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POSTHARVEST STORAGE PRACTICES AND TECHNIQUES:

A CASE STUDY OF MAIZE FARMERS IN THREE DISTRICTS OF THE ASHANTI REGION IN GHANA

BY

PAUL AMOH KORANG

APRIL, 2016

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A THESIS SUBMITTED TO THE SCHOOL OF RESEARCH AND GRADUATE STUDIES, KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF DEGREE OF MASTER OF PHILOSOPHY IN

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DECLARATION

I hereby declare that this submission is my own work towards the M.PHIL degree in postharvest and that, to the best of my knowledge, it contains no material previously published by another person or material which has been accepted for the award of any other degree of this University, or elsewhere except where due acknowledgement has been made in the text.

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(Head of Department)	Signature	Date

DEDICATION

This dissertation is dedicated to my dear wife, Lydia and children Agyiewaah and Nyarko, through whose sacrifices my M.PHIL. programme has been successful. Thank you for your support and cooperation. May Jehovah richly bless you!

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ABSTRACT

Maize production in Ghana dates back to some hundreds of years in the history of the country. The production and storage of maize in Ghana has been characterized by grain losses especially during the storage period. An assessment by the Ministry of Food and Agriculture in 2007 identified about 20% - 30% loss in terms of stored grains. The study aimed at assessing farmers‘ experiences in the use of storage facilities and techniques in three maize growing districts in the Ashanti Region. The study employed a combination of simple random sampling and stratified sampling procedures to select three districts from the Ashanti region (Atwima Nwabiagya, Ejura Sekyedumase Municipal and Offinso South Municipal) and 120 respondents selected to complete a semi structured set of questionnaires. The results showed that the average quantity of maize grains lost during storage was about 20% for all three districts. The various storage facilities that were used for the harvested maize included storage in wider cribs (38.5%); storage in bags in warehouses (34.2%); storage in other places (rooms, veranda, kitchen etc.) (20%) and storage in narrow cribs (10%). Challenges faced by farmers in order of severity included high cost of storage facility; heavy rains; rodents and termites attack; handling of grains before storage; high moisture content; inadequate storage facilities and theft. Some remedies to increase the effectiveness of the primary storage facilities used by the farmers included drying; dehusking; chemical treatment; clean bagging and; frequent moisture content testing. Laboratory tests were also done on maize samples acquired from selected respondents for their proximate composition. Mould and weevil infested grains were analysed with fresh healthy and uninfested grains as control. Results from the analyses indicated that mould and weevil infestation caused significant loss in nutritional quality of stored grain. It is recommended that the state empowers farmers and maize sellers to patronize the best storage to ensure food security.

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CHAPTER ONE

1.0 INTRODUCTION

Maize (*Zea mays* L.), in Canada and the United Sates, is often referred to as corn, and the world over, it ranks as the most important cereal grain after wheat and rice (Golob *et al.*, 2004). Considering the high regard placed on the great use of its main products and by-products and its nutritional value, maize has been branded the cereal of the future (Lee, 1999). Having already indicated it importance in the world after wheat and rice, it must be noted that it is mostly used and marketed as a foremost feed crop. Beside its role in the production of ethanol, maize stands as a great food staple (Nyoro, 2004). Maize, a major staple in Ghana, is widely cultivated all over the country. Economically, the significance of maize and its position in guaranteeing Ghana‘s food security cannot be overstated. From the year 2000, the yearly production of maize often exceeds 1,000,000 MT. Human consumption of maize is greatest in the Southern parts of the country where a myriad of maize foods such as *banku,tuozafi*, *banku,*and *akple*. Consumption of maize in the poultry sector is as important as human consumption averaging 1,282,000MT over the period 2002 to 2004 (MOFA, 2007).

Subsistence farming, in most parts of Africa *(Ghana inclusive)* involves the use of open-air storage facilities for maize (emphasis mine) (Lindblad and Druben, 1980; Akaninwor and Sodje, 2005). This allows for re-wetting and associated pest (weevil, mould, birds, and rodent) activities, occasioning damage to stored maize. Factors including the weather and its components such as relative humidity and temperature, the growth of microorganisms, and insects should be guarded against at the storage stage to ensure high quality maize (Oyekale *et al.*, 2012). The losses in maize grains at the storage stage caused by microorganisms and insects in developing countries are threatening as Campbell *et al.*, (2004) posit that the recent estimation of these losses stand at the cost of $500 million to $1 billion annually. Tuite and Foster (1979) also reported that the growth of mould brought about by heightened content of moisture and temperature is due to the presence of insects in the grains; these conditions creates passages in the grain making it prone to attack.

Research has shown that the combined effect of maize weevils and moulds alone is capable of causing up to 100% maize damage (Demissie *et al*., 2008; Weinberg, *et al.*, 2008). This is of economic importance, considering that weevil activity introduces moulds, especially since subsistence farmers lack adequate drying equipment and maize may be stored while relatively moist and warm (Mendoza *et al.*, 1982; Bankole, *et al.*, 2005). A number of internally and externally feeding pest species infest maize and other grains under poor storage conditions. These include the granary weevil (*Sitophilus granarius*) and maize weevils (*Sitophilus zeamais*, Motschulsky) which are among the most destructive pests (FAO, 1997). The feeding and activities of these pests are responsible for decline in the nutrient quality of maize and contamination of the interior content by producing toxic compounds and allergens (Rajendran and Parveen, 2005).

Moulds are responsible for reduction in nutritional value by enzymatic digestion, producing unpleasant flavors and appearance, making feed lumps and reducing palatability of stored maize (Lim *et al.,* 2008).

Odeyemi and Daramola, 2000 observed that, during hot and dry weathers in tropical areas, there can be great losses in stored foods as storage facilities can record temperatures as high as 50C. In such a condition, respiration is accentuated in the foods hence weight is lost in them. Foods also rot faster during hot or wet times.

Grains and legumes are often likely to take in water from the atmosphere at increased humidity and temperature. This condition makes the foods deteriorate. In her production of maize, Ghana is self-sufficient. However, challenges of maize insecurity during the period after the harvest season caused by poor storage practices, challenges in distribution, and expensive charges on the grains are not included in projections of staple maize availability in Ghana (Armah and Asante, 2006). Postharvest losses in grains in Ghana can be as high as 20 % - 30 % (MOFA, 2007).

In its ideal sense, unceasing food supply, cessation of food spoilage, and the preservation of food quality are the reasons for storing foods. Unfortunately, the foods are directly or indirectly affected when in storage due to climatic factors such as, rainfall, temperature, humidity and sunshine. Physical and chemical processes usually precipitate direct effects on the foods. On the other hand, agents of biological deterioration and other influences are responsible for indirect effects (Odeyemi and Daramola, 2000).

Dzisi *et al.* (2007) and Edusah (2006) identified field and postharvest losses as the most important constraints militating maize production in Ghana. They reported losses in the field and postharvest sectors as 5-10% and 15-30% respectively. From the MOFA-SRID, 2000 report, annual production of maize exceeds 1,000,000MT. Thirty percent of this value is three hundred thousand metric tonnes. It goes therefore without mention that intensified efforts to mitigate losses in the postharvest sector will lead to saving significant quantities of our maize.

Against the backdrop that maize is a major staple in Ghana, it is imperative that all stakeholders in the country, especially the government (with its duties in this regard delegated to the Ministry of Food and Agriculture (MOFA) and other relevant ministries and agencies) make certain that maize consumed in the country is of finest quality and in quantities that will meet the ever-increasing demand for maize and its by-products in the country. Consumption of quality food will improve the health of people and also if the quantities are also enhanced, maize could become an economically important export commodity for the country.

The preservation of the quality and quantity of stored products therefore depends to a large extent on the storage facilities and practices. This study hopes to identify and assess some of these storage facilities and practices.

The main objective of this study was to assess maize storage facilities and practices carried out in the Ejura Sekyedumase Municipal, Offinso South Municipal and Atwima Nwabiagya district. The specific objectives of the study were:

1. To identify the types of storage facilities in use at Ejura Sekyedumase Municipal, Offinso South Municipal and Atwima Nwabiagya district.
2. To determine the storage practices carried out on maize at Ejura Sekyedumase Municipal, Offinso South Municipal and Atwima Nwabiagya district.
3. To determine the level of insect pest, fungal and rodent infestation associated with the identified storage facilities.
4. To examine the nutritional quality of maize from the assessed storage structures after a period of storage through laboratory analysis.

CHAPTER TWO

2.0 LITERATURE REVIEW

Raised all over the country in various environments, maize (*Zea mays* L.) is the chief grain crop in Ghana. To achieve maximum output in the cultivation of maize, the farmer must pay attention that production inputs are correctly applied; and eventually, the environment sustained. The inputs include, among other things, adapted cultivars, plant population, soil tillage, fertilization, disease, weed, and insect control, harvesting, post-harvest management, marketing and financial capital. Maize is largely utilized as a second cycle product in advanced nations just like meat, dairy products, and eggs. It is however directly utilized in developing nations and it is the chief food for about 200 million people. Many people consider maize as a morning meal. It can also be processed for starch and ethanol (used as fuel). Further, products such as sorbic and lactic acid, dextrine, sorbitol and home articles like ice cream, shoe polish, beer, glue, syrup, batteries, fireworks, inks, paint, mustard, aspirin, and cosmetics are acquired through the enzymatic conversion of starch (Prinsloo *et al.*, 2003). Ghana is known to be approximately 99% self-sufficient in maize cultivation (Nyateng and Asuming-Bempong, 2003).

Left to rain-fed backdrop and production methods that are traditional, cultivation results are down under their significant levels – approximately, average maize yields in Ghana stand at 1.5 metric tons per hectare. On the other hand, when farmers use effective seeds, irrigation, mechanization, and fertilizers, high yields as much as 5.05.5 metric tons per hectare are realized (Armah, 2006). White maize comprises half of the total production of maize and it goes for consumption by humans.

2.1 MAIZE TAXONOMY AND AGRONOMY

Maize is a member of the tribe *Maydeae* and of the family *Poaceae*. The Zea genus comprises four species and of them all, Zea mays L. is of great economic value (Doebley, 1990).

2.1.1 Morphology, Growth and Development

2.1.1.1 Leaves

The maize plant grows to have 8 to 20 leaves that are arranged helically on the stem. The positioning of the leaves on the stem is such that they are found in succession and opposite one another. The ligules, blade, auricles, and a sheath comprise the main parts of the maize leaf; quintessential of grass leaves. The blade of the leaf is undulating, extended, slim, and recedes to its extremity and it could be bare or hairy. A notable mid-rib bolster up the leaf along its length. Spreads across the surface of the leaf are rows of stomata. The belly of the leaf records more stomata than the surface further up (Hanway and Ritchie, 1984).

2.1.1.2 Stem

There is a recognizable variation in the stems of the maize; below 0.6 m in certain genotypes to above 5.0 m (that is in acute situations) in others. The stem is solid, tubular, and is bisected at nodes and internodes. The internodes could be 8 to 21 with those located just under the initial four leaves are not elongated while the ones under the sixth, seventh and eighth leaves elongate to about 25 mm, 50 mm and 90 mm, respectively (Hanway and Ritchie,1984).

2.1.1.3 Inflorescence

As individual inflorescences, both male and female flowers are contained on a single with the male flowers in the tassel while the ear bears the female flowers.

2.1.1.4 Maize ear

Often, midway on the stem, the maize ear (the female inflorescence) destroys one or more lateral branches. The ear is surrounded by bracts. The flowers on the lower part of the ear develop their silk earlier than the flowers higher up. After ten days, their receptiveness to pollen reduces but their receptiveness can last for about three weeks.

2.1.1.5 Maize kernel

The embryo, tip cap, a pericarp, and endosperm are the components of the maize kernel. Major carbohydrates are contained in the endosperm; the embryo houses the parts that produce the next generation; and the function of covering the whole kernel is left to pericarp and tip cap. The contents of the endosperm on the kernel are thusly distributed: carbohydrates (about 80 %), fat (about 20 %), and minerals (about 25 %). That of the embryo are as follows; fat (about 80 %), minerals (about 75 %), and protein (about 20%). These usually comprise the Endosperm, Germ, Pericarp, Tip and cap. Maize kernels are known to be of the dent or flint (round) kinds. The crowns of dent kernels are dented; a feature that is acquired during drying, a time which allows the softer starch at the centre of the kernel to shrink quicker than the outer sides that are more translucent. The dent kernel possesses two flat sides facing each other with one of the sides containing the embryo. The components that aid in the production of the next generation are contained in the embryo. Flint kernels may have round or flat appearances and their main content is translucent starch, while their centre contains little soft starch – that explains their name. The whole kernel is covered by the pericarp and tip cap. Determined by the type, the tally of the rows of kernel can be dissimilar between four and 40. One plant can produce as much as 1, 000 kernels. Though one pollen grain is needed in the production of one kernel, each tassel can produce as much as 25,000,000 pollen grains. Therefore, a kernel gets around 25,000 grains. Consequently, about 40 % of the tassels in a planting could be lost with no role in influencing pollination. Other contributing factors remain influential in this regard (Prinsloo *et al*, 2003).

2.1.1.6 Root system

The maize plant has a majorly branched, fine root system. In very favourable conditions, when the root hairs are not considered, the root can be as long as 1,500 m. in the absence of restrictions, the roots of a matured maize plant can averagely travel 1.5 sidewise; downward, they can go 2.0 m on the average or even further. Adventitious and prop roots may develop in the permanent root systems of maize plants. Adventitious roots grow in a crown of roots out of nodes beneath the surface of soil. When these crown of roots are arranged in bands, usually, about four to six adventitious roots are formed per band. Prop roots grow into bands out of the initial two to three nodes that are aerially exposed after the plant tassels. The prop roots are by comparison bulky, tinctured, and coated with a waxen material.

2.1.1.7 Growth and development stages of corn

The leaf collar approach (the system where the topmost leaf with a collar) is used to stage corn before it tassels. When whole tassel becomes observable, then it indicates that the concluding vegetative stage has been reached. This is denoted as VT. The initial propagative stage takes place approximately two to three days after **VT** and it is represented with **R1** (figure 1).

