*), also called corn, is one of the most crucial and strategic cereal crops in Africa and the developing world in general. It is produced in different parts of the continent under diverse climatic and ecological conditions. Due to its increasing importance, maize has become a major staple and cash crop for smallholder farmers (Manyong *et al.*, 2000).

Maize is a preferred staple for about 900 million poor consumers and a critical meal for about one third of all malnourished children. It is estimated that by 2050, the demand for maize in developing countries will double, and by 2025, maize would have become the crop with the greatest production globally and in developing countries (CIMMYT and IITA, 2010). Maize is also one of the most important commodities used for food aid. Since maize is cheaper than other cereals such as rice and wheat, it is more affordable to the vast majority of the population, and therefore occupies a prominent position in the agricultural development agenda of several countries in Africa (FARA, 2009).

FARA also reported that Africa spends close to US$2.0 billion on net imports of maize and that the average annual value of maize imports rose from US$1.14 billion in 1995-97 to US$2.25 billion in 2005-07. During the same period receipts from maize exports dropped from US$350 million to US$264 million. Maize is grown for human consumption (Pingali, 2001), and provides food and income for more than 300 million smallholder farmers (La Rovere *et al.*, 2010). Farmers in developing countries experience postharvest losses which are highly variable (5–30%) depending on weather conditions at harvesting, storage length and presence of pests (Rembold *et al.*, 2011). Postharvest grain losses are estimated to be worth US$1.6 billion per year in Eastern and Southern Africa alone (FAO and World Bank, 2010). Postharvest Loss (PHL) include losses from harvesting and drying, threshing and selling, transport, on-farm storage, and marketing. The total PHL in Africa from maize are estimated to range from 14% to 36%, and the on-farm storage losses from 4% to 10% (Tefera, 2012). In another analysis, based on an extensive review of the literature, the storage weight losses for maize in Eastern and Southern Africa for 2007 was estimated at 17.5%, valued at $920 million (Rembold *et al.*, 2011).

2.2 Maize production in Ghana and its contribution to the economy

Maize is the number one crop in terms of area planted and accounts for 50-60% of total cereal production (MiDA, 2012). Maize is the most important cereal crop on the domestic market in Ghana however it is only the 7th largest agricultural commodity in terms of value of production over the period 2005-2010 accounting for 3.3% of total agricultural production value (MAFAP, 2012).

Most of it is grown for human consumption (Pingali, 2001) and provides food and income for more than 300 million smallholder farmers (La Rovere *et al.,* 2010). Additionally, maize represents the second largest commodity crop in the country after cocoa (MiDA, 2010). Although maize is not native to Ghana, it has become the most widely cultivated staple crop in the country and accounts for a significant proportion of daily caloric intake (Morris *et al.*, 1999, Akinola *et al.*, 2007). White maize is commonly produced in Ghana while the imported maize is yellow maize used mainly as poultry feed. Its production is essentially by smallholder farmers using simple hand tools such as hoe and cutlass under traditional tillage and rain-fed conditions. Although production occurs in all of Ghana's ten administrative regions, more than 70% of maize output comes from five regions in three of the six agro-ecological zones. The five principal growing regions are Northern, Brong-Ahafo, Ashanti, Central and Eastern and the three agro-ecological zones are guinea savanna, forest savanna transition and semi-deciduous rainforest (Egyir, 2003, Amanor-Boadu, 2012).

In the Ghana Living Standard Survey (GLSS, 2000), the ecological zones were categorized into three, the northern savannah, coastal savannah and forest zones. In the forest zone the climate is dominated most of the year by moist air and conventional rainfall frequent.The rainfall is usually between 1000 and 2000 cm per annum, falling in two seasons with only a short dry season of reduced rainfall between them. In southern Ghana where this condition is prevalent two cropping seasons of maize are possible. The savannah areas may have two short rainy seasons and a pronounced intervening dry season, as in the coastal areas, or a medium length rainy season and a long dry season as found in most of northern Ghana. Millet and sorghum which are relatively short-term and drought-resistant crops are almost limited to the northern savannah zones (GLSS, 2000; Egyir, 2003, MoFA, 2008).

Maize is a major staple eaten throughout Ghana. It is also used in a variety of dishes such as “banku” and “kenkey”. The per capital consumption of maize in Ghana in the year 2000 was estimated at 42.5 kg (MoFA, 2000) and an estimated national consumption of 943,000 Mt in 2006 (MoFA, 2008). Maize accounts for 50% of caloric intake (Sinha, 2007), at least 70% of maize seeds are sourced from prior year’s harvest (Gemeda *et al.*, 2001; Dhliwayo *et al.,* 2003), and chemical maize preservatives used in post-harvest storage are toxic, costly and often do not work.

Over 40% of all household in all agro-ecological zones grow maize while less than 20% grow millet, sorghum and rice (GLSS, 2000). Very few commercial maize farms are in operation in the country at present (e.g. Ejura Farms and the Grain Development farms). The level of production on individual farms is very low, hence the need to minimize postharvest losses.

The harvested maize cobs in sheath, are either stored on a wooden frame erected in the kitchen, stored inside the room either in loose piles or in well-constructed stacks or the crib. Although Greater Accra Region is not part of the principal regions its production has increased steadily from 2776 to 4681MT over the last 6 years, recording a growth rate of 68.7% from 2007 to 2012 (Table 2.1). Table 2.1 shows the volume of maize production in Ghana from 2000-2012 in the 10 regions of Ghana (in Metric Tonnes). The total hectare of land under maize cultivation and production in Ghana from 2005-2006 is also shown in Table 2.2.

Estimated cereals grown, annum value and average annual consumption level of per capital consumption and it is about three times the demand levels of the other grains (GLSS, 2005-2006). Thus, to meet the increasing demands of maize, farmers may have to adopt improved production and handling systems. In the Greater Accra Region of Ghana, the total maize production in the years 2010, 2011, 2012 were 3584, 4461 and 4681 MT, respectively and it accounts for about 0.19%, 0.26% and 0.23% respectively of the total cereal production in Ghana (MoFA, 2013).

Table 2.1 Volume of maize production in Ghana from 2000-2012 (Mt)

Regions	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Western	86,520	86,520	159,622	72,135	73,210	75,406	77,553	79,010	74,191	71,285	82,825
Central	247,110	247,110	159,622	164,398	166,847	176,222	225,214	226,420	195,394	202,362	192,069
Eastern	218,900	244,000	241,621	206,467	209,542	227,505	280,806	303,400	380,505	364,166	405,377
Gt. Accra	2,610	2,610	2,714	2,103	2,134	2,775	2,763	3,310	3,584	4,461	4,681
Volta	58,630	58,630	53,868	47,577	48,286	49,978	72,858	97,060	93,887	97,857	84,922
Ashanti	187,000	193,920	183,032	161,816	164,226	169,383	182,848	186,830	253,374	173,735	205,419
Bron-Ahafo	295,680	295,680	281,267	358,259	363,595	381,435	402,688	446,260	510,172	434,741	570,350
Northern	79,050	79,050	74,566	96,717	98,157	88,037	131,857	155,500	202,316	192,604	209,353
Upper-West	60,710	60,710	60,801	47,422	48,128	40,104	55,233	70,660	96,018	82,651	192,090
Upper- East	20,370	20,370	14,650	14,496	14,712	8,756	27528	51,140	62,256	75,273	65,819
Total	**1,256,580**	**1,288,600**	**1,231,763**	**1,171,390**	**1,188,837**	**1,219,601**	**1,231,371**	1,619,590	**1,871,697**	**1,699,135**	**2,012,905**

Source: Statistics, Research and Information Directorate (SRID), MoFA (2013).

Table 2.2 Area planted to selected food crops ('000 ha)

Crop	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Maize	713	940	792	733	740	793	790	846	954	992	1,023	1,042
Millet	193	198	207	182	185	200	163	182	187	177	179	172
Rice	135	123	118	119	120	125	109	133	162	181	197	189
Sorghum	329	337	346	298	305	320	208	276	267	253	243	231
Total	**1370**	**1598**	**1463**	**1332**	**1350**	**1438**	**1270**	**1437**	**1570**	**1603**	**1642**	**1634**

Source: Statistics, Research and Information Directorate (SRID), MoFA (2013).

Table 2.3 Production of selected food crops ('000 Mt)

Crop	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Maize	1400	1289	1158	1171	1189	1220	1470	1620	1872	1683	1950
Millet	159	176	144	185	165	113	194	246	219	183	180
Rice (paddy)	280	239	242	237	250	185	302	391	492	463	481
Rice (milled)	193	165	167	164	173	128	208	270	3395	319	332
Sorghum	316	338	287	305	315	155	331	351	324	287	280
Total	2348	2207	1998	2062	2092	1801	2505	2878	6302	2935	3223

Source; SRID, MoFA (2013).

Agriculture plays an important role in the economy of Ghana and the lives of her people. The contribution of agriculture to GDP was 38% in 2007 at a growth of 4.3% and it contributed about 42.5% of foreign exchange earnings (ISSER, 2008). In terms of both harvest and sale values, maize is an important cash crop in Ghana.

2.2 Maize Storage Methods and Structures in Africa

Maize storage technologies are diverse among farmers and these variations have economic implications (Adetunji, 2007). Traditional methods of storage still predominate in most parts of Africa (Brice, 2002). A survey by Nyanteng (1972) and Addo *et al.*, (2002) indicated that these traditional storage methods dominate in all the 10 regions of Ghana.Farmers usually make use of storage techniques that are most suitable to them and their pocket at a point in time (As iedu *et al*, 2002) They have been developed to suit the needs of a simple, subsistence farming system. However, as production systems become modernized these storage methods may not be able to cope with increases in population. Modern storage techniques are the best because they have the highest difference in gross margin and the highest margin rate of return (Adetunji, 2007). Nyanteng (1972), Igbeka and Olumeko (1996) and Adetunji (2007) outlined various traditional storage structures. These include farmhouses, cribs, barns, platform, warehouse, silos, pens, yards and sheds deep litter houses; palm fronts woven baskets, hutches and cages.

Although a number of materials are available for construction, cost is found to be a major factor in the selection of materials. There was extensive use of locally sourced materials such as wood, natural fibres and earth for the construction of the identified structures (Itto and Wongo, 2002) and (Atukwase, 2012). These structures are relatively inexpensive but are not airtight and often exposes the stored maize to harsh environmental conditions such as sun and rain (Olakojo and Akinlosotu, 2004).The factors which tend to reduce the service life and efficiency of these facilities include rainfall, temperature and insects.

The probability of using local storage is enhanced by farmer’s age, semi modern structures is influence by quantity of maize stored while the probability of using modern storage structures is increased by years of experience, educational level of the farmers and quantity of maize stored by the farmer (Adetunji, 2007). Farmers store their food crops in various traditional structures including barns, baskets, sacks, rooms and open sheds. Middlemen in grain trade, package grains in sack and store them in their warehouses/storerooms in the market whiles sales goes on (Adetunji, 2007). These traditional grain storage systems may provide some security for traditional farmers. However, this is normally for a limited period and losses can be high. The traditional storage structures provide limited protection against fungal growth, insect and rodent damage, especially in areas where the climate is warm and humid or where grain is stored for extended periods (Mejia, 2003). The increasing demand for cereals has meant that traditional farming systems be improved by introducing and producing high yielding varieties of grains by farmers. Ngamo et al.(, 2007) reported that traditional storage structures expose grain to rodents and insect attack, and provide favorable climatic conditions for their proliferation, as well as for that of microorganisms, thus leading to substantial post-harvest losses . However, good storage methods therefore become an important aspect of household food security and rural livelihoods since they ensure a continuous stable supply of food and better farm incomes (Tefera, 2012; Thamaga-Chitja et al., 2004). It has therefore become necessary to identify the various traditional postharvest practices and storage structures used by the smallholder maize farmers, the weak areas in the practices and structures so as to find better and improved measures to correct such inefficiencies.

2.3 Traditional Storage Practices of Maize Farmers

Various traditional practices are used by different farmers based on the knowledge and experience they have acquired from their parents. Traditional storage practices are activities that smallholder farmers undertake to protect grains or maize they produce against pest attacks and maintain the quality of maize stored (Karthikeyan *et al.*, 2008). Farmers and traditional grain processors have been evolving a number of traditional practices through trial and error methods, to avoid huge losses that are occurring in stored grains due to insect pest infestation (Karthikeyan *et al.*, 2008).

The researchers also pointed out that these practices are unique to a given culture of the society and vary between communities, regions and countries. traditional practices has two advantages over scientific knowledge, it has little or no cost and readily available.

Environmental conditions, traditional farming methods and improper grain drying and storage practices facilitate quality reduction and insect infestation (Kerstin *et al.*, 2010). Smallholder farmers employ different storage practices to store their harvested maize. Thomaga-Chitja *et al.*, (2004) Maize seed was stored by hanging cobs from the roof over the cooking area (open wood fire) by seven percent of sample household. The smoke fumigate the seed and prevent insect damage.

However Tefera *et al.*, (2010) concluded that although traditional storage practices in developing countries are inexpensive and readily available, they cannot guarantee protection against major storage pests of staple food crops like maize, leading to 20-30% grain losses, particularly due to post-harvest insect pests and grain pathogens.

The research would now attempt to give a brief characterization of the ways some of the traditional postharvest activities are performed in grain value chains in Africa especially Ghana, emphasizing on how these different activities can influence postharvest losses along the different value chain stages.

2.3.1 Harvesting

Hodges & Stathers (2012) recommended that, harvesting of maize should be done as soon as they are physiologically matured, however, on reaching the physiological maturity, maize grains are still too moist and soft to be threshed so most smallholder farmers leave them to dry naturally in the field for several weeks prior to harvest.

Kaaya et al., (2006) observed that harvesting is very crucial as regards the subsequent storage quality of the grains. Early harvesting has been advocated as a means to reducing the risk of aflatoxin contaminations (Bankole and Adebanjo, 2003: Rachaputi *et al.,* 2002).

The optimum time of harvesting maize is when the stalks have dried and moisture of grain is about 17-20% (FAO, 2011). African farmers harvest grain crops once the grain reaches physiological maturity (moisture content is 20–30%) (World Bank, FAO, NRI, 2011 and Boxall *et al*., 2002). Pioneer Agronomy Science (2009) noted that harvesting grain at a moisture which is too high can result in severe kernel damage during threshing and drying. Conversely, allowing corn to field dry too long can lead to reduced yield and quality, increasing stalk or ear rot diseases and insect feeding damage (Pioneer Agronomy Sciences, 2009).

When harvesting is done close to the start of a rainy season, a delay can result in the harvest been undertaken in damp, cloudy weather, and the crop will be insufficiently dried (World Bank, FAO, NRI, 2011). Harvesting by hand is the traditional method used by small producers in Africa (Ganesh 2001 and Agona 2008). Hand harvesting is less wasteful, but labour constraints can lead to delays in or failures to harvest; these then can result in significant postharvest losses. Late harvesting may also cause a problem as the fields need to be released for the planting of other crops (Hodges and Stathers ,2012).

World Bank, (2011) reported that unseasonal rains at this stage (harvesting period) can dampen the crop, resulting in mould growth and the associated risk of aflatoxin or other mycotoxin contamination. Weather conditions at the time of harvest are a critical factor influencing PHL. Hodges and Stathers, (2012) suggested that if rain delays the maize harvest, then turn cobs down by breaking stem just below cob so the cob hangs down to prevent water from entering it. However, Alakonya et al.,(2008) reported that delayed harvesting increases lodging incidence that allows ears to touch the ground exacerbate the problem of ear rot. Harvesting efficiently and at the right time is critical to avoid losses down the chain (World Bank,FAO, NRI, 2011). For most smallholders in Africa, mechanical harvesting is not an option because the scale is inappropriate and this requires high capital investment.

2.3.2 Piling or heaping harvested maize cobs on the ground

Chomchalow (2003) observed that in most developing countries including Ghana, major portions of stored foods are kept on-farms, although a significant portion is also transported for storage in households. A very small percentage is stored in community or commercial storage facilities where modern technology such as the use of chemicals like fumigants, is employed for stored food protection (Chomchalom, 2003).Hell, (2000) observed that farmers in Benin heap their harvested maize as a pre-storage practice. Additionally, Kaaya *et al*,(2006) reported that heaping maize on the floor is a common storage practice among the farmers in Uganda .They however, indicated that heaping maize grain during storage promotes mould and insect proliferation when the grain is inadeaquately dried due to heat build-up.

This practice is common among smallholder farmers because their farms are located in distance areas away from their storage structures. As a result, they heap harvested cobs on the ground or on local waterproof materials before transporting them to where it would be processed and stored finally. Farmers engage in this practice because harvesting by hand is the traditional method used by small producers in Africa and very time consuming (World Bank, FAO, NRI, 2011).

After harvesting the cobs, they are piled on the ground mostly unprotected awaiting transport to a safer location (FAO, 2003). Losses are small for short periods because the maize sheath provides a smooth–surface which sheds rain down its slopes quite well, permitting very little penetration. But with time, depressions develop on the surfaces, allowing rain to soak downward and destroy sections of grains in the cobs. The floor of the pile absorbs moisture from the ground, and surface water creeps under the edges of the pile (USAID, 2011). The grains in the cobs are exposed to rodents, birds, insects and wind so that losses become severe within a few weeks. This practice also encourages further drying of the maize and cobs, and provides adequate time for the farmer to construct, repair or treat the storage structures before they receive the harvested maize grains.

2.3.3 Drying

The main purposes of drying are to prevent germination, the growth of bacteria and fungi, and considerably retard the development of mites and insects (FAO, 2003). FAO (2011) therefore puts drying of maize into two methods: natural drying and artificial drying. The natural method makes use of exposure of the wet grain to the sun and wind. Artificial drying employs the application of heat from combust of fossil and biomass resources directly and indirectly. The amount of drying in the field depends on parameters such as corn maturity, hybrid, and moisture content, air temperature and relative humidity, solar radiation, and wind speed (Hellenvang, 2011). The moisture content to which maize will dry is determined by the corn's equilibrium moisture content (EMC) which is based on air temperature and relative humidity (Hellenvang, 2011).

However, drying grain quickly and effectively after harvest and before storage retains maximum quality, to attain a moisture content sufficiently low to minimize infestation by insect and microorganism and to prevent germination (FAO, 2011). Most farmers in Africa, both small and large, rely almost exclusively on natural drying of crops from a combination of sunshine and movement of atmospheric air through the product, so damp weather at harvest time can be a serious cause of postharvest losses Drying grains should ensure that there is minimal damage to grain quality and contamination whiles achieving the desired moisture content (World Bank, FAO,NRI 2011) . Most maize farmers practice field drying where the maize are left to dry in the field for 4-7 weeks after maturity, either in stalks, stacks or heaps (FAO, 2003; Thamaga-Chitja, 2004).

Maize cobs are dried either in dehusked or in sheaths forms. Dehusked cobs take shorter time to dry than in sheaths. After drying farmers prefer to store maize on the cobs, rather than as loose grains because less work is required in preparation. Again the harvesting period usually coincides with periods of intense labour activities on farms with cash crops such as cotton and cocoa which need to be attended to. Some farmers shell late harvested crop (16-20%) for drying in grain form at the farm yard or homes. FAO,(2003) reported that,smallholder farmers in Africa employ the following traditional techniques in drying their harvested maize and these include: maize cob dried dehusked or in sheaths, suspended maize cobs above fire places in kitchen houses in the form of stringed-up cobs, use of round or rectangular slatted wall farm structures to dry, poles or tree-branch to dry . The heat and smoke from fire help in drying and scaring off insect pests from the crop, keeping the grain intact and safe for future planting (Hell, 2000 and Modi, 2003). This form of drying however is used for small quantities of maize seeds. The use of round or rectangular slatted wall farm structures to dry and store maize in cobs is another form of drying.

These often have a roof-thatch of grass, banana or palm leaves. This form of drying is very popular in some part of West Africa (FAO, 2003). One of the major problems with this traditional practice of drying maize in Ghana is frequent rains during the drying period with consequent high relative humidity, poor insulation or protection of the maize and shortage of labour. This practice also exposes the maize to field pests. Drying maize on the bare ground is the most common practice used by farmers all over Africa (Kaaya *et al.*, 2006 & Atukwase *et al.*, 2009). The maize ear is evenly spread on the bare ground and open sun-dried kills moisture content to reach 14% (Kaaya & Kyamuhangire, 2010). Also, bare ground drying of maize is regarded to be a feature associated with mould and aflatoxin contamination of maize (Kaaya *et al.*, 2005 and Kaaya *et al., 2006*). However, Hamilton (2000) reported that drying harvested maize to 15.5% moisture content within 24-48 hours reduced the risk of fungi growth and consequently aflatoxin production.

This practice is preferred because these farmers do not have drying facilities at the homes or farm yard. Field drying does not attain recommended moisture level for safe storage. The crop must therefore be further dried at the farm yard or homes before storage. IieIleji, (2010) in a research conducted in Ejura and Techiman reported that improper drying of maize leads to spoilage, aflatoxin contamination and prevents the use of PICS, technology.

2.3.4 Shelling and Cleaning

Shelling is the removal of maize grains from the cob. FAO (2003) observed that maize shelling is difficult at moisture content above 25%. With this moisture content, grain stripping efficiency is very poor with high operational energy and causing mechanical damage to the kernels. A more efficient shelling is achieved when the grain has been suitable dry to 13-14% moisture content (FAO, 2003).

Hellevang (2011) made allusions that more fines are produced when corn is wet, because more aggressive shelling is required, which causes more kernel cracking and breaking. He concluded that fines cause storage problems because they spoil faster than whole kernels, they have high airflow resistance, and they accumulate in high concentrations under the fill hole unless a spreader or distributor is used.

Traditionally shelling of maize grains from cobs is mostly done by women and children using the hands which cause minimum losses (Agona, 2008 and Matita and Dambolachepa 2015). However it is very labour intensive and time consuming (Itto and Wongo, 2002). FAO (2003) indicated that hand shelling results in less than 1% average loss of grains. For most large farms in Ghana, farmers result to beating the maize cobs in sacks with sticks or a confined floor space where farmers can afford it to shell the grains from the cobs (US Department of State 2013). It also observed that this method of shelling maize leads to breakage of kernel, mycotoxins contamination and higher percentage of foreign matter. This practice although requires more labour and time, results in physical damage which makes the resulting grains more vulnerable to pests, moulds and damage to the germ as well as contamination. Again, there are very high losses due to unseparated grains on the cobs. Hellevang (2011) observed that most African farmers would like to use mechanical shellers which are more efficient for their maize; however, they cannot afford such technology. Machine shelling losses considering broken kernels and grain lost with chaff into the soil range from 2 to 5% (FAO, 2003 and Hodges, 2012). Farmers are aware that shelling of maize facilitates further drying and indicates that such maize can be stored within the house thereby preventing maize loss from theft (Matita and Dambolachepa,2015).

Cleaning involves separating the chaff in broken bits of cob from the grain and cleaning of grain substantially improves its quality and hence its grade and price

(Hodges and Stathers 2012). A simple way is winnowing, where farmers drop shelled grains from certain height and the natural wind eliminates the impurities, however, this method is tedious, inefficient and causes grain losses. Cleaning of grains is useful since it reduces the impurities, mould and insect development and increases market value of the grains (Hodges and Stathers, 2012).Ransom, (2000) argued that shelled grain should be carefully sorted and broken and damaged kernels removed before storage. Most farmers however shell their maize only when sales or home consumption is to be done.Sorting out diseased , damaged and discoloured maize kernels as well as cleaning before storage were associated with reduced aflatoxin(Kaaya *et al.,* 2006).

2.3.5 Bagging

Bagging is another traditional storage practice of most maize farmers in Africa. Bag storage is the most convenient way of keeping grain but the bags should be stored on platforms in order to prevent moisture absorption from the ground(Agona 2008). The bags serve as containers where the maize produce is kept before being placed into the appropriate storage structures. The bags provide some form of protection to the grains, make easy handling and transportation as well as serve as unit of measurement during trading (Kaaya *et al.,* 2006).However, Thamaga-Chitja *et al.,* (2004) reported that storing maize seeds in sacks provided little protection against insects and maize stored in this manner absorbed moisture. The efficacy of storage in bags largely depends on where they are kept. If they are exposed to rain or not well sealed, insects and water may enter, causing damage to the grain (Rochat and Guenat, 2013).The introduction of PIC bags by Purdu University has brought a great relief to farmers who bags to store maize.Baoua, *et al.*, (2014) reported that PIC bagscan be used for maize storage even in areas with prevalance of *P. truncatus* but storage should be soon after harvest and drying to minimizing bag damage. PICS bags. PICS bags arrest the development of storage insect pests, which can spread the mold through the container, as reported by Hell *et al.*, (2000). Grain that had been stored in PICS bag was generally less contaminated than that from the control bags, possibly because the hypoxia and hypercarbia (IFPRI, 2010) associated with hermetic storage hinders the development of the pathogen. The PICS technology promises to be useful for storage of dry maize, causing extensive mortality of the two main pests, P. truncatus and S. Oryzae (Baoua *et al*., 2014).

2.3.6 Storage Structures Used

The storage arrangements and methods currently in use in many societies are the result of age-old experience and tradition, and have become perfectly suited to local conditions. 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 (Agona , 2008) . During storage, the grain must remain dry, clean, secure, free from pest infestation and protected from harsh environmental conditions, fire and theft (FAO, 2011).

Karthikeyen *et al.*, (2009) stated that the logic behind the use of indigenous structures for storage is that they are user friendly and also associated with some scientific reasoning. They also hinted that farmers stored the grains to meet their own consumption, seed and for sales. They further reported that the form of storage is either in containers or in bulk whiles FAO (2011) stated the place of storage to be either outside, suspended or on platforms, or in granaries, or even inside their homes. The type and volume of maize variety to be stored, the availability of local materials and the environmental conditions determine the type, duration and capacity of the facility (FAO, 2011).

Udoh *et al.,* (2000) classified traditional storage structures to be at farm and domestic level which includes local cribs and rhombus, platform, open field, roof and fireplace. Other authors identified some more traditional storage structures to include storage on the ground, under the ground, platform, crib, dwellings (room), banco granaries and bag storage (FAO, 2011, Govender *et al.*, 2008 and Thamaga-Chitja *et al.*, 2004). In most developing countries, the major portion of stored food is kept on-farms, although a significant portion is also transported for storage in households. A very small percentage is stored in community or commercial storage facilities where modern technology such as the use of chemical fumigants, is employed in stored food protection (Chomchalow, 2003).

However, the majority of farmers sell off their maize grains cheaply soon after harvesting due to anticipated losses in storage and later buy food at exorbitant prices (Gavender *et al.*, 2008). Although storage lengths of maize ranged from 3 to 24 months in Northern Kwazulu-Natal, the average storage length ranged from 5.6 to 8.6 months, indicating that grain is commonly consumed prior to or by the time the new season's maize is ready for harvesting (Thomaga-Chitja, 2004).