Figure 2.1. Growth stages of maize from vegetative (VT) to reproductive stage (R)

R1 represents the stage where pollination and fertilization in the plant occur; also known as silking. At the time when silks appear at the nib of the ear shoot on not less than 50% of the plants, R1 takes place. The silks that appears workable and receptive to pollen for up to 10 days. On the cob, every silk is linked to a prospective kernel. The ovule which is the kernel is fertilized when at pollination; the female part of the plant which is the ear accepts pollen from the tassel. Nib silks appear last while silks joined to prospective kernels cob‘s bottom usually appear first. From without, the kernel looks white; within, the parts look clear. The kernels could go unfertilized the pollination process is defective. The fill pattern of silks may vary since they appear in varying accruals depending on the prospective kernels they get connected to.

At **R1**, the plant consumes much water each day. The water content in silks is higher than in the other parts of the plants. Ergo, at R1, the plants should not be made to suffer water deprivation.

Blister stage (R2) takes place post-silking; approximately, 10 to 14 days afterward. Here, the kernel is observable and looks like a blister on the cob and it is packed at this stage with crystalline sap. Should the kernel be cut up, an embryo will be found – it is the part that develops a year later after the seed is sowed. The kernel is known to be made up of 80% liquid. This content reduces when they develop toward maturity. At R2 or R3, kernels could be taken off from the nib downward to reduce the burden on the plant when it suffers harsh conditions.

Milk stage (R3) takes place around 18-22 days post-silking. Within, the kernel gets filled with a milky-white liquid but without, it is yellow as starch also quickly accumulates inside the kernel. Cell division completes in the endosperm by this stage. Starch-fill and cell expansion are the main causes of kernel development that occurs at this stage.

Dough stage (R4) takes place around 24-28 days post-silking. Within, the kernel thickens like dough or paste-like material. The kernels must have reached approximately half of their mature dry weight. Dire situations cannot cause kernels to be done away with at this stage. As R5 approaches, the kernels start to dent at the nib of the ear (dent begins).

Dent stage (R5) takes place around 35-42 days post-silking. At their uppermost parts, the kernels are dented in and are desiccated. At the initial stages of R5, the water value in the kernels stands at 55%. An observable line divides yellow and white on the kernel progressing further down as the kernel continues to grow; the starch in it also solidifies. At this stage, stress can only decrease the weight of the kernel as dry matter is not allowed accumulate.

Physiological maturity (R6) takes place around 55-65 days post-silking. As the starchy film is totally removed to the cob, every kernel gets its dry matter to accumulate to utmost levels. At this stage, a black or brown film is observable at the bottom of every kernel. Tip kernels achieve this black layer before the base kernels. Water content in kernel now stands between 30-35% varying mostly because of hybrid and environment. When the plant is still green, it makes it easy for the removal of water from the kernel. Dire situations that occur at this stage insignificantly affect crop yield. However, insect feeding on the ear and poor plant lodging can affect yield
(Hanway and Ritchie, 1984; Nielsen, 2004).

2.1.1.8. Climatic and soil requirements

As adaptable as it is, the maize crop can be cultivated in various agro climatic areas. In this regard, it is unrivalled. It can be cultivated from 58$_o$N to 40$_o$S; beneath sea level to altitudes beyond 3000 m, and in areas with 250 mm to more than 5000 mm of annual rainfall. It also possesses cultivation rotation ranging from 3 to 13 months (Shaw, 1988; Dowswell *et. al.,* 1996).
Maize is well cultivated in temperate weathers. It does not thrive in regions whose mean temperature daily is below 19 ºC as well as regions where during the months of summer, the mean daily temperature is below 23 ºC. Though the crop can germinate at a minimal temperature of 10 ºC, the ideal soil temperature necessary for quicker and less varying germination is 16 to 18 ºC.

It takes five to six days for maize to sprout out of the soil at 20 ºC. Temperatures around 32 ºC are known to be detrimental to crop yield in maize crops. Across all the stages of the development of maize, frost can have very damaging effects on the crop. To avoid crop damage, a period of 120 to 140 days should be without frost. Frost damage is not severe on fresh leaves as the maturing point is beneath soil surface. Frost can easily destroy the leaves of already grown plants; grain filling can also be seriously affected (Prinsloo *et al.*, 2003).

Largely, the seasonal water supply needed by maize which is 450 to 600 mm is provided from stockpile in the soil. Every millimetre of water used up by the plant can assure the yield of around 15.0 kg of grain. 250 L of water is used up by every plant before it reaches maturity. On each plant, the total leaf area at maturity could be beyond one square metre. When the plants reach the flowering stage, they assimilate phosphorus, potassium, and nitrogen in very large doses. Nutrients intake in a plant at maturity is thusly distributed: phosphorus (5.1 g), potassium (4.0 g), and nitrogen (8.7 g). At the production of every ton of grain, the following amounts of nutrients are used up by the plant from the soil: 2.5 to 3.0 kg of phosphorus, 3.0 to 4.0 kg of potassium, and 15.0 to 18.0 kg of nitrogen. In its efficient utilization of sunlight, the maize crop is unparalleled by any other crop; no grain crop parallels its yield per hectare (Prinsloo *et al.*, 2003).

To be fit for the cultivation of the maize crop, a soil must possess the following features: i. a good and powerful vertical drop, ii. appreciative morphological features, iii. excellent inner drainage, iv. choicest liquid regime, v. adequate and balanced supply of plant nutrients and chemical features advantageous particularly for the cultivation of maize. The ideal soil texture for the cultivation of the maize crop stands between 10 and 30% and the soil must have excellent air and liquid regimes necessary for maize cultivation. However, extensive cultivation of maize can also be carried on sandy soils whose clay content is below 10% and in clay and clay-loam soils whose clay content is at most 30% (Prinsloo *et al.*, 2003).

2.1.1.9 Land preparation

The most cost rewarding method for in land preparation is soil tillage, especially primary tillage, forms the basis for all crop cultivation system.

2.1.1.10 Planting and seed rates

As long as the necessary conditions for effective germination such as conducive soil temperature and ground water are available, planting can start. Germination can be successful if a minimal air temperature of 10 to 15 ºC can be sustained for seven continuous days. Under 10 ºC, just about no germination or growth occurs. The planting should be planned in such a way that the stages of plant growth that require much heat and water – the flowering phase – do not occur the same time as a period of prolonged water shortage. Factors such as soil type and the date of planting often affect the planting depth of maize whose planting depth ranges from 5 to 10 cm. Comparing sandy soil to soil that is heavy, it is ideal that shallower planting is done in the latter than in the former. Particular row width is not a necessary factor as plant population per unit area in planting. In dry land situations, row widths may differ from 0.91 m to 2.1 or 2.3 m, determined by the mechanical equipment accessible and the kind of soil tillage method adopted (Prinsloo *et al.*, 2003).

2.1.1.11 Fertilization

At the maximum, N and K implementation could be 70, 50 and 30 kg/ha for the various row widths. Although substantial amounts can be applied, they must be deposited 70 to 100 mm on the side and beneath the seed. Normally, factors such as leftover N inside the soil and the weather determines the times when much N can be applied. However, plant fertilizer concoctions must contain N.

2.1.1.12 Weed management

Efficient weed management is a necessary factor in the realization of success in the cultivation of maize. It is in fact vital particularly in the initial six to eight weeks postplanting as weeds are known to forcibly fight for water and nutrients from the crop during this phase.

Annually, depletion in yields (which stands around 10%) is accounted for in weed infestations that affected the crops. These losses are an outcome of weeds rivalling the crops for nutrients, light, and water. At the time of harvest, the existence of weeds can decelerate the process, create odours in the grain, contaminate the grain with seeds; these degrade the crop value or even attract more charges to remove seeds. The presence of weeds during harvesting may slow the process, pollute grain with seeds, transmit odours to grain, causing downgrading, or incur additional costs for removal of seeds. Some of these seeds like that of the thorn apple (Datura), can be deadly if animals or humans ingest them.

2.1.2 Pests and Disease Management

The approach where systems are adopted to safeguard crops by limiting insect population and damage is referred to as Integrated Pest Management. This management practice includes all practical approaches in pest control in a pest management system. These procedures comprise biological control, chemical control, cultivation control, and plant resistance.

2.1.3 Harvesting

Done mechanically on large farms but mostly done manually at the small scale and subsistence levels especially in Sub-Saharan Africa.

2.2 USES OF MAIZE

In the production of paper and artifacts like clothing, pharmaceutical tablets, foods, and adhesives, the starchy portion of the kernel is utilized. Transformed into sweeteners, the starch is utilized in the production of jams, soft drinks, bakery products, sweets, among others. Products such as margarine, salad dressings, and cooking oils can be derived from the oil produced in the embryo. In the production of poultry feed too, the hulls, the soluble portion of the kernel, and protein are utilized (Prinsloo *et al*, 2003).

2.3 CHEMICAL COMPOSITION AND NUTRITIONAL VALUE OF MAIZE

It is a generally accepted fact that cereal grains significantly serve the nutritional demands of humans because of the ability to supply significant quantities of energy and protein to the greater percentage of people particularly in developing countries (FAO, 2011). From Nuss and Tanumihardjo (2011), about 10% of the calories need and 15% of the protein need of the globe are supplied by maize. The pliant quality of the maize is further highlighted in the fact that humans can consume it as food and it can be utilized in the food processing industry because of its vast nutritional properties as it is used as an ingredient in the production of animal feed (Ullah *et al.*, 2010).

Table 1 presents representative approximations of the constituents of the major components of the maize kernel (yellow dent corn). Chemically, dried maize kernel averagely has the following composition: moist (10.4 %), protein (6.8 % to 12 %), lipid (4%), ash (1.2 %), fiber (2.0 %), and carbohydrate (72 % to 74 %) (Katz *et al.*, 1974; Kulp and Joseph, 2000). Micro and macro nutrients are also distributed in maize in the following proportions: calcium (7 mg/100 g), phosphorus (210 mg/100 g), iron (2.7 mg/100 g), sodium (35 mg/100 g), potassium (287 mg/100 g), zinc (2.2 mg/100 g), copper (0.3 mg/100 g), magnesium (127 mg/100 g), and manganese (0.45 mg/100 g); all in dry matter basis (db) (Nuss and Tanumihardjo, 2010). Principal vitamins are also found in maize in the following proportions: thiamine (0.38 mg/100 g), riboflavin (0.20 mg/100 g), and niacin (3.63 mg/100 g), pantothenic acid (0.42 mg/100 g) and folate (19 μg/100 g) (Nuss and Tanumihardjo, 2010). These may differ considering factors such as growing seasons, soil conditions, hybrid, and variety.

2.4 STORAGE OF MAIZE IN GHANA

Maize, in particular is stored either on the farm or off farm. The amount of maize farmer can store depends on the size of his holding and volume of produce at the end of the harvest. At the farm level a farmer may store maize in cribs, bins and silos. He may store the maize either shelled or unshelled in sacks or in bulk. At distribution or export points, that is, the ports, maize may be stored in reasonably complex grain silos or elevators. Inadequate storage and conditioning facilities, or complete absence of them, contribute to great losses of stored maize. Maize will, therefore, deteriorate in storage if it is not properly conditioned before being stored (Lampteh *et al*, 1993).

2.4.1 Storage Structures of Maize

A storage structure does more than just carrying the load of the stored produce. In addition to containing the maize it must maintain the quality and quantity of the maize. This means that it must protect the maize from the weather, living organisms, from addition of moisture and high temperatures. The efficiency of the structure in fulfillment of its objectives or requirements is dependent on the design of the structure; the initial status of the grain to be stored; the material used to construct the structure and sitting of the structure. The design of the structure requires basic knowledge of some disciplines in engineering and will therefore be reserved for a future higher level course (Lampteh *et al*, 1993).

2.4.2 Storage Techniques Adopted in Maize Storage

Maize is handled and stored in two main forms; shelled and unshelled. Unshelled maize is either stored with or without the sheath. Maize may be stored at three levels. These are at the farm level (by the farmer); trader or middle person level and depots or commercial stores. Unshelled grain may be stored by the farmer either on the farm or at home (Lampteh *et al*, 1993). Whenever grain is stored unshelled the real quantities are usually small and in relative simple structures made up of cheap materials. Shelled maize may be stored in sacks, or loose in various structures or containers (or various materials). The choice of a structure (or container) to hold the grain may depend on local factors, such as: the type of grain to be stored, the quantity to be stored, the value of the grains, the duration of storage, the cost and availability of structural material and the climatic conditions of the area (Lampteh *et al*, 1993).

2.4.3 Structures for Unshelled Maize

When maize is stored unshelled it is usually held in either covered or uncovered structures. Uncovered structures may be as simple as branches of trees in the compound vertical poles on the farm and horizontal cords or ropes. In all these, the grain is hung on wooden material and may be in the open without cover. If stored in this way, small amounts are taken periodically and shelled by hand for sale or for consumption by the household. Maize stored this way is not intended to last for long. This is so, because the grain is left at the mercy of the weather and can spoil easily. It is, however cheap to construct and maintain this structures (Lampteh *et al.*, 1993).

A slight improvement of this type of storage is found in situation where poles and cords are under a roof of some sort. The roofs may be of thatch or corrugated metal sheet, or even bamboo splits. In situations where the cobs are hanging in the kitchen, the heat from burning wood will further dry the maize and may last a little bit longer than when it is stored in the open and without a cover. The second method is relatively more expensive than the first method.

Baskets which are woven from grass or other plant material may be used to store unshelled maize. Such baskets may be with or without lids and are usually placed in a corner of a room or kitchen. Seeds for the next season planting are kept this way. In addition to baskets are clay jars and gourds which are also used to store maize.

Platforms may also be used to store maize. These are usually of plant material. The platform may be from 1 to 2 metres high and on woven staves or supports. The grain is heaped on the platform and is covered with either thatch, plastic or metal sheet (Lampteh *et al*, 1993).