Tefera *et al.,* (2008) reported that maize in traditional storage structures lost some quality attributes (weight loss, germination losses, flour formation and increased insect population) after the maize was stored for 30, 60 and 90 days in the lab. There are improved storage structures that can maintain the grain quality until market prices for grains are favourable (USAID, 2011). Grain storage can be extended for up to 2 years without any significant reduction in quantity and quality. Each type of grain storage arrangement must undergo continued improvements in order to give commodities the greatest protection against pests and adverse environment (FAO, 2011).

2.3.7 Preservation Methods

Proper storage of food grains is necessary to prevent spoilage, keeping quality and for monetary reasons. The practice of using natural resources for storage of various household items dates back to the very earliest periods of known history. Traditionally, stored produce has been protected against insect damage by using protectants like Neem leaves (Azadirachta indica), pepper (*Piper* guineense), ash, ash mixed with sand, kerosene, smoke, cooking fire or manure (Hell *et al.,* 2000). These treatments are usually applied to maize cobs. The cobs are subjected to smoke and heat from the kitchen fire or when outside the house from a fire lit underneath the maize platform to facilitate cob drying, the fire raises the temperature of the cobs often scorching the other husk (Kaaya *et al.*, 2006). *Sitophilus* species are said to be particularly sensitive to this treatment (Kaaya *et al.*, 2006).

2.3.7.1 Smoking

The use of smoke as a preservation method is one of the oldest if not the oldest traditional preservation methods. This treatment is usually applied to maize cobs. The cobs are subjected to smoke and heat from the kitchen fire or when outside the house from a fire lit underneath the maize platform to facilitate cob drying, the fire raises the temperature of the cobs often scorching the other husk (Kaaya *et al.*, 2006). Maize seeds are stored by hanging cobs from the roof over the cooking area (open wood fire) usually in households where proper supervision is enforced to prevent maize cobs from burning. The smoke fumigates the seeds, preventing insect damage. *Sitophilus* species are said to

Maize stored above fire place was effective against insect damage and diseases (Thamaga-Chitja *et al.*, (2004). Udoh (1997) reported that between 3.6 and 12% of the farmers in the different agro-ecological zones of Nigeria used smoke to protect their maize and afflation levels decreased when smoke was used to protect maize.Thomaga-Chitja *et al.,* (2004) pointed out that the smoke prevented the seed from spoiling and from pest infestation, but lamented that the quality of the maize seed stored in this way may be inferior. However, recent research on seed vigour shows that roof-stored seed had more vigour during germination than commercially available

maize seed (Modi, 2003). Bankole and Adebanjo,(2003) observed that the problem with somking is that if not carefully applied ,it may discolour the product and change the taste.

Hell, (2000) indicated that smoking of maize in Benin was associated with lower aflatoxins contamination. Smoking was a very effective means of protecting maize against storage insects and compared well with chemical insecticides like Actellic1 (pirimiphos-methyl). The seed moisture content at the time of storage, frequency of lighting fires, temperature and humidity at the storage place are possible factors that could affect the efficiency of this storage method.

2.3.7.2 Botanicals

Throughout the developing world, poor rural communities have used their knowledge and insight about their environment to improve their livelihoods. This indigenous knowledge has provided Ghanaian farmers with an understanding of plant chemistry and modes of action for plant species they are already using (Belmain and Stevenson

(2001). Their experiences have proved that these pesticidal plants can be reliably and safely used to treat grain and legumes when stored in small quantities at the farm level. Some plants used for post-harvest storage protection in Ghana had already been studied for various pesticidal and medicinal uses. For example, chilli peppers, orange peel, neem leaves, neem oil, ash mixed with sand and manure are well-known botanicals for post-harvest protection (Hell *et al*., 2000; Karthikeyan *et al.*, 2008).

Belmain and Stevenson (2001) identified 16 plant species been used by farmers in northern Ghana as botanicals. Some of these plant species include *Cassia sophera*, *Securidaca longepedunculata*, *Ocimum americanum*, *Lippia multiflora*, *Synedrella nodiflora* and *Azadirachta indica*. Rochat and Guenat (2013) also observed that the neem tree, *Azadirachta indica*, was probably the most well-known botanical and was used widely throughout Africa for a variety of medicinal and agricultural uses. Neem products are relatively harmless to most beneficial arthropods, are biodegradable and appear less likely to build up genetic resistance in target pests (Obeng-Ofori, 1999).

Pesticides derived from neem are broad spectrum in their activity, affecting over 300 species of insects, as well as mites, nematodes, fungi, bacteria and viruses (Schmutterer, 1995). These plant materials are used in many forms such as leaves, roots, flowers or their derivatives in solutions, powders, oils and cakes (Shehu *et al.*, 2010 and Karthikayam *et al.*, 2009). Many botanical pesticides are effective against pests as antifeedants, repellents or toxicants, and are less hazardous than synthetic pesticides to people and the environment (Obeng-Ofori, 2007).

Many plant substances that are used in grain storage are also used in traditional medicine. It has been reported that *A. flavus* can grow on medicinal plants and develop aflatoxins (Samina *et al*., 2014). Thus the mixing of plant substances with stored maize cobs may actually increase the risk of aflatoxin development instead of controlling it.

Also plant materials such as leaves may increase the relative humidity inside the grain store if not properly dried.

Often, ash is effective in controlling insect damage (Almekinders and Louwaars, 1999). Ash is used both as an inert filler and for its other negative effects on insects. As an inert filler, ash works by filling up the space around the seed and impeding the movement of insects as well as, in sealed containers, reducing the volume of air available to the insects for respiration. Ash has been reported to damage the cuticle of insects causing them to dehydrate and also has detrimental effect on egg development (Almekinders and Louwaars, 1999, Grant, 1990, Naito, 1999 and Wright *et al.*, 1994). The application of ash should be done well before infestation by insects begins as this would ensure the effectiveness of the ash in reducing insect damage.

Traditional storage methods of using indigenous plants with insecticidal properties could, if improved, offer a safer, low-cost and more dependable method of storage protection while reducing the increasing reliance upon conventional pesticides and pest resistance.

2.3.7.3 Chemical Usage

The most frequently used chemical is Sofagrain, a synthetic pyrethrinoid, which is packed in small bags that are spread in the granary. It is effective for three months, and the grains should not be consumed during this period (Rochat and Guenat, 2013). . Sofagrain is the main chemical sold at CeCPA . Although Atelic Super Dust, which has the same active ingredient, is seemingly more effective, it is more expensive and its application requires more labour. Farmers therefore prefer Sofagrain and they use it a lot (Rochat and Guenat, 2013).

Otherwise, the storage treatment varied from farmer to farmer and within regions. Those who treated their maize used commercial insecticides, either a specific formulation for stored grains such as Sofagrain1 (pirimiphos-methyl and permethrin), Actellic1 (pirimiphos-methyl) or Percal M1 (permethrin and malathion) or insecticides commonly used against cotton pests. Few Beninese farmers used rodenticides. Another method of resolving storage problems was to sell the maize (Hell *et al.*, 2000).

In this practice about 1g of camphor pieces per 5kg of grains was placed as such in the jute bags. This practice of placing the camphor inside the grains storage bags repelled the storage insects due to the strong odour emanating from the camphor. This method keeps the grains safe for a maximum of 3 months after which the grains are dried and fresh camphor added to prolong the strong (Karthikayam *et al.*, 2009).

2.3.8 Management of Grain Losses

The farmers' reaction to storage problems is varied. The reward of all farmers for all their hard work is in the maize produce which they later translate into food or cash. They try as much as possible to reduce losses using the traditional preservation methods they know best. However when they notice the produce are losing quality and quantity due to pest and theft, they quickly implement measures that would save them some value. Some of the measures implemented include further drying the grains in high temperature sunlight to expel the insects, reduce moisture and promote aeration. Again some farmers shell and bag the maize grains into appropriate containers to prolong the shelf life as well as reduce further losses. Hell *et al.*, (2000) observed that maize farmers in Benin sell off their maize grains when they start experiencing losses in storage. When farmers observe that the grain damage is beyond the safe consumption level, they either discard the produce or feed it to their livestock. Hell *et* *al.*, (2000) further observed that approximately 50% of the questioned farmers did not do anything to counter storage problems (Hell *et al.*, 2000).

2.4 Traditional Storage Structures

Nyanteng (1972) and Addo *et al.*, (2002) observed that traditional storage methods and structures are used in all the 10 regions in Ghana and that these structures have been developed to suit the needs of simple subsistence farming. All maize storage structures, no matter the make, form or shape, should keep the produce dry and cool, and protect it against insects, fungi, rodents, domestic animals and thieves. However the choice of storage structure depends on the type of maize, duration of storage, financial capabilities, available materials and the external circumstances (climate) under which the produce would be stored. Safe storage of maize at the farm-level is crucial, as it directly impacts on poverty alleviation, food and income security and prosperity for the smallholder farmers.

Without appropriate grain storage technologies, farmers are forced to sell maize when prices are low to avoid post-harvest losses from storage pests and pathogens. Again they cannot use their harvest as collateral to access credit and ultimately their food security is undermined (Semple *et al.*, 1992). 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. Udoh *et al.*, (2000) classified traditional storage structures to be at farm and domestic level which includes local cribs and rhombus, platform, open field, roof and fireplace.

Other authors identified some more traditional storage structures to include storage on the ground, under the ground, platform, crib, dwellings (room), banco granaries and bag storage (Thamaga-Chitja *et al.*, 2004, Govender *et al.*, 2008 and FAO, 2011).

Rainfall, temperature and insects are factors which turn to reduce the service life and efficiency of these storage structures. However Jayas and White (2003) reported that the most important factors that influence storage are temperature, moisture, carbon dioxide, oxygen, grain characteristics, microorganisms, insects, mites, rodents, birds, geographical location and the storage facility itself.

2.4.1 Platform Storage Structure

A platform consists essentially of a number of relatively straight poles laid horizontally on a series of upright posts with a flat top. Platforms are usually rectangular in shape, but circular or polygonal platforms are common in some countries (FAO, 2011). The platforms are usually roofed with thatch of grass, palm leaves or papyrus.

Locally available materials and skills are used for the construction to minimise cost. Grain is stored on platforms in heaps, in woven baskets or in bags. When heaped, the peripheral are built carefully to form a wall, the inner cobs are loosely packed. The stacked maize cobs are girdled at intervals with ropes or twines made from tree bark to provide physical support. Platforms in the open may be raised at least 1 meter above ground.

In humid countries fires may be lit under elevated platforms, to dry the produce and deter insects or other pests (FAO, 2011). In other places the kitchen or cooking areas are set under the elevated places with the intention that the heat from the daily cooking would provide some form of protection to the maize. Again the poles are sometimes fitted with rodent guards; the structure is treated with chemicals to protect it and its contents from insect pests. Due to the inefficiency of this storage structure it can only store for up to 6 months (Hayma, 2003).

a b

Plate 2.1 Platform Storage Structure with (a) well thatched roof (b) poor thatched roof

2.4.2 Crib Structure

The crib structure is a distinct improvement on the platform in that a crib has ventilated sides made of bamboo planks or even wire netting and its orientation is such that the prevailing winds blow perpendicular to the length (FAO, 2011). The traditional crib is used for dry-storing maize after harvesting. The maize crib in its many forms acts as both a dryer and a storage structure. The rate and uniformity of drying are controlled by the relative humidity of the air and the ease with which air can pass through the bed of cobs (Johnson, 2000).

The degree of movement of air through the loaded crib is largely attributable to the width of the crib; research in West Africa has shown that crib widths should not exceed 0.6 m (FAO, 2011). A survey conducted by Amankwah (2009) in Odumase showed that all the crib structures used by the maize farmers had average widths exceeding the standard. He further noted that aside the wide width, the low clearance from ground and little or no space left between walls members do not make for effective ventilation of maize kept in the cribs.

The maize crib is suitable for the storage of maize cobs in the humid and dry tropics (FAO, 2011). They are mostly located on the field or at home to ensure some form of security against theft. Due to the exposed nature of the structure the maize is stored with the husk on, usually cobs with full husk covering are preferred for storage. Udoh *et al.*, 2000 observed that sorting of poorly covered maize cobs and storing maize in a crib was associated with decreased aflatoxin contamination in the stored maize.

However the presence of insects was a significant contributing factor to increased aflatoxin levels. The maize cobs were not arranged in the structure. Locally available materials used for the construction include lumber, tree bark, bamboo and cement, with thatch grass, iron sheets and veneer waste as roofing materials. Although most of the traditional crib structures are raised above the ground, they do not protect the maize from flying pests and rainfall entry (Johnson, 2000).

a **b**

Plate 2.2 Crib Storage Structure made with (a) bamboo (b) sawn wood

2.4.3 Shed Storage structure

The shed storage structure is another simplified form of platform structure. It is mostly constructed inside a building, it may be raised just 35 - 40 cm above ground level to facilitate cleaning and inspection (FAO, 2011). Its main function is to promote drying of the harvest but not storage. Due to this reason it is unable to keep the produce for a long time without experiencing serious postharvest losses. The shed structure becomes a storage structure when the maize is kept in them long after the drying period. They are mostly unable to protect the maize against all the postharvest causes of loss such as pests, theft, harsh climatic conditions and fires (FAO, 2011).

a **b**

Plate 2.3 Shed Storage Structure with (a) poor roofing sheet (b) earth and roofing sheet walling

2.4.5 Barn and Ava Storage Structures

This consists of radiating sticks constructed on the legs of wooden stalks of ten to fifteen feet. The barn, commonly referred to as Ewe Barn, is mainly used for storing maize (Boxall *et al.*, 2002). They observed the maize cobs to be stacked into a compact cylinder with pointed ends of the maize directed inwards and at an angle. This is automatic arrangement following the shape of the barn. They concluded that the arrangement provided some sort of safe drainage system for rain water falling on the maize. Back of trees, raffia leaves are sometimes used to cover the stack of maize to prevent rainfall from reaching it. Instead of being horizontal and flat, it may be conical in shape which is the point at the bottom. It may be as wide as 3m in diameter.

The platforms are usually between 2 and 3 meters in diameter but some may be more than 6 meters wide, with a maximum height of 2.5m at the centre and 1.5m at the periphery (Boxall *et al.*, 2002). At the top they consist of a frame of horizontal poles which is square, circular or polygonal in shape, against which the timbers which form the cone rest. These timbers meet at the bottom on a wide central supporting post (FAO, 2011). Such structures facilitate drying because of their funnel shape (Boxall, 2001). In southern Benin, Togo and Ghana, for example, maximum cobs in the sheaths are laid in layers on circular platforms with their tips pointing inwards. In Ghana such granary is called "Ewe" barn.

a

b

Plate 2.4 (a) Barn Storage Structure (b) Ava Storage Structure

2.4.6 Room Storage Structure

Room storage structures are suitable for both the dry and the wet tropics. They are built to protect the grains from rain by a roof and the bottom floor made of (reinforced) concrete or (fired) bricks. These structures provide air- and watertight storage particularly when they are painted with for example chlorinated rubber-based paint, coal tar or bitumen (Hayma, 2003). Room structures are built in many forms and sizes, and are usually located near the home of the farmer.

Most of the room storage structures used by smallholder farmers are improvised structures for storing husked or dehusked maize in sacks, bags or on the bare floor. This type of structure is used by farmers who produce relatively large output and have the financial means to put up cement or brick structures. The structure offers better protection for the grains from rodents, theft and harsh external environmental conditions such as rainfall and harsh temperature (Hayma, 2003). However when the maize are placed on the bare ground or on the concrete floors, they become exposed to spores of aflatoxins and moulds which later reproduce and multiple when storage conditions become very favourable (Mejia, 2003).

Payne (1998) reported that aflatoxins are produced by four species of soil and plant debris-inhabiting moulds of the genus *Aspergillus*. Some further dry the dehusked maize in the room structures on the floor exposing the grains to mould spores under conditions of high relative humidity and temperature, accelerating development of the pathogens (IFPRI, 2010). The farmers sometimes mixed old and new stock together in storage further contaminating the new stock (Baoua *et al.*, 2014). The structures may have windows with insect proof netting to control insect and rodent entry as well as doors to restrict access to the stored maize (Hayma, 2003). However much work has not been done on the effectiveness of room storage structures in protecting the maize grains stored in them.

a

b

Plate 2.5 Room Storage Structure with (a) built with earth material (b) unhusked maize.

2.4.7 Kitchen Storage Structure

The use of the kitchen as a storage structure is a cheaper alternative to the Room storage structure for most rural maize farmers in Ghana. This is because most farmers have adequately built structures which they used as their kitchens. So due to lack of space most of the famers store their produce in their kitchens. This practice is very common in the tropics particularly Africa (Hayma, 2003).

The practice of kitchen storage is preferred because most farmers believe the heat and smoke from the kitchen would protect the maize stored from insect attack and damage (Mejia, 2003). He noticed that they place the husked or dehusked maize on the bare ground in sacks near the fireplace. Some also place them on platform or hang them directly above the fireplace. This they do by constructing an airy platform above the fireplace in such a way that the smoke and hot air can move easily through the product (Hayma, 2003).

Traditionally, smoke is used to minimize insect damage as well as to reduce moisture content to a suitable level (Almekinders and Louwaars, (1999), Modi, (2004) and Wright *et al.*, 1994)). The heat and smoke from the fire help in drying the maize below

10-12% moisture content and scaring off insects keeping the grains safe and intact (FAO, 2003). It has been argued that the combined effect of smoke and high temperatures during smoking has a permanent effect on seed testa which prevents oxygen rise around the embryo during storage thus increasing hermetic conditions as far as the embryo is concerned (Wambugu *et al.*, 2009). Udoh *et al.*, (2000) reported the use of smoke had a drying effect on maize which significantly reduced the aflatoxin content however increased insect number resulted in higher levels of aflatoxins.

Wambugu *et al.*, (2009) observed that maize stored above the fireplace after 6 months had very low vigour and viability among Kenya maize farmers. In South Africa, maize stored above the fireplace had inferior seed quality which led to low germination and poor yields (Thamaga-Chitja *et al.*, 2004). This contradiction in results can partly be attributed to the differences in the manner in which smoking was done. The seed moisture content at the time of storage, frequency of lighting fires, temperature and humidity at the storage place are possible factors that could affect the outcome of the storage methods (Muli *et al.*, 2004). These authors found that smoking is less effective under roofs of corrugated iron sheets than under grass or palm leaf roofs. They concluded that corrugated iron sheets generated more heat inside the house than other types of roofs such as grass thatched ones and that temperature is probably the main factor involved in determining the effectiveness of smoking.

a b

Plate 2.6 Kitchen Storage Structure with (a) neem leaves as insect repellent (b) maize cobs stored as seeds.

2.4.8 Bag Storage Structure

The use of bags or sacks as storage structure is often very cheap in terms of cost and management of maize in storage. The bags can be made of different materials but the most used materials include jute, cotton, rubber/plastic, straw or sisal. These materials can be put into many different colours and sizes of bags. These bags also may be labelled and provide good conditions for fumigation practices. The bags, particularly plastic bags, are suitable for storage in the humid and dry tropics. In general jute sacks are cheaper than sacks made of cotton, plastics or sisal (Viller *et al.*, (2008), Yakubu *et al.*, (2011) and Anankware *et al.*, (2012).

The maize can be stored as husked or unhusked maize cob or as shelled grains. However the maize has to be well dried because after storage almost no further drying occurs (Hayma, 2003). Even in open plastic bags the product does not dry because there is very little or no air circulation. If the plastic bags are closed well, airtight storage is obtained with all its advantages and disadvantages. Plastic bags do not offer much protection against rodents, fire and so extra attention is required. Also certain seeds, such as some varieties of maize, have sharp points that can perforate the plastic bags. Although the storage bags serve as a unit of measurement, they are easily damaged during handling and transportation.

Hayma further reported that if the stored product is to be marketed and a lot of transport is involved before getting to the marketing centre, then the use of plastic bags are very vulnerable to damage. This depends, of course, on the thickness and strength of the plastic material used. If cereals infected with grain weevils or bean beetles are stored, it is possible that the insects will puncture the plastic when trying to escape from the bag. This can be prevented by putting a bag of tightly woven cotton inside the plastic bag. Plastic becomes weak or brittle after continued exposure to ultra violet light, therefore no plastic package will last indefinitely in direct sunlight (Hayma, 2003).

An advantage of transparent plastic is that the product remains visible, which makes checking the contents easier. Although the product may look alright from the outside, its quality may be disappointing when it is felt by hand, or it may be musty. A disadvantage of transparent plastic is that lizards and mice can see insects and grains inside, and may prey on them, which will damage the plastic. The main disadvantages of bag storage structures are that they are not fire, rodent and theft proof and require suitable storage location. When plastic bags used for storing produce are tied such that the bags become air tight then they are referred to as hermetic bags storage.

Plate 2.7 Sack Storage Structure in a secure room.

2.4.9 Hermetic Storage Structure

When a sealed container does not allow oxygen and water to move between the outside atmosphere and the internally stored grain, the internal built-up of carbon dioxide will eventually reach a level of toxicity where it is impossible for insects and moulds to survive. Such a storage structure is referred to as hermetic (Costa, 2014). Costa further explained that hermetic storage therefore involves storage of commodities in an airtight and watertight or low permeability environment, that provides negligible or no gas exchange between the hermetic environment and external environment.

Many hermetic containers made from different locally available materials are been used traditionally for storing maize. Some of them include plastic bags, PVC tanks, recycled food containers such as metallic barrels and drums, edible oil containers ("Kuffour" gallons), gourds and clay pots. Hermetic storage has been proven to be effective under hot and humid, tropical conditions. The use of hermetic bags has the advantage of simplicity, durability and low cost and producing chemical-, contaminant-, and pathogen-free, high quality maize after storage (Yakubu, 2012).

Hermetic methods for maize storage in Africa have been considered in part because of the high cost and limited availability of good quality pesticides. Metal silos are being promoted in the sub-Saharan zone (Tefera *et al.,* 2011; Yusuf and He, 2011), but their use by farmers is hindered by the high initial investment and limited availability of the technology. Simplier and cheaper alternatives have been offered and adapted by some maize farmers in Ghana (MoFA, 2008). Some of these include the Super Grain Bag produced by GrainPro, Purdue Improved Crop Storage (PICS) bag, Purdue triple bag system, triple layer hermetic bag and galvanized steel silo (Villers *et al.*, 2008, Baributsa *et al.*, 2010, Yakubu *et al.*, 2011 and Anankware *et al.*, 2012).

Many research works have been conducted on the use of hermetic storage structures and the results show that these structures are the best and safest in terms of maintaining grain quality and wholesomeness. These structures have demonstrated to maintain the moisture content and germination (Edoh Ognakosan *et al.*, (2013), Yakubu, (2012); reduced or eliminated insect infestation, damage, weight loss; (Yakubu *et al.*, 2011, Van Chin and Kieu, 2006, Bauoua *et al.*, 2014) and aflatoxins content (IFPRI, 2010, Ellis *et al.*, 1994, Hell *et al.*, 2000) of maize grains stored in them for a minimum of 6.5 months. However these structures come with their own disadvantages.

The Super Grain Bag produced by GrainPro is a bag made of high-tech oxygen-impermeable plastic films that represents an alternative to metal silos (Villers *et al.*, 2008). Recent surveys in Kenya and Benin concluded that the GrainPro technology is inadequate for the long-term storage of maize infested by *P. truncatus* due to perforations of the bag caused by the insect (De Groote *et al.*, 2013; Edoh Ognakossan *et al.*, 2013). Baoua *et al.*, 2014 recommended that the grains be put into the PICS storage as soon as possible after harvest and drying and also to evaluate the relationship between PICS storage and aflatoxins accumulation, particularly of the relationship between moisture content, oxygen levels and *Aspergillus* growth and aflatoxin production.

Again the grains have to be well dried, the structure must be airtight throughout the storage period and the inability to monitor the grains while in storage. Other challenges to implementing this method are capacity development (farmer education), commercial production and distribution of the hermetic storage structures and further field support for the farmers. The use of these modern silos by farmers is hindered by the high initial investment and limited availability of the technology (Tefera *et al.*, 2011; Yusuf and He, 2011).

Hermetic storage is a safe, cost effective storage method that eliminates insects and molds through the synergistic effect of O_2 depletion and CO_2 accumulation in the storage ecosystem (Yakubu, 2012).

a **b**

Plate 2.8 Hermetic Storage Bags (a) in secure room (b) sealed with rope.

2.5 Storage Pests (Insects)

Insects of the Coleoptera and Lepidoptera are known to cause most damage to grain products throughout the world (Fatope *et al.,* 1995; Boxall, 2001). These may occur on commodities as primary or secondary pests and the extent of the damage depends on the stage of the development or growth of the insect. In Ghana, the most frequently encountered storage insect pests of cereals are *Sitophilus oryzae*, *Sitophilus zeamais*, *Tribolium castaneum*, and most recently *Prostephilus truncatus* (Horn) (Fatope *et al.*,(1995); Abate *et al.*, (2000).

Insects and mites that attack cereals can be described as either primary or secondary pests. Insects which are able to attack grain which has not been damaged are called primary insects although they can still feed on damaged grain. The common primary insects are the *Sitophilus spp*, *Rhyzopertha dominica*, *Prostephanus truncatus*, *Sitotroga cerealella* and *Trogodema granarium* (USAID, 2011).

Anankware *et al.,* (2012) reported that in stored maize, heavy infestation by *P. truncatus* and *S. zeamais* may cause weight losses of as much as 30- 40%. *S. zeamai*s has been found to be amongst the most important pests of maize in a number of studies; in steel silos, in sacks and barns throughout Ghana. According to Omondi *et al.*, (2011), mean losses due to *Prostephanus truncatus* are around 9% which is twice that of all indigenous storage pests together. Again maize contaminated with the insect bodies, frass and the food substrate can be exposed to quinines that are released from the thoracic and abdominal defence glads of the adults (Kabir *et al.,* 2011).

Overall, 20-30% of Ethiopian stored maize is lost to *S. zeamais* infestation, while 100% damage has been found in maize stored for 6 to 8 months in the Bako Region of the country (Demissie *et al.,* 2008a). Mulungu *et al*., (2007) also found about 18% of shelled maize in store were weevil damaged in Tanzania, while Demissie *et al.*, (2008b) found levels of 11-59% weevil infestation in husk-covered maize stored at Bako, Ethiopia, after one month of storage.

Secondary pests are predominately associated with commodities which have suffered previous physical damage caused by a primary infestation or a milling or handling process. Many are pests of cereal products, but others are associated with oil seeds, spices and other commodities. The major moth pests are *Ephestia cautella, Ephestia kuehniella, Ephestia elutella, Plodia interpunctella, Corcyra cephalonica* and *Sitotroga cerealella*, and *Tribolium castaneum* (Red rust flour beetle) (USAID, 2011).