Crib storage is also available. Cribs are similar to the platform, except that the cribs may have side walls and roof. Maize on the cob and with or without sheath is packed loosely into the crib. Rodents and insects damage are most likely in crop storage. In hot humid areas, mouldy spots may be created if the stacking of maize is done properly. On large farms, the use of crib is to hold the grain temporarily and to reduce its moisture to the desired level for shelling. Currently, it is widely recognized that storage systems that are traditional like cribs are well suited to the local situations. Also, waste from grain storage with these methods are largely minimal and It is now generally accepted that traditional local storage systems such as cribs are usually welladapted to local conditions and losses from grain storage are generally low and satisfactory to farmers (Compton, 1992).

Granaries are also available for maize storage. They are constructed with plant material and are usually raised off the ground. Some are thatched roofed. Mud may also be used to construct a granary. Granaries are usually outdoor structures, and may be wrapped with ―skirts‖ of grass or other plant material. In the northern part of Ghana ―Zanua‖ (woven grass stalks and leaves) protect granaries from both the sun and rains. Granaries have low storage capacities. The top cover (thatch roof) is like a hat and can be taken off for filling and emptying.

Barns are also used to store maize on cob and with or without sheath. Barns are structurally more complex than the others we have discussed already. They may be used on peasant or commercial farms. In both cases the grain may be held in the barn and dried by natural air movement before shelling. Barns are usually raised about 1 to 1.5 metres high on wood or concrete columns or supports. They have floors and walls of planks of wood or split bamboo. Traditional barns are thatch roofed. Others may be roofed with aluminium sheets, galvanized steel or asbestos, depending on the strength of walls and the supports (Lampteh *et al*, 1993).

Figure 2.2 Traditional structures for unshelled maize

2.4.4 Structures for Shelled Maize

Shelled maize is generally handled in bulk. When grain is stored in bulk, the full space in the storage structure is effectively utilized. That is, storage of wanted parts of the maize and therefore ineffective usage of the storage space is prevented. However, bulk storage is characterized by high capital cost and depends on skilled personnel for design, construction and management. These factors usually place this storage technique beyond the reach of many small scale farmers. Shelled grains may be stored in either sacks or simply in bulk in a structure of some sort.

2.4.4.1 Bags (Sacks)

These may be used to store grains at the farmer‘s, traders or commercial distribution levels. Sacks storage is very useful where labour is cheap and when maize is moved in small quantities over short distances. High loses due to rodents and re-infestation by pests is major problems associated with sack storage (Lampteh *et al*, 1993). Sack storage does not require any special structure and can be kept under any convenient shelter with adequate ventilation. Protection from floor moisture is also necessary for sack storage. Stacks of sacks of maize may require just a cover or plastic material. Sadly, majority of farmers who keep their maize in bags / sacks do not have access to drying depots (Compton, 1992). In commercial stores and warehouses, sacks may be piled up with facilities for fumigation and ventilation. Figure 2.3 shows maize in sacks to be stored.

Figure 2.3: Maize in sacks.

2.4.4.2 Bins and silos

These are usually upright structures and are taller than broad. Bins and silos are similar in form and shape. The difference is in their design details and size. Silos are usually more a permanent structures than bins. Both may be either rectangular or cylindrical in shape. Bins and silos may either be flat bottomed or hopper. Flat bottom types are easier and cheaper to construct, and they provide more storage space than the hopper types with the same dimensions. Bins and silos are usually constructed with almost all structural materials available, that is, metal concrete, mud or bricks, wood (including plywood), and butyl rubber. Hoppers are more convenient for unloading as maize flows out by gravity and, therefore, are regarded as self-cleaning.

Hoppers are very useful in frequently emptied bins. If properly designed and managed bins and silos can keep the quality of the maize for reasonably long periods of time and at a reduced storage cost (Lampteh *et al.*, 1993).

Condensation has been reported to occur in metal silos. However, if the maize has been well dried before put into storage, the problem of condensation and redistribution of moisture within the maize bulk may be eliminated. Similar problems have been associated with concrete in the tropics. In both cases the structure must be well designed and the maize well dried before being put in storage. Steel or concrete bins and silos may be provided with perforated floors to facilitate drying and ventilation and sometimes as a means of applying insecticide to the maize in store.

2.4.3 Maize Seed Management – Post-harvest Treatment and Storage

Researchers, during the past twenty years, have invented several fresh technologies for the production of various crop systems. Measures including the use of intercrops, the use of mineral fertilizer, the production of enhanced varieties, and the use of rotations have immensely bolstered production. That notwithstanding, it appears that the great yields that are supposed to be realized from these technologies are hindered by awful post-production skills in processing, handling, and in the storing of these expanded production. So much is getting invested in the production of crops, losses after production affecting quality and quantity must be minimized.

Factors such as crops damage caused by pest organisms which results in decreases in the volume or weight of the crop, unpredictable harvest strategies, and when the products are spilled at transportation, quantity is negatively affected. Quality of the products can be lost too to factors like taste, colour, and smell changes, contagion from noxious substances, pathogens, insects and rodent excreta; nutritional quality can also decrease, or loss of viability when the harvest is meant for seed. Improvements are coming in the production of materials derived botanically meant to safeguard produce that are stored. In past tests in the laboratory and field, plant parts ethno botanically recognized for the storage of food to protect ants have indicated variable activity. Heightened reliance on botanical insecticides contributes to them being promoted as less costly and environmentally sustainable as compared to synthetic pesticides.

Though most of the botanical pesticides are currently undergoing examination to ascertain their real ability to protect crops against pests, some like *Azadirachta indica* are already used by farmers.

2.4.4 Major Enemies to Stored Maize

Insect pests: Some pests can still infest the maize that is harvested even when it has been harvested in due time, properly dried and shelled, and kept in hygienic conditions. They are the most serious threat to maize that is stored. They are very difficult to track – except when they are many - due to their small body size which in length, barely exceeds 2 mm. Unfortunately, they are able to increase exponentially. Hence, within a very limited time, the farmer could have thousands of them infesting the maize. Their ability to increase rapidly is largely the factor that makes them the greatest threat in food losses in grain that is stored. They thrive in darkness, and they are able move freely in limited area and in stored grain. Several insect species are associated with stored grain, however, only a few are economically valuable. The following is a list of insects that are often found as pests on maize in storage: the grain weevil with flying ability (*Sitophilus zeamais*) and the granary weevil without flying ability (*Sitophilus granarius*; angoumois grain moths (*Sitotrogacerealella*). There are the grain borers too: the larger grain borer (*Prostephanus truncates*) and the lesser grain borer (*Rhyzopertha dominica*). There are termites too who can wrought severe harm to the maize crop in all stages – right from when they are seedlings to storage. Maize stock infestation by *Prostephanus truncatus* translates into large losses for small producers (Borgemeister *et al.*, 1997).

Microorganisms: almost every environment crawls with huge numbers of microorganisms such as fungi, yeasts, and bacteria. Some destroy the crop from within it and others from without. Microorganisms are known to be able to infest maize in storage across various periods; before they dry well, when the storage area is moist, or when it accumulates moisture. Usually, when the grain is infested with bacteria, it acquires an offensive rotting odour. Also, grain infested with yeasts acquires a slimy texture coupled with a damp, and fermented odour. Fungal infestation is the commonest in stored grain and they can be identified as mold or caking on the affected ear or grain. When this happens, the maize loses colour, and its viability is lost and also, food value is reduced. The by-product of fungal attack that is highly dreaded is the creation of the noxious substances called mycotoxins; they are lethal to both humans and livestock.

Fungal infestation: The chances for fungal attack after harvest can be very much increased when the crops are inappropriately handled. Every damage that happens to the stored grains makes them more prone to fungal infestation (Tagliaferri *et al*., 1993). It must be mentioned as a matter of fact that insect activity has great effect in the spread of fungal diseases as they can transfer the spores thereby enlarging the surface area liable to fungal infestation therrby also increasing the creation of mycotoxins. Dunkel (1988) showed that certain storage insect species are disseminators of storage fungi while others are exterminators. The relationship between certain insects and fungi can be hostile. For instance, certain storage fungi attract storage insects and enhance the explosion of their population. Meanwhile, others repel and secrete poisons harmful to insects. Hence, effective management of grain in storage requires a great deal of knowledge in fundamental biological relationship between fungi and insects. Many researches show the relevance of insect pests as agents that can enhance fungal infestation. Pande and Mehrotra (1988) sampled maize seeds of *Sitophilus zeamais* and realized *Aspergilus flavus* was the frequently present species in their alimentary canals while *Rhizopus* and *Mucor species* were found in *Tribolium castaneum*. This shows the probability that *S. zeamais* transmits fungus spores from affected grains unto healthier ones. Also, aflatoxin degrees in affected maize multiplied as the number of *A. flavus* contaminated *S. zeamais*, and *S. zeamais* carried spores inside and outside on their exoskeleton. In certain crops, attempts at removing fragmented and discolored grains can well decrease the creation of mycotoxins.

Domestic rodents: Comprising mice and rats, this category accounts some of the greatest losses to maize in storage. Their preference lies with foods rich in oil and protein hence they can only consume the germ of the maize and leave the remainder of the grains in storage. The food preferences of rodents are not just genetically fixed, but are often learned and therefore variable in time and place [Deutsche Gesellschaft fur Technische Zusammenarbeit (GTZ), 1989]. A rat can consume food around 7% of its body weight every day thereby accounting for around 7 kg of grain every year. Their faeces and urine and other pathogens like fleas pollute the grains in storage. When this happens, removing the contaminants becomes impractical. Meanwhile, the affected grains become spoiled and unwholesome to be consumed by humans.

2.5 PEST DAMAGE TO MAIZE GRAINS AND NUTRIENT LOSS

To begin with, it must be always accepted that an unharmed grain is a vital factor for success in storage. Breakages or cracks on grains serve as gateways for infestation from moulds and insects when in storage. Ruins on grains could happen due to inappropriate post-harvest practices like drying or transporting (Rowley, 1984; Simone *et al.*, 1994). Removing grains from their protective coverings (threshing), can physically injure the grains (Laubscher and Cairns, 1983; Swamy and Gowda, 1987; Wilson, 1987). Wongo and Pedersen (1990) have established maize grains that got threshed were more prone to *Tribolium species* than those that were not threshed. The grains, especially in moist areas, is usually kept in their shucks. However, in modern ones, the shucks are discarded. In the event of this, the grains can be effectively cared for through application of insect repellents and antifeedants. Crop transportation is also a stage where losses occur a lot. When the transportation takes too long, grains could be physically damaged, spilled, or even deteriorate.

However, when attention is paid to appropriate packing, loading and handling of the grains, these wastages can be done away with (Youdeowei & Service, 1983).

Grain quality could deteriorate at storage because of inappropriate storage conditions which bring about contamination from insect and fungi attack. The infestations on grains in storage primarily begin from the field where the crops are grown (Youdeowei, 1989).

The situation is even worsened in the position of small scale African farmers who always plant or store their produce close to old granaries.

The infestation can easily move to and from storage sites. Also, when the same waste holders are used every year, an unending cycle of infestation is set in motion. Insects are capable of hibernating or even feeding on wooden structures in the store or stay within holes and cracks in the walls. When new grains are introduced, they go back to infest and feed on them. On the general level, storage causes changes in the rate of quality in the seeds as they respire depleting their nutrients after some time (Piergiovanni *et al*., 1993; Kadlag *et al*., 1995).

When such inherent factors like respiration in the seeds are coupled with the external factors such as attack by insects and mould, the crop quality may deteriorate even more rapidly. As respiration from insect and fungal activities continues, it is bound to cause increase in temperature. The heat creates moisture condensation in cool areas within the grain mass. Fungal development and insect infestation are enhanced when this also happens (Imura & Sinha, 1989). Though necessary moist levels differ from grain to grain, moisture levels should not go beyond the limits of 12 to 13 percent in most grains (Youdeowei & Service, 1983).

The damages caused by insect pests are largely from their eating of the grains. Some species consume the endosperm which leads to loss of weight and quality. Other species also consume the germ and it also makes the seeds not viable for germination; they even do poorly when they germinate (Malek and Parveen, 1989; Santos *et al*., 1990). Beside the threat of their immediate consumption of the grains, insect pests, through their excrements, dead bodies and moulting violate the grains they feed on. Even their presence in the produce makes it commercially undesirable.

Further infections from diseases caused by bacteria and fungus are encouraged through the activities of insect pests as they transfer their spores. ―Hot spots‖ are also created from the presence of insect pests in grains as their feeding increases the temperature of the products (Mills, 1989). Humidity is further concentrated in the grain because of the spots and this makes the seeds to deteriorate as well as promote the activities of fungi. Okiwelu *et al*., (1987) have noted that the capability of the *Sitophilus zeamais* to germinate reduces in the presence of high moisture levels combined with infestations.

2.6 POST HARVEST LOSSES IN MAIZE

In the pre-harvest, harvest and post-harvest phases, maize can be lost. Prior to the harvest, pre-harvest losses take place as a result of insect activity, and the presence of rusts and weeds. In between the commencing and ending periods of harvesting is where harvest losses are recorded. Losses at these stages are mainly as a result of breakages. The period between harvest and consumption by humans marks the stage of postharvest losses. Such losses come from activities on the farm like threshing, winnowing, and drying. Further losses at this stage can be counted during the transport, storage, and processing phases. In developing nations, especially in Africa, losses on the farm are prevalent especially when the grains are in storage for autoconsumption or when the farmer waits for market for his produce or price rise.

2.6.1 Potential for Loss

Across all stages in the maize value chain, losses are bound to occur (Reining, 1976). At shelling (when grains are stripped from the cob), when shelling is done mechanically but is not followed up with manual checking of grains that were missed by the machine, great losses can be recorded. The maize could even be physically harmed by some shellers which will later make way for insect penetration. Spilling, damage to grain and partial retrieving of the grain are major cause of losses in crops other than maize at the threshing stage. Post-threshing (i.e. at winnowing), losses could be recorded from inappropriate separation of the seeds from the chaff. Especially during the harvest period when labour is hard to come by and is costly in some areas, partial threshing often occurs. There are mechanical threshers made particularly to dry the grains.

2.6.2 Loss Assessment Methods

In seeking to minimize grain losses, much attention should be paid to realizing the enormity of the losses. It would be unwise when substantial resources are spent in this regard when the value of the losses is quite minimal (Greeley and Harman, 1976). It has however been difficult to develop an ideal strategy for accounting for maize losses. One of the challenges hindering the realization of this technique is the inconsistent sequence in the provision of maize from the farmer to the consumer.