The adults of these secondary insects are mostly not destructive but their larvae. Female lay eggs throughout their lives loosely among their food and the larvae feed and complete their life cycle without necessarily leaving the food commodity. Some of their larvae also spin copious quantities of webbing as they feed causing both quality and quantity losses (Abate *et al*., (2000), Farrell *et al*., (2002) and Golob *et al*., (2002).

Handling processes which may physically damage the grains include harvesting, drying, shelling, transportation, packing and processing. Crop transportation is another process where losses are common. However, such damages and losses can be avoided through proper packing, loading, handling of the crops and clean storage hygiene (Hell *et al*., 2000 and Mejia, 2003).

2.6 Storage Pathogens (Fungi) and Storage Diseases

Seed-borne pathogens, of which, fungi accounts for 75% of reported cases of association have also been found to cause maximum damage such as abortion, rot, necrosis, discolouration, and reduced germination and vigour (Shetty, 1988). The relationship between insect damage and aflatoxin development has been studied by many authors (Beti, (1995); Setamou *et al.*, (1998), Lynch *et al.*, (1991); Gormang and Kang, (1991). Insect-attack in the field or store facilitates easy fungal infection.

However varieties with high resistance to ear-infesting insects and tough kernels are less susceptible to *A. flavus* infection and aflatoxin contamination. Local maize varieties often have more complete husk cover than improved varieties, and less infestation with *S. zeamais* (Kossou *et al.*, 1992, 1993) and this is one of the reasons why farmers store maize in the husk because it gives protection against weevils.

Fungi that produce toxins in food are classified into field fungi and storage fungi based on their ecological requirement for growth (Bankole, 1994). The field fungi require grain moisture above 20% in cereals and often cause ear rot and toxin production before harvest. *Fusarium* sp. is the most important field fungi of maize worldwide and is known to produce over 100 secondary metabolites that can adversely affect human and animal health (Visconti, 2001). *Fusarium moniliforme* has been found to be most wide spread and most frequent in preharvest and stored maize in Nigeria (Essien, 2000). *Aspergillus flavus, A. parasiticus* and *A. nominus* have also been reported to be wide spread in Nigeria on seeds and chips of several crops.

Aside these fungi can cause diseases on the field, they are also known for the production of toxic metabolites. Bankole and Adebanjo (2003) reported that inhabitant of Sub-Sahara Africa are experiencing heavy dietary exposure to food borne mycotoxins particularly fumonisins produced by *F. moniliforme* and aflatoxins from infection by *Aspergillus* sp.

Insects have been known to be associated with spread of the fungus, *Aspergillus flavus* and grain contamination by aflatoxin (Beti *et al.*, 1995; Setamou *et al.*, 1998). A reduction in insect numbers can contribute significantly to the reduction of aflatoxin in stored maize (Lillehoj *et al.*, 1978; Sinha and Ranjan, 1989). Specifically the maize weevil, *Sitophilus zeamais*, has been reported to contribute significantly to A. flavus infection in maize and subsequent production of aflatoxin (Miller, 1995; Beti *et al.,* 1995) by increasing surface area susceptible to fungal infection and increasing moisture content as a result of weevil metabolic activity.

Early harvesting and rapid drying have been advocated as a means of reducing the incidence of seed-borne pathogen and consequently reducing the level of toxic metabolites production. Kossou *et al.,* 1993 reported that harvesting maize with the husk on was associated with reduction in aflatoxin contamination and less infestation with *S. zeamais*.

Weevils facilitate the growth of *A. flavus* and aflatoxin production in maize by increasing surface area susceptible to fungal infection and increasing moisture content as a result of their metabolic activities (Beti *et al.,* 1995). They also observed that sorting of damaged cobs and cobs with poor husk covering led to a significant reduction in aflatoxin contamination. Many plant extracts have been shown to possess fungitoxic properties (Cardwell and Dongo, 1994; Awuah, 1995).

The use of local plant leaves/extracts such as bitter leaf and ginger, also significantly reduced aflatoxin contamination. Toma and Faqi Abdulla (2013) however cautioned that care must be exercised in their application as they have a high tendency to serve as suitable growth media for the pathogens (*A. flavus*). Udoh *et al.,* (2000) reported that smoking / heating of maize was related to lower levels moisture content, weevil damage and aflatoxin contamination of maize.

For maize seeds to be free from major seed-borne field and store pathogens, ears should be harvested at the appropriate time, well dried, handled appropriately and stored in suitable structures to minimise if not eliminate exposure of the grains to the pathogens.

2.7 Storage Pest (Rodents and Birds)

Rodents and birds are major pests of grains that attack cereals on the field and in storage due to their peculiar characteristics (Olakojo, 2001, Fayenuwo and Akande, 2002 and Mwanjabe *et al.*, 2002). Rodents are rats and mice which live in the fields and places where people live. The fact that they are found everywhere, their fertility, the extent of the damage they cause and their ability to reach all sources of food make the control of these pests a difficult matter and eradicating them a very uncertain business (Parshad (1999) and Farrell *et al.*, 2002).

Rodents are also of particular interest as they can cause severe damage to the commodity and also to bagging materials, electrical wiring and store structures (Kilonzo, 2005). Apart from feeding on the grains they also spread droppings and urine while feeding (Gregory, 2002). Rodents harbour fleas, lice and tapeworms and can spread protozoa and bacteria that can cause toxoplasmosis and leptospirosis (USAID, 2011). They also can spread ricketisia and hantaan fever. Common rodents found in storage include the house mouse and black rats. Rodents can be discouraged or trapped by mounting rodent guards or baiting them with poisoned food materials (Parshad, 1999).

Birds will normally nest and feed on the field but a few do build nests on buildings and can cause damage to the structures. The common grain pests among birds are feral pigeons, house sparrows and starlings (USAID, 2011). Birds are attracted to easily found loose grains such as field and open drying of maize grains on a platform or bare ground. Birds contaminate grains through their droppings and can spread salmonella (USAID, 2011). The best way to control birds is to ensure the building has wire mesh on the eaves, any flat surfaces outside the building and openings so that the birds do not have access in and out of the stores. Daily sweeping of the external areas of the store, collecting the grain and disposing away from the warehouse will also reduce the reason for the birds to come near or to the buildings. Another cost effective approach is the use of home-made scarecrow dummies on the field or around the drying areas.

2.8 Post Harvest Losses

Grain storage is one of the most important aspects in sustaining food security in developing countries such as Ghana. The postharvest (postproduction) is a chain of interconnected activities from the time of harvest to the delivery of the food to the consumer, often referred to as "farm to fork" (World Bank, FAO, NRI, 2011). Any loss of produce or product during this period of "farm to fork" is postharvest loss. This postharvest loss (PHL) has been described using different approaches. The World Bank (2011) referred to it as either direct or indirect loss of food. They held that PHL can be quantitative (e.g., physical weight losses) or qualitative (e.g., loss in edibility, nutritional quality, caloric value, consumer acceptability, capital, natural resources, human effort, etc.).

Mejia (2003) refer instead to *direct* and *indirect* losses. Direct losses are related to the total or partial loss of product resulting from spoilage caused by mechanical, physical, physiological, or biological damage; indirect losses relate to qualitative loss (Mejia (2003), FAO (2011) and World Bank (2012). World Bank (2012) suggests that other researcher use the term *opportunity losses* to refer to losses resulting in lost sales or sales only made in low-value markets due to quality problems and other market constrains. Some further include External losses as additional category. These categories fall on both the value-chain participants and society as a whole—for example, cases in which the chemical pesticides used to protect grain impact the environment or human health. Lubulwa, (1995) however pointed out that external losses can be difficult to estimate in economic terms (an example of this is cyanide in cassava).

These interconnected activities from farm to fork influence postharvest losses along the different chain stages. The primary role of an effective postharvest system is ensuring that the harvested product reaches the consumer, while fulfilling market/consumer expectations in terms of volume, quality, and other product and transaction attributes, including nutrition, food security, and product safety (Thamaga-Chitja *et al.*, (2004).

Once harvested, products are subject to biological deterioration, but the rate of deterioration is highly influenced by factors and practices that increase product exposure along the chain to extreme temperatures, excessive rain, contamination by microorganisms, mechanical damage, chemical contamination, etc. (World Bank, FAO, NRI, 2011). Some postharvest practices include harvesting, drying, shelling, cleaning, packaging, on-farm storage, transportation and market handling (Mejia (2003) and World Bank (2001)).

Mejia (2003) iterated that a critical step in minimizing PHL is the understanding of the influence of biological and environmental factors, as well as handling practices, postharvest technologies and practices that will slow down these processes and maintain quality and safety of the product. While the causes of the PHL are manifold and can occur at any stage between harvest and consumption. PHL can greatly be influenced by production conditions (pre-harvest stages). For example, Grolleard (2002) suggested early rainfall season and mechanical damage to grains during pre-harvest are important factors contributing to aflatoxins contamination and subsequent mould growth during postharvest stages.

Maize grain losses in store varies but are estimated to range from 20-30% (Egyir, 2003). It has been found that with maize in Ghana for every 1% damage in grain above

5% (i.e. damage grains refer to grains with insect holes in them), the value of grain decreases by 1%. So if undamaged grain is worth US$ 1/kg then grain with 1% damage is worth only US$ 0.90/kg. These potential losses in value can make a substantial difference to a family livelihood (FAO, 2011 and Compton *et al.,* 1998).

2.9 Quality of maize and quality related issues.

Maize quality is very important to growers because it determines marketable yield and price (Kohl and Uhl, 1998). Quality of produce comprises sensory properties (appearance, texture, taste and aroma), nutritive values, chemical constituents, mechanical properties, functional properties and defects (Abbott, 1999). Quality is a measure of how much the end-user values a product. Shewfelt (1999) pointed out that quality is often defined from either a product orientation or a consumer orientation.

The customer could be any of the agents in the value chain i.e. the grower, packer, distributor and: or wholesaler, retailer, produce manager, shopper, and finally the ultimate consumer who actually utilises the product. These two different views of quality can sometimes result in disagreements between producers and consumers. In order to settle such misunderstandings, Shewfelt (1999) suggested that the combination of characteristics of the product itself be termed quality and that the consumer's perception and response to those characteristics be referred to as acceptability.

Since product quality can be subjective, objective market standards have been developed for many commodities that define what is "marketable" and establishes "grades" of marketable produce and other commodities (FAO, 2011). Some product quality attributes for which grades have been developed include variety, moisture content, percentage germination, nutritional content, percentage weight loss, percentage insect count, percentage mould count and aflatoxins (toxicity) count. Consumer acceptability of maize produce and product considers the grain colour, presence of foreign materials and insects, and percentage of broken grains (FAO, 2011).

2.9.1 Maize (Product) Quality Attributes

This is the intrinsic characteristics of the produce, maize, which is used to grade or group the produce into different degrees of quality after objective scrutiny of these physical attributes. Some intrinsic quality attributes of maize most institutions require include variety, moisture content, percentage germination, nutritional content, percentage weight loss, percentage insect count, percentage mould count and aflatoxin (toxicity) count (USAID, 2011).

Abbott (1999) concludes that the choice of what attribute to measure, how to measure it, and what values are acceptable are determined by the person or institution requiring the measurement, with consideration of the intended use of the produce/product and of the measurement, available technology, economics and often tradition. The definition of quality therefore is formalized and institutionalized so it has the same meaning for everyone using it. However product quality or market grades are not the only measure of quality.

2.9.1.1 Maize Varieties

Maize variety as an intrinsic quality attribute is very important for research and institution purposes as well as international trade because it guarantees uniform produce (FAO, 2011). However on the local market level variety is not a very crucial factor provided the varieties all have similar colours (all white or all yellow but not a mixture). At the production level local maize varieties are preferred by small holder farmers to improved hybrids. Sienzo *et al.*, (2013) in their work with Nkronza maize farmers, realised that the famers preferred to use local maize varieties than hybrids.

The researchers concluded that local maize varieties produce high yields with less rainfall, are resistant to the prevailing pests and has high market preference. The choice of variety of maize may affect grain size, shape, colour, yield and susceptibility to pests' attacks. A mixture of maize varieties is an indication of poor pre- and post-harvest management and supervision, e.g. seed selection, lot segregation and treatment, contamination, etc. (FAO, 2011). Grains differing in size and other characteristics affect processing potential and consumer preference hence the prize. CODEX STAN 153 has many standards covering maize as a produce. Again some grain varieties store better than some others.

2.9.1.2 Moisture Content

The moisture content of maize is the amount of free water or moisture in the produce. Maize grains loose moisture after they reach their physiological maturity in anticipation for storage. The moisture content of maize grains is one of the most important prerequisites for effective and efficient storage. Obeng-Ofori *et al.*, (2008) reported that for cereals and grains to store well in maintaining the quality and quantity the moisture content of the grains should be kept below 13% and that maize should have 10 – 12% moisture content value to be safe in storage for a long time. The viability of seed maize is strongly affected if the grains are stored at below 10% moisture content.

However where the free moisture in the grains are over and above 12% in store, these provide suitable condition and moisture for the production and growth of pests and microorganisms such as fungi, moulds and mites. FAO (2011) reported that stored maize with high moisture content promotes the growth and development of moulds and other species like *Aspergillus, Penicillium* and *Fusarium,* and their secondary metabolites (toxins). The FAO bulletin also stated that moisture content has an appreciable effect on the bulk density, hardness, flowability and angle of repose of grains. High moisture content gives the produce a false weight which affects the market price and cost of transportation, haulage and processing.

2.9.1.3 Percentage Germination

Seed maize germination percentage and seed vigour are very important attributes for seed companies and farmers who would replant in the next season as this indicates the viability of the seeds. Nielsen (2000) defined germination as the renewal of enzymatic activity that results in cell division and elongation and, ultimately, embryo emergence through the seed coat. However germination in practical terms is the emergence of seedlings on the soil surface. Germination is triggered by absorption of water through the seed coat (Nielsen, 2000). He also stated that the repeated wetting and drying cycles of seed maize in store can decrease seed viability and in severe cases stop germination altogether.

Many methods exist to measure the degree of viability of a sample of seed. Uniform germination and emergence of maize help set the stage for maximum grain yield at the end of the season. Seed germination is often above 90% and viable seeds are often above 95%. The Plant Protection Act (1976) of South Africa mandates that all maize grain should have a minimum of 70% germination percentage. After eight months of maize storage in the “uncontrolled” warehouse in South Africa, the germination declined from 87-99% to 50–80% (Tekrony *et al.*, 2005). Stored grains should therefore meet these strict requirements other than that this would have serious implications for production and cost for the growers.

2.9.1.4 Nutritional content

The nutritional content of maize consists of its composition, e.g. protein, carbohydrate, lipids and their breakdown products. These compositions play a major role in influencing the quality of the finished product in which it is processed into. Qualitatively it may influence product acceptability by affecting texture and taste (Cantwell and Kadder, 2006). Quality changes evolve slowly in stored grain and more rapidly in milled or processed intermediary products. Some grain components, for example husk, are inedible and quantitatively influence product yield and gross nutrient available to the consumer (Cantwell and Kadder, 2006). For instance Pro-Vitamin A maize which is low in vitamin A as required may affect the nutritional content and availability of vitamins when used for preparing baby food. Enhancing the pro-vitamin A content of staple food crops like maize that are consumed in large quanti ti es

every day and used as the main component in most of the local weaning foods has been considered an important approach with good prospect of contributi ng to reducti ons in vitamin A defi ciency(Bouis and Welch, 2010).

2.9.1.5 Weight Loss

Weight loss which is a quantitative loss is another important quality attribute of maize since price is determined on the weight of the produce. Hence any drop in weight has direct effect on the price and quality (Devereau *et al.*, 2002). The change in weight which is usually a drop, may be attributed to changes in moisture content of the grains or reduction of the grain matter in store. Devereau and colleagues further reported that changes in weight due to moisture content may be as a result of inappropriate drying to the required moisture content before keeping the produce in store.

Reduction in maize grain matter in store can also be caused by stored pests when grains were not properly handled and treated before been put into store. Boxall (2001) reported that although postharvest losses of maize in store have been estimated to be range between 20 to 30% due to storage insect pests, *P. truncatus* and *S. zeamais* alone have recorded losses of 34 to 40% and 10 to 20% respectively in maize after 3 months of storage on the farm. The pests and microorganisms feed on the grains directly hence reducing the weight of grains affecting quality and price (Baoua *et al*., 2014).

2.9.1.6 Percentage Insect Count

In as much as the activities of these insects particularly their feeding behaviour cause great weight losses, their mere presence and the evidence of their activities affect the quality particularly consumer acceptability (Baoua *et al*., 2014). Some particular quality defects observed by Mejia (2003) that results in product unacceptability include kernels with obvious weevil-bored holes or which have evidence of boring or tunneling, indicating the presence of insects, insect webbing or insect refuse, or degermed grains, chewed in one or more than one part of the kernel which exhibit evident traces of an attack by vermin. CODEX (1985) recommends a maximum range of insect presence to be between 1.0-3.0% by weight.

2.9.1.7 Mould and Mycotoxins Count

Most moulds attack the maize produce on the field when the moisture content is very high. However very few species attack the grains when the moisture content is very low even below the recommended moisture content (FAO, 2011). Some species, including those of *Aspergillus*, *Penicillium* and *Fusarium*, can occur both in the field and in storage. Some secondary metabolites produced by moulds are highly toxic to animals, humans and plants. The major mycotoxin-producing moulds include certain *Aspergillus*, *Fusarium* and *Penicillium* species (Miller, 1991).

The ingestion of mycotoxins can produce both acute and chronic toxicities ranging from death to chronic interferences with the function of the central nervous, cardiovascular and pulmonary systems, and of the alimentary tract (Lewis *et al.*, 2002 and Tefera *et al.*, 2011). Some mycotoxins are carcinogenic, mutagenic, teratogenic and immunosuppressive (FAO, 2011). The presence of these mycotoxins results in rejection of the produce by consumers, reduced sales and ultimately food shortages. FAO (2011) restated the ISO 16050 standard for aflatoxins in maize grains for human consumption shall not exceed 5 µg/kg (ppb).

2.9.2 Consumer (Quality) Acceptability

Acquired characteristics are induced by elements outside the grain (environment or processing) which cause either positive or negative changes on the grain kernel (Harrelson *et al.*, (2006). These elements may work on the grains which forces it to alter and acquire new characteristics. Harrelson *et al.*, (2006) concluded that in most cases these acquired characteristics affect the grain quality negatively to the detriment of grain usage and sales. In the majority of cases, acquired characteristics are detrimental to the overall quality of the grain concerned. As a result any assessment of the utilitarian or monetary value of the grain must take into account acquired characteristics (USAID, 2011). Acquired characteristics are mostly in the following forms: age, foreign matter, moisture content, physical damage, pest and contamination, and odour and aroma grain.

2.9.2.1 Age of Grains

During the post-harvest phase, grain undergoes complex biochemical changes termed 'aging' (FAO, 2011). Changes to carbohydrate, lipids and protein fractions in the grain affect the quality adversely, for example, darkening of colour in white maize may be interpreted by consumers as mould growth or contamination. Labuschagne *et al.,* (2014) demonstrated that after 6-12 months of storing maize at 30°C significantly reduced the amylose and starch content of the grains.

Consumer acceptability of a grain product when plotted against its age after harvesting is generally considered to be maturing during the upward curve of the graph, and deteriorating only when the curve changes direction downwards (FAO, 2011). For as long as grain is alive it is subject to the natural process of ageing during which time the physical characteristics and composition of the grain changes.

The rate at which ageing takes place varies according to the type or variety of grain, but ageing may also be influenced by environmental conditions (USAID, 2011). Reduction of germination potential is probably the most obvious consequence of ageing, but other characteristics of the grain such as milling quality may also be affected by aging. The age of the grain is thus an important factor to take into account when assessing the overall quality of grain (USAID, 2011).

2.9.2.2 Foreign Matter

At several stages in the supply chain, grains are liable to acquire foreign matter. Foreign matter is any material mixed with the grain which does not resemble the type of grain concerned but excluding broken and other grain kernels (EAS, 2011). The presence of this foreign matter in the product may reduce the value, and may also affect handling and processing. The materials that make up the foreign matter may be straw, weeds, cobs, seed coats, parts of stem, husks, leaves, stones, mud, dust, glass, metals, oil products and chemical residues (EAS, (2011) and WFP, (2011).

The presence of foreign matter can have far reaching effect on the overall quality of grain even to the extent of rendering the grain unfit for human consumption (WFP, 2011). Potentially the greatest threat to health probably is from micro-contamination with the bacterial and mould products due to poor sanitation, and with toxins and chemical residues (USAID, 2011). The presence of foreign matter also affects the bulk density, flowability, angle of repose and other physical characteristics of the grain as well as damage equipment and storage structures (USAID, 2011).

2.9.2.3 Pests and Contamination

Pests and their contaminations in grains all constitute foreign materials. However due to the seriousness consumers attached to these, they are being discussed separately. These pests may be alive or dead (whole or fragmented), such as insects, mites, rodents, birds and microorganisms. Pest damage will occur if the grain is susceptible to infestation and is not protected from such damage. Insects cause damage to grain either by chewing it from the outside or boring holes into it (Mejia (2003) and EAS, (2011). Rodents will also chew grain usually starting at the embryo end (Gregory, 2002).

Moulds and bacteria will spread into and through grains and may cause unhealthy discoloration and lesions which may be the only manifestations of infection indicating the grain was dried poorly. Contaminants are different than foreign matter in the sense that they cannot be readily removed from the grain by physical means. Examples include soluble excretions (of pests and animals), oil, paint, chemical residue and toxins (EAS, 2011). Pathogenic microorganisms spread by rodents and some insect species and toxins produced by certain moulds may also be classified as contaminants of grain.

WFP, (2011) reported that potentially the greatest threat to health probably is from micro-contamination with their by-products of poor sanitation, and with toxins and chemical residues. Organic foreign matter is food for many storage pests and microorganisms and can be a source of cross infestation. Foreign matter shortens the storage life of the grain through the translocation of heat or moisture generated by the infested condition of foreign matter (USAID, 2011). Grain mass, and therefore yield, is reduced by infestation. Contamination not only has direct food hygiene implications but also indirect ones, as invading micro-organisms may produce toxins under certain conditions which may lead to acute or chronic illness (Lewis *et al.*, (2002) and Tefera *et al.*, (2011).

2.9.2.4 Moisture Content

Moisture content of grain plays a crucial role in post-harvest processing and is associated with most of the induced characteristics. Devereau *et al.*, (2002) stated that abnormal moisture content may occur if the grain has been excessively dried or if it has been exposed to rain, condensation or if water has been added deliberately in order to increase the weight of the grain. Water vapour will diffuse throughout a bulk of grain and this will tend to equalise. Asiedu *et al.,* (2002) reported that 'Hot spots' may occur at a site of increased respiration (caused by sprouting, infestation or microbial activity), and condensation may occur on cold grain or containers. This undesired moisture can also result in unwanted chemical changes in the grain, germination or premature aging. This also leads to increase in temperature leading to heat damage and even self-destruction of the grain.

Grain with abnormally low moisture becomes very brittle such that it is liable to crack or break easily (Hellevang, 2011). Hellevang observed that this is undesirable if whole grain is preferred by the consumer and processors. However, grain with low moisture content is unlikely to become badly infested by insect pests and the risk of micro-biological infection is low (Hellevang, 2011). Therefore abnormally low moisture content often presents fewer problems during handling and storage than abnormally high moisture content.

2.9.2.5 Physical Damage

Grain is marketed normally in whole grain form and is considered to be of inferior quality if broken. Breakage may occur from fissures as a result of excessive drying/weathering conditions in the field or during handling (FAO, 2011). Breakage reduces quality by reducing acceptability and by increasing susceptibility to infestation during storage. This affects milling yield by contributing to weight loss (Hellevang, 2011).

Physical damage (breaking, splitting or cracking) of the grain renders it more prone to infestation by insects and microorganisms than when it is undamaged (FAO, 2011). Exposure of the internal parts of the grain to air also induces changes in the composition of the grain. While the consequences of physical damage may be confined for a while to the grains affected, the effects often spread to adjacent whole grains and eventually to the whole stock of grain (USAID, 2011).

Empty grains result from sterility, pre-harvest infections or insect attack. Thin white (usually opaque) grains are caused by incomplete grain filling and may result from pests or disease (FAO, 2011). Undeveloped grain is grain which died during the early stages of development. Shrivelled or wrinkled grain is grain having an abnormally convoluted seed coat. Grains may also develop faded natural appearance if over exposed to rain (FAO, 2011).

Grain may become discoloured as a result of heat damage caused by over exposure to the sun or excessive artificial drying or association of the grain with “hot spots” in bulk grain (USAID, 2011). Chalkiness is caused by incompletely filled starchy endosperm which has lower mechanical strength on crush tests and may break during handling (Hellevang, 2011). The broken portion is more easily invaded by certain storage pests (secondary pests) (FAO, 2011).

2.9.2.6 Odour and Aroma

Most grain types, when fresh, have a distinctive natural odour or aroma. This is generally accepted as an indicator of good quality, although some people prefer grain which smells 'old' or even fermented (HGCA, 2011). As with most natural produce, some grain varieties are better-liked than others because of their odour (Hodges, 2012). Certain cultivars of maize, for example, have been developed to possess aromatic qualities which are considered desirable by some consumers (FAO, 2011).

2.9.3 Physical Factors that affect grain quality

The principal physical factors that affect grain in storage are temperature, moisture content and relative humidity. Other factors such as oxygen, carbon dioxide and concentration of atmospheric gases around stored products are of particular interest only in hermetic storage where infestation will decrease the concentration of oxygen with corresponding increase of carbon dioxide (USAID, 2011).

The optimum temperature for most insects is around 30°C; temperatures of 40°C or higher will sooner or later kill off all insect species (Hayma, (2003) and Child, (2007). However insect reproduction ceases below 20°C. Below 10°C, insects become dormant and they cannot survive below 0°C (Hayma, (2003) and Child, (2007). Grain moisture content is expressed as a percentage of moisture based on wet weight (wet basis) or dry matter (dry basis) (HGCA, 2011). The moisture content of dry grain ranges from 6% to 15% depending on the type of grain. Moisture content determines whether or not mould growth would occur on the produce (USAID, 2011).

Relative humidity is the percentage of the amount of water vapour in air (air between the grains). It is defined as the ratio of the water vapour pressure of a sample of air to the saturation water vapour pressure point at the same temperature expressed as a percentage (Devereau *et al.*, (2002) and HGCA (2011). Susceptibility of grain to deterioration is directly related to the level of relative humidity and moisture content (USAID, 2011).

A rise in temperature will cause the grain to lose moisture to the air thereby increasing the relative humidity while a drop in temperature will cause the relative humidity in the air to turn to water (dew) which settles on the grain (HGCA, 2011). As some of the dew settles on the grain and gets re-absorbed it causes changes in texture and colour, flavour and nutritive value. When temperature rises again, water remaining outside of the grain causes the formation of moulds and pests.

In cereals, a 10°C rise will cause an increase of about 3% in relative humidity. Conversely a decrease in temperature of 10°C will induce a decrease of about 3% in relative humidity of the air in the container (USAID, 2011). Warm air can hold more moisture than cool air. Asiedu *et al.*, (2002) observed that if the amount of moisture in the air remains the same but the temperature changes, then the relative humidity also changes in the opposite way to temperature changes. Hence for food grains to store well it is best to lower both the relative humidity and temperature. This is achieved by ventilation, which is allowing or forcing dry air into the store (USAID, 2011).

All stored grains and their products are hygroscopic, that is, they lose moisture to dry air and gain moisture from humid air until there is no moisture movement (an equilibrium is reached) (Golob *et al.*, 2002). They hinted that if the relative humidity of the air is high the grain will absorb moisture. However if the relative humidity of the air is low the grain will give off its moisture to the air. These changes take place very slowly until a new equilibrium moisture content of the grain is reached together with a corresponding equilibrium relative humidity of the surrounding air. USAID (2011) report stated that at a moisture content of 14%, most grains have a relative humidity around 70%. For storage pests to thrive other things being equal, the ideal relative humidity has to be between 40 and 80% (USAID, 2011).

CHAPTER THREE

3.0 METHODOLOGY

3.1 Study Area

The study was conducted in Shai-Osudoku District in the Greater Accra Region of Ghana which has Dodowa as its administrative capital. It is situated in the Southeastern part of Ghana, lying between latitude 5º 45' South and 6º 05' North and longitude 0º 05' East and 0º 20 West. The district was carved out of the former Dangme West District in 2012. The district covers a land area of 1,442 km^2. It shares boundaries with Yilo Krobo District, Manya Krobo District and Asuogyaman District (all in the Eastern Region) to the North respectively, to the East with Ada West, to the South with Ningo-Prampram District and to the West with Akuapem North Municipal and Tema Metropolitan respectively (www.shaiosudoku.ghanadistricts.gov.gh). According to the Ghana Statistical Service (2012), the population of the Shai-Osudoku District was 122,836 and is growing at a rate of 2.1%. Out of this, 58806 (47.87%) are males and 64030 (52.13%) are females. The District lies within Dry-equatorial zone with double rainfall seasons. The rainfall ranges from 762.5 mm to 1200 mm. The temperature however ranges between 30ºC and 40ºC. It has high relative humidity throughout the year. The land under cultivation is 45,600 hectares. The vegetation is mainly coastal savannah with a small transitional zone along the foothills of the Akuapem ridge. Also, the soil type is mainly of the heavy Akuse series with sandy and sandy-loams in certain areas. The main agricultural activities undertaken are livestock and crop production. The crop production includes maize, cassava, rice, tomatoes, garden eggs, okro, pepper, watermelon, banana and pawpaw and that of tree crop grown is mango while the livestock production comprises cattle, sheep and goat.

(www.shaiosudoku.ghanadistricts.gov.gh). Accessed on 20/02/2016.

3.2 Survey

The research design used included observation, survey and laboratory experimentation. The traditional storage practices and storage structures used for storing maize were assesed to determine their effeectiveness. Maize producers in Shai Osudoku District in the Greater Accra Region in Ghana were interacted with to understand their views on the quality of maize stored in traditional storage structures and traditional storage practices used. Both physical loss assessments from the field and laboratory experiments were adpoted. Structured questionnaires were administered through personal interviews to obtain primary and other information from farmers. Secondary information source included materials from literature and the District profile were obtained from the offices of Ministry of Food and Agriculture (MoFA) in Shai Osudoku District by personal communication.

3.3 Mode of Data Collection

Questionaires were administered from 4th of January to 5th of February, 2014 to obtain information on post harvest losses, traditional storage practices and the traditional storage structures used. Questionaires were both open and close ended. Stratified questionaires were administered to ninety (90) farmers selected from six (6) farming communities in the District namely Doryumu, Ayikuma, Agomeda, Asebi, Mampong Shai and Asuture. By stratified random sampling fifteen (15) farmers were selected from each of the communities where the questionares were administered with the help agric. of extension officers within the district. The questionaires were pre-tested to ensure that they were applicable and relevant. Formal and local languages that were understood by the farmers were used. Questions asked included demographics, production and storage practices, storage structures, loss encurred after storage, use of stored maize and marketing of the maize.

3.4 Surveillance of farmers

Suprised and unannounced visits were made to the various farmers to examine how they carried out various storage practices before and after harvest. Purposive sampling was used to identify district best farmers and that of district best maize farmers. They were interviewed and asked to give reasons to the various storage practices and structures employed in storing their maize. Views of farmers were on the effect of traditional storage practices and structures on the quality of maize stored.

Plate 3.1 A farmer and his family dehusking maize after five months of storage.

3.5 Laboratory Analysis

The laboratory experiment was carried out in the Entomology laboratory at the Crop Science Department of the School of Agriculture in the University of Ghana. Fifteen to twenty sample cobs of maize were taken from each of the 6 communities and used for the study. These were brought to the entomology laboratory for the experiment. The sampled cobs included both infested and diseased maize for further lab analysis.

3.5.1 Identification of Insects

About 1 kg of maize was taken from each of the various communities to the laboratory for insect identification. The grains were sieved and the insects collected were identified using specimen collection of the Department of Crop Science of University of Ghana.

Plate 3.2 Some grains showing damage from insect activities.

3.5.2 Assessment of Grain Losses

Although the duration of grain storage may not be exactly the same, since all the farmers cultivate in the same ecological zone it suffice to say they would all have fairly uniform storage duration. The count and weigh method as described by Boxall (1986) was used to assess grain loss. Losses could be due to insect infestation, discolouration of grains, mouldness of grains and attack by micro organism.

Procedure

Two kilograms of maize were taken from the collected / sampled maize from each of the communities. Maize samples were sieved and foreign materials and dust removed. Four samples of 1000 grain each taken and separated into damage and undamaged grains. The number of grains in each category was counted and their weights determined after which their percentage weight loss was determined using the formula.

$$\% \text{ Weight Loss} = \frac{UNu - DNd}{DNd + UNu} \times 100$$

Where Nu – Number of undamaged grains

Nd – Number of damaged grains

U – Weight of undamaged grains

D – Weight of damaged grains

3.5.3 Germination Test

The paper method of seed germination test was used to determine seed germination loss. About 250 g of maize were taken from the sampled maize from each of the six communities. The grains were sieved to remove unwanted materials and infested grains from it. Twenty (20) grains were placed in sterilized petri dish with moist filter paper. Each treatment was replicated four (4) times. Date and time were recorded. The grains were observed daily over a seven day period. The number of germinated seeds was counted in each petri dish and germination percentage was estimated by the following formula:

$$\text{Germination \%} = \frac{Number\ germinated\ seed}{Total\ number\ of\ seeds\ soaked\ in\ each\ petri\ dish} \times 100$$

Plate 3.3 Set up for germination test of maize sampled from the communities.

3.5.4 Discolouration of Grains

Grains were classified as discoloured when they deviated from the original colour grown by the farmers. A kilogram of shelled maize sampled was collected from each of the communities. It was separated into normal and discoloured grains. The number of discoloured grains from each community was countered and the mean number of discoloured grains was computed.

3.5.6 Presence of Foreign Materials

About 250 g of shelled grains were taken from the sampled maize collected from six the communities, sieved and grouped into grains and foreign materials. The two groups were weighed and the percentage foreign materials were computed. The materials that made up the foreign matter included straw, weeds, cobs, seed coats, parts of stem, husks, leaves, stones, mud, dust, glass, metals, other seeds, living and fragments of dead insects and excreta.

3.5.7 Grain Incubation / Insect Count

About 250 g of shelled grains were taken from the sampled maize collected from six communities, were weighed into 1 L Kilner jar that had been washed and sterilized for 3 hours in a Gallenkamp oven at a temperature of 60^{o}C to kill any available insect and microorganism in them. The jars were kept in the laboratory at a temperature of 27 ± 2^{o}C and 65 – 70% RH. After visual inspection of the shelled grains to detect infestation, the grains were also incubated for further investigation. There was daily observation and insects that emerged were recorded and kept for subsequent identification. Each jar was covered tightly with muslin cloth. This facilitated adequate ventilation while keeping away any unwanted insect from contaminating the culture. The jars were neatly labelled and placed on a shelf and grains were incubated between 30–45 days. The insects were identified by using specimen collection of the Department of Crop Science of University of Ghana, Legon.

3.5.8 Moisture Content

Ample maize samples from all storage structures from all communities were collected and sent to the lab for the determination of their moisture content. Three readings were taken from each community and structure using the Protimeter Grain Master. The averages of their moisture content were computed and analysed.

3.5.9 Isolation and Identification of Fungi

Only mouldy grains were taken from the storage structures identified in the study area and brought (ten grains) to pathology laboratory, Crop Science, University of Ghana for culturing and identification of causal agent. Isolation of fungi on/from mouldy grains was done on Water Agar (WA) and on Potato Dextrose Agar (PDA), using the Miles and Misra method (Collins and Lyena, 1976). Portion of advancing margins of disease tissue were removed with flamed scapel, surface sterlized in 1.0% sodium hypochlorite for two minutes and planted on water agar plates. The plates were tied up in clean cellophane bags and incubated at temperature of 24 -30°C for five days in the laboratory. Pure fungi, which were developed from the plated tissues, were subcultured on PDA plates. The mycelia plugs were mounted on slides for microscopic examination using distilled water. The prepared slides were examined under a compound microscope at low and high powers. Final identification of fungi isolates was done based on the following characteristics: growth rate, colour, morphology of mycelia, conidia and sporulating structures. Photos were taken using a Samsung digital camera [SL202, 10.2 mega pixels, Samsung Electronics America].

3.6 Statistical Analysis

Data from questionnaire were analyzed using SPSS (Statistical Package for Social Science). Data generated from the laboratory studies was analyzed using GenStat Software version 9 and subjected to analysis of variance at 95% level of significant.

Significant means were separated using Least Significant Difference (LSD). Results were presented using tables, charts and plates.

CHAPTER FOUR

4.0 RESULTS

4.1 Socio-Economic Characteristics of Maize Farmers

Males formed the majority of respondents (67.8%) and females accounted for 32.2% (Table 4.2.1). Forty seven of the respondents were aged between 41-60 yrs with 11 being the least age of 61-80 yrs. Majority of the respondents (87.9%) were married, 11.1% were single and 1.1% were widowed. Forty six (46) percent of the respondents had no formal education, 43.3% had basic education and 8.8% had secondary education and 1.1% had tertiary education. Ninety two (92.2%) of respondents had been farming for at least 40 yrs. 62.2% of the respondents were solely farmers whiles 37.8% were engaged other activities as well (Table 4.1).

Table 4.1 A summary of socio-economic characteristics of respondents

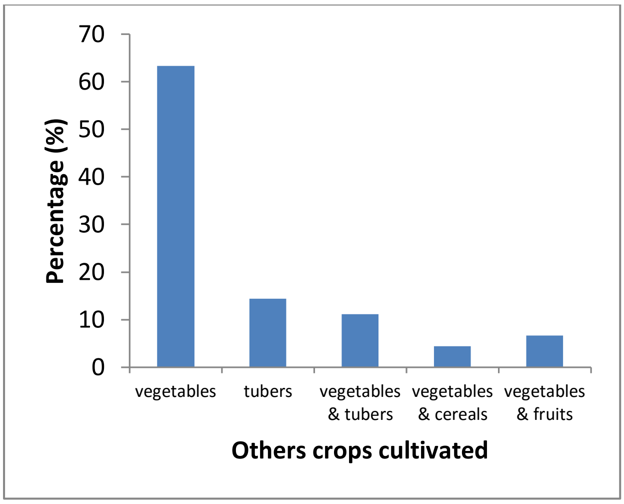
Farmers Gender	Frequency	Percentage
Male	61	67.8
Females	29	32.2
Total	90	100.0
Age of farmers		
20-40	32	35.6
41-60	47	52.2
61-80	11	12.2
Total	90	100.0
Marital Status		
Single	10	11.1
Married	79	87.8
Widowed	1	1.1
Total	90	100.0
Educational Level		
No formal education	42	46.7
Basic education	39	43.3
Sec. Education	8	8.9
Tertiary	1	1.1
Total	90	100.0
Farmers' Experiences (yrs)		
0-10	25	27.78
11-20	24	26.67
21-30	22	24.44
31-40	12	13.33
41-50	6	6.67
51-60	1	1.11
Total	90	100.00

4.2 Production and Harvesting Practices

4.2.1 Production Practices

4.2.1.1 Crops Grown

Most of the farmers cultivated maize as their major crop. However majority (96.7%) of them grew other crops while 3.3% did not grow other crops. The crops they cultivated aside maize were vegetables (63.3%), tubers (14.4%), vegetables and tubers (14.4%), vegetables and cereals (11.1%), and vegetables and fruits (6.6%) respectively (Figure 4.1). Most the farmers (64.4%) cultivated crops only while 35.6% of the rest produced both crops and animals (Figure 4.2).



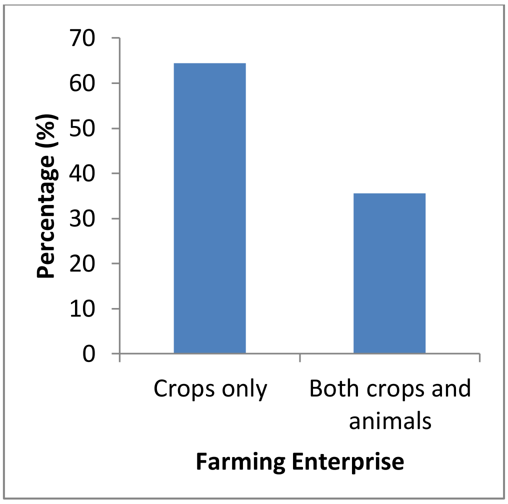


Figure 4.1 Other crops grown by farmers

Figure 4.2 Farming enterprise of farmers

4.2.1.3 Variety of Maize Cultivated

About 58.8% of the farmers used local maize varieties as compared to 22.2% and 18.9% who used either hybrid or both local and hybrid varieties (Figure 4.3). 79 of them used row planting technique of sowing their seeds as compared to 11 for row spacing.

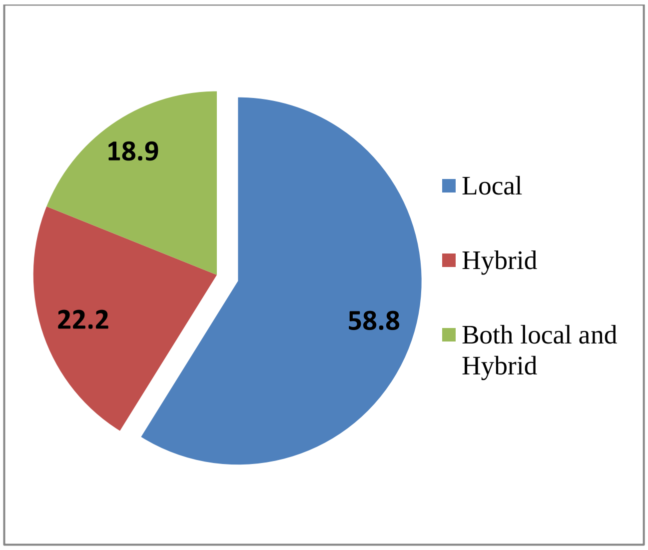


Figure 4.3 Type of maize variety cultivated

4.2.1.4 Soil Amendments and Chemical Usage

A high percentage of farmers (70%) did not use soil amendments to improve the soil fertility. Only a few farmers (30%) used soil amendments in the form of fertilizers, cow dung or both while the majority (72.2%) rely on chemicals such as weedicides, pesticides or both with only 27.8% minority of farmers who did not use chemicals to protect their crops (Figure 4.4).

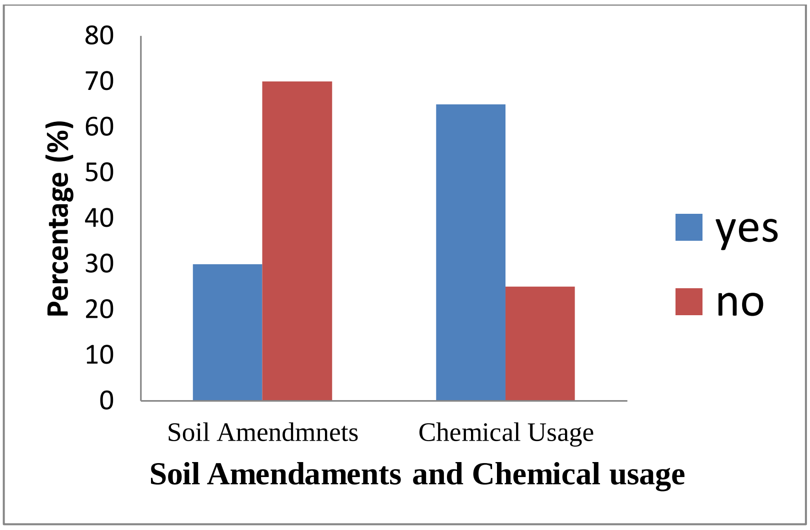


Figure 4.4 Soil amendment and chemical usage by farmers

4.2.2 Harvesting Practices

The survey revealed that majority of farmers (76.7%) harvested their maize produce when the cobs were well matured and dried on the field while 23.3% harvested their produce when they were either green matured or dried matured. When harvesting, most farmers used their bare hands (68.9%) whiles the rest 30% and 1.1% used either hand with knife/cutlass or both hand and cutlass, respectively. Almost all the farmers interviewed (97.8%) stored their produce after harvesting (Table 4.2).

Table 4.2 Harvesting practices of respondents

Harvesting Time	Frequency	Percentage (%)
Well Dried matured ear	69	76.7
Both green and well dried matured ear	21	23.3
Total	90	100
Mode of Harvesting		
Hand only	62	68.9
Hand with knife/cutlass	27	30.0
Both hand and cutlass	1	1.1
Total	90	100
Maize storage		
Yes	88	97.8
No	2	2.2
Total	90	100

4.2.3 Reasons for Maize Storage

Of the 88 farmers who stored their produce, 1.1% of the farmers stored their maize purposely for consumption or as seed. Consumption as a reason for storage scored 2.2% while consumption, sales and seed scored 44.4%. Majority of farmers (51.1%) had consumption, sales and seed as the main reason for storing their maize produce (Figure 4.6).

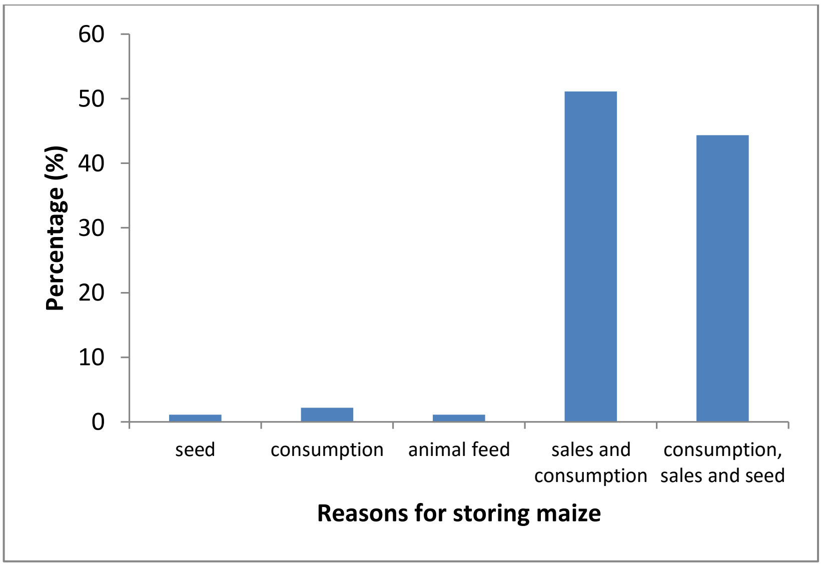


Figure 4.5 Reasons for maize storage

4.3 Postharvest Practices Before Storages

Majority (83.3%) of farmers did not dry their produce before storing (Table 4.3). The remaining farmers who dried their produce before storing had dried their maize cobs with or without husk on or simply shelled them into grains. After drying, the maize was heaped in the field until transport and storage structures were ready to receive the maize from the farm. Shelling was done before storage and this was achieved using a Simple Sheller or hands to do the shelling. The farmers estimated that less than 20% of the shelled grains were lost during the shelling process. All farmers shelled their produce into grains before selling or consumption (Table 4.3).

Table 4.3 Post-harvest practices of respondents

Post-harvest drying before storage	Frequency	Percentage (%)
Yes	15	16.7
No	75	83.3
Total	90	100.0
Form of drying before storage		
Cobs with husks	6	40.0
Cobs without husks	6	40.0
Shelled grains	3	20.0
Total	15	100.0
Method of shelling		
Simple Sheller	6	40.0
Hand	7	46.7
Others	2	13.3
Total	15	100.0
Estimate of grain loss during shelling (%)		
Less than 10	14	93.3
10-19	1	6.67
Total	15	100.0

4.4 Storage Practices of Farmers

4.4.1 Treatment of Storage Structure Before Filling

About 74.5% of farmers treated their storage structures before filling with maize. These farmers used synthetic chemicals such as Dursband, Magic Powder, Conti-Zol 5 and Protex. However most of the farmers used botanical such as Neem leaf extracts. The storage structures were treated mostly on monthly or yearly basis. A few farmers however treated their stores on quarterly and biannual basis (Table 4.4). The rest of the farmers (25.5%) did not provide any form of treatment to their stores before filling with maize.

Table 4.4 Treatment of storage structure before filling

Pre-storage treatment	Frequency	Percentage (%)
Yes	67	74.5
No	23	25.5
Frequency of storage		
Monthly	36	40.0
Quarterly	6	6.7
Biannual	3	3.3
Yearly	45	50.0
Total	90	100.0
Treatment used in storage structure		
Synthetic Chemical	32	47.8
Botanical	35	52.2
Total	67	100.0

4.4.2 Form of Storage and Storage of Seed Maize

Maize was stored in different forms depending on the preference of the farmer and the storage structure at his disposal. From observation, it was realised that most farmers stored their maize with the husk on while others stored or shelled form. Farmers who stored their maize with the cobs mostly arranged the cobs in the store whiles others just heaped them in the store. About 86.7% of farmers kept some of their maize grains as seed maize while 13.3% did not keep their maize as seed maize.

4.4.3 Length of Storage

Majority of the farmers (41.1%) stored their produce for more than 6 months while the least storage duration was from 1 to 2 months (Figure 4.6).

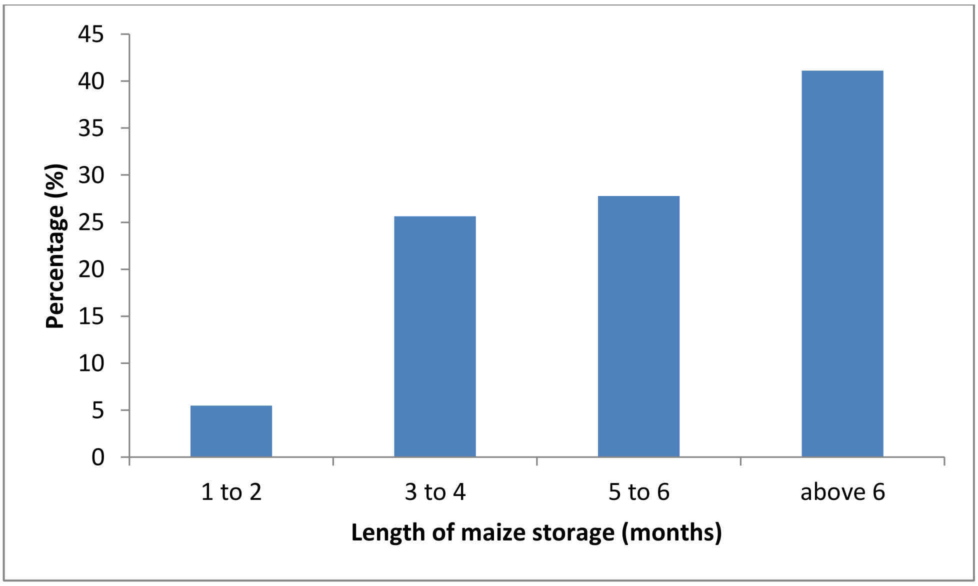


Figure 4.6 Length of maize storage

4.4.4 Treatment of Stored Produce Whiles in Store

Considering treatment provided to maize whiles in storage, 72.2% did not provide any form of treatment while only 25% provided some form of treatment to the produce (synthetic chemicals and botanicals). This minority provided these treatments on yearly, monthly and quarterly basis (Table 4.5).

Table 4.5 Treatment of stored produce whiles in store

Treatment of produce whiles in store	**Frequency**	**Percentage (%)**
Yes	25	27.78
No	65	72.22
Total	90	100
Freq. of treatment whiles in store		
Monthly	6	24
Quarterly	3	12
Yearly	16	64
Total	25	100

4.4.5 Control measures of maize during storage

During storage when farmers observed that the grains in store were being damaged, most (34.4%) farmers applied chemicals such as Dursband, Magic Powder, Conti-Zol 5 and Protex, to prevent further damage. The other farmers practiced other actions such as smoking/drying, rebagging produce, short storage, Neem leave usage and sales. However 17.8% of farmers did not treat the damaging grains when they noticed the damage (Figure 4.7).

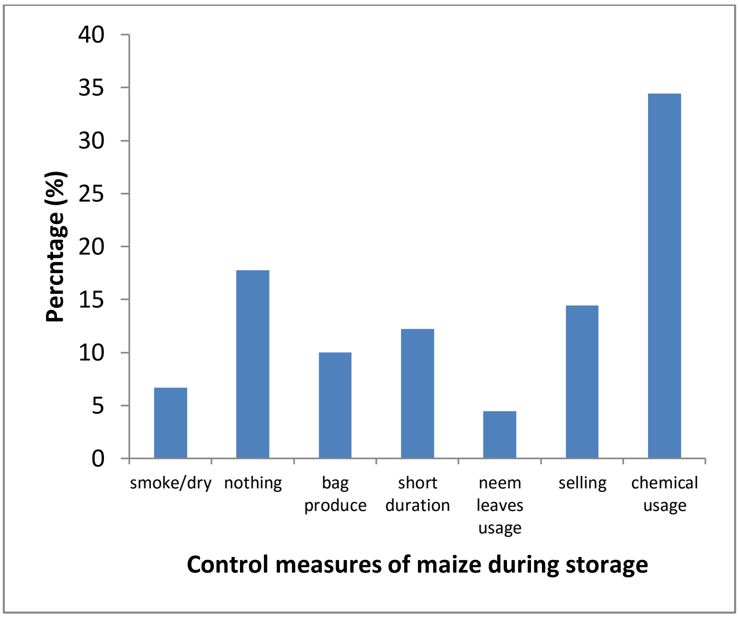


Figure 4.7 Control measure of maize during storage

4.4.6 Training on Harvesting, Drying and Storage

Interactions with the farmers revealed that 77.8% had never received any formal training from extension officials in relation to harvesting, drying and storage practices on maize production (Table 4.6). Most of their knowledge in harvesting, drying and storage were experiences they gained from their parents. The rest (22.3%) had received some form of formal training in these practices.