Some famer‘s and their families subsist on the grains they harvest; other seeds are collected by the farmers for replanting. Portions of the harvest may be hoarded short or long term and through several marketing channels, the remainder is sold either all at a go or across a period of time (Kenton *et al*, 1976). Even on the farm, accounting for grain losses is very difficult considering that the producers incessantly remove the grains from storage to consume. Moreover, the excesses that a farmer generates in any harvest determine the quantity that is stored and the quantity sold. This may affect the loss values. While the chain remains inconsistent, generalizations from individual evaluations must be well guarded and guided. Unreasonably low and high instances must be put in their due place rather than being overemphasized like it has been experienced in certain cases (Harris *et al.*, 1976).

Estimations on grain losses have not been sound considering the challenges that persist and more so is the fact that it can be a very demanding exercise to be well executed (Gwinner *et al.*, 1990). As a way of confronting the challenges, the African Post Harvest Losses Information System (APHLIS), founded in 2009, intends to get estimates of losses as time goes on with the availability of information. They also intend to rely on a network of indigenous experts to provide current data. In their calculations, they hope to present data that is transparent; alterable every year as per circumstances, and can be bettered as authentic data becomes accessible.

CHAPTER THREE

3.0 MATERIALS AND METHODS

The research comprised two parts:

1) a field survey and 2) laboratory analyses.

The survey to identify handling and storage facilities was conducted through questionnaire administration, personal interviews and independent laboratory analysis. Maize samples were collected from storage facilities of farmers who were willing to cooperate with the researcher. The various analyses were carried out at the laboratories of the College of Agriculture and Natural Resources in KNUST.

3.1 THE STUDY AREA

3.1.1 Location

The Ashanti Region is centrally located in the middle belt of Ghana. It lies between longitudes 0.15W and 2.25W, and latitudes 5.50N and 7.46N. Beyond its eastern border is the Eastern Region; to its north is the Brong-Ahafo Region; the Central Region is to its the south; and the Western Region is south-west of this territory. These comprise four regions out of the ten political regions in Ghana and their geographic location with respect to the Ashanti Region (Ghana Statistical Service,
2012).

Figure 3.1 below shows the map of Ashanti Region with the studied Districts.

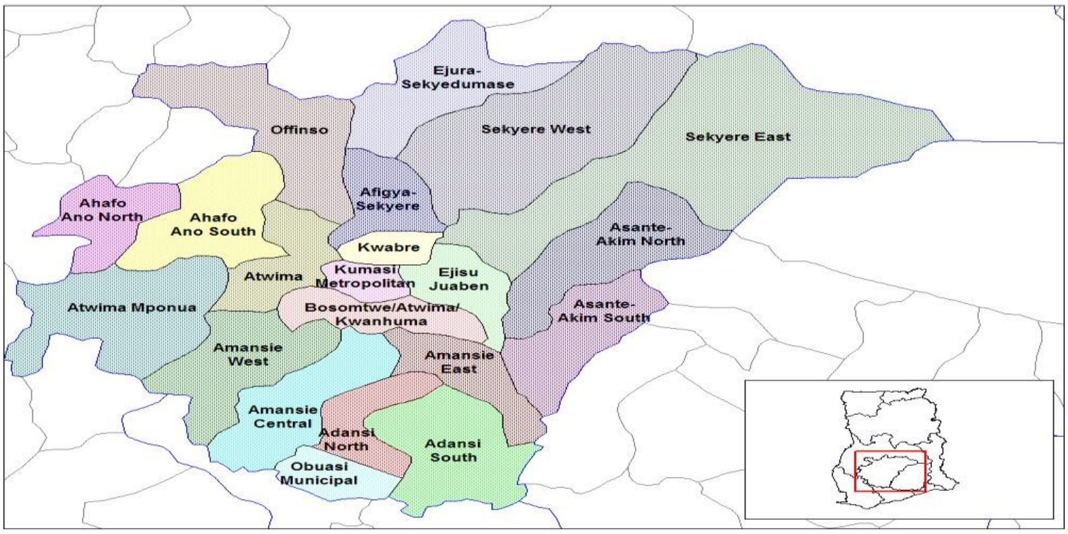

Figure 3.1. Map of Ashanti region with the study districts

3.1.2 Physical Features

Occupying a total land area of 24,389 square kilometres which represents 10.2% of the total land area of Ghana, the Ashanti Region is the third largest region after the Northern Region (70,384 sq. km) and Brong Ahafo (39,557 sq. km) regions and it contains a population density of 148.1 persons per square kilometre; a feature which also places it third after Greater Accra and Central Regions. The wet semi-equatorial forest zone houses beyond a half of the region.

The forest vegetation areas of the region, especially the north-eastern areas, are turned to savannah as a result of careless human activities and disasters like bushfires. When it comes to its rainfall patterns, the region annually enjoys an average rainfall of 1270 mm and two rainy seasons. On the average, the daily temperature of the area is in the regions of 27 degrees Celsius. The major rainy season starts in March, with a major pick in May. There is a slight dip in July and a peak in August, tapering off in November. December to February is dry, hot, and dusty (MOFA-SRID, 2012).

3.1.3 Occupation

The following represents the occupational distribution among the population of the region:

42.3 % of the population is engaged in Agriculture, Animal Husbandry, Hunting, and Fishing; 19.9 % is into Production, Transport, Equipment; 17.8 % represents those into Sales; and 6.4 % goes to the population involved in Services. These are the main occupational distributions in the various districts that make up the region.

Below is the distribution for the male population in the region:

40.8 % of the men are involved in Agriculture and its related works; the Production occupation engages 24.8 % of the men; 11.7 % of the men are into Sales; the Clerical occupation and its various forms also engage 7.7 % of the male population; and 7.5 % of the men are into Professional, Technical, and their related works.

The female population is thusly distributed: Agriculture and its related works - (43.9 %); Sales - (24.3 %); Production, Transport, Equipment - (14.6 %); and Services (8.5 %).

With the Kumasi Metropolis and the Kwabre District as exceptions, agriculture and its varying work forms form the dominant occupations for both males and females in all the districts in the region. In all the districts in the Ashanti Region, the population engaged in agriculture in the rural areas exceeds that of the urban areas. Sales and Production work tend to be the dominant occupations that engage those in the urban areas. Particularly, sales and production are predominant in the Kumasi Metropolis and the Kwabre District. This statistic can be explained by the fact that the Kumasi Metropolis is the major commercial and industrial centre in the region. As the Kwabre District is one of the districts very close to the Kumasi Metropolis, it is a viable ground to receive the surplus of the population from the Kumasi Metropolis further explaining why many of the people in the district are into sales and production works. A handful of the populations, that is those in active labour in the various districts, are found in professional and technical works (Ghana Statistical Service, 2012).

3.2 DISTRICTS IN ASHANTI REGION CHOSEN FOR THE STUDY

3.2.1. Atwima Nwabiagya District

Atwima Nwabiagya District is one of the largest districts in the Ashanti Region.

The District lies approximately on latitude 6°75‘ N and is fixed between longitude 1° 45‘ and 2° 00‘ West. Ghana has 27 political and administrative districts. The Atwima Nwabiagya District is one of them (Ghana Statistical Service, 2011). Sharing borders with Ahafo Ano South and Atwima Mponua Districts to its west; the Offinso Municipal to the North; Amansie–West and Bosomtwe-Atwima Kwanwoma Districts to the South; and the Kumasi Metropolis and Kwabre Districts to the East, the Atwima Nwabiagya District is located in the Western part of the Ashanti Region. It spreads over an approximated land space of 294.84 sq. km. Nkawie is the capital of this district.

There is a number of industries situated in the district which specialize in the production of certain items. The district can boast of 126 settlements. All major towns in the area are linked to the National Power Grid which is a great help to the industrial progress of the place. With its many rivers and streams, the area encourages small scale irrigation and fish farming. This makes the district to possess great potential in agriculture (Ghana Statistical Service, 2011).

The prominent agricultural engagements in the district include farming and the rearing of livestock. Fish farming is present but not on a large scale. The predominant agricultural activity in the area is crop farming. Maize, rice, ginger, citrus, oil palm, cocoa, plantain, cassava, yam, cocoyam and vegetables are part of the main crops cultivated in the area. An amplitude of vegetables including pepper, tomatoes, garden eggs, and okra are cultivated. Much of what is cultivated is not on a large scale but mainly to supply their subsistent needs. Commercial farming is done by a few people. Sadly, in the face of these paltry representations given of the population into farming, the lands in the area are very fertile and appreciable for large scale production.

Because of awful practices after the harvest of crops – from poor handling, poor storage, poor post-harvest management, inadequate market and unfavourable pricing, absence of credit facilities to high transportation charges and lack of processing – a larger portion of the foodstuffs cultivated by farmers go to waste. The narrow crib storage system with improved ventilation is the storage system usually adopted in this area. It is used very much especially in the areas where they produce maize. This storage system has been helpful. By way of illustrating this, statistical data suggest that losses for maize in 2002 which stood at 45% went down to 30 % in 2005 (Ghana Statistical Service, 2011). For the other crops, though usually inefficient, majority is kept with the use of traditional storage methods. Unfortunately for most farmers, considering that their products will waste for nothing, many cultivators cheaply sell their produce to escape the gruesome effects of the absence of storage facilities particularly when perishable products like citruses and vegetables like tomatoes and garden eggs are in season.

3.2.2 Ejura-Sekyedumase Municipal

As a part of the decentralization programme implemented by the government of Ghana on 29th November, 1988, the Ejura-Sekyedumase District was birthed from the two former districts, Sekyere and Offinso. Under the legislative instrument PNDC

L.I 1400, 1988, the district was created. The area is lodged within longitudes 1°5‘ W and 1°39‘ W and latitudes 7°9‘ N and 7˚36‘ N. Its land space is quite huge; 1,782.2 sq.km (690.781 sq. miles) and by this feature, it is placed as the fifth largest district among the 26 districts in the region. 7.3 % of the total land space of the region is accounted for in Ejura-Sekyedumase. A third of this percentage of land space lies in the Afram Plains (Ghana Districts, 2011).

The area is in the North of the Ashanti Region. To its north are two districts in the Brong-Ahafo Region - Atebubu and Nkoranza Districts; to its west is the Offinso District; the Sekyere East District is to its east; and on its south are Sekyere West and Afigya Sekyere district.

Agriculture and agro-processing are the prominent and lucrative investment opportunities in the area especially for farmers who invest maize, cashew and cowpea as well as poultry farming and livestock rearing. The Ejura-Sekyedumase area can also boast of very fertile lands for crop farming – a feature which makes it stands among the best in the region (Ghana Statistical Service, 2011). Economically, the agriculture

sector employs the majority of the population (68.2 %); even higher than the national level which is at 60 % (Ghana Statistical Service, 2011). Hence, the need pay critical attention to the agriculture of the area cannot be overemphasized as it forms the pivot of the economy of Ejura-Sekyedumase District. The agrarian qualities of the district comprise both livestock rearing and crop production. During the survey, it was realized that mixed farming, mixed cropping and mono-cropping are the main farming systems used in the area. Maize is the crop type cultivated most in the district. This makes it valid to approximate that the soil type in the district helps maize cultivation. Most workers are engaged in the production of maize. Beans, yam, water melon, are among the other crops produced in this area. Post-harvest wastage of crops is a great challenge to this district. Hence, perishable produce like tomatoes and others like it need to be given good processing methods so that they do not go to waste as this recurrent situation is only discouraging most farmers from intensifying their input for large-scale production. Below is an outline of post-harvest losses recorded in the area: in the major season, wastage for staple crops stands at 20 % whereas that for vegetables is between 30-35 %. Poor storage practices account largely for these losses. Nationally, Ghana records post-harvest losses in the ranges 8 % and 20 %
(Ghana Statistical Service, 2011).

3.2.3 Offinso South Municipal

This district is found farther north-west in the Ashanti Region. The Offinso South Municipal is situated between longitude 1° 65‘ W and 1° 45‘ E and latitudes 6° 45‘N and 7° 25‘ S. The space occupied by the district is 1255 km^2. As one out of the 26 districts in the region, it also has almost half of its north and west boundaries shared with the Brong-Ahafo Region. Covered to her south by the Ahafo-Ano South, Sekyere

South, Atwima-Nwabiagya, and Kwabre Districts, its eastern border is shared with the Ejura-Sekyedumase District (Ghana Statistical Service, 2011).

Offinso New Town serves as capital of the municipality. The highway that links Kumasi and Accra to the north divides the area. It is known to be a segment of the Trans-African Highway; also known to serve as the important entryway into the Ashanti Region from the Northern and Brong-Ahafo Regions. Culturally, the population in the area is Akan-culture-dominated. It must however be added that settlers from the north are found there and they also practice their own culture (Ghana Statistical Service, 2011).

The Municipal enjoys an agrarian economy with about 62 % of the labour force engaged in agriculture. Food crops and livestock contribute about 55 % and 20 % respectively to household income generation in the Municipality. Major food crops grown are maize, cassava, yam, plantain, cowpea and rice. About 8,000 hectares of the total land area have been put under permanent cultivation having been planted with tree crops, whilst about 12,000 hectares are put under food crop production each year. Major tree crops grown in the Municipality are cocoa, citrus and oil palm (Ghana Statistical Service, 2011).

3.3 THE RESEARCH DESIGN

3.3.1 Data Collection

In the light of the objectives associated with this research, both qualitative and quantitative information gathering methods were adopted. It comprised primary and secondary data. The primary data was derived from interviewing key individuals like farmers and middlemen in the maize value chain through administration of structured questionnaires and personal interviews. Secondary data was sourced from institutions such as MOFA, Research Institutions, the Universities in addition to consultation of relevant journals, dissertations and other literature.

3.3.2 Questionnaire Design and Administration

The study made use of open and close type questions in the questionnaire design as seen in the appendices. It was categorized into five sections focusing on the features;

- Demographic Features of Respondents
- Storage Facilities Identification for Maize in the Study Areas,
- Effectiveness of the Storage Facilities for Maize,
- Challenges with the use of Storage Facilities,
- Losses and nature of losses associated with the storage facilities.