Table 4.6 Training on harvesting, drying and storage

Training on harvesting, drying and storage	Frequency	Percentage (%)
Yes	20	22.3
No	70	77.8
Total	90	100.0

4.4.7 Traditional Storage Structures Used by Maize Farmers

Traditional storage structures included both indigenous and improved traditional storage structures (Plates 4.1 to 4.9). Some functional and operational defects were also observed on some structures on the field.

4.4.8 Traditional storage structures used in the district

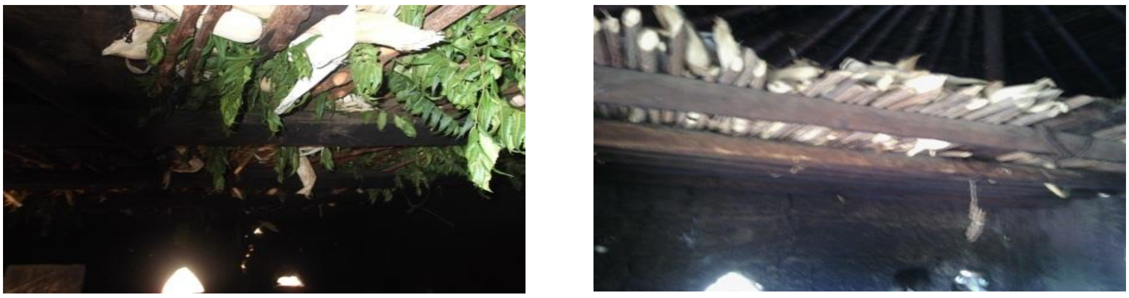
A B C

Plate 4.1 Platform Storage Structure with (a) poor slate roofing (b) poor thatched roof (c) well thatched roof

A B C

Plate 4.2 Ava structure with (a) very little covering (b) thatch covering (c) plastic covering

Plate 4.3 Barn Structure with packed maize and adequate covering



A B

C D

Plate 4.4 Kitchen Storage with (a) botanicals as insect repellent (b) above fire place (c) exposed maize cobs (d) maize cobs stored as seeds

A B C

Plate 4.5 Sack storage structure (a) with shelled grains (b) kept in a secured room (c) dehusked maize cobs

A B

Plate 4.6 Hermetic Storage bags (a) in secured room (b) sealed with rope

A B C

Plate 4.7 Shed Storage Structure with (a) poor alu-sheets (b) wire woven nets (c) earth and alu-sheet walling.

A B C

Plate 4.8 Room Storage Structure with (a) unhusked maize (b) dehusked maize on concrete floor (c) built with earth material.

A B C

Plate 4.9 Crib Storage Structure made with (a) bamboo (b) sawn wood and wire mesh (c) with rodent-guards

4.5 Description of Some Identified Traditional Storage Structures Used in the District

4.5.1 Platform Storage Structures

Platform storage structures identified on the field were mostly made of thatched roof (Plates 4.1 B&C). Some of the thatch were not well place over the maize cobs and this exposed the produce to moisture be it rainfall or dewdrops. A few of these Platform structures had slate roofs which served as ample protection against rainfall, dewdrops and severe temperature (Plate 4.1A).

Again most the Platform structures observed were high enough for the farmer to use the space under for other purposes such as cooking or relaxing areas (Plates 4.1 B&C). However most Platform structures have one or two sides of the structure exposed and these exposed ends may serve as entry points for insects, rodents, birds and moisture during heavy windy rainfall.

4.5.2 Ava Storage Structures

Ava Storage structure was the most used structure among all the traditional storage structures observed. Most of them had their apex raised above the bare ground usually with stones, sticks or sand crate blocks (Plates 4.2 A&B). The maize cobs were usually arranged into the cone of the structure neatly with Neem leaves as bedding material acting as insect repellent. The thatch is mostly used as roofing material (Plates 4.2 A&B) although some farmers used polythene sheets (Plate 4.2 C). The thatch is not a very good moisture proof material against heavy rainfall, winds and high temperature. Again the base of the cone even though raised may be affected by high runoff, insect and rodent attacks. The whole structure is mostly not durable and fire resistant.

4.5.3 Barn Storage Structures

Barn structures were observed in Agomeda and Ayikuma communities only. The farmers in these communities also incorporated Neem leaves as bedding material and arranged the maize cobs before covering with polythene sheets (Plate 4.3). It was noticed that most of the polythene sheets were old with perforations which reduced their effectiveness in reducing moisture into the structure. Again the underside of the structures had very little protection from insects and rodents due to the gaps inbetween the base sticks used for the floor. The whole structure however was exposed to thieves and fire (Plate 4.3).

4.5.4 Kitchen Storage Structures

Kitchen Storage structure was observed in 4 communities in the district. Majority of the structures were of the form of raised platform above the fire place in the kitchen (Plates 4.4 A&B). Again some employed the use of botanicals such as Neem leaves (Plate 4.4A). However a few of them had no platform and the maize cobs were placed close to the fire place on the bare ground (Plate 4.4C) or hanged above the fire place (Plate 4.4D). Most seed maize were preserved and stored by hanging above the fire place. The smoke from the kitchen served as both fumigant and repellent against insects. The maize cobs are not arranged and are usually not protected against most insects, rodents, birds and even rainfall. The maize cobs can catch fire if there was a fire outbreak accidentally (Plates 4.4 C&D).

4.5.5 Sack Storage Structures

The use of maxi bags for storing maize produce was observed in Agomeda community only. The bags were in different sizes and colours. The maize was stored in these bags as shelled grains or in dehusked form (Plates 4.5 D&C). The farmers impregnated the produce with fumigants (Protex) in tablet form before sealing (by sowing) the bags and this preserved the grains for longer storage periods (Plate 4.5C). Due to the vulnerability of the bags to fire, rodents and moisture, the bags were further kept in secured rooms (Plates 4.5 B&C). The farmers reported that the fumigants have a pesticidal effect on all insects in or on the produce and that these killed or repelled insects hence preserving the produce for a long time as required.

4.5.6 Hermetic Storage Bags

Hermetic storage structure was also observed in only Agomeda community. It is different from the Sack bag storage in that it has an inner polythene bag which creates an airtight environment inside the sacks / maxi bags (Plates 4.6 A&B). Again the inner polythene bags are not sealed by sowing but by tying with a rope (Plate 4.6B). They are secured in rooms from rodents and harsh environment. The sacks and hermetic bags also come in different colours and sizes.

4.5.7 Shed Storage Structures

Shed storage structures were observed in only Asutsuare and Doryumu communities only. Three different forms of Shed structures were noticed in the two communities. One type was covered completely with rusting and old aluminium sheets with holes (Plate 4.7A) and not securely fastened on the wooden frames. The second had a raised platform with one side of the structure exposed. Its other sides were well secured and covered with aluminium sheets (Plate 4.7B). The last type had the lower part of the walls made of earth and the rest were made with aluminium sheets with aluminium doors and raised platform inside (Plate 4.7C). The produces were stored in these structures in bags of shelled grains, husked or unhusked maize cobs. Although this structure protects the produce from theft, fire and rainfall, the produces however were not vulnerable to insects and rodents infestations. Again any ineffectiveness on the part of the aluminium sheets would predispose the produce to rainfall, dewdrops and further attacks from insects and rodents.

4.5.8 Room Storage Structures

Asutsuare community is the only community in which farmers were observed to have stored their produce in Rooms as storage structures. The Rooms were built of either earth (Plate 4.8C) or concrete materials (Plate 4.8A). The maize produced were either stored in sacks with or without the husk on the cobs. Again some farmers removed the husk and placed the maize produce on the bare ground in no special arrangement (Plates 4.8 A&B). The buildings were mostly roofed with thatch (Plate 4.8C) whiles a few of them had aluminium or slate roofing sheets (Plates 4.8 A&B). Although the Room structures provided adequate protection against insects, rodents, rainfall and thieves, it did very little protection when the insects and rodents were already in the room.

4.5.9 Crib Storage Structures

Crib Storage structures were observed in three different communities (Ayikuma, Doryumu and Mampong Shai). The structures were mostly made of sawn timber (Plate 4.9A), bamboo (Plate 4.9B) or untreated wood (Plate 4.9C). Most of them had rodent guards on the columns with aluminium roofing sheets and wire mesh (Plates 4.9 A&C). Some farmers also covered their Crib structures with moisture proof materials in areas where they face very strong winds with heavy rainfall to prevent moisture inflows (Plate 4.9C). The roofing materials, the moisture proof materials and rodent guards all aid in reducing the insects and rodents attacks as well as controlling the moisture flow into the Crib storage structures. These structures are also relatively strong and durable.

4.6 Distribution of The Traditional Storage Structures Observed in The Study Area

A total of nine different traditional storage structures were identified among maize farmers in the Shai-Osudoku District of Greater Accra Region of Ghana. The traditional storage structures of maize identified included Ava, Barn, Crib, Hermetic, Kitchen, Platform, Room, Sack and Shed structures. Some of these observed traditional storage structures had some modifications to improve their performance. Of all the structures observed, the Ava Structure was the most used representing 36.7%, followed by kitchen Structure (16.7%) with Room storage (2.2%) being the least used (Figure 4.8). Apart from Asebi and Agomeda communities which had only three (3) different traditional storage structures, all the other communities had four (4) different structures each. Of the 15 maize farmers interviewed from each community, Ava structure was the most used in 5 communities (Asebi, Asutsare, Ayikuma, Doryumu and Mampong Shai) whiles Room the least used was observed only in Asutsuare. However Hermetic, Sack and Room storage structures were present only in Agomeda and Asutsuare communities in that order (Table 4.7).

Table 4.7 The distribution of different traditional storage structures in the communities

Community	Storage Structures (%)									
	Ava	Barn	Crib	Hermetic	Kitchen	Platform	Room	Sack	Shed	Total
Agomeda	0.0	20.0	0.0	40.0	0.0	0.0	0.0	40	0.0	100.0
Asebi	26.7	0.0	0.0	0.0	40.0	33.3	0.0	0.0	0.0	100.0
Asutsuare	53.3	0.0	0.0	0.0	13.3	0.0	13.3	0.0	20.0	100.0
Ayikuma	40.0	26.7	6.7	0.0	0.0	26.7	0.0	0.0	0.0	100.0
Doryumu	66.7	0.0	6.7	0.0	20.0	0.0	0.0	0.0	6.7	100.0
Mampong Shai	33.3	0.0	26.7	0.0	26.7	13.3	0.0	0.0	0.0	100.0
Total	36.7	7.8	6.7	6.7	16.7	12.2	2.2	6.7	4.4	100.0

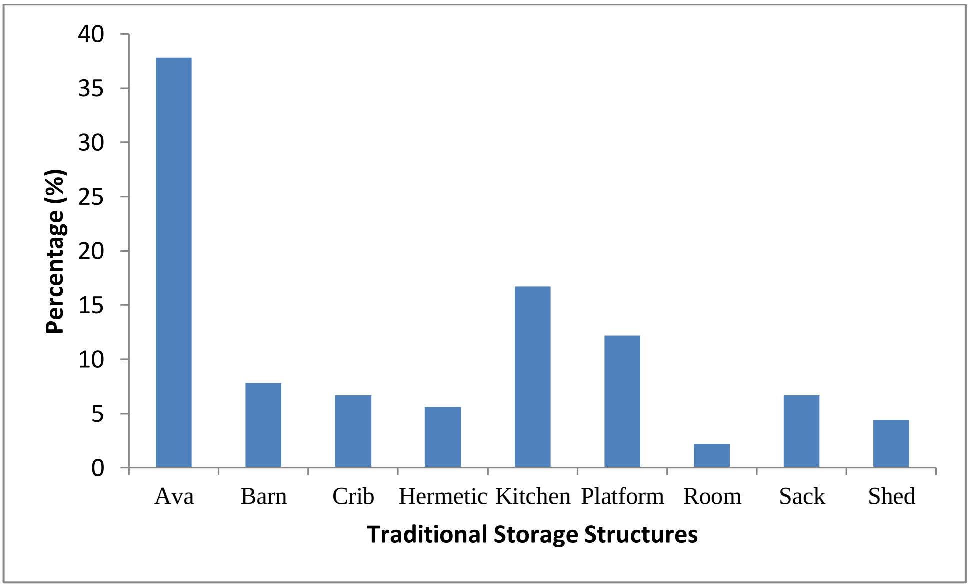


Figure 4.8 Types of the traditional storage structures in the study area

4.6.1 Age, Condition And Challenges of Storage Structure

The ages and condition of the storage structures used by all respondents are illustrated in Figures 4.9 and 4.10. It also examines store practices and the challenges the structures encounter. Majority (71.1%) of the farmers have storage structures which were less than 8yrs old from the time of construction. Structures aged between 9-16 yrs, 17-24 yrs, 25-32 yrs and 33-440 yrs had 15.7%, 5.6%, 4.4% and 3.3% of famers. About 62.2% of farmers claimed their structures were in good condition while 31.1%, 3.3% and 3.3% affirmed that their structures were in very good, fair and bad conditions. The challenges faced by the farmers using these structures were insects and rodents (34.4%), insect infestations (23.3%), rodent infestations (13.3), rainfall, durability and rodents (12.2%), insect and rainfall (8.9%), and rainfall, insect and rodent infestations (7.8%) (Figure 4.11).

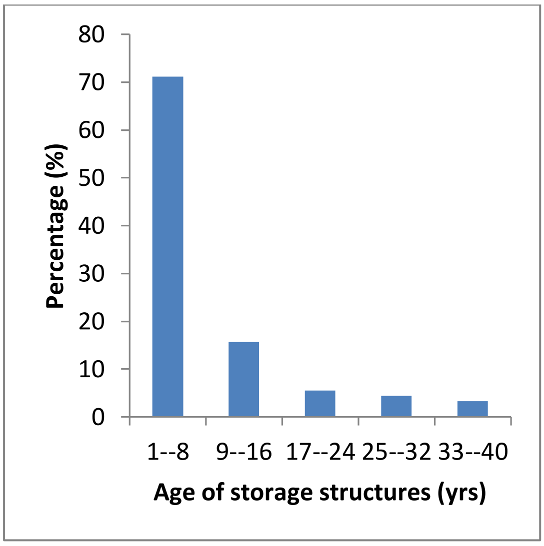


Figure 4.9 Age of storage structures

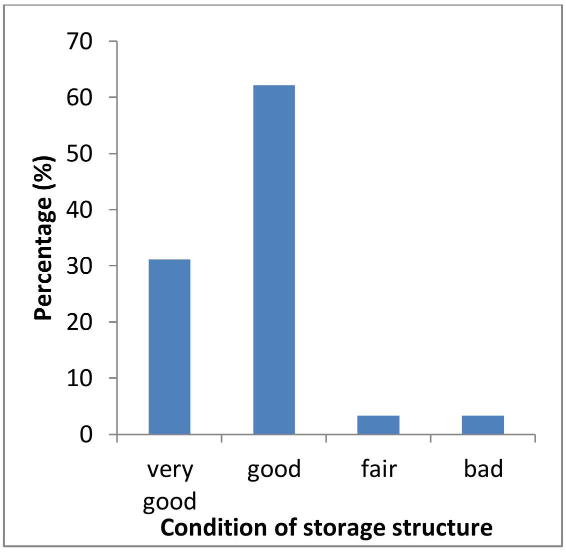


Figure 4.10 Condition of storage structure

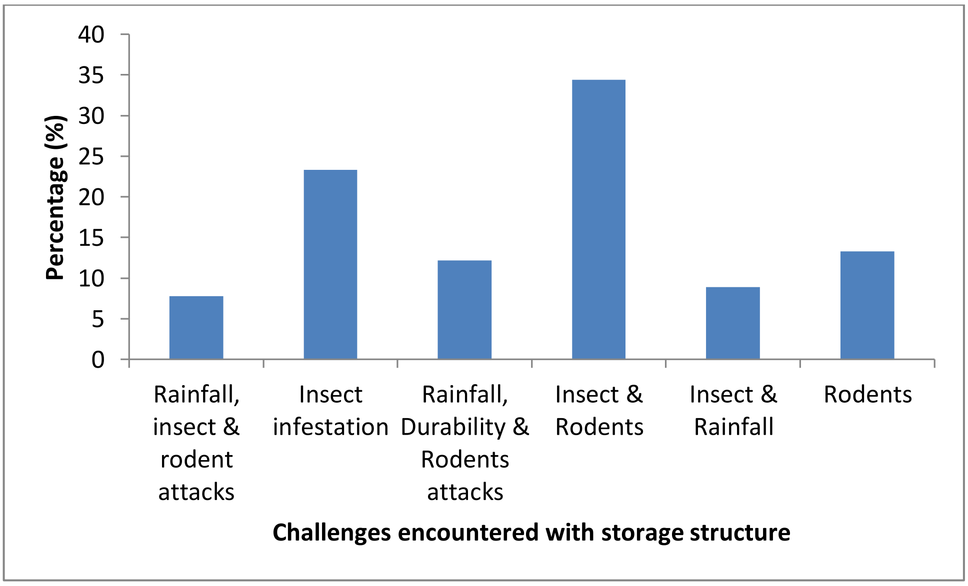


Figure 4.11 Challenges encountered by farmers with storage structure

4.6.2 Farmers' assessment of storage losses

About 82.1% of those who answered "Yes'' to storage loss assessment estimated the grains damaged to be less than 20% whiles 7.9% estimated damage more than 20% (Table 4.8). They attributed the cause of the grain damage to be insects, moulds, insect and rainfall, insect and moulds, and insects and rodents representing 79.0%, 9.2%, 1.3% and 5.3% respectively (Figure 4.12). Although 76 farmers accepted that the grains were damaged in the store, 73.7% of them were of the opinion that the damage did not affect the quality of the maize. However 26.3% of them were of the opinion that the damaged grains affected the quality of the grains in store (Table 4.8). The damaged maize were in the form of powered grains (35%), holes or broken grains (35%), reduced nutrition (15%) and discoloured grains (15%) (Figure 4.13).

Table 4.8 Post-harvest losses, causes and effect on quality of maize grains

Extent of damage (%) estimated	Frequency	Percentage (%)
Less than 10	40	52.6
10-19	30	39.5
20-29	5	6.6
30-39	1	1.3
Total	76	100.0

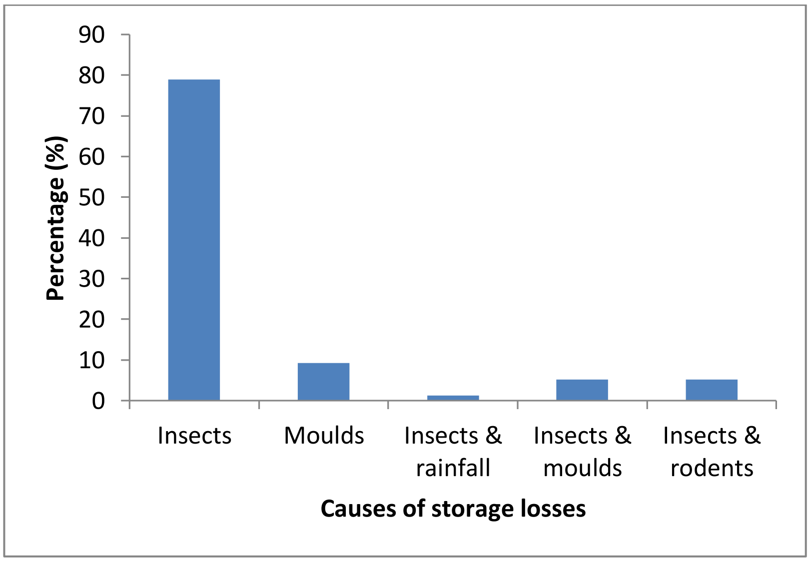


Figure 4.12 Causes of storage losses in store

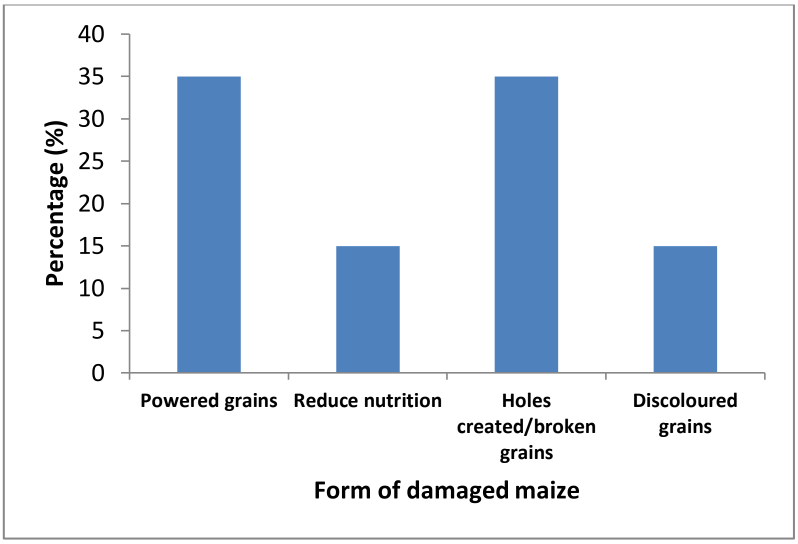


Figure 4.13 Form of damaged maize

4.6.3 Visual Observation of Storage Losses

Some insect infested maize caused maize grains to have broken grains and exit holes as the insects fed on the grains. Some storage structures with heavy infestation had most of their grains reduced to powder form with the presence of insect frass Plates 4.10 (a) and (b). The major postharvest insect pests identified were *Sitophilus zeamais* (Motschulsky) (maize weevil), *Tribolium castaneum* (Herbst) (Red-rust flour beetle), *Rhizopertha dominica* (Fabricius) (L*esser grain borer*) and *Prostephilus truncatus* (Horn) (larger grain borer).

A B

Plates 4.10 Some insect damaged maize (a) insect infested grains with holes (b) reduced to powder.

Rodent damage was another form of grain damaged observed on the field. Rodent pests attacked both husked and unhusked maize cobs and chewed off the grains from the cobs. They left teeth marks on the produce as captured in Plates 4.11 (a) and (b).

A

B

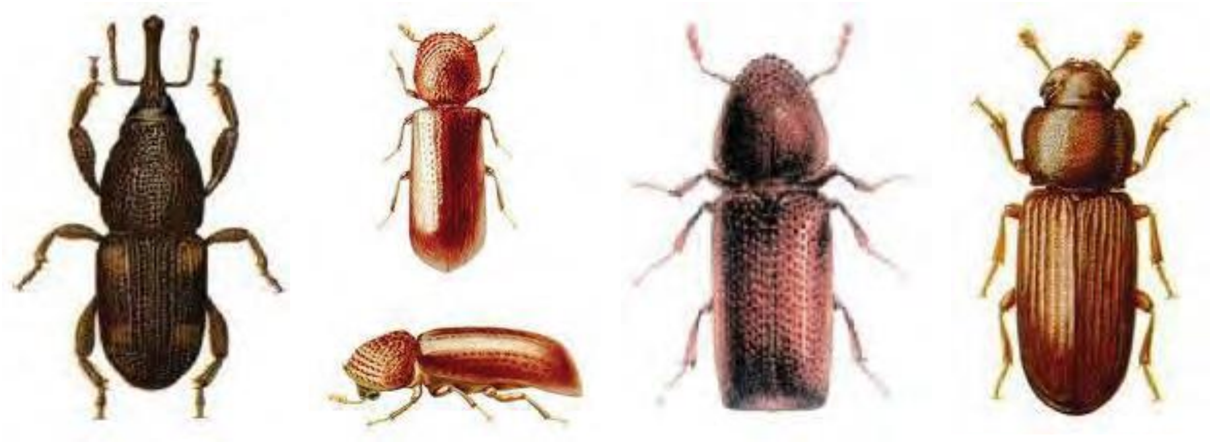
Plates 4.11 Rodent damaged maize (a) cobs without husk (b) cobs with husk

Some grains observed mostly in Ava and Shed storage structures showing discoloured and mouldy grains. Some of these mouldy grains started rotting in the husk (Plates 4.12 (a) and (b)).

A

B

Plates 4.12 Maize damaged by moulds (a) rotten grains (b) discoloured grains



A B C D

Plates 4.13 Some identified insects (a) Maize Weevil (b) Lesser grain borer) (c) Larger grain borer) (d) Red rust flour beetle

4.6.4 Farmers' Perception of Maize Quality

Most farmers (84.4%) responded "Yes" that the maize showed signs of damage when using the traditional storage structures. However 15.6% of them were of the opinion that the grains showed signs of damage when stored in traditional storage structures. From the farmers who responded that they experienced some damage after storing in the various storage structures, 73.7% were of the opinion that the damage affected the maize quality while 26.3% had a contrary view (Table 4.9).

Table 4.9 Farmers perception on effect of damage on quality

Grains showing signs of damage	Frequency	Percentage (%)
Yes	76	84.4
No	14	15.6
Total	90	100.0
Damage affect quality in your opinion		
Yes	20	26.32
No	56	73.68
Total	76	100.0

4.6.5 Marketing Practices of Maize Farmers in The District

From the responses obtained from the farmers, it was clear that over 80% of them representing 72 farmers had sold more than 30% of their grains in storage while 18 farmers representing less than 20% had sold less than 30% of their grains in their stores. With respect to the quality of the grains they sold, 78 (86.7%) admitted that the grains they sold were either good or slightly damaged. Some farmers 13.3% however claimed that the maize grains they sold out were of damaged quality (Table 4.10).

Table 4.10 Quality and grade of maize sold after storage

Quantity sold after storage (%)	**Frequency**	**Percentage (%)**
Less than 10	4	4.4
10 – 19	6	6.7
20 – 29	8	8.9
30 – 39	17	18.9
40 – 49	24	26.7
50 and above	31	34.4
Total	90	100.0
Grade of maize sold after storage		
Damaged	12	13.3
Slightly damaged	1	1.1
Good	77	85.6
Total	**90**	**100.0**

4.6.6 Usage of Damaged Maize Grains

Majority of the farmers used the damaged maize to feed farm animals. Sales, donations, disposal, feed animals, sale and consumption, and animal feed and disposal were other uses for the damaged maize produce (Figure 4.14).