Questionnaires were adopted as the researcher believed them to be an efficiently tool to getting straightforward and exact replies from respondents. Also, a Focus Group discussion meant to acquaint the respondents to the research‘s purpose as well as the questionnaire was carried out before the questionnaires were administered. Literate respondents were given questionnaires to answer independently as we interviewed those who cannot comprehend from written work. The questionnaire was pre-tested in the Ejura Sekyedumase Municipal to help the researcher fine tune the questions and improve on the skills of the questionnaire administrators in order to have reliable and efficient data. The secondary data sources consisted of a desk study of books, dissertations, journals, correspondence, relevant literature from the Ministry of Food and Agriculture, the district and municipal assemblies, as well as other relevant agencies to extract information and statistics for the study.

3.3.3 Sampling Method and Techniques

The survey districts were purposively selected based on their being highest maize producers in the Ashanti Region according to MOFA- Statistical Research and Information Directorate (2010). Once they were identified as producers or traders in the three Districts - namely Offinso South Municipal, Ejura Sekyedumase Municipal and Atwima Nwabiagya – the respondents were simple randomly sampled. This was to allow for equal participation of all the districts covered by maize production and storage for the survey, and also to avoid biasness by the researcher.

The estimated total population for the three study areas was 311, 366 people (Ghana Statistical Service, 2010). With a confidence level of 95 % and 5% precision level with an estimated population of 311, 366, a sampling formula of $n=N/1+N(e)^2$ was used to arrive at the sample size.

Where, n =Sample size

N =Population size

E= Level of precision N=

311, 366 e = 0.05 at a confidence

level of 95 % n =

$$n = \frac{311,366}{1+311,366(0.05)^2}$$

N = 384

Due to resource, budgetary and time constraints, the calculated sample space was scaled down to a representative sample size of **120** for the survey. A representative sample size helps a great deal to researches of this nature as the immense liberty it provides the models influence their behaviour positively (Sarantakos, 1997).

The target population for this study was households with farmers being the sampling units of the study area. Purposive sampling was used to determine the sampling units and the target population of the study. This was used because of the nature of the research objectives as it focused on crop farmers. Simple random sampling was then adopted in selecting farmers for the survey. In ensuring that every farmer stood the chance of being selected for the study, the simple random method of sampling was adopted. It also allowed for maximum selection of both male and female farmers as well as cash and non-cash crop farmers.

Table 3.1. Study Area, Population and Sample size Distribution

DISTRICT/MUNICIPAL	POPULATION	SAMPLE SIZE SELECTED
Atwima Nwabiagya District	149, 035	57
Ejura Sekyedumase Municipal	85, 446	33
Offinso South Municipal	76, 895	30
Total	**311, 366**	**120**

Source: (Ghana Statistical Service, 2010)

Using proportions of the district‘s respective population from Table 3.1 and their total sum of 311,366 with 120 as the sample size, Atwima Nwabiagya was 57, Ejura Sekyedumase 33 and Offinso South was 30 as shown in table 3.2 above for the study. Proportions were used to determine the sample distribution for each district because it allowed for a fair sample size representation and distribution from the respective district population as shown above for the study.

3.4 LABORATORY ASSESSMENT

3.4.1 Determination of sample moisture content (MC)

MCs of the samples collected were measured using a FARMEX Moisture Meter. The instrument was calibrated using a new DOLE Moisture Meter at the Agricultural Engineering Department, KNUST. For each sample, the grain was thoroughly mixed and 3 MC readings taken and the average of the 3 computed and used as the mean MC of the sample. The grain used in each measurement was discarded and a fresh quantity taken from the sample for the subsequent measurement.

3.4.2 Determination of insect infestation level

A no. 8 Tyler sieve was used to sieve out insects in each of the samples collected just after the MC had been determined and the sample weighed. Small portions of the sample were sieved at a time until the whole mass of the sample had been sieved. This was to facilitate vigorous shaking and the removal of as many insects as possible. The count was made of insects sieved out (live and dead together) and the number for each sample recorded. The level of infestation was computed as no. of insects per kg of grain.

3.4.3 Determination of mould infection and fungal evaluation

Mould infection was determined by sorting out all visibly moulded grain from a 1-kg sub sample. The sorted out moulded grain was weighed using an electronic scale and expressed as a percentage of the 1-kg sub sample.

The fungal evaluation in samples collected was done at the Pathology Laboratory. of the Agriculture Faculty of the KNUST. A medium of Potato Dextrose Agar sterilized in an autoclave at 121ºC for 3 hours was used. Petri dishes were sterilized in an oven for 3 hours at a temperature of 160ºC. The table was also sterilized with 70% ethanol.

Kernels were selected randomly for incubation and they were sterilized in a 1% sodium hypochlorite solution for two minutes and then washed twice in sterile water. 5 grains were plated on each Petri dish and the dishes were covered and stored at room temperature (25ºC) for the fungi to grow. Each grain was examined under the microscope after 5 days for identification of the colonising fungi. The number of grains colonised by various fungi detected was recorded.

3.4.4 Proximate Analysis

Selected maize grains from the various storage facilities were analysed for their proximate nutrient composition using Weende analysis method (Lim et al., 2008). The following parameters were determined;

- dry matter (carbohydrate) (DM),
- crude protein (CP),
- crude lipid (CL) crude fibre (CF) and
- Nitrogen free extract.

These were done in accordance with standard procedures of AOAC. The nitrogen free extracts were calculated by difference from dry matter percentage (Lim *et al.*, 2008). Results of the proximate analysis were summarized as means and displayed graphically to depict changes in proximate composition.

3.4.4.1 Determining dry matter

Aluminium dishes to be used in the determination were dried at 135°C for 2 hours in the oven. The containers were moved rapidly to desiccators. The desiccators were immediately covered and the dishes allowed to cool to room temperature in about an hour after samples had been placed in them. One after the other out of the desiccator, the empty dishes were weighed (W1) while the desiccator was kept sealed among container removals. 2g (W2) of ground samples were weighed into each container after the balance had been tared. The dishes were mildly shaken to achieve uniform distribution in the sample and in order to get the maximum area to dry, it was exposed. They were then placed into the preheated oven and left to dry for 2 hours at 135°C. Later, they were moved to the desiccator after which they were allowed to cool to room temperature. Containers and dreid samples were then weighed (W3) and recorded. Dry matter was determined by the relation;

$$DM\% = \frac{W3 - W1}{W2 - W1} \times 100$$

3.4.4.2 Determining crude protein

In determining crude protein, the study made use of the Kjeldahl method. In this method, a sample of the test material was heated in the presence of a catalyst (0.7g mercury oxide and potassium sulphate) and digested till the hydrogen and carbon were oxidised and the nitrogen in the protein changed to ammonium sulphate. The concentrated NaOH was added and digest heated to remove the liberated ammonium sulphate into a volume of standard acid solution. The untreated acid was determined and by calculation, the percentage nitrogen in the sample determined. In the calculation, the assumption was that, N is derived from protein containing 16% N, and when the N value was multiplied by 100/16 or 6.25, an estimated protein value was gained.

3.4.4.3 Determining crude lipids

Crude lipids are also known in some literature as crude fat or ether extract. In determining this, a previously dried round bottom flask was weighed and 2.00g of dried ground sample was transferred into a paper thimble. A small cotton swab was placed in the thimble to prevent loss of sample. 150ml of petroleum spirit was added to the round bottom flask and the apparatus assembled. The quick-fit condenser to the Soxhlet extractor was then connected and refluxed for 4 hours on high heat (100105°C) on the heating mantle. After extraction, the thimble was removed and the solvent recovered by distillation. The flask with the fat was then heated for 30 minutes in an oven at a temperature of 103°C. The flask and its content were then cooled to room temperature in a dessicator. The final step involved accurately weighing the flask and determining the weight of the fat collected. The fat content expressed as a percentage by weight was calculated as below (Lim *et al.*, 2008):

$$\text{Percentage fat (\%)} = \frac{\text{Mass (g)of the extracted matter}}{\text{Mass of the tested sample}} \times 100$$

3.4.4.3 Determining crude fibre

The crude lipid sample that was determined was carried into a 750ml Erlenmeyer flask; approximately, ½ g of asbestos was added. The next step involved adding 200ml of boiling 1.25% H_2SO_4 and immediately setting the flask on a hot plate and connecting the condenser. The contents started boiling within a minute. Adequate care was taken in preventing the material from sticking to the sides of the flask. After 30 minutes, the flask was taken and the material immediately sieved through a linen cloth placed in a funnel and washed with a large volume of water till the residue was acidic no more. Into the flask containing 200ml boiling 1.25% NaOH solution, the product of the previous filtration containing the sample from the acidic hydrolysis and asbestos was washed back. The flask condenser was connected and boiled for exactly 30 minutes. The contents in the flask were filtered again through a linen cloth and cleansed completely with boiling water till residue washing was basic no more. The next step involved washing the filtered residue with approximately 15ml alcohol and transferred to a porcelain crucible quantitatively with water. The crucibles together with its constituents were next desiccated for one hour at 105°C. The sample was then cooled in the desiccator and reweighed. The crucible was ignited again in a furnace for 30 minutes (Lim *et al.*, 2008).

3.4.4.4 Determining Nitrogen Free Extract (NFE)

The determination of nitrogen free extract (NFE) was conducted after completing the analysis for the other components; crude fibre, crude lipids, crude protein etc. the calculation was made by putting together the percentage values on sapless matter basis of the analysed constituents and deducting them from 100%. It is represented below;

NFE (%) =100% - (CRUDE PROTEIN % + CRUDE LIPIDS % + CRUDE FIBRE %+ ASH %) (Lim *et al.*, 2008).

3.4.5 Data Analysis

Descriptive analysis modules including frequency distribution tables and bar charts were used for analysing the collected data. Statistical softwares used were GENSTAT 12.1 and SPSS. MS Excel was used in producing some of the graphs and frequency distribution tables.

Analysis of the data from the laboratory tests was done with the Completely Randomised Design at a significance level of 5%.

CHAPTER FOUR

4.0 RESULTS

4.1 SOCIO DEMOGRAPHIC FEATURES OF RESPONDENTS

The results of socio-demographic characteristics of the selected maize value chain actors have been presented in the tables and charts in this chapter.

4.1.1 Gender Classification of Respondents

The study showed that about 79.2% of the respondents were males whilst the remaining 20.8% were females (Figure 4.1).

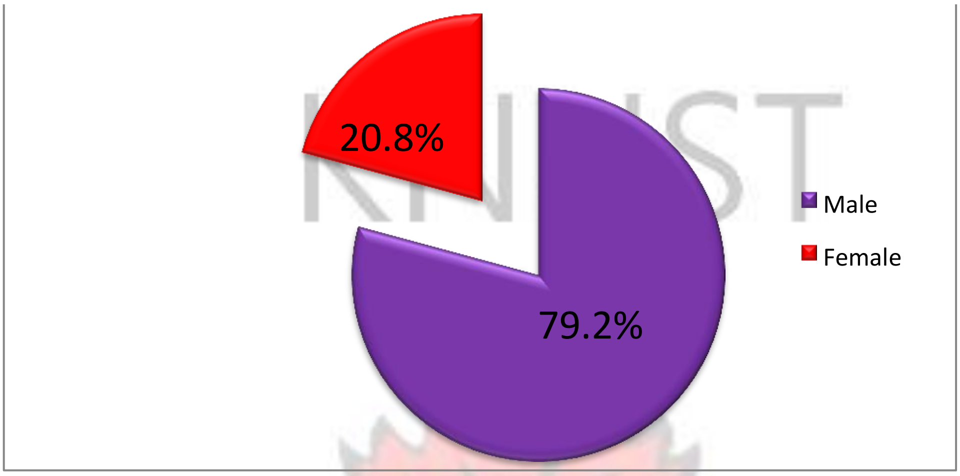

Figure 4.1. Gender distribution of respondents

A cross tabulation between the districts and the gender of the respondents showed that in all the 3 districts, male dominated with a percentage range of 78.8% in Ejura Sekyedumasi and 80% in Offinso South. The female respondents were 20% in Offinso South and 20.2% in Ejura Sekyedumasi. The Atwima Nwabiagya district had 78.9% of its respondents as males and the remaining 21.1% were females (Table 4.1). Offinso South District has the highest percentage of males in maize production. However, Ejura Sekyeredumasi had the highest proportion of females in the production of maize with 21.2% (Table 4.1).

Table 4.1 District and gender distribution of respondents

	Gender of respondents		
	Male	Female	Total

District of respondents	Atwima Nwabiagya	Count	45	12	57
		% within District of respondents	78.9%	21.1%	100.0%
		% within Gender of respondents	47.4%	48.0%	47.5%
	Ejura Sekyedumasi	Count	26	7	33
		% within District of respondents	78.8%	21.2%	100.0%
		% within Gender of respondents	27.4%	28.0%	27.5%
	Offinso South	Count	24	6	30
		% within District of respondents	80.0%	20.0%	100.0%
		% within Gender of respondents	25.3%	24.0%	25.0%
Total		Count	95	25	120
		% within District of respondents	79.2%	20.8%	100.0%
		% within Gender of respondents	100.0%	100.0%	100.0%

4.1.2. Age Distribution of Respondents

Averagely, the age of each respondent was approximated to be 35.3 years. However, the years of the respondents showed that about 13.3% of the respondents were less than 20 years. About 19.2% of the respondents were also between 21 and 30 years and 26.7% were between the age ranges of 31 to 40. About 22.5% and 18.3% of the respondents were between 41 and 50 years and more than 51 years respectively

(Table 2).

Table 4.2 Age distribution of respondents

Age of respor	Frequency	Percent	Valid Percent	Mean

Valid	< 20 years	16	13.33333	13.33333	
	21 - 30 years	23	19.16667	19.16667	
	31 - 40 years	32	26.66667	26.66667	
	41 - 50 years	27	22.5	22.5	
	> 51years	22	18.33333	18.33333	
	Total	120	100	100	35.275

The study revealed that of the three Ejura Sekyeredumasi district had a more youthful maize farmer population with respondents aged below 20 years (24.24%) and up to 30 years (33.33%) constituting 57% of respondents. Atwima Nwabiagya district had the oldest maize farmer population with most of the respondents aged between 41 and 50 years (33.33%) and more than 51 years (24.56%). Offinso South district had the highest proportion of respondents between 31 and 40 years (30%).

Table 2.3 Age of respondents and their districts

Districts and age of respondents	AtwimaNwabiagya		EjuraSekyeredumasi		Offinso South		
	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage	Total
< 20 years	3	5.26	8	24.24	5	16.67	16
21 - 30 years	5	8.77	11	33.33	7	23.33	23
31 - 40 years	16	28.07	7	21.21	9	30	32
41 - 50 years	19	33.33	2	6.06	6	20	27
> 51years	14	24.56	5	15.15	3	10	22
Total	57	100	33	100	30	100	120

4.1.3 Level of Education among Respondents

The research showed that the majority (45%) of the respondents were not educated. 13% of the respondents had completed primary school. Another 15% had also fully enjoyed Junior High School (JHS) education and 4% had received Senior High School (SHS) education. 19% of the respondents have a Middle School Leavers Certificate (MSLC). The remaining 4% of the respondents have completed a tertiary or vocational institution as indicated in Figure 4.2.

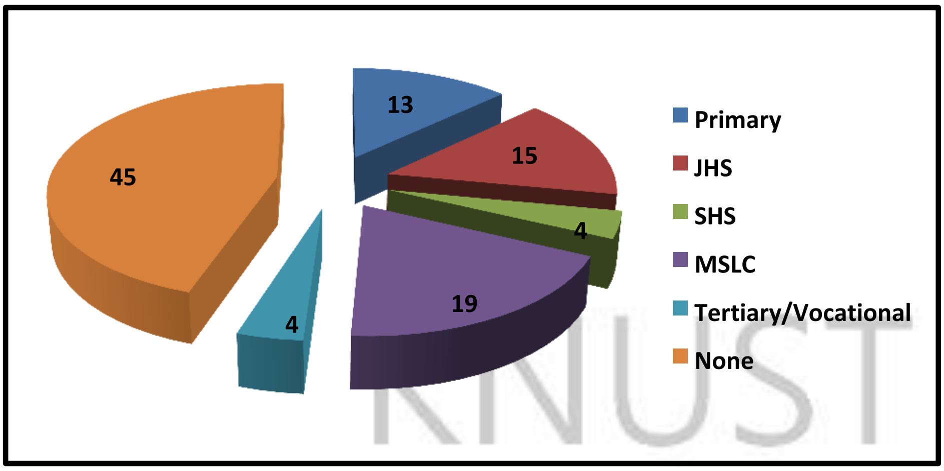

Figure 4.2 Educational Levels of Respondents

Majority of the respondents who were uneducated were from the Ejura Sekyeredumasi district (72.73%). The Offinso South district has the highest proportion of respondents with Tertiary/Vocational level of education (10%) and JHS level (20%). The Atwima Nwabiagya district had the highest proportion in the primary level (14.04%); SHS level (5.26%) and MSLC level (28.07%)

4.1.4 Size of farms

About 13.3% of the respondents had a farm size of more than 5 acres. About 23.3% of the respondents also had less than 1 acre of maize farm whilst 30% had farm size ranging from 1 to 3 acres. The majority (33.3%) of the respondents had farm size of 3 to 5 acres. The average size of maize farms in the three areas was 2.83 acres. (Table 4.4).

The study revealed as presented in Table 5 the Ejura Sekyeredumasi district had the highest proportion of farms which measure more than 5 acres (2.24%) and 1 to 3 acres (51.52%). The Offinso South district had the highest proportion of farm sizes between

3 and 5 acres (46.67%). The Atwima Nwabiagya district recorded the lowest acreages of farm size with majority of respondents‘ farms being less than an acre in size (31.58%).

Table 4.4 Distribution of farm sizes and districts

	Atwima Nwabiagya		Ejura Sekyeredumasi		Offinso South		Total
	Distribution	%	Distribution	%	Distribution	%	
< 1 acre	18	31.58	3	9.09	7	23.33	28
1 - 3 acres	14	24.56	17	51.52	5	16.67	36
3 - 5 acres	21	36.84	5	15.15	14	46.67	40
> 5 acres	4	7.02	8	24.24	4	13.33	16
Total	57	100	33	100	30	100	120

4.1.5 Cultivation Seasons

A majority of respondents, representing 79.17% planted maize both in the major and minor seasons. Only 14.17% planted during the major season alone whilst the rest of 6.67% also cultivated during the minor season alone (Table 4.5).

Table 4.5 Distribution of cultivation seasons of maize

Season		Distribution	Percentage	Valid Percentage	Cumulative Percentage
Valid	Minor	8	6.7	6.7	6.7
	Major	17	14.2	14.2	20.8
	Both	95	79.2	79.2	100.0
	Total	120	100.0	100.0	

Atwima Nwabiagya district had the highest proportion of farmers practicing maize cultivation in both major and minor seasons (85.96%). Offinso south had the highest proportion of farmers practicing major season cultivation of maize (20%). The minor season was mainly cultivated by the farmers in the Ejura Sekyeredumasi district (15.15%) (Table 4.6).

Table 4.6 Cross tabulation between season distribution of maize cultivation and the districts

	AtwimaNwabiagya		EjuraSekyeredumasi		Offinso South		Total
	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage	
Minor	1	1.75	5	15.15	2	6.67	8
Major	7	12.28	4	12.12	6	20	17
Both	49	85.96	24	72.73	22	73.33	95
Total	57	100	33	100	30	100	120

4.1.6. Variety of Maize Used by Respondents

About 65.8% of the respondents indicated that they cultivate the improved varieties of maize whilst 25.8% cultivated the local variety. About 8.4% of the respondents indicated that they cultivated both varieties. The reasons ascribed by the respondents for primarily using the improved varieties of maize include the following: higher yields; high quality and nutritious; longer storage life; high demand by buyers; high price that comes with a higher income and more profit. Users of the local variety attributed its use to its cheapness; weather resistance; and readily available (Table 4.7).

Table 4.7 Variety of Maize Used by Respondents

Variety	Frequency	Percentage
Local	31	25.8
Improved	79	65.8
Both	10	8.4
Total	120	100

4.2 STORAGE PRACTICES AND FACILITIES IN THE STUDY AREA

4.2.1: Storage of Maize

94.2% of the respondents indicated that they store their maize after harvest. The remaining 5.8% of the respondents stated otherwise (Figure 4.3).

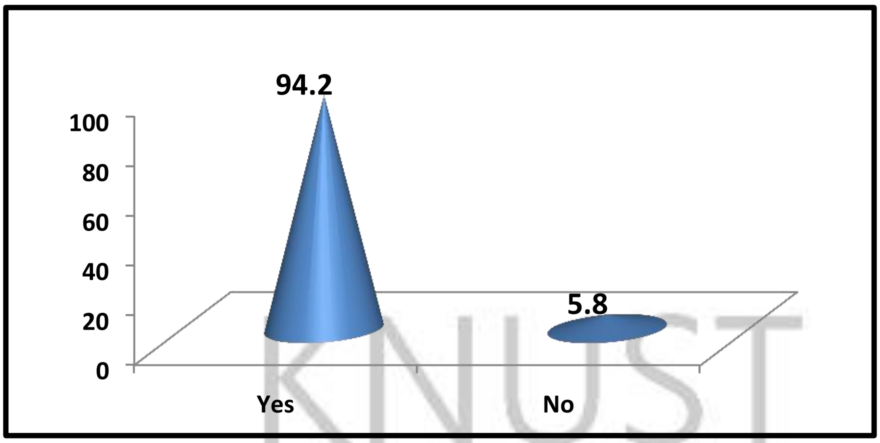

Figure 2.3 Percentage distribution of respondents who store maize after harvest

4.2.2 Drying of maize before storage

63.33% of respondents dried their produce before storage whiles 36.67% waited for the maize to dry on the field before harvesting (Figure 4.4). The drying methods include sun drying and mechanical drying at the warehouses.

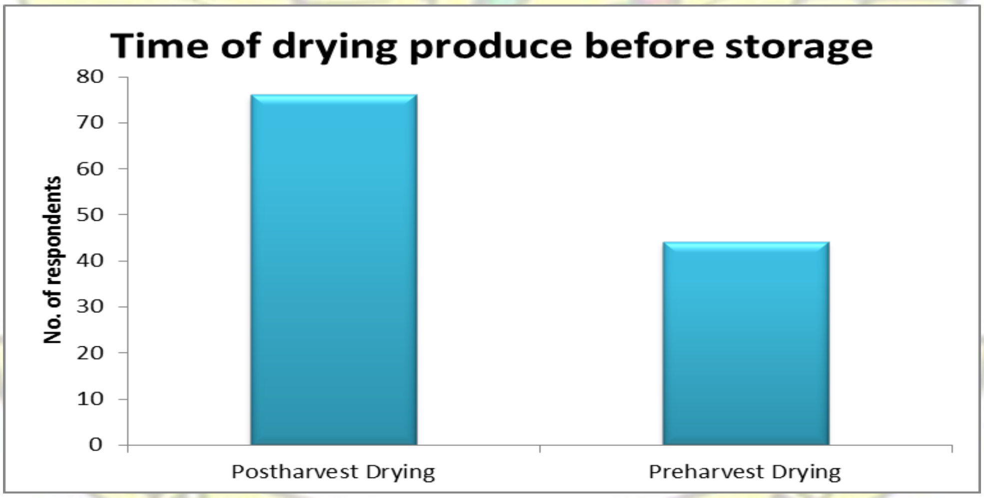

Figure 4.4. Time of drying before storage of produce

4.2.3 Storage Facility Used by Respondents

35.8% of the respondents identified storage in wider cribs (Figure 4.5) as the primary storage facility they used. About 10% of the respondents also identified that they used the storage in narrow cribs (Figure 4.6). Another 34.2% of the respondents identified storage in bags in warehouses. The remaining 20% of the respondents packaged in bags and stored in other places (rooms, veranda, kitchen etc.).

Figure. 4.5 Wider crib (WC) for maize storage

Figure 4.6. Narrow crib (NC) for maize storage

The various reasons that the respondents gave for the choice of their storage facilities included the following: cheapness; convenience; easy accessibility; low loss associated with storage; ability to store quantities of maize and; a minimal number of times of checking grains during storage.

Table 4.8 Storage facilities used by respondents

Facility	Frequency	Percentage
Storage in wider cribs	43	35.8
Storage in narrow cribs	12	10
Storage in bags in warehouse	41	34.2
Storage in bags in other places (rooms, veranda, kitchen etc)	24	20
Total	120	100

The highest proportion of respondents who stored maize in bags in other places such as rooms, veranda and kitchen was in the Offinso south district (26.7%). The Ejura Sekyeredumasi district recorded the highest proportion in terms of storing maize in bags in warehouses (39.4 %) and storage in wider cribs (54.5%). The Atwima Nwabiagya district had the highest proportion of respondents who stored maize in narrow cribs (Table 9).

Table 4.9 Cross tabulation between storage facilities used and the districts Cross tabulation between type of facilities and districts

	AtwimaNwabiagya		EjuraSekyeredumasi		Offinso South		
	Freq	Percentage	Freq	Percentage	Freq	Percentage	Total
Storage in wider cribs (WC)	17	29.8	18	54.5	8	26.7	43
Storage in narrow cribs (NC)	8	14	1	3	3	10	12
Storage in bags in warehouse (BWH)	17	29.8	13	39.4	11	36.7	41
Storage in bags in other places (rooms, veranda, kitchen etc)(BRV)	15	26.3	1	3	8	26.7	24
Total	57	100	33	100	30	100	120

4.2.3: Chi – square test

The Pearson chi – square has a value of 1.226E2 with a p = .000. This indicates that there is a statistically valuable connection between the kind of primary storage facility selected by the farmer and the convenience of the storage facility at a statistical level of 1% (Table 11). **Table 4.10 Chi-square test**

	Value	Df	Asymp. Sig. (2-sided)
Pearson Chi-Square	1.226E2a	21	.000
Likelihood Ratio	115.416	21	.000
No. of Valid Cases	50		

a. 32 cells (100.0%) have expected count less than 5. The minimum expected count is .66

4.2.2 Damage and Losses Associated With Storage Facilities

Table 4.11 Damage associated with the storage facilities

Storage	Pest Infestation		
	WEEVILS	**RODENTS**	**MOULD**
BRV	8.2	2.1	1.8
BWH	2.3	1.5	1.4
WC	38.4	4.3	3.1
NC	19.2	14.7	10.2
Lsd (5%)	1.293	0.871	0.743

The study established from the laboratory analyses of the maize samples that despite the popular choice of respondents for the crib storage facilities, both wider crib and narrow crib (WC and NC), the best storage facility as far as maintenance of grain quality was concerned was the bagged grain in warehouses (BWH) as seen in Table

12.