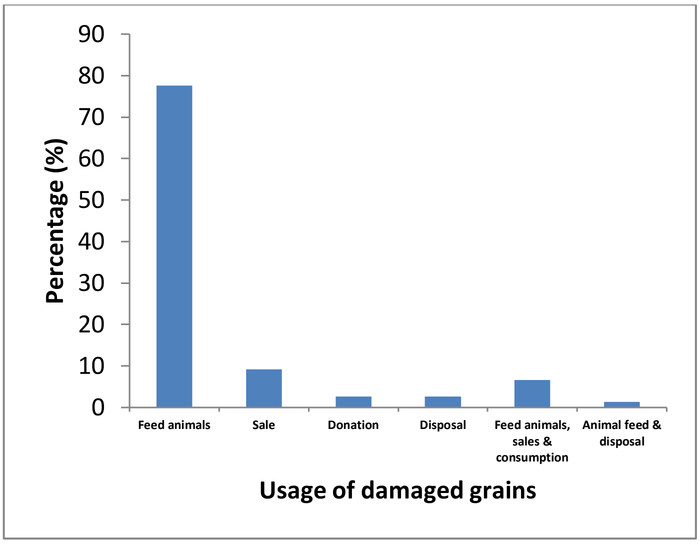


Figure 4.14 Usage of damaged maize grains

4.7 Laboratory Analysis of Grains From The Field

The quality of maize grains obtained from the different communities and various storage structures revealed a great deal of differences among the six (6) quality attributes measured in the laboratory.

4.7.1 Insect Count (*Sitophilus zeamais*) in Maize

Although four major insect pests were identified after the incubation period only *Sitophilus zeamais* (maize weevil) was counted because it had the largest population and was represented in all the storage structures. The number of maize weevils counted after incubation from all 9 storage structures was significant ($P<0.05$) across all structures. The number of weevils counted ranged from a minimum of 9.33 in Sack bags to a maximum of 34.40 in Ava storage structures. Mean insects count values in Sack, Shed and Ava structures showed significant differences ($P<0.05$) among them. There were similarities among Sack, Hermetic, Room and Crib storage structures, and also among Kitchen, Barn, Shed and Crib. Equally, there were similarities in Kitchen, Barn, Shed, Crib and Room storage structures (Table 4.11).

Table 4.11 Mean insect count analysed from all storage structures

Structure	Mean Insect Count
Ava	34.40
Barn	16.67
Crib	13.44
Hermetic	9.67
Kitchen	16.75
Platform	18.14
Room	12.67
Sack	9.33
Shed	16.33
LSD (0.05)	**4.96**

4.7.2 Grain Loss Assessment (Weight Loss) in Maize

There were substantial differences ($p<0.05$) among the mean percentage weight loss among all the storage structures. Ava storage structures recorded the highest (6.60%) mean percentage weight loss while Sack bags recorded the least value (3.08%). Grains from Sack, Hermetic, Room and Barn structures were similar statistically ($p<0.05$) just as those from Shed, Kitchen, Platform and Ava structures with respect to their mean percentage weight loss. However these two groups of structures were statistically different from each other (Table 4.12).

Table 4.12 Mean weight loss analysis from all storage structures

Storage Structure	Means weight loss (%)
Ava	6.6
Barn	4.8
Crib	4.84
Hermetic	3.43
Kitchen	5.48
Platform	5.78
Room	3.85
Sack	3.08
Shed	5.4
LSD (0.05)	**1.04**

4.7.3 Germination Assessment in Maize Grains

Grains from Ava recorded the lowest mean germination percentage (75%) while Sack and Hermetic storage bags recorded the highest (92%). Grains from Ava, Kitchen, Platform, Crib, Hermetic and Sack storage structures were unrelated statistically ($p<0.05$) with respect to their mean percentage germination values. However mean germination vsalues were similar among Kitchen, Platform, Barn and Shed storage structures as well as Room, Hermetic and Sack structures too. There were noteworthy differences ($p<0.05$) among grains analyzed from all storage structures in the study area (Figure 4.15).

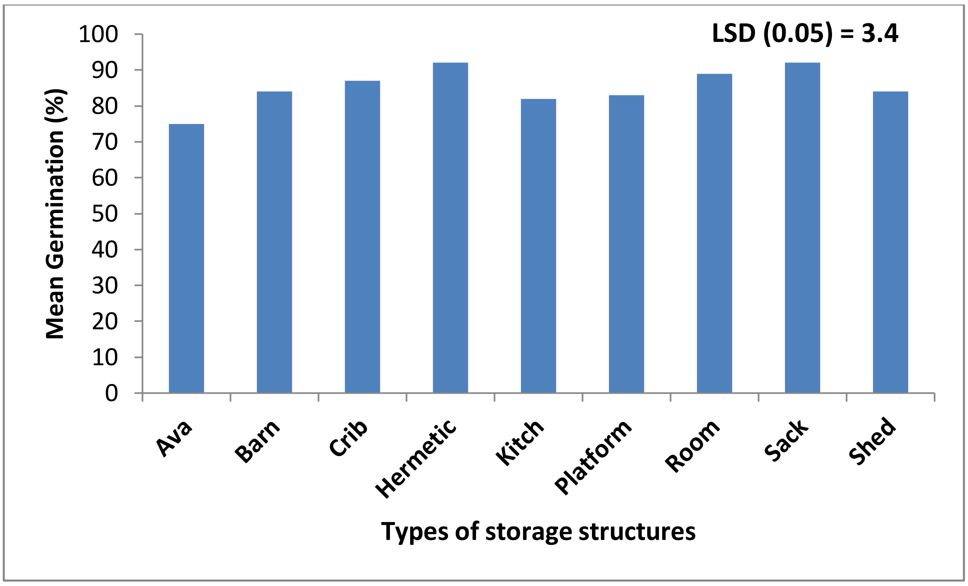


Fig. 4.15 Mean Germination (%) of maize grains from the different storage structures

4.7.4 Assessment of Discolouration of Maize Grains

Maize grains analysed from Hermetic bags recorded the lowest (706) mean values while Ava recorded the highest values (1387). Hermetic, Sack, Room and Crib storage structures all recorded statistically similar ($p<0.05$) mean grain discolouration values so also was Kitchen as well as Platform, Shed and Ava, and Room. However there were significant differences ($p<0.05$) between mean discolouration values for Hermetic, Room, Platform and Ava storage structures (Table 4.13).

Table 4.13 Grain discolouration analysis from all storage structures

Structure	Mean discolouration number
Ava	1387
Barn	1008
Crib	996
Hermetic	706
Kitchen	1123
Platform	1149
Room	854
Sack	740
Shed	1205
LSD (0.05)	**294**

4.7.5 Assessment of Debris of Foreign Materials in Maize Grains

Foreign materials identified in the sampled maize grains included stones, fragments of maize husk and cobs, live and dead insects and their fragments, webbings and cocoons. Maize grains analysed from all the storage structures in the study area recorded significantly different ($p<0.05$) mean percentage debris of foreign materials. Grains from Hermetic bags recorded the lowest mean values (0.293%) of debris and whiles highest value (5.127%) was recorded by Ava storage structures. There were significant differences ($p<0.05$) among Hermetic, Barn, Kitchen, Shed and Ava structures considering mean debris of foreign materials in maize grains however there were similarities between Crib and Sack as well as Platform and Room structures respectively (Figure 4.16).

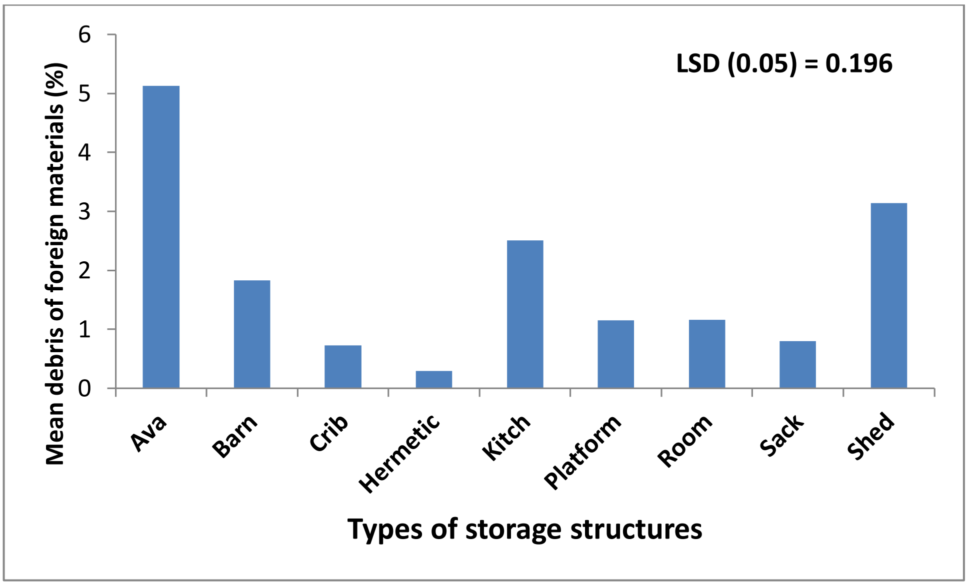


Fig. 4.16 Mean Debris of foreign materials (%) of maize in the identified storage structures

4.7.6 Assessment of Moisture Content in Maize Grains

There were significant differences ($p<0.05$) among mean percentage moisture content of grains from all the traditional storage structures identified on the field. Grains from Hermetic bags recorded the lowest mean values (13.94%) of moisture content and while the highest value (15.12%) were recorded by Ava storage structures. Mean moisture content values of maize in Ava Structures were statistically different (p<0.05) from those obtained from the remaining structures. Mean moisture content of maize grains computered from Hermetic, Barn, Sack and Room structures were similar statistically (p<0.05) but different from Kitchen, Platform and Ava structures (Figure 4.17).

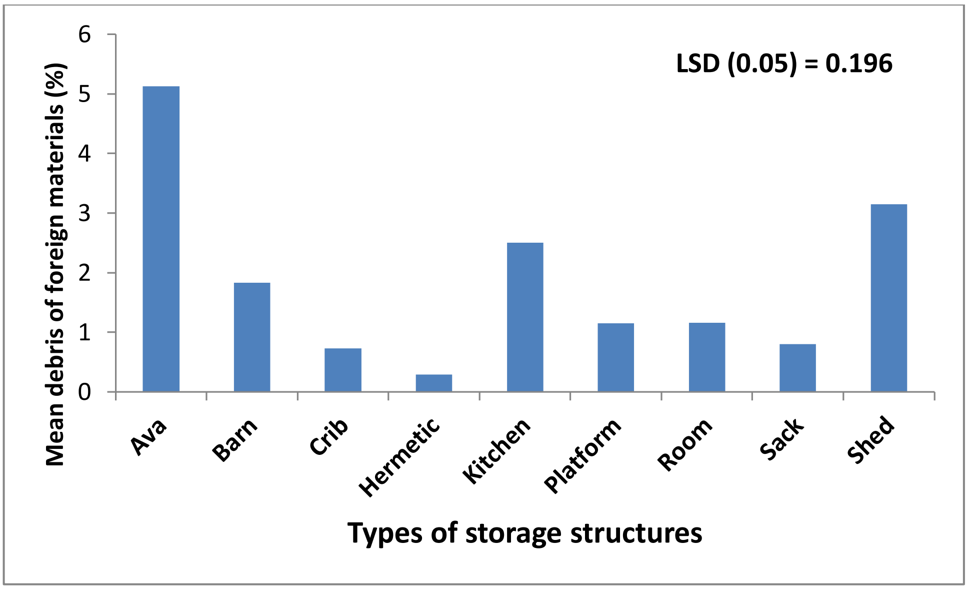
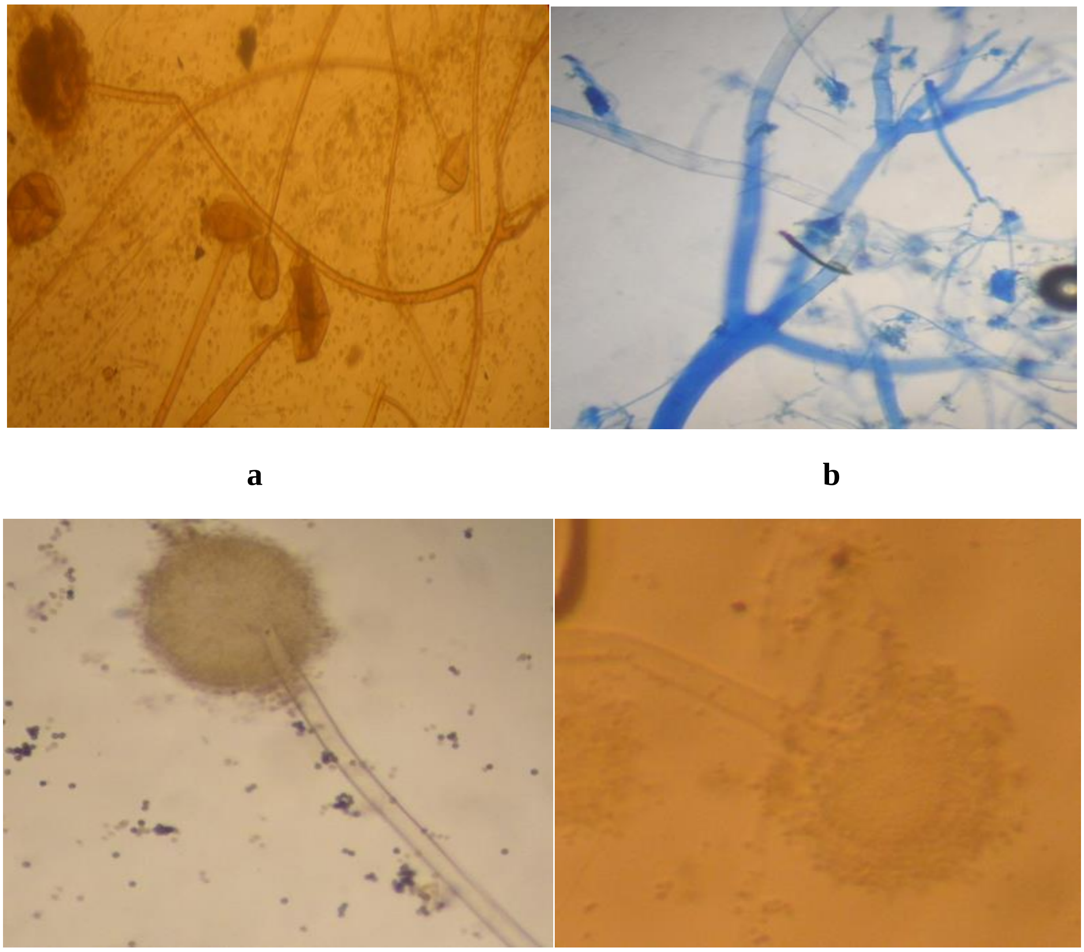


Fig. 4.17 Mean moisture content (%) of maize in the identified storage structures

4.8 Microorganisms Isolated From Mouldy Grains Sampled From All Traditional Storage Structures Used in The District

Mouldy grains were sampled from all the traditional storage structures, isolated and cultured. The micro-organisms identified under the light compound microscope were *Aspergillus flavus, Rhizopus stolonifer, Pencillium sp.* and *Aspergillus niger*. Below are plates (Plates 4.14a - d) of micro-organisms isolated and identified in the laboratory.



c d

Plate 4.14 Micrograph of some pathogens identified (a) *Rhizopus stolonifer* (b) *Pencillum sp.* (c) *Aspergillus niger* (d) *Aspergillus flavus*

4.8.1 Distribution Of Pathogens Isolated From Mouldy Maize Grains Sampled From All Traditional Storage Structures Observed In The Study Area

The results obtained from pathogen identification indicated that *Aspergillus flavus* was the most prevalent across all the 9 storage structures and among the pathogens identified with *Pencillium* sp. being the least in number (Table 4.14). *Pencillium* sp. was identified on grains sampled from only 3 structures (Shed, Kitchen and Ava structures). Ava storage structures recorded the highest occurrence number (26.7%) of *Pencillium* sp. pathogens followed closely by Shed (20.0%) and Kitchen recorded the lowest pathogen incidence (6.7%). *Aspergillus niger* prevalence rate in Ava, Kitchen, Platform and Sack structures recorded the same highest values (13.3%) Barn recorded the least value (6.7%). Aspergillus flavus was identified in all the storage structures. Ava and Shed structures recorded the highest occurrence rates of 100% and 86.76% while Sack and Hermetic storage bags scored the least rates of 53.33% and 46.67% respectively. *Rhizopus stolonifer* pathogens were not observed in grains from Hermetic and Sack bags storage structures. Ava and Kitchen storage structures recorded the highest prevalence rates of 60.00% and 46.67% while grains from Crib and Room structures recorded the lowest rates of 13.33% and 6.67% respectively.

Table 4.14 Percentage occurrence of pathogens isolated from mouldy maize grains sampled from different storage structures in Shai-Osudoku District.

Structure	*Aspergillus flavus*	*Rhizopus stolonifer*	*Pencillium* sp.	*Aspergillus niger*	Mean
Barn	66.7	33.3	0.0	6.7	26.7
Ava	100.0	60.0	26.7	13.3	50.0
Kitchen	73.3	46.7	6.7	13.3	35.0
Hermetic	46.7	0.0	0.0	0.0	11.7
Room	66.7	6.7	0.0	0.0	18.3
Sack	53.3	0.0	0.0	0.0	13.3
Platform	66.7	40.0	0.0	13.3	30.0
Shed	86.8	46.7	20.0	13.3	41.7
Crib	66.7	13.3	0.0	0.0	20.0
Mean	69.6	27.4	5.9	6.7	-

CHAPTER FIVE

5.0 DISCUSSION

5.1 Socio-Economic Characteristics of Maize Farmers

From the results, majority of the maize farmers interviewed were males who outnumbered the females by a ratio of 2:1. Most of them were married and aged over 40 years with basic education being the highest level of education attained.

Farming in Africa and in Ghana for that matter has traditionally been regarded as a male activity so this may have attributed to the low female participation in maize farming in the district. Adjei-Nsiah *et al.* (2007) suggested that women refrain from maize production for fear of crop failure during drought and the lack of capital to purchase required inputs and labour. The noble profession of farming was perceived in Greater Accra as one for the aged and poor in society. This perceived image may have contributed to discouraging the youth who were highly educated and skilled from the profession. Agyare *et al.* (2014) observed a similar trend among maize farmers in Ashanti and Brong Ahafo Regions of Ghana.

With respect to farm assistance, almost all maize farmers interviewed used one form of farm assistant or another, but the majority of them used family workforce as opposed to hired labour or both. Most of the farmers cultivate on small farm lands for less than 40 years and so were unable to generate sufficient income to hire external labour. This confirmed Takane (2008) findings of maize farmers in Malawi. The few who had other sources of income coupled with the inadequate time employ the services of hired labour on their farms. Obuobie *et al.* (2006) in a similar work with vegetable farmers in Accra reported that, 33% of the farmers do it (other economic activities) as a supplementary source of income. They also indicated that most of the farmers engaged in watchman / security services while the rest were employed as masons, painters, mechanics or cleaners.

5.2 Production and Harvesting Practices

5.2.1 Production Practices

Most of the farmers cultivate maize as their major crop. Aside the maize crops, they also cultivate vegetables and tubers. Though, most farmers are into crop production while a few produce both crops and livestock. They grow other crops and raise animals mostly to supplement the household's food and income.

The farm sizes on which the farmers grow their crops range from less than a hecter to over 6 hecters. The majority of farmers produce on less than 1ha of land. The small farm land sizes may be due to the high economic demand on the lands for commercial structures. Altieri (2002) reported that most African farmers, mostly women, cultivate on less than 2ha of farm land.

Most of the farmers cultivate local maize varieties with a few of them planting either mixed or hybrid varieties generally using row planting method. From the interactions with them, the farmers claimed that the local maize varieties were more tolerant to pests attack than the hybrid ones hence their preference for local maize varieties. This finding agrees with Obaa (2005) who suggested that maize varieties which store longer without much quantity and quality losses are deem more desirable for their marketing values. Hybrid maize growers, hence, depend greatly on the use of chemicals to control pests. Nkronza maize farmers prefer to use local maize varieties than hybrids due to high yields with less rainfall, pest resistance and market preference (Sienso *et al.*, 2013).

Most famers do not use soil amendments to improve the soil fertility. However, the few who do use fertilizers, cow dung or both, claim that soil amendments are very expensive and not easily accessible and so they resort to the use of cheap fertilizers and cow dung. Almost all farmers use one form of chemical or another i.e. weedicides, pesticides or both. A similar result was reported in Tanzania and Uganda where farmers used less than 1kg/ha/yr of fertilizer on their farms (Wynen and Vanzetti, 2002). The majority of them used chemicals mostly weedicides and pesticides to control weeds and pests respectively. The dependency on chemicals may be due to the build-up of pests on the farm land as a result of the continuous use of these crops over many years of production. A few farmers nonetheless grow their maize organically due to their inability to afford the chemicals.

5.2.2 Harvesting Practices

Most farmers do late harvesting when the maize cobs are much matured, well dried and drooping on the field. Thamaga-Chitja *et al.,* (2004) reported that maize is traditionally left to dry in the fields prior to harvesting and that a high percentage of respondent households (87%) stored maize in Northern KwaZulu-Natal. Pioneer Agronomy Science (2009) also reported that when maize is allowed to dry too long on the field, it can lead to reduced yield and quality.

Late harvesting of the produce on the field predisposes the maize produce to attacks and infestations by insects, rodents and birds. Sudden rainfall during the harvesting period may affect the drying quality, promote moisture absorption and mould growth later in storage. Harvesting effectively and at the right time is critical to avoid losses down the value chain.

Harvesting is done manually by most farmers because it is faster and requires less labour particularly when the cobs are well dried on the field. A report by World Bank (2010) indicated that harvesting manually is the traditional skill used by small producers. Aside those who harvest fresh matured maize for sale, all the other farmers store their dried maize in anticipation for better prices during the learn season. The main reasons for storing their maize are for consumption, sales and seed.

5.3 Postharvest Practices before Storage

Most maize farmers in the district do not dry their produce before storing. The farmers claim they do not have pre-storage drying facilities so they allow their produce to completely dry on the farm before harvesting. Heaping of the produce on the farm before being transported to the house for further processing such as dehusking, shelling, drying, etc. was another practice observed among farmers in the district.

Chomchalow (2003) indicated that smallholder farmers keep their produce on farm awaiting transport and completion of storage structures. However, those who practice pre-storage drying dry their maize cobs with or without husk on or as shelled grains depending on the available drying space and supervision. Drying of maize grains after harvesting and before storage help to reduce insects infestation, discolouration and the development of micro-organism. Armarh and Asante (2003) reported that reduction in storage losses due to discolouration in bag storage can be attained through rapid drying before storage. After which, shelling is done using their hands or a Simple Sheller resulting in as much as 10% loss of the grains (FAO, 2003).

5.4 Storage Practices of Farmers

5.4.1 Treatment of Storage Structure Before Filling

Irrespective of the storage structure being used, most of the farmers in the district provide some form of treatment to their storage structures before the maize is stored in them. HGCA (2011) also observed similar practices among maize farmers. It was observed that most of the farmers used neem leaves as bedding materials on which the maize were placed, nonetheless, the leaves had to be replaced frequently to maintain the potency level. This they did on monthly or yearly basis using chemical or botanical formulations such as Dursband, Magic Powder, Conti-Zol 5, Paratex and Neem leaf extracts respectively. The chemicals or disinfectant been used by the farmers to treat the storage structures were not appropriate for food approved disinfectants. This contradicts the recommendation by HGCA (2011) that storage structures should be disinfected with approved disinfectant or sanitazers.

They believe this would prevent or reduce pest infestations in the store. The Neem tree, *Azadirachta indica*, is probably the most well-known botanical and is used widely throughout Asia and Africa for a variety of medicinal and agricultural uses (Puri, 1999 and Hell *et al.*, 2000). Although the chemicals most of the farmers were using were recommended and approved ones, their correct usage was very much questionable as observed on the field.

5.4.2 Form of Storage And Storage of Seed Maize

Maize is stored in different forms depending on the preference of the farmer and the storage structure at his disposal. Good storage hygiene is a key step in eliminating insect presence and infestation problems. Kaaya *et al*., (2006) observed similar findings among Uganda maize farmers. From observation, it was realised that most farmers stored their maize with the husk on.

Golob and Hanks (1990) reported that storage of maize with the husk on cobs provided some protection against insect infestation and that the husk acts as a physical barrier to insect penetration immediately after harvest and during storage. Majority of the farmers keep some of the maize grains as seeds for the next production season. They keep some maize grains as seed because the local maize varieties are not easily available on the market.

5.4.3 Length of Storage

Field observation revealed that almost all farmers do not sort their produce before taking them to store. Most of the farmers store their produce for more than 5 months. The duration of storage is often determined by the effectiveness of storage structure used, quality of the maize grains in store and the prevailing market price of maize. Komen *et al.,* (2010) proposed similar reasons. Farmers who stored their maize for a short period were those using hybrid maize varieties and poor storage structures to store their maize. This validates Golob and Muwalo (1984) that hybrid varieties of maize stored under traditional storage system are susceptible to insect storage losses than the traditional varieties.

Tefera *et al.,* (2008) proved that the longer the storage period the more the damage experienced by the grain, particularly maize stored in traditional storage structures. Hell *et al.* (2000) observed similar findings among married maize farmers in Benin who stored their maize between the periods of 5 to 12 months. Demissre *et al.*, (2008) recorded 100% damage in maize stored for 6 to 8 months by S. *zeamais* (weevil) in Ethiopia. On the contrary Smith (1991) reported that some farmers in Benin store their maize for a longer period apparently for sociological reasons.

5.4.4 Treatment of Stored Produce Whiles in Store

Most farmers do not treat their produce while in store. This may be due to financial constraints or inadequate knowledge in postharvest management of the produce. Non-treated maize in store is quickly infested and damage begins in a very short time which forces the farmers to sell off resulting in low income. The researcher observed that farmers using Kitchen, Barn and Platform storage structures set fire under them as a way of controlling the insects. This practice was consistent with Udoh *et al.,* (2000) that the smoke from the fire helps to keep the cobs dry and repel insects.Daramola (1991) also observed that smoking reduces the levels of weevil damage and moisture content which leads to reduction in aflatoxin levels. Hodges *et al.* (1983) reported that *Sitophilus spp.* were sensitive to this kind of treatment

Tefera *et al.*, (2010) indicated that due to early postharvest losses, farmers sell their grains soon after harvest only to buy them back at expensive prices. The farmers who treat their produce while in store do so mostly on yearly basis. Some strategies adopted when they noticed the maize is being damaged are by bagging them, further drying/smoking and just ignoring the produce totally.

5.5 Training on Harvesting, Drying and Storage

Majority of the farmers had not received any formal training on harvesting, drying and storage practices on maize production. The farmers were using their knowledge to perform these activities. This supports the findings of Karthiekeyen *et al.*, (2009). The lack of such formal training for the farmers may have negatively influenced their attitude and skills in operations. This supports Bellon (2001) findings that training of farmers help them to make good use of storage pesticides and reduce losses.