4.3 FUNGAL AND INSECT INFESTATION AND PROXIMATE ANALYSIS OF STORED MAIZE

4.3.1 Changes in Proximate Composition of Weevil and Fungus Infested Stored Maize

The changes in the nutritional and proximate composition of maize samples tested are represented in the charts below;

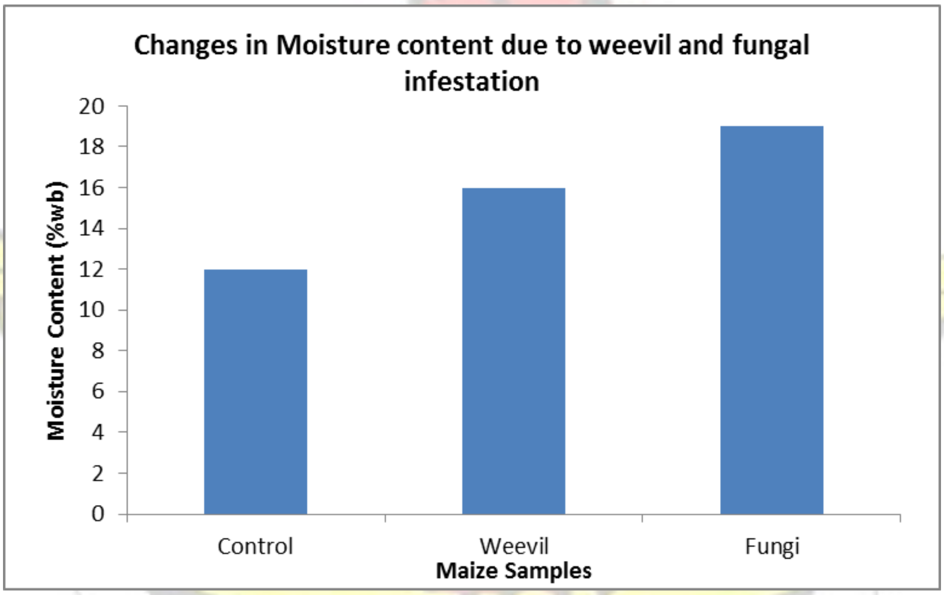

Figure 4.7. Changes in moisture due to weevil and fungal infestation

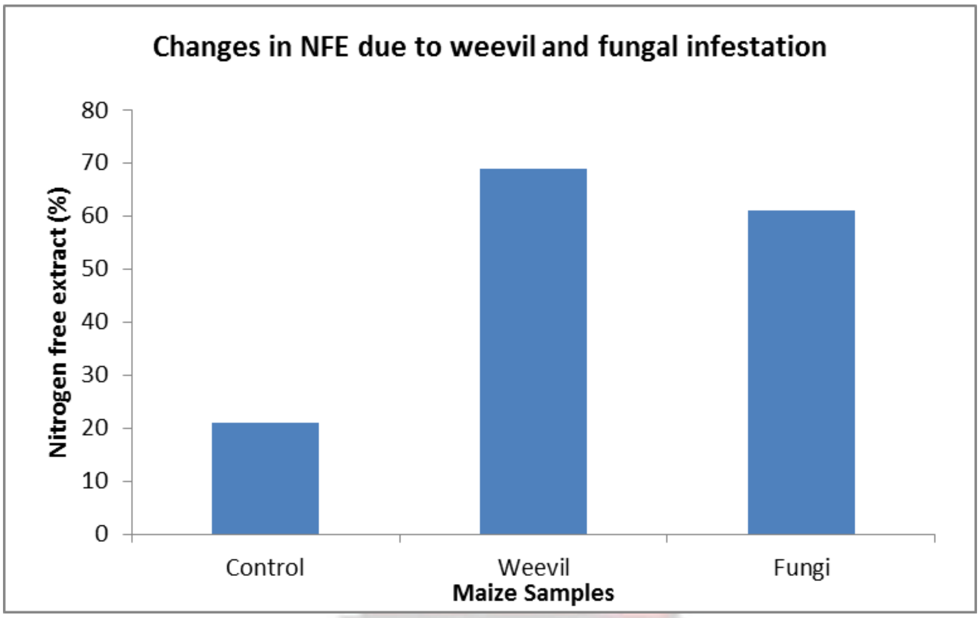

Figure 4.8. Changes in nitrogen free extract due to weevil and fungal infestation

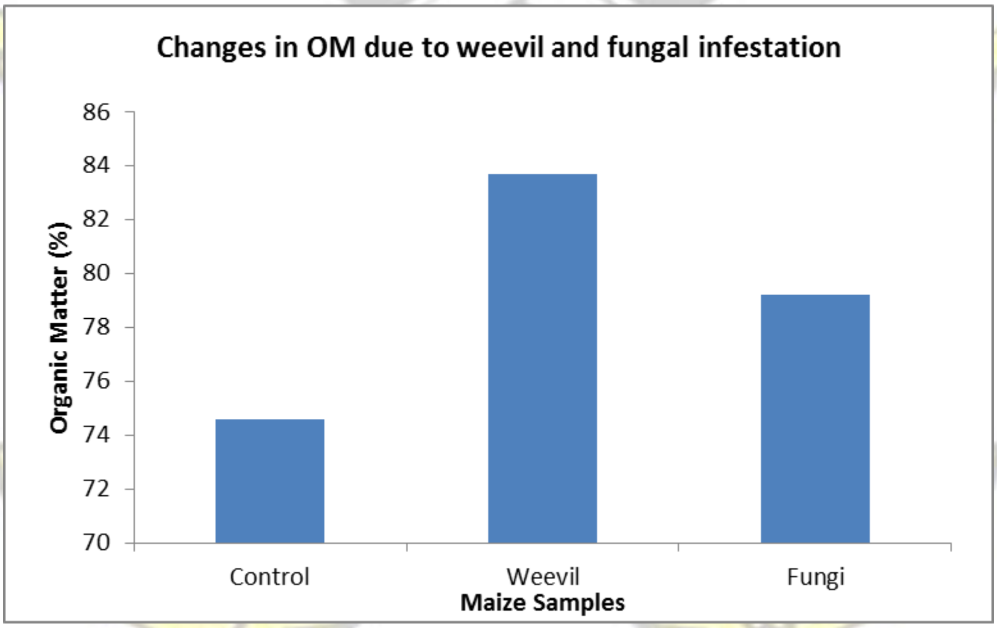

Figure 4.9 Changes in organic matter due to weevil and fungal infestation

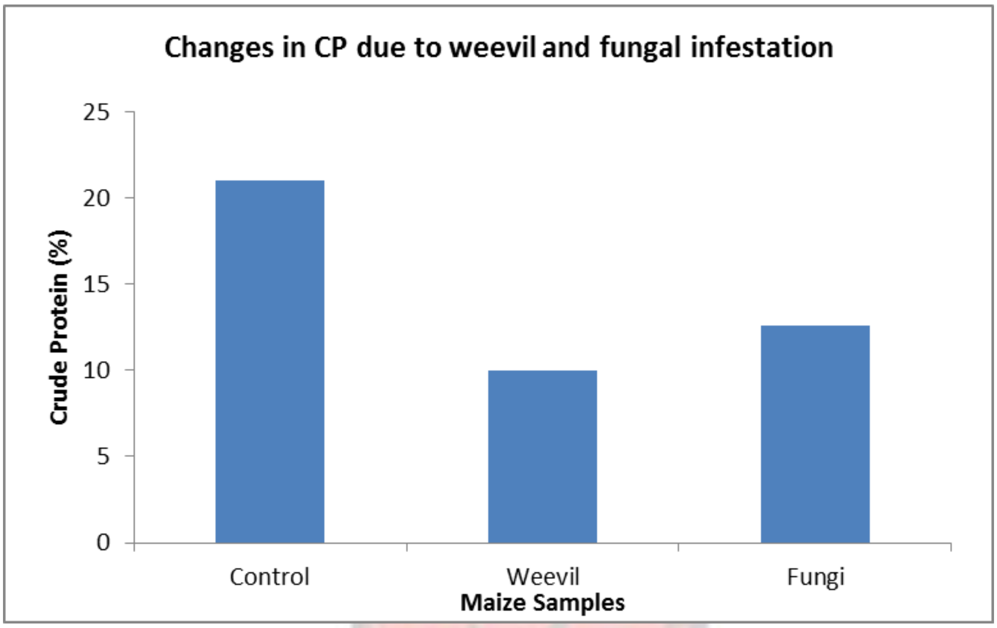

Figure 4.10 Changes in Crude Protein due to weevil and fungal infestation

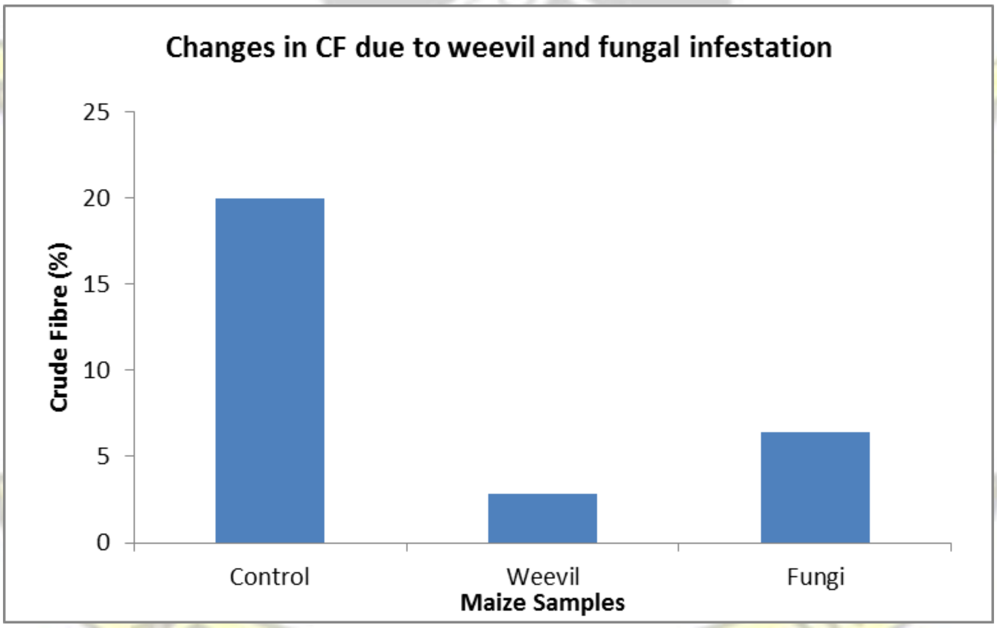

Figure 4.11 Changes in crude fibre due to weevil and fungal infestation

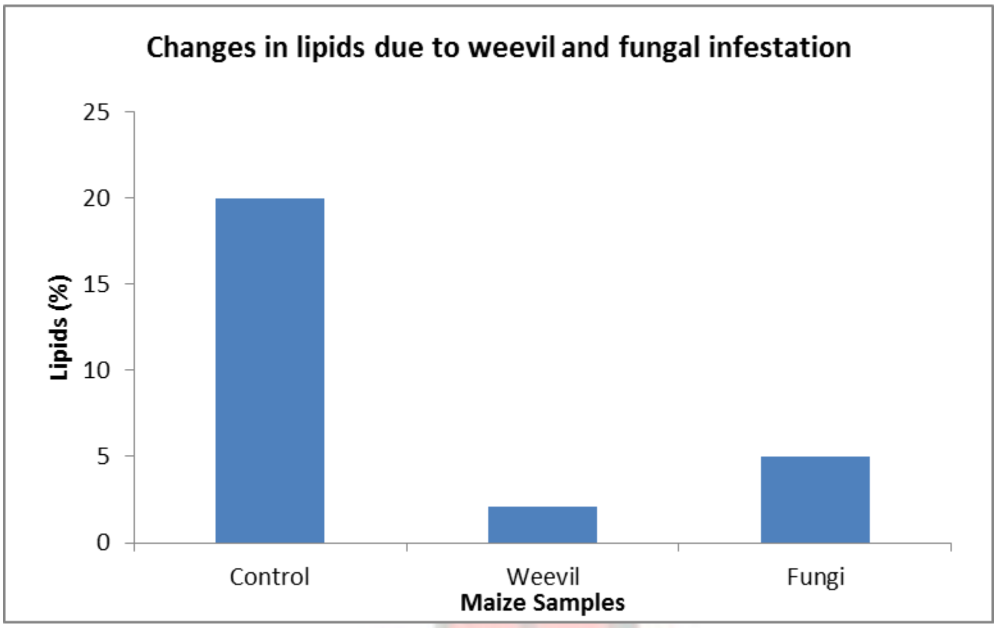

Figure 4.12 Changes in lipids due to weevil and fungal infestation

Table 4.12 Mean differences of nutrients contents of maize samples from the various storage structures

Storage		Proximate			
	NFE	DM	CL	CF	CP
BRV	19.41 b	78.88 c	18.51 c	19.00 c	9.380 c
BWH	20.41 c	77.60 c	20.28 d	20.44 d	9.910 c
WC	16.68 a	63.12 a	14.67 a	14.94 a	5.527 a
NC	17.14 a	69.48 b	15.98 b	16.42 b	7.417 b
Lsd (5%)	0.852	5.248	1.070	1.394	1.244

Lsd: Least significant difference
*Means with the same alphabets indicate no significant difference

CHAPTER FIVE

5.0 DISCUSSION

This chapter is a discussion of the results of the study and takes a look at possible explanations for the findings made. Existing literature have also been reviewed to compare and contrast the findings made in this study to earlier related works.

5.1 SOCIO-DEMOGRAPHIC FEATURES OF RESPONDENTS

Maize farming in the selected districts is done mainly by males (Fig. 5) and this probably may be as a result of the physical demand associated with most farming activities in general. This could also be as a result of the tradition in most of these areas where there is a specialization of labour in which women are concentrated in marketing while men concern themselves with the production of food. The issue of the physical demand of farming gains currency as it is observed that EjuraSekyeredumase which had had the most youthful population (Table 3) also recorded the highest acreages in cultivation of the maize as can referred from Table 4. Another possible reason for the large acreages in cultivation in the Ejura-Sekyedumase would be the availability of farmlands as compared to the two other districts. Educational level was also low for most respondents. These findings resonate with FAO (2012) reports on gender and equity issues in Sub Saharan Africa. Educational levels, acreages under cultivation and the physical abilities of the farmers are important factors in agricultural productivity since they affect level of technology adoption, post production practices etc. Weir (1999), found that formal education had a positive correlation with agricultural productivity among rural farmers in Ethiopia.

5.2 STORAGE PRACTICES AND FACILITIES

The various storage facilities that were used for the harvested maize includes storage in wider cribs (WC); storage in bags in warehouses (BWH); storage in bags in other places (rooms, veranda, kitchen etc) (BRV); storage in narrow cribs as indicated in Table 8. The most commonly used storage facility was the wider cribs. This was as a result of the ability to acquire cheap materials to construct them as well as the ownership associated with them. The farmers preferred to use the wider cribs because of the easy accessibility to the crib. Although the narrow cribs can withstand termite and rodent attacks based on their height from the ground, the farmers explained that their small nature (allows it to store small quantities of grains) and the height involved in its construction discouraged its use. Farmers were expected to pay a fee for the storage of their grains in the warehouse and as such discouraged them. Again, the small spaces available in their houses that were used to store the grains such as the kitchen, rooms and verandas were usually limited.