5.6 Traditional Storage Structures Used by Maize Farmers

5.6.1 Distribution of The Traditional Storage Structures Observed in The Study Area

The traditional storage structures of maize identified in the district include Ava, Barn, Crib, Hermetic, Kitchen, Platform, Room, Sack and Shed structures. Ava structure is the most used structure with Room being the least. From the interactions with the farmers it was clear that the Ava structure is the easiest to construct, requiring easily available local materials, little floor space and less capital involvement.

Room storage structure was the least used due to its high capital requirement in constructing the structure. Using cement or clay blocks requires large floor space with adequate roofing. Agomeda is the only community that uses the Hermetic and Sack Bags as storage structures. Although most of the maize farmers in this community produce on small scale, most of them had basic education which was complemented with training they had received from extension agents. These agents have informed them to use improved methods (Barn, Sacks and Hermetic bags) to protect their grains since most of them cultivate both hybrid and local maize varieties.

Asutsuare is the only community that used the Room as a storage structure. Although most of the farmers had not had any access to extension services (in maize production and preservation), their relatively high educational background and income levels have contributed to most of them using the Clay Room structures as alternative to the Ava in protecting the hybrid maize produced.

From my interactions with the farmers in the district, the Ava, Kitchen, Shed and Platform storage structures are the indigenous storage structures of the people and so that accounts for their wide usage. The Crib and Barn structures must have been introduced later to the farmers by officials of the Ministry of Food and Agriculture (MoFA). Johnson (2000) suggested that Food and Agriculture Organisation (FAO) may have recommended the use of these structures to small scale farmers in Ghana through the agricultural ministry.

5.6.2 Materials for Constructing and Condition of Storage Structures

The materials that farmers in the study area used for the construction of the storage structures were bamboo, natural fibers for roofing and fencing, wire, thatch, earth or block for constructions of walls and floors, rubber to cover the grains in stores and wood products. These materials were not different from those identified by Nyanteng (1972), Itto and Wongo (2002) and Atukwase *et al.,* (2012). These materials were all obtained locally except a few such as cement, nails and galvanized zinc or roofing sheet and these were used in the construction of rooms and shed. The various materials were observed to be non-resistant to one form of deterioration or the other. The walls of some rooms used as grain store were

constructed from earth mud. The mud was subjected to rain erosion and in some cases, there were cracks that induced water immigration into the rooms or they totally collapsed. Natural fibres are prone to fire hazard arising from indiscriminate use of fire. Those used as roofs thin out resulting in roof leak. Wood products, because of their availability locally and ease of use are substantially used for construction. Some problems identified with its usage were breakages, decay and termite infestation. At times when it was dried especially those used to construct Ava and platform or barns were picked by children as firewood. Some of these wood species used were not naturally durable and were often used untreated. When it was in used, no attempt was made to apply any preservation. These components were often attacked by insect pest. Those used as column for platform and traditional crib were susceptible to either buckling or breakages due to overloading. When metal roofing was used, corrosion was a common problem especially along the nail part which could lead to leakage thereby causing the grain to discolour and increasing activities of micro organisms. The choice of a particular storage structure for the storage of maize grain depended on several factors. The performance of different storage structure was a function of quantity of maize harvested, maize acreage, cost construction and risks associated with grain losses Komen *et al.*, (2010).
Efficient storage of produce depends on a number of factors, one of which is the availability of structures to hold the produce. The effectiveness of storage structures in any farming community was related to the availability and affordability of its construction materials as well as the appropriateness of the technology and efficiency (Itto and Wongo, 2002).

The traditional storage structures of maize identified in the district includes Ava, Barn, Crib, Hermetic, Kitchen, Platform, Room, Sack, and Shed structures. Ava structure was the most used structure with Room being the least. From the interactions with the farmers it was clear that the Ava structure was the easiest to construct, requiring easily available local materials, little floor space and less capital. Room storage structure was the least used due to its high capital requirement in constructing the structure using cement or clay blocks requires large floor space with adequate roofing. Agomeda was the only community that was using the Hermetic and sack bag as storage structures. From my interaction with the famers in the district, the Ava, Kitchen, Shed and Platform and barn storage structures were the indigenous storage structures of the people and so that account for their wide usage.It was observed that the particular storage structure was ethnic based. Most of the traditional storage structures identified on the field were similar in shape and form as observed in literature, however, some of them had some slight differentiations which could account for the various changes in the quality of maize grains observed after some time of being kept in storage. Farmers using the Ava and Barn had Ewe background. The Crib structures must have been introduced later to the farmers by officials of the ministry of Food and Agriculture (MoFA) which was confirmed by one of the best farmers in the district. He said, he was introduced to the use of crib as a storage structure by MoFA and it became a research based. This confirmed earlier work by Johnson (2000) who suggested that Food and Agricultural Organisation (FAO) may have recommended the use of these structures to small scale farmers in Ghana through the Ministry of Food and Agriculture.

5.6.3 Age And Challenges of Storage Structure

Most farmers interviewed had relatively new or young storage structures which were in good conditions. This may be due to the fact that most of the traditional storage structures (Ava, barn, platform) were mostly not durable and so had been replaced with new ones. Again the use of Barn, Crib, Room and Hermetic storage structures were relatively more durable and hence their repeated use over several growing seasons.

The storage structures found in the study area were in good condition in terms of its physical appearance but its ability to perform the function is another. Majority of the storage structures were in the range of 1 to 8 years or below 6 years. This might be due to the fact that most of these storage structures were newly constructed. The farmers using the Ava and barn structures reliably informed the researcher that they reconstructed these structures every two years. The finding was consistent with that by Itto and Wongo (2000) who also identified that the age of farmers stores were 3 to 4 years old. The age of storage structures above 10 years were those using the room, kitchen, cribs, shed and platform. These structures were constructed with durable materials which last long before destruction Itto and Wongo (2000). One problem associated with these structures was the roof and wood used in constructing them were not strong. These defects render the storage structure ineffective to maintain the quality of the grains stored and also create good condition for the deterioration of stored grain by insect and fungi. This observation was in line with Thamaga-Chitjaetal (2004) who observed that storage structure often exposed the stored maize to harsh environmental condition such as sun and rain because of their fallible construction and composition. Holes in the storage were often large enough for rat to access stored maize, increasing maize loses and compromising the quality and safety of the grain. Farmers revealed that the storage structure being used to store maize poses a lot of challenges to the stored produce. They reported insect manifestation as a major problem they face. Insect infestation caused a considerable damage to stored grain which resulted in storage loses. Famers report storage loses of 5% - 30% by their own assessment. Farmers in developing countries experience postharvest losses which are highly variable (5–30%) depending on weather conditions at harvesting, storage length and presence of pests (Rembold *et al.*, 2011). Most of the farmers complained of rainfall, insect infestation, rodent attacks and durability of storage structures as some of the challenges they faced using the various storage structures in the district. However insect, rodent and both insect and rodent infestations accounted for the most prevailing. These may be due to the poor storage structures being used with inadequate roofing, poor or no rodent guards and inappropriate materials for constructing the structures. Udoh *et al.*, (2000) reported fungi, insects and rodent attacks in maize storage in Nigeria.

5.7 Storage Losses

5.7.1 Farmers' Assessment of Storage Losses

Majority of the farmers accepted that their produce experienced some form of damage after storage when using these storage structures and that the damages were mostly less than 20% of the total maize volume stored. These estimates were consistent with that reported by Rochat and Guent, (2013). However most farmers interviewed in Agomeda and Asutsuare experienced less than 9% damage and this may be due to the Hermetic and Room storage structures they employ. Laboratoery weight loss analysis revealed a weight loss of between 3 and 6.6% across all storage structures. These values although small were relatively large considering that the assessment was undertaken at the beginning of the storage period. Most of the damaged grains were in the form of powered grains, broken grains, grains with holes and discoloured grains. The presence of maize pests such as insects (maize weevil, red-rust flour beetle or larger grain borer), rodents; moulds coupled with rainfall may be attributed to these damages. Storage pests were the major constraints in maize value chain with losses reaching 30% (Baoua *et al.*, 2014). Boxall (2001) also indicated that losses due to post harvest pest of maize were estimated to average between 20-30% after three months of storage. He further identified P. *truncatus*, S. *zeamais* and R. *dominica* as the key insect pest of maize in West African and that the pests caused 51.7% seed damage to maize grains and 21.6% loss in grain weight after 6.5 months of storage. Ngamo*et al.* (2007) observed that traditional storage structures exposed grains to rodents and insect attacks, and unfavourable climatic conditions for their proliferation as well as for microorganisms thus leading to substantial losses.

5.7.2 Visual Observation of Storage Losses

A closer observation of some insect infested maize in the stores of various farms revealed the presence of *Sitophilus zeamais* (Motschulsky) (maize weevil), *Tribolium castaneum* (Herbst) (Red-rust flour beetle), *Carpophilus dimidiatus* (Fabriatus) and *Prostephinus truncatus* (Horn) (larger grain borer). These insects were responsible for causing holes, cracks and reducing the grains to powder. Baoua *et al.*, (2014) in their work with PICS bags for the post-harvest storage of maize in West Africa identified P. *truncatus*, S. *zeamais* and R. *dominica* as major insect pests of maize.

Damages caused by rodents can be very significant if not checked. They cause both quantitative and qualitative losses. The physical removal of the cobs (with or without husk) and grains by chewing, can reduce the quantity of maize in store while their fair, excreta and urine can pollute the produce as well. They may also transmit diseases like rabies. Some grains showed signs of discolouration different from the normal colours of the maize grown. The discolouration may be due to inadequate drying and the accumulation of insects.

5.7.3 Pest Control Measures By Farmers

Majority of the farmers in the study area used different methods to control pest. They employed methods such as smoking, drying, bagging of produce, use of synthetic chemicals (Protex, Magic Powder and dust barn) and rodent grid. Some of the sampled grain showed the presence of insect, it was observed by the researcher that farmers using crib storage structure had rodent grid to protect and prevent them from assessing the grain. The usage of botanical like neem leave was ineffective because farmers were only placing the leaves as layers or the bedding material. When the leaves dry up its potency was reduced thereby causing grain storage losses. Farmers using the Ava storage structure as platform, kitchen and barn make use of neem leaves protectant hence high storage losses in Ava.

The use of insecticides to control or treat stored maize is a practice the farmers learn from each other. The study revealed that most of the chemicals used by some of the farmers in the study area were not of the recommended type for maize. This was interesting to note that the chemicals they were using were not given the desire result yet they were still using them every year. Farmers who were found to use unapproved chemicals gave reasons like lack of information on the chemical from recommended agents, information of extent of such synthetic chemical and also where to find the sale post of such chemicals for the treatment of stored grain. The use of smoke, drying and bagging somehow minimized the rate of damage as describe in other areas.

5.7.4 Farmers' Perception of Quality

Although some farmers claimed they did not experience any damages, it was practically impossible not to have any damages. Most of the farmers who experienced damages on their grains believed the damage did not affect the quality of their grains. Assessment of grain quality by the farmers revealed an important fact that needed serious attention from all stake holders. Assessment of quality of grain was a very difficult task. This was because quality as an attribute was subjective. Majority of the farmers interacted with reported or complained of damaged grains as a result of insect infestation, microbial activity and feeding activities of rodents. But they claimed the damage did not affect the quality of grain they stored. This assertion from the farmers may be due to inadequate knowledge in the assessment of grain quality. This confirmed the earlier findings of Hodges (2012) which indicated that quality change was difficult to determine as it was not necessarily expressed as single factor. Their assessment contradicts the work of Muzemu *et al.,* (2013) that insect damage reduced the quality of grains and Dubale *et al.,* (2014) also argued that fungi affect the quality of grain as a result increased fatty acid and decreased germination and production of toxins. The quality of grains although majority of the farmers had basic education but their knowledge in determining the quality of stored grain. This could be due to the fact that they had not received any training concerning factors that result in lowering the quality of grain they stored. This validated the findings of Hodges (2012) suggested that official grading of grains did not take place until it was in the formal market. Additionally it was detected that farmers did not get the needed training from the extension officers. Farmers should be educated to help to store quality maize. The use of damaged grains to prepare food and also for feeding farm animals was observed by the researcher. But Hodges warns that if the quality of grain had declined it was not fit for human consumption. Wagacha and Muthomi, (2008) also stated that loss of quality or quantity may result in grain of lowered human nutritional value or present a health hazard.

5.8 Reasons For Storing Maize

Most of the farmers indicated that the primary reason for storing maize was for food and supplus sold if there were any. Farmers in Asebi reported that food becomes difficult during the lean season therefore they do not sell their stored maize. Other farmers especially, those who grow on a large scale, do sell thier maize. As at the time of conducting this research, most of the farmers had sold more than 30% of their produce in store. This may be due to the increase in demand for the grains and also the demand on them to make money available as the new academic term begins for first and second cycle schools in the district. The majority of these farmers believed that the grains they were selling to the public were of good quality although some of them alluded to the fact that they had sold some damaged and slightly damaged grains. In a community where people’s expectations of quality were so low with low purchasing power, these damaged and slightly damaged grains would get buyers and hence be sold. The farmers used the damaged grains to feed their own or other peoples' livestock. This was a very common practice observed among farmers in this district.

5.9 Laboratory Analysis of Grains From The Field

5.9.1 Effects Of The Different Traditional Storage Practices And Storage Structures On The Quality Of Stored Maize In The Shai-Osudoku District

The quality of maize grains obtained from the different communities and various storage structures revealed a great deal of differences among the six (6) quality attributes measured in the laboratory. Now the researcher was focused on explaining or making a link between the cause and effect relationship of these actions and structures on the quality of maize after storage.

5.9.1.1 Insect Count in Maize

Insect problem was a major challenge many maize farmers face during production in Ghana. Yakubu *et al.*, (2010) commented that *S. zeamais* was responsible for up to 50% damage of maize in storage. In Ethiopia, as much as 100% loss was experienced when maize grains were stored for between 6 and 8 months (Demissie *et al.* 2008).

There were great differences among the insect count values among all storage structures. Ava storage structures performed poorly by recording the highest insect count values while Sack and Hermetic Bag storage recorded the least. The high number of insects in Ava storage structure could be due to high moisture content which promotes metabolic activities of insects and micro-organism (Obeng-ofori and Boateng, 2008). High insect population in the storage structure should be of concern to farmers because insects promote the activies of microorganisms like fungi which produces aflatoxin which is harmful to human health. This observation is consistent with Udoh *et al.*, (2000).

The low number of insect count in the hermetic bags was its ability to create modified storage atmosphere that was lethal to storage insects and molds, maintains constant moisture and preserves stored commodity (Villers *et al.,* 2004; Navarro *et al.,* 2007; IRRI, 2004). The low values recorded in Hermetic and Sack storage structures may be due to the practices of early harvesting, shelling and proper secondary drying the grains before storing in their respective structures (World Bank, FAO, NRI, 2011 and Dubale *et al.*, 2014).

These coupled with the appropriateness of the storage structures and the uses of pesticides (Protext) prevent insect entry, re-entry and multiplication in the stores (bags). The high numbers of insects observed in some structures could be due to inappropriate practices like late harvesting, heaping and mixing of fresh and old stock together in the same storage structure (Hell *et al.*, 2000).

5.9.1.2 Grain Loss Assessment (Weight Loss) in Maize

Grain loss and deterioration of grain was an important determinant that determined the quality of grain stored in the various storage structures. The losses being qualitative or quantitative affect the acceptability of the grain by the consumer. Grain loss may occur very early in the storage period especially when storage conditions are poor (Boxall, 2001). The losses occurred because the storage practices adopted by the farmers in the area were not able to effectively reduce storage losses, this was consistent with Tefera *et al.,* (2011) who reported that traditional storage practices in developing countries could not guarantee protection against major storage pests of staple food crops like maize, leading to 20–30% grains losses, particularly due to post-harvest pest and pathogen. There was a significant weight loss among the storage structures being used by the farmer. The highest weight loss estimated was in Ava storage structure and the lowest was in hermetic storage structure. The findings contradict the work of Itto and Wongo (2002), who reported weight loss of 4.2%

using the count and weigh method. Similar weight loss percent of about 5% was reported by Boxall Tyler (1984) while the loss of 1.4% was also reported by the Itto and Wongo (2002) in the traditional storage system in Sudan. Difference in the percentage weight loss using count and weigh method was due to the fact that, the count and the weigh method suffered more systematic bias associated with damage grains than hype conventional count weigh method which seriously under estimate true weight loss when many grains were destroyed by insect. This may lead to wrong estimation especially where destroyed grains are significant (Compton *et al.*, 1998).

The losses in weight may be due to the consumption behaviour of pest, in the Ava structure. This observation is in line with the work of Boxall (1986).

These losses pose a lot of threat to the farmers and their families. Boxall (2001) reported that losses of stored grains have several negative impact at the farmer's level, including deterioration in the nutritional qualities of a maize grain, reduce food availability for families, resultants need to purchase food product at high price during lean seasons, financial and profitability losses, disruption of the planned family food supply and reducing local maize processing industry. The research revealed that among the storage structures, weight loss in maize grain was also higher in platform, kitchen, shed, crib and barn. The weight loss of 5% in the crib was in agreement with (Armarh and Asante 2003). The lower weight in the crib could be due to its ability to reduce moisture and also dry the maize in stored. Thus, the quality of the grain stored in the crib was better and this also confirmed an assertion postulated by Johnson (2000). The lower weights obtained in both sacks and hermetic bags could be due to effective drying of maize grain before storage. Farmers who used the sacks store the maize with chemical or insecticide to store the maize.

5.9.1.3 Germination Assessment in Maize Grains

All storage structures produced grains with very high germination values of over 75% higher than the minimum 70% stated in the Plant Protection Act of 1976 for maize seeds in South Africa. Grains from Sack and Hermetic bags storage structures produced the highest germination percentage of 92%. This high performance could be attributed to the protection offered by the bag and fumigants against insects and fungi through the practice of early harvesting, proper drying and the choice of storage structure used.

Good quality seed inspired the confidence of the farmers, because all other inputs merely assist the seed to produce optimally (Owolade *et al.,* 2005). The seed is the nucleus of farmer's production activities hence; its quality should be guaranteed at all times (Owolade *et al.,* 2001). Majority of the farmers were found to use the maize grain stored as seed for the next farming season. This agreed with Wright *et al.,* (1995) that farmers in Ghana derive their seed from their own stocks saved from the previous season. This observation makes germination test an important determinant to assess the quality of grains stored by the farmers. Msuya and Stefano (2010) pointed out that one traditional method that farmers used to improve quality of their seed was by selection. Farmers always carefully selected the largest and most healthy looking and best filled cobs and handled them separately for seed. They also indicated that if the seed was taken from the reserved of the threshed grain crop, they sort seed and select for size, against insect damage, microbial decay and discolouration, cracks or any sort of mechanical damage.

All the storage structures produced grains with high germination values above 80% except grains from Ava storage structure. Though in the Ava storage structure, the mean germination percentage of 75% was above the germination percentage acceptable by plant protection Act (1976) but it did not meet the ITSA recommendation for maize. The lowest mean percentage germination in Ava could be attributed to insect infestation, because it happened to the highest insect emergence and this finding also confirms earlier work of Muzemu *et al.* 2013, who argued that insect pest causes damage to maize grain through the reduction of its weight, quality and germination vigour.

The poor performance of Ava storage structure could be due to the improper protection the structure offered the grain from moisture inflow. This was consistent with the work of Chattha *et al.*, 2015 and Owolade *et al.*, 2005 who reported that high moisture content reduced seed germination and stimulated the life of micro organism. Reduction in the germinability of maize grain in the Ava storage structure could also be accounted for by the activities of the micro organisms such as fungi. These fungi caused the grains to discolour and produce mycotoxm. This confirmed Dubale *et al.*, (2014), who reported that fungi affect the grain, thereby causing a reduction in germination, increase in its mustiness and production of toxin. However, there were similar mean germination percentages among kitchen, platform, barn, shed, room and crib storage structure being used by the farmer in the study area. It was also observed by the researcher that some insect damage or infested grains germinated. This might be due to the fact that the insect did not damage the embryo of the seed or grain and this observation supports the findings of Muzemu *et al.*, (2013).

5.9.1.4 Assessment of Discolouration of Maize Grains

Discolouration is an attribute that affected the quality of grains as well as sales. Obeng-Ofori and Cornelius (2008) suggested that discoloured grains were disliked by consumers and manufacturers. In terms of maintaining the colour of the grains stored, Hermetic bags were the most efficient and Ava storage structures were the least. This was an indication that hermetic storage systems were better at protecting the grains from conditions that predispose the grains to discolouration. The poor performance of Ava storage structures may be due to the improper protection the structures offered the grains from moisture inflows, the presence of insects and fungi. Again the structure could create a suitable condition for the growth and development of fungi and moulds which attacked the grains on the field before harvesting. Lock, (1994) observed that fungal growth lead to unsightly discolouration, unpleasant odour and off-flavour and loss of viability of grains. Late harvesting of maize coupled with high moisture content could predispose and promote fungal growth and development by creating favourable conditions for the microbes. World Bank (2011) observed that unseasonal rains dampen the crops on the field resulting in mould growth and its associated risk of aflatoxin or mycotoxin contamination. High proportions of discoloured grains were undesirable and indicate inferior grain quality (Golob *et al.*, 2002).

Bankole and Adebanjo (2003) reported that the use of smoke if not carefully applied may discolour the grains and affect the taste. According to Armah and Asante (2003), reduction in losses due to discolouration could be attained through rapid drying of the grains before storing. The finding confirmed what Ngamo *et al.*, 2007 hinted, that traditional storage structures were ineffective in protecting the grains from micro-organisms and harsh climatic factors.

5.9.1.5 Assessment of Debris of Foreign Materials in Maize Grains

The presence of foreign materials (debris) was another quality attribute measured. Foreign materials contaminate the grains from previous or nearby stored products. Foreign materials were assessed based on the presence of bodies of life and dead insects, webbing, cocoons, excreta and frass. The highest foreign materials were identified in the Ava storage structure. Most of the Ava structures observed in the district were not properly handled and exposed the grains to more foreign materials. Devereau *et al.*, (2002) reported that the presence of foreign materials create favourable conditions which promote the activities of microorganisms and insects leading to high moisture content. Again the high levels could results in increased qualitative losses (Itto and Wongo, 2002). Hermetic bags recorded the least foreign material content. The practice of early harvesting, shelling, cleaning and secondary drying all reduced the amount of debris entering the store. The types of storage structures used also determined the level of re-entry by pests and thieves resulting in more debris. Hermetic and Sack bags have more protection from re-entry than Ava and Shed structures.

5.9.1.6 Assessment of Moisture Content in Maize Grains

Moisture content of grains stored in the different storage structures affected the quantity and quality. The effect of moisture on the grain contributed to a great loss of maize in terms of weight and quality losses. The laboratory reports indicated that there were significant differences among the mean percentage moisture content from all the storage structures observed. This was consistent with the observations made by Itto and Wongo *et al.*, 2002 which indicated significant differences in moisture content in maize stored in different storage structures over time. Although the moisture content recorded in all the storage structures were over and above the recommended and safe moisture content of 10 – 12% (Obeng-Ofori *et al.*, 2008), grains from Hermetic and Sack bags yielded the lowest moisture contents while those from Ava structures yielded the highest. This could bring about a chain of chemical and biological reaction, including the development and growth of storage fungi and production of toxins (Farrel *et al.*, 2002). Early harvesting, shelling, secondary drying and the protection offered by these storage structures against moisture entry and ere-entry play a great role in affecting the moisture content of the grains in store.

The Ava storage structure was unable to promote further drying in the store due to the compact nature of packing the maize. This traps the evaporated moisture and makes free water available for insect and microorganism to use promoting furtherdeterioration. The high moisture content of these grains may predispose the produce to fungi and mould growth as well as increased weight loss. This supports the claim by Obeng-Ofori and Boateng (2008) that insect and microbial activities were rapid in grains with 14-15% moisture content and their activities promoted higher moisture absorption leading to quantitative and qualitative losses of the grains.

5.9.2 Pathogens Isolated From Mouldy Maize Grains Sampled From All Traditional Storage Structures Observed In The Study Area.

The inoculation procedure in the lab identified four (4) main pathogens responsible for causing the discolouration in the maize grains from the various structures in the district. These were *Aspergillus flavus, Rhizopus stolonifer, Pencillium sp.* And *Aspergillus niger*. The fungi, *Aspergillus flavus*, were present on maize grains from all storage structures. This could be due to delay in harvesting maize in the district which predisposes the maize to *Penicillium sp.* and *Aspergillus sp.* infection on the field (Kpodo 1996 and Agrios, 2005). The nature of the spores of *Aspergillus flavus* makes it very airborne and easily contaminates food.

However Hermetic and Sack bags storage structures provided the least incidence of the fungi while Ava had as much as 100% incidence of the pathogen on all their grains. This high incidence rate may be attributed to the high moisture content and favourable environmental conditions created in the Ava structures which promoted the growth and development of these pathogens (Obeng-Ofori and Boateng, 2008).There was no occurrence of *Rhizopus stolonifer* and *Aspergillus niger* in Hermetic and Sack bags structures.

Ava, Kitchen, Platform and Shed all recorded the presence of *Aspergillus niger* in various degrees. *Pencillium sp.* was only observed in grains from Ava (highest incidence), Kitchen and Shed structures. Grains from Ava structures again recorded the highest incidence in both

Pencillium sp. and *Aspergillus niger*. The low incidence of the fungi species on grains from Hermetic and Sack bags storage structures may be attributed to the relatively low moisture content and insect count of grains due to early harvesting, shelling and secondary drying of the grains as well as the pesticides incorporated in the bags during storage.

Ileleji (2010) detected that improper drying of grains could lead to spoilage and aflatoxin contamination in maize. Mycotoxins contamination (especially aflatoxins produced by *Aspergillus flavus*) makes grains unsafe for food and animal consumption thus, making food and feed unsafe. Tefera *et al.*, (2010) reported that consumption of high doses of aflatoxins leads to aflatoxicosis that can result in acute illness and death usually through the liver. Proper storage methods and structures are recommended to reduce the proliferation of storage pathogens.

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

Most maize farmers in Shai Osudoku District were observed to do late harvesting when the maize cobs were well dried on the field. They heaped the harvested maize on the field till the storage structures were ready for use. They mostly did not sort or dry the maize after harvest and usually stored them with or without the hust on the cobs. The storage structures were treated with either botanical or synthetic chemical formulations before the maize were stored. Consequently the maize was not treated whiles in store. Duration of storage was mostly more than 3 months depending on the storage structure and the quality of the maize in store. All farmers shelled the maize into grains before selling. Most of these storage practices were observed to predispose the maize produce to enimical conditions such as bad weather, insects, theft, birds, rodents and fire. This ineffectiveness is translated into grain losses such as shelling losses (<10%) and storage losses (<20%).

Field observation identified 8 different traditional and 1 modern (Hermetic) storage structures in the Shai Osudoku District of the Greater Accra Region. These structures were Ava, Barn, Crib, Hermetic and Sack bags, Kitchen, Platform, Room and Shed structures. With the exception of Barn storage structure, all the other structures had at least one form of improvement from the other. The Ava storage structure was the most used and found in 5 different communities (Asebi, Asutsuare, Ayikuma, Doryumu and Mampong Shai). Although Room Structures was the least used, it was observed in two (2) communities (Agomeda and Asutsuare) just as Hermetic and Sack bag storage structures. Majority of the farmers had storage structures less than 8 years old and they claimed the structures were in good condition as at the time of conducting this research.

The major postharvest insect pests identified associated with the damaged grains were *Sitophilus zeamais* (Motschulsky) (maize weevil), *Tribolium castaneum* (Herbst) (Red-rust flour beetle), and *Prostephanus truncatus* (Horn) (larger grain borer) *Rhyzopertha dominica* (Fabricius) (lesser grain borer). Pathogens that caused discolouration in the grains were isolated and identified to be *Aspergillus flavus, Rhizopus stolonifer, Pencillium sp.* and *Aspergillus niger*.

Maize grains analysed from Ava storage structures performed poorly in all 6 quality attributes measured (debris of foreign materials, moisture content, weight loss, insect count, discolouration and percentage germination). Grains from Shed and Platform structures performed just better than Ava structures in some quality attributes such as debris of foreign materials and discolouration; and moisture content, weight loss and insect count respectively in the entire district. Grains from Hermetic bag storage performed the best by recording the lowest values in debris of foreign materials, discolouration, moisture content and highest in percentage germination in the whole district. It also was the next best to Sack storage structure in performance in terms of weight loss and insect content. Maize grains analysed from Sack storage structure in the district achieved great results in recording the lowest values in weight loss and insect count, and highest values in percentage germination. Again it was observed to be the second next best results after Hermetic bag storage in terms of debris of foreign materials and moisture content.

Shai-Osudoku District has been the major maize producing district in Greater Accra and therefore has achieved a greater feet but there was more to be done to be the best district in Ghana in terms of maize production. Some of the storage practices undertaken by the farmers did not protect the quality of the maize produced. In fact these practices promoted their destruction. Practices such as late harvesting, prolonged heaping of maize on the field, non-sorting of the maize and the inappropriate use of agrochemicals in storage could be attributed to the cause of the postharvest losses experienced by these farmers. Again most of the traditional storage structures being used currently are inefficient in protecting the grains from fire, insect and pest attacks, thief, harsh environmental conditions and finally they were observed to be not very durable. Maize taken from Agomeda community (Hermetic and Sack storage structures) were observed to have the highest quality as a results of high efficient storage practices and structures undertaken by the farmers to preserve the high variety of maize they cultivate.

6.2 Recommendations

Quality is a very important factor in determining the prize of food produce particularly cereals. The quality of maize was influenced by both the handling practices and the storage structures into which the produce was kept. To increase food availability and reduce postharvest losses of maize due to handling practices and storage structures in the Shai-Osudoku District, the following recommendations have been proposed.

1. Maize farmers in the district must be assisted to acquire the needed education and training on good agricultural practices particularly on early and proper harvesting and appropriate use of agro-chemicals. This would help reduce the exposure of the dried matured maize to unfavourable weather conditions and pests' infestation on the field.
2. After harvesting the maize, it should be shelled, cleaned and well dried before taken to the store for storage. These practices would help reduce the amount of insects, field moisture and foreign materials that are transferred to the store after harvesting.
3. The practice of pre-treating the storage structures before filling with the dried shelled maize should be standardised with appropriate chemicals and botanicals approved by the Environmental Protection Agency, Ministry of Health, Ministry of Food and

Agriculture and other regulatory bodies. This would help reduce and eliminate food poisoning and other related illnesses.

4. The Shai-Osudoku District Assemble in partnership with other stakeholders should collaborate with the farmers to facilitate the switch to the use of Hermetic bags and Sack storage structures which provide adequate protection for the maize grains in maintaining the quality over long periods in storage. The collaboration can be in the form of making the Hermetic bags and Sacks easily accessible and affordable as well as training the farmers on the proper use of the fumigants in preserving the grains in these structures.
5. However for the farmers who would be unwilling to change the traditional storage structures they are used to, the following traditional storage structures are being proposed to them based on the performance of the identified storage structures in their communities. Kitchen, Room and Barn storage structures are recommended for the Asebi, Asutsuare and Ayikuma communities respectively. Crib storage structures are suggested for both Doryumu and Mampong Shai communities.
6. Further work is advocated to examine the effect of these practices and structures on the aflatoxins content, chemical residue levels and the nutritional content of maize produced from this district for the general public.

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APPENDIX I

Analysis of variance for all structures against all communities under PERCENTAGE GERMINATION

Variate: percentages

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Structure	8	696.000	87.000	21.75	<.001
Residual	18	72.000	4.000		
Total	26	768.000			

Analysis of variance for Mampong Shai Community

Variate: %_Germinated

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Structure	3	179.000	59.667	6.75	0.014
Residual	8	70.667	8.833		
Total	11	249.667			

Analysis of variance for Asebi Community

Variate: %_Germinated

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Structure	2	580.67	290.33	21.96	0.002
Residual	6	79.33	13.22		
Total	8	660.00			

Analysis of variance for Agomeda Community

Variate: %_Germinated

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Structure	2	366.000	183.000	109.80	<.001
Residual	6	10.000	1.667		
Total	8	376.000			

Analysis of variance for Asuture Community

Variate: %_Germinated

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Structure	3	1206.00	402.00	9.44	0.005
Residual	8	340.67	42.58		
Total	11	1546.67			

Analysis of variance Ayikuma Community

Variate: %_Germinated

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Structure	3	215.000	71.667	13.44	0.002
Residual	8	42.667	5.333		
Total	11	257.667			

Analysis of variance for Doryumu Community

Variate: %_Germinated

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Structure	3	86.917	28.972	6.10	0.018
Residual	8	38.000	4.750		
Total	11	124.917			

Analysis of variance for community with crib structure

Variate: %_Germinated

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Community	2	11.556	5.778	0.65	0.555
Residual	6	53.333	8.889		
Total	8	64.889			

Analysis of variance for community with kitchen structures only

Variate: %_Germinated

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Community	3	198.667	66.222	9.46	0.005
Residual	8	56.000	7.000		
Total	11	254.667			

Analysis of variance for community with barn structure

Variate: %_Germinated

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Community	1	192.6667	192.6667	289.00	<.001
Residual	4	2.6667	0.6667		
Total	5	195.3333			

Analysis of variance for community with shed structure

Variate: %_Germinated

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Community	1	66.67	66.67	2.86	0.166
Residual	4	93.33	23.33		
Total	5	160.00			

Analysis of variance for community with Ava structure

Variate: %_Germinated

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Community	4	754.67	188.67	7.29	0.005
Residual	10	258.67	25.87		
Total	14	1013.33			

Analysis of variance for all structures in the district (all 9 structures with weight loss)

Analysis of variance

Variate: %_wt_2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Structure	8	32.1780	4.0222	10.94	<.001
Residual	18	6.6203	0.3678		
Total	26	38.7983			

Analysis of variance for Mampong Shai Community
Variate: %_weight_loss

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Structure	3	7.738	2.579	2.19	0.167
Residual	8	9.418	1.177		
Total	11	17.156			

Analysis of variance for Asebi Comm.
Variate: %_weight_loss

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Structure	2	15.615	7.807	5.15	0.050
Residual	6	9.096	1.516		
Total	8	24.711			

Analysis for % Weight Loss
Analysis of variance for Agomeda Comm.
Variate: %_weight_loss

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Structure	2	4.9195	2.4597	13.77	0.006
Residual	6	1.0718	0.1786		
Total	8	5.9913			

Analysis of variance for Asuture Comm.
Variate: %_weight_loss

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Structure	3	45.740	15.247	7.76	0.009
Residual	8	15.712	1.964		
Total	11	61.452			

Analysis of variance for Ayikuma Comm.
Variate: %_weight_loss

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Structure	3	4.1513	1.3838	1.69	0.246
Residual	8	6.5666	0.8208		

Analysis of variance Doryumu Comm.
Variate: %_weight_loss

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Structure	3	12.461	4.154	3.48	0.070
Residual	8	9.552	1.194		

Analysis based on Structure basis
Analysis of variance for weight loss based on Ava Structure
Variate: %_weight_loss

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Community	4	33.523	8.381	3.38	0.054
Residual	10	24.804	2.480		
Total	14	58.327			

Analysis of variance for weight loss based on Crib structure

Variate: %_weight_loss

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Community	2	3.376	1.688	0.95	0.439
Residual	6	10.705	1.784		
Total	8	14.081			

Analysis of variance for weight loss on Kitchen structure

Variate: %_weight_loss

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Community	3	4.5962	1.5321	1.62	0.259
Residual	8	7.5528	0.9441		
Total	11	12.1490			

Analysis of variance for weight loss on Platform Structure

Variate: %_weight_loss

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Community	2	2.2344	1.1172	1.66	0.267
Residual	6	4.0440	0.6740		
Total	8	6.2784			

Analysis of variance for weight loss on BARN Structure

Variate: %_weight_loss

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Community	1	0.1233	0.1233	0.33	0.595
Residual	4	1.4837	0.3709		
Total	5	1.6070			

INSECT COUNT BASIS (General)

Analysis of variance for all structures in the District on insect count

Variate: Insect_Count_No

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Structure	8	1335.529	166.941	19.97	<.001
Residual	18	150.500	8.361		
Total	26	1486.029			

Community Basis

Analysis of variance for insect count in Mampong Shai Comm.

Variate: Insect_Count_N0

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Structure	3	778.00	259.33	4.60	0.037
Residual	8	450.67	56.33		
Total	11	1228.67			

Analysis of variance for insect count in Asebi Comm.

Variate: Insect_Count_N0

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Structure	2	2314.67	1157.33	41.50	<.001
Residual	6	167.33	27.89		
Total	8	2482.00			

Analysis of variance for insect count in Agomeda Comm.

Variate: Insect_Count_N0

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Structure	2	382.889	191.444	21.27	0.002
Residual	6	54.000	9.000		
Total	8	436.889			

Analysis of variance for insect count in Asuture Comm.

Variate: Insect_Count_N0

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Structure	3	4532.67	1510.89	17.27	<.001
Residual	8	700.00	87.50		
Total	11	5232.67			

Analysis of variance for insect count in Ayikuma Comm.

Variate: Insect_Count_N0

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Structure	3	572.67	190.89	11.45	0.003
Residual	8	133.33	16.67		
Total	11	706.00			

Analysis of variance for Doryumu Comm.

Variate: Insect_Count_N0

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Structure	3	64.667	21.556	3.92	0.054
Residual	8	44.000	5.500		
Total	11	108.667			

Structure Basis

Analysis of variance for insect count on Ava Structure

Variate: Insect_Count_No

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Community	4	4387.6	1096.9	8.61	0.003
Residual	10	1274.0	127.4		
Total	14	5661.6			

Analysis of variance for insect count on CRIB Structure

Variate: Insect_Count_No

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Community	2	37.556	18.778	2.52	0.160
Residual	6	44.667	7.444		
Total	8	82.222			

Analysis of variance for insect count on BARN Structure

Variate: Insect_Count_No

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Community	1	266.67	266.67	21.05	0.010
Residual	4	50.67	12.67		
Total	5	317.33			

Analysis of variance for insect count on KITCHEN STRUCTURE
Variate: Insect_Count_No

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Community	3	220.917	73.639	25.25	<.001
Residual	8	23.333	2.917		
Total	11	244.250			

Analysis of variance for insect count on SHED STRUCTURE
Variate: Insect_Count_No

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Community	1	0.667	0.667	0.21	0.670
Residual	4	12.667	3.167		
Total	5	13.333			

Debris (g) All structures in the district (9 Structures)
Analysis of variance for debris for all structures in the district
Variate: %_Debris

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Structure	8	55.73376	6.96672	531.96	<.001
Residual	18	0.23573	0.01310		
Total	26	55.96950			

Community Basis
Analysis of variance for debris in Mampong Shai Comm.
Variate: Debris_g

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Structure	3	106.756625	35.585542	25418.24	<.001
Residual	8	0.011200	0.001400		
Total	11	106.767825			

Analysis of variance for Debris in Asebi Comm.
Variate: Debris_g

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Structure	2	24.509600	12.254800	1327.23	<.001
Residual	6	0.055400	0.009233		
Total	8	24.565000			

Analysis of variance for Debris in Agomeda Comm.
Variate: Debris_g

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Structure	2	14.45282	7.22641	409.30	<.001
Residual	6	0.10593	0.01766		
Total	8	14.55876			

Analysis of variance for Debris in Asuture Comm.
Variate: Debris_g

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Structure	3	57.4234	19.1411	121.34	<.001
Residual	8	1.2620	0.1578		
Total	11	58.6854			

Analysis of variance fro Debris in Ayikuma Comm.

Variate: Debris_g

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Structure	3	12.03069	4.01023	65.06	<.001
Residual	8	0.49313	0.06164		
Total	11	12.52382			

Analysis of variance for Debris in Doryumu Comm.

Variate: Debris_g

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Structure	3	34.648558	11.549519	1469.72	<.001
Residual	8	0.062867	0.007858		
Total	11	34.711425			

Structure Basis on DEBRIS

Analysis of variance for Ava Structure in all comm.

Variate: Debris_g

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Community	4	58.8137	14.7034	121.95	<.001
Residual	10	1.2057	0.1206		
Total	14	60.0194			

Analysis of variance for CRIB structure in all comm.

Variate: Debris_g

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Community	2	2.23269	1.11634	24.84	0.001
Residual	6	0.26960	0.04493		
Total	8	2.50229			

Analysis of variance for BARN Structure in all comm.

Variate: Debris_g

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Community	1	11.31627	11.31627	532.11	<.001
Residual	4	0.08507	0.02127		
Total	5	11.40133			

Analysis of variance for KITCHEN in all comm.

Variate: Debris_g

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Community	3	24.844167	8.281389	1068.57	<.001
Residual	8	0.062000	0.007750		
Total	11	24.906167			

Analysis of variance for PLATFORM in all comm.

Variate: Debris_g

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Community	2	0.23287	0.11643	4.73	0.058
Residual	6	0.14773	0.02462		
Total	8	0.38060			

Moisture Content (%)

Analysis of variance for all 9 STRUCTURES in the District

Variate: MC_%

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Structure	8	3.97427	0.49678	9.59	<.001
Residual	18	0.93233	0.05180		
Total	26	4.90660			

MC% on Community bases

Analysis of variance for all structures in Mampong Shai Comm.

Variate: MC_%

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Structure	3	0.6048	0.2016	2.00	0.192
Residual	8	0.8050	0.1006		
Total	11	1.4098			

Analysis of variance for all structures in Asebi Comm.

Variate: MC_%

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Structure	2	0.75902	0.37951	3.85	0.084
Residual	6	0.59127	0.09854		
Total	8	1.35029			

Analysis of variance for all structures in Agomeda Comm.

Variate: MC_%

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Structure	2	0.69962	0.34981	9.44	0.014
Residual	6	0.22233	0.03706		
Total	8	0.92196			

Analysis of variance for all structures in Asuture Comm.

Variate: MC_%

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Structure	3	4.6263	1.5421	6.35	0.016
Residual	8	1.9437	0.2430		
Total	11	6.5700			

Analysis of variance for all structures in Ayikuma Comm.

Variate: MC_%

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Structure	3	0.5375	0.1792	1.49	0.290
Residual	8	0.9629	0.1204		
Total	11	1.5004			

Analysis of variance for all structures in Doryumu Comm.

Variate: MC_%

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Structure	3	1.1690	0.3897	2.74	0.113
Residual	8	1.1369	0.1421		

Total	11	2.3059

MC% on STRUCTURE BASES

Analysis of variance for all comm. With AVA structure

Variate: MC_%

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Community	4	2.9962	0.7490	3.02	0.071
Residual	10	2.4836	0.2484		
Total	14	5.4798			

Analysis of variance for all comm. With BARN Structure

Variate: MC_%

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Community	1	0.00735	0.00735	0.10	0.772
Residual	4	0.30533	0.07633		
Total	5	0.31268			

Analysis of variance for all comm. with kitchen structures

Variate: MC_%

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Community	3	0.53476	0.17825	2.09	0.181
Residual	8	0.68373	0.08547		
Total	11	1.21849			

Analysis of variance for all comm. with SHED Structures

Variate: MC_%

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Community	1	2.80167	2.80167	31.47	0.005
Residual	4	0.35607	0.08902		
Total	5	3.15773			

Analysis of variance for all comms. with PLATFORM Structures

Variate: MC_%

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Community	2	0.08142	0.04071	1.01	0.418
Residual	6	0.24093	0.04016		
Total	8	0.32236			

DISCOLOURED GRAINS (DCG) ANALYSIS

Analysis of variance for all STRUCTURES in the District

Variate: Discol_ed_Grains

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Structure	8	1204205.	150526.	5.11	0.002
Residual	18	530071.	29448.		
Total	26	1734276.			

Community Basis

Analysis of variance for all structures in Mampong Shai Comm.

Variate: Discol_ed_Grains

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Structure	3	311042.	103681.	2.48	0.135
Residual	8	334500.	41812.		
Total	11	645542.			

Analysis of variance for all structures in ASEBI Comm.

Variate: Discol_ed_Grains

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Structure	2	886574.	443287.	2.28	0.183
Residual	6	1166660.	194443.		
Total	8	2053234.			

Analysis of variance for all structures in Agomeda Comm.

Variate: Discol_ed_Grains

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Structure	2	139372.	69686.	21.03	0.002
Residual	6	19879.	3313.		
Total	8	159250.			

Analysis of variance for all structures in ASUTURE Comm.

Variate: Discol_ed_Grains

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Structure	3	1752756.	584252.	3.44	0.072
Residual	8	1358952.	169869.		
Total	11	3111708.			

Analysis of variance for all structures in Ayikuma Comm.

Variate: Discol_ed_Grains

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Structure	3	83658.	27886.	1.36	0.324
Residual	8	164519.	20565.		
Total	11	248177.			

Analysis of variance for all structures in DORYUMU Comm.

Variate: Discol_ed_Grains

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Structure	3	1187889.	395963.	2.33	0.151
Residual	8	1361950.	170244.		
Total	11	2549839.			

STRUCTURE BASIS

Analysis of variance for all comm. With AVA structure

Variate: Discol_ed_Grains

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Community	4	1584621.	396155.	1.50	0.274
Residual	10	2642895.	264289.		
Total	14	4227515.			

Analysis of variance for all comm. With CRIB Structure

Variate: Discol_ed_Grains

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Community	2	40898.	20449.	0.45	0.657
Residual	6	271788.	45298.		
Total	8	312686.			

Analysis of variance for all comm. with BARN Structure

Variate: Discol_ed_Grains

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Community	1	3038.	3038.	0.24	0.650
Residual	4	50773.	12693.		
Total	5	53811.			

Analysis of variance for all comm. with KITCHEN Structure

Variate: Discol_ed_Grains

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Community	3	221485.	73828.	1.90	0.207
Residual	8	310223.	38778.		
Total	11	531708.			

Analysis of variance for all comm. With SHED Structures

Variate: Discol_ed_Grains

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Community	1	1750680.	1750680.	6.84	0.059
Residual	4	1023655.	255914.		
Total	5	2774335.			

Analysis of variance for all comm. With PLATFORM Structures

Variate: Discol_ed_Grains

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Community	2	40611.	20305.	1.35	0.327
Residual	6	90076.	15013.		
Total	8	130687.			

APPENDIX II

UNIVERSITY OF GHANA, LEGON

COLLEGE OF AGRICULTURE AND CONSUMER SCIENCES

QUESTIONNAIRE

TOPIC: The effect of traditional storage practices and structures on the quality of maize in the Shai- Osudoku District in Greater Accra Region of Ghana.

This research is an academic exercise and all information shall be used solely for the purposes stated. All information given will be treated as confidential.

Section A – General information about farmer

1. Age: ....
2. Gender: Male ☐ Female ☐
3. Marital status: Single ☐ Married ☐ Divorce ☐ Others ☐
4. Highest level of education attained: Illiterate ☐ Basic Education ☐ Secondary Education ☐ Tertiary Education ☐
5. How long have you been farming maize? ………………………….. (Months)
6. What is the size of your farm? Less 1ha ☐ 1 – 6ha ☐ More than 6ha ☐
7. Type of farming enterprise? Crop Production ☐ Animal Production Both ☐
8. What is the level of production? Small Scale ☐ Large Scale ☐
9. Do you do any other kind of work other than farming? Yes ☐ No ☐
10. If yes, please specify. ……………………………………………………
11. Do you have any assistant(s) on your farm? Yes ☐ No ☐
12. If yes, are they family or hired? ....

Section B – Cultural and storage Practice

13. What variety (ies) of maize do you grow? Local ☐ Hybrid (once grow) ☐ Both ☐
14. Please list the varieties cultivated. ……………………………………………………… ……………………………………………………………………………………………
15. Do you cultivate other crops aside maize? Yes ☐ No ☐
16. If yes, please choose as many as applicable. Okra ☐ Pepper ☐ tomatoes ☐ Others ☐

17. By what method do you plant your maize seeds? Row spacing ☐ Row planting ☐ Others ☐
18. Do you use any soil amendment practices during production? Yes ☐ No ☐
19. If yes, please mention the type you use. …………………………………………..
20. Do you use any chemical during production? Yes ☐ No ☐
21. If yes, what chemical and against what? ……………………………………………
22. When do you harvest your produce from the farm? When the maize is: green matured ☐ dried matured ☐ drooped dried ☐
23. How do you harvest the maize product? By: hand only ☐ hand with knife/cutlass ☐ mechanical means ☐
24. Do you store your maize produce after harvest? Yes ☐ No ☐
25. If yes, please rank your reasons with 5 being highest and 1 lowest. For: consumption ☐ seeds ☐ sales ☐ feed animals ☐ others ☐
26. Do you dry the maize after harvest before storage? Yes ☐ No ☐
27. If no, please explain. ……………………………………………………………….
28. If yes, in what forms do you dry them? Cobs (with husks) ☐ Cobs (without husks) ☐ Shelled grains ☐
29. How do you dry your maize? Natural drying ☐ Mechanical drying ☐
30. How long do you dry your maize? <1 month ☐ 1-2 ☐ 3-4 ☐ 5-6 ☐ >6months ☐
31. In what form do you store your maize after drying? Cobs (with husks) ☐ Cobs (without husks) Shelled grains☐
32. If shelled, how do you shell it? By: hands ☐ Simple Sheller ☐ Others
33. Please estimate the quantity of grains loss during shelling? <10% ☐ 10-19% ☐ 20-29% ☐ 30-39% ☐ 40-49% ☐ >50% ☐
34. What quantity of maize produced do you put into store? <10% ☐ 10-19% ☐ 20-29% ☐ 30-39% ☐ 40-49% ☐ >50% ☐
35. Do you keep any maize as seeds? Yes ☐ No ☐
36. Have you received any training on harvesting, drying and storage of maize? Yes ☐No☐
37. If yes, from who or which organization? Please specify: ....

38. What challenges do you face during storage? Please tick as many as apply in your situation. Rainfall ☐ Insect Infestation ☐ Mice Infestation ☐ Goat Destruction ☐ Others ☐

Section C – Storage Structure

39. If you store your produce, what storage structure(s) do you use? Barn ☐ Shed ☐ Crib☐ Warehouse ☐ Kitchen ☐ Others ☐
40. How old is your storage structure (months)? ....
41. What is the current condition of the storage structure? Very good ☐ Good ☐ Fair ☐ bad ☐
42. Do you do anything to treat the storage structure before filling it with produce? Yes ☐ No ☐
43. Please explain your answer: ....
44. If yes, please state what you use to treat? ....
45. How often do you treat the structure? Monthly ☐ Quarterly ☐ Biannual ☐ Yearly ☐
46. Do you give any treatment to the produce before storage? Yes ☐ No ☐
47. Please explain your answer: ....
48. If yes, what did you use to the treat it? ....
49. How often do you apply it/them? Monthly ☐ Quarterly ☐ Biannual ☐ Yearly
50. Do you give any treatment to the produce whiles in store? Yes ☐ No ☐
51. Please explain your answer: ....
52. If yes, what did you use to treat it? ....
53. How often do you treat it? Monthly ☐ Quarterly ☐ Biannual ☐ Yearly ☐
54. What are some of the challenges you face whiles using this storage structure? Please rank in other of importance from highest to lowest with 4 being highest and 1 lowest on a 4 point score scale.

Rainfall	
Durability	
Insect Infestation	
Rodent Attacks	

Section D – Uses of stored maize

55. How long do you usually store your maize? <1 ☐ 1-2☐ 3-4☐ 5-6 ☐ >6months☐
56. How often do you take maize out of your store? Weekly ☐ Fortnightly ☐ Monthly Quarterly ☐ More ☐
57. From which part of the stack do you pick the maize? Top ☐ Bottom ☐ Side ☐ Front☐ Back ☐ Others ☐
58. What is/are the purpose(s) for taking maize from the store? Please rank in other of importance from highest to lowest with 5 being highest and 1 lowest on a 5 point score scale.

Human Consumption	
Animal Feeding	
Sales	
Gifts / Donations	
Seed / Replanting	

Section E – Losses

59. Does the maize you store show any signs of damage? Yes ☐ No ☐
60. If yes, what was the extent of damage? <10% ☐ 10-19% ☐ 20-29% ☐ 30-39% ☐ 40-49% ☐ >50% ☐
61. What in your opinion causes the damage? Insects☐ Moulds ☐ Rats ☐ Others ☐
62. What do you do to prevent damage to your stored products? Please explain: ………………………………………………………….…………
63. In your opinion does this damage affect the quality of maize in store? Yes ☐ No ☐
64. If yes, explain how? ....
65. What do you do with the damage maize? Feed animals ☐ Sale ☐ Donation ☐Disposal ☐ Others ☐

Section F – Marketing

66. In what form do you sell your produce? Fresh Cobs (with husks) ☐ Dried cobs (with husks) ☐ Dried cobs (without husks) ☐ Shelled grains ☐
67. What proportion of the total produce do you sell after storage? <10% ☐ 10-19% ☐ 20-29% ☐ 30-39% ☐ 40-49% ☐ >50% ☐
68. What grade of maize do you sell after storage? Good ☐ Slightly damaged ☐ Damage☐
69. Does the quality of produce remain the same after the storage period? Yes ☐ No ☐
70. If no, was the change in quality for better or worse? Please explain: ……………………

……………………………………………………………………………………………………