However, access to the grains was very easy. According to Lampteh *et al.*, (1993), maize storage can be done in both shelled and unshelled forms. Compton (1992) explained that farmers will usually consider several factors in choosing a particular storage facility to store their grains. These factors include the following: accessibility to grains; cost involved in storage of grains; efficiency of the storage system; and handling of the grains before storage.

5.3 FUNGAL AND INSECT INFESTATION AND PROXIMATE ANALYSIS OF STORED MAIZE

It is revealed from this study that both weevil and mould infestation caused significant changes on the nutrients composition of maize grains stored under local conditions as seen in Figs 8-12. These could have far more reaching consequences for the keeping quality and feeding value of maize and its products for both human and animal feed. According to FAO (1994) moulds usually attack grains following primary weevil infestation. The occurrence of only small proportions of concurrent weevil and mould infestation suggests that major cause of mould infestation was probably mechanical damage rather than primary weevil damage.

A study by Effiong and Sanni (2009) in Nigeria found significant increase in moisture content due to weevil and mould infestation. They found the moisture content to increase by 20%. In Zimbabwe Giga *et al.,* (1991) also recorded 20-80 moisture increase and in Ethiopia, Demissie et al., (2008) reported 20–30% increase in moisture due to weevil infestation. These wide variations reported across different regions could be explained by local storage technologies, duration of storage or climatic factors. Youdeowei, and Service, 1983 who reported that traditionally stored maize in Ugandan storerooms for six months at 12.5% relative humidity lost 8-9% of their weight.

According to FAO (1994), tropical heat, moisture and open-air storage promote rapid insect multiplication and mold formation in stored maize with rapid insect development occurring in the temperature range of 25 to 35°C. The significant increase in organic matter caused by weevil and mould infestation could be brought by addition of dead pests to the grains or loss of the inorganic component or both. The experimental protocol was unable to isolate the dead pests and their contribution would therefore boost the organic matter content. Furthermore, when these pests feed on grain, they produce heat and moisture (Youdeowei, and Service, 1983), which alters the microenvironment of the infested grains leading to leaching away of mineral elements. The slight less damage caused by mould compared to weevils could be explained by their feeding habits. According to Haile, (2006), the weevil *Sitophilus zeamais* is macrophagous and an internal feeder whose activity is more damaging than the saprophytic behavior of moulds. By the time the grains are mouldy, more severe damage would have occurred. Chijindu and Boateng (2008) also found positive correlations between the severity of infestation by insect pests and the contents of vital nutrient contents of stored food such as ash, crude fiber, crude protein, crude fat, starch and sugars. Although maize is generally regarded as a poor source of protein, protein levels determined in the samples in this study were quite high because most of the farmers were growing the improved maize varieties commonly referred to as Quality Protein Maize (QPM).Weevil damage and mould infestation reduced the protein content slightly. The weevils and moulds that remain in the grains could have partly contributed to enhanced crude protein content. Barney *et al.*, (1991) and Chijindu and Boateng, (2008), reported that weevil infestation increases crude protein content of maize grains. In addition, the relative loss in dry matter of infested grains would lead to relative concentration of nutrients that are less consumed such as proteins. The decline in crude fiber content of mouldy grains compared to weevil infested grains was consistent with the role of the latter as a secondary pest. Moreover, while insect pests prefer to feed on the soluble carbohydrate nutrients (Chijindu and Boateng, (2008)), moulds are able to digests plant cell wall components that make up most of the crude fiber fractions in soluble and digestible sugars (Allsopp *et al.*, 2004). This would improve the overall digestibility of mouldy grains compared to weevil infested grains especially if they are meant for livestock feeding. However, it must be noted that *Aspergillus flavus*, which produces the hepatotoxic aflatoxin, was a most common mould infesting maize grains (Okereke *et al.*, 1987). The crude lipid is normally a small and insignificant fraction of the energy content of maize grains. Results in this study showed that the decline in crude lipid contents were nearly equal for both weevil infested and mouldy grains (Fig. 14). However, Barney *et al.*, (1991) reported increase in lipid content of corn kennel in weevil infested maize.

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

Below are the conclusions made from the study and have been grouped under the specific objectives that this study set out to achieve;

Specific objective 1

The predominant storage facilities that are used for storing harvested maize within the studied districts are storage in wider cribs; storage in bags in warehouses; storage in other places (rooms, veranda, kitchen etc.) and storage in narrow cribs. The Wider Crib storage facility was the most commonly patronised facility across the districts. This was as a result of the ability to acquire cheap materials to construct them as well as the convenience of ownership associated with them.

Specific objective 2

A high majority of farmers (94.2% of respondents) in the selected districts store their maize after harvest. 63.33% of respondents dried their produce before storage whiles 36.67% waited for the maize to dry on the field before harvesting.

Specific objective 3

The study established that of the four storage structures assessed, bags in warehouse had the least infestation by weevils, mould and rodents. This was followed by the narrow crib, bags in rooms and verandas and the wider crib in that order. It was revealed that storage in Bags in The choice of storage facilities by farmers in the selected districts depended highly on the cheapness; convenience; easy accessibility; low loss associated with storage; ability to store quantities of maize and; a minimal number of times of checking grains during storage.

Specific objective 4

Warehouses were the most effective storage facility for maintenance of grain quality. It was however not the most popular choice by farmers across the districts because of the cost associated with it. Laboratory analysis revealed that the proximate composition of stored maize was affected by the storage structure. Maize from the bags in warehouses had the highest quality, followed by bags in rooms and verandas, narrow crib and wide crib.

6.2 RECOMMENDATIONS

It is recommended as a result of the findings in this studies that;

1. There should be sustained education and training of farmers on the importance of simple postharvest practices such as sorting and infestation control as well as best ways of carrying them out. This holds immense relevance considering the fact that a considerable number (55%) of farmers in the research area have some formal education.
2. There should be improvement in haulage services from the farm gate to the storage facilities during the harvesting period. The best approaches in this respect will be- maintaining feeder roads and farm tracks as harvesting approaches and empowering haulers to expand the service. These are interventions require government support to help reduce the time lapse between harvesting and packing into store.

3. There will also be the need to revamp the Grains Development Board to ensure that the government can be able to purchase and store maize grains during the bumper harvests to avoid wastage.
4. Maize co-operatives should be encouraged in these areas to enhance and facilitate maize storage and trading activities.

6.2 RECOMMENDATIONS FOR FURTHER RESEARCH

1. The research study could be extended to other study areas and the sample size can also be increased.
2. Future research studies could also consider the impact of the type of variety of maize cultivated on the storage life of the grains.
3. There will also be the need to empirically assess the type of storage facility used by the famer and the relation to the profit made by the farmer.
4. Other studies could consider the cost – benefit ratio assessment of the various storage facilities used by farmers in the storage of their grains.

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APPENDICES

APPENDIX 1: QUESTIONNAIRE

Hello,
Thank you for taking part in this survey. I am a post-graduate student from the **KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY** who is carrying out a research titled:

POSTHARVEST STORAGE PRACTICES AND TECHNIQUES:

A CASE STUDY OF MAIZE FARMERS IN THREE DISTRICTS OF THE

ASHANTI REGION IN GHANA

The results of this survey will be presented in my final year Postgraduate dissertation. I promise that all the information received will be kept confidential and will not be used for any further research or academic work. No identification is required in your response.

Please feel free to ask for any assistance while answering the questions.

Please tick the appropriate box

SECTION A: DEMOGRAPHICS OF RESPONDENTS:

1. District: AtwimaNwabiagya ☐ EjuraSekyedumasi ☐ Offinso south ☐

☐

2. Gender: Male ☐ Female

3. Age of respondent:

20 year and below ☐ 21 – 30 years ☐

31 – 40 years ☐ 41 – 50 years ☐

51 years and above ☐

4. Highest level of education

Primary ☐ JHS ☐ SHS ☐ Tertiary ☐ MSLC ☐

Tertiary ☐

SECTION B: BACKGROUND IN FARMING

5. Size of farm

Less than 1 acre ☐ 1 – 3 acres ☐ 3 – 5 acres ☐ More than 5 acres ☐

6. Which season do you usually cultivate maize?

Minor ☐ Major ☐ Both ☐

7. What variety of maize do you plant?

Local ☐ Improved ☐ Both ☐

8. Why do you plant that variety?
……………………………………………………………………………………………………
……………………………………………………………………………………………………
…………………………………………………………

SECTION C: HARVESTING PRACTICES

1. When is maize ready for harvesting?

- silk falls out - cobs and husk are completely dry

- cobs fall down - grain can't be scratched with the fingernail

- other

2. Are you able to harvest as soon as the crop is mature? (Yes / No)

3. If no why not? (No labour available / Other activities in this period / Other)

4. How do you harvest? (cut the whole stalk / collect the ears / bend the stalk before harvest to let it dry then harvest / other)

5. Why do you particularly use the harvest procedure indicated?

6. Do you harvest your maize all at once or in bits …………………………

7. If you harvest in bits why is this so? (labour problem / non-uniform drying / other reason ……………………………………)

8. Do you leave the cobs on the plant to dry before harvesting? (Yes / No)

9. If yes how long do you leave the cobs on the plant to dry? ……… Weeks ☐

SECTION D: STORAGE OF MAIZE AND FACILITIES USED

9. Do you store maize after harvest? Yes ☐ No ☐

10. What facility do you primarily use to store the maize?

Warehouse ☐ Narrow crib ☐ Bags ☐ Silos ☐

11. Why do you choose this type of storage system?

Cheap ☐ Convenient ☐ Easily accessible ☐ low loss ☐

Bulky storage ☐ Less check time ☐

12. How much grain is lost during the storage period?

< 10% ☐ 10% - 20% ☐ 20% - 30% ☐ 40% - 50% ☐ > 50%

12. What are the forms of grain loss associated with the use of the storage facility?

Mouldiness ☐ Termite infestation ☐ Rodent infestation ☐

Powdery contamination ☐ Others................................

13. What are the challenges in the use of the primary storage facility?

High cost of storage facility	☐	Heavy rains	☐
Rodents and termites attack	☐	Handling of grains before storage	☐
High moisture content	☐	inadequate storage facilities	☐

14. What measures must be undertaken to ensure effective storage?

Appropriate drying	☐	Dehusking	☐
Chemical treatment	☐	Clean bagging	☐
Moisture content testing	☐		

15.

If you have any other comments which have not been included above kindly please add them here.

Analysis of variance

APPENDIX 2

GENSTAT SUMMARY OF CRUDE FIBRE ANALYSIS

Variate: CF

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
INFESTATION	2	736.79752	368.39876	4157.74	<.001
Residual	9	0.79745	0.08861		
Total	11	737.59497			

Tables of means

Variate: CF

Grand mean 11.008

INFESTATION	CTRL	MI	WI
	21.955	7.027	4.043

Standard errors of differences of means

Table	INFESTATION
rep.	4
d.f.	9
s.e.d.	0.2105

Least significant differences of means (5% level)

Table	INFESTATION
rep.	4
d.f.	9
l.s.d.	0.4761

Stratum standard errors and coefficients of variation

Variate: CF

d.f.	s.e.	cv%
9	0.2977	2.7

Analysis of variance

APPENDIX 3

GENSTAT SUMMARY OF DRY MATTER ANALYSIS

Variate: DM

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
INFESTATION	2	16.0172	8.0086	13.31	0.002
Residual	9	5.4159	0.6018		
Total	11	21.4331			

Tables of means

Variate: DM

Grand mean 80.72

INFESTATION	CTRL	MI	WI
	79.82	80.00	82.36

Standard errors of differences of means

Table	INFESTATION
rep.	4
d.f.	9
s.e.d.	0.549

Least significant differences of means (5% level)

Table	INFESTATION
rep.	4
d.f.	9

Analysis of variance

l.s.d.	1.241

Stratum standard errors and coefficients of variation

Variate: DM

d.f.	s.e.	cv%
9	0.776	1.0

APPENDIX 4

GENSTAT SUMMARY OF CRUDE PROTEIN ANALYSIS

Variate: CP

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
INFESTATION	2	14.05005	7.02503	85.98	<.001
Residual	9	0.73537	0.08171		
Total	11	14.78543			

Tables of means

Variate: CP

Grand mean 9.758

INFESTATION	CTRL	MI	WI
	11.045	9.830	8.398

Standard errors of differences of means

Analysis of variance

Table INFESTATION rep. 4 d.f.
9
s.e.d. 0.2021

Least significant differences of means (5% level)

Table INFESTATION rep. 4 d.f.
9
l.s.d. 0.4572

Stratum standard errors and coefficients of variation

Variate: CP

d.f.	s.e.	cv%
9	0.2858	2.9

APPENDIX 5

GENSTAT SUMMARY OF CRUDE LIPID ANALYSIS

Variate: CL

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
INFESTATION	2	873.18065	436.59033	5044.37	<.001
Residual	9	0.77895	0.08655		
Total	11	873.95960			

Message: the following units have large residuals.

units 11 -0.518 s.e. 0.255

Analysis of variance

Tables of means

Variate: CL

Grand mean 9.040

INFESTATION	CTRL	MI	WI
	21.047	4.043	2.030

Standard errors of differences of means

Table	INFESTATION
rep.	4
d.f.	9
s.e.d.	0.2080

Least significant differences of means (5% level)

Table	INFESTATION
rep.	4
d.f.	9
l.s.d.	0.4706

Stratum standard errors and coefficients of variation

Variate: CL

d.f.	s.e.	cv%
9	0.2942	3.3

APPENDIX 6

GENSTAT SUMMARY OF NITROGEN FREE EXTRACT ANALYSIS

Analysis of variance

Variate: NFE

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
INFESTATION	2	5289.8139	2644.9070	3630.87	<.001
Residual	9	6.5561	0.7285		
Total	11	5296.3700			

Tables of means

Variate: NFE

Grand mean 50.37

INFESTATION	CTRL	MI	WI
	21.04	61.05	69.03

Standard errors of differences of means

Table C1 rep. 4 d.f.
9
s.e.d. 0.604

Least significant differences of means (5% level)

Table INFESTATION rep. 4 d.f.
9
l.s.d. 1.365

Stratum standard errors and coefficients of variation

Variate: NFE

d.f.	s.e.	cv%
9	0.853	1.7