KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY,

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COLLEGE OF AGRICULTURE AND NATURAL RESOURCES

FACULTY OF HORTICULTURE

DEPARTMENT OF POSTHARVEST TECHNOLOGY

ASSESSMENT OF POSTHARVEST LOSSES OF MAIZE IN THE SISSALA EAST AND WEST DISTRICTS OF THE UPPER WEST REGION OF GHANA

BY

JOSEPH K. KANSAKI

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DECLARATION

I hereby declare that, except for references to other peoples work which have been duly cited, this work, submitted to the school of Research and Graduate Studies, Kwame Nkrumah University of Science and Technology, Kumasi is the result of my own original research and that this dissertation has neither in whole nor in part been presented for another degree elsewhere.

Kansaki k. Joseph ………………………………… …………………………

(Student) Signature Date

Certified by

Dr. Francis Appiah ………………………………… …………………………

(Supervisor) Signature Date

Certified by

Dr. Francis Appiah ………………………………… …………………………

(Head of Department) Signature Date

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May the everlasting father bless and protect everyone who contributed one way or the other to the success of this work.

DEDICATION

I humbly dedicate this work to my dear family, especially my dad, mum and my lovely wife Apungu Celestine and my lovely son Kansaki Wepia Jeffrey.

ABSTRACT

In order to minimize postharvest losses in maize and provide postharvest loss information to policy makers and postharvest manager, it was important to quantify the losses along the postharvest value chain. During the study, postharvest loss of maize along the value chain in the Sissala East and West Districts of the Upper West Region of Ghana was assessed. Ten communities in each district were selected for the study. In each community postharvest losses incurred by ten farmers were assessed. Loss was assessed at harvest, transportation, shelling and winnowing, storage, and processing stages of the value chain. The results showed that varied losses ($p<0.05$) between the communities with respect to the harvesting, shelling and winnowing losses, weevil infestation and number of holes in grains per 50gram of grains. The study revealed that there were no significant differences ($p>0.05$) between the two districts for harvesting, shelling and winnowing, and transportation. Harvesting losses ranged between 154.65 and 281kg/ha, whereas shelling, transportation and processing losses ranged between 154.00 - 281kg/ha, 3.35kg/ha, and 8.46kg/100kg, respectively. By the end of the fourth (4th) month storage losses in the Sissala West district was 39.6% and was not statistically different ($p>0.05$) from the Sissala East (40.3%). There was a 10 per cent reduction in weight of the stored grains with every one month of storage, which was attributed to weevil infestation. The study revealed that more than 50% of maize produced and stored in both the Sissala East and West District are lost due to poor postharvest handling. This has serious economic and food security implication in the districts. Measures aimed at reducing the losses need to be implemented to reduce the losses.

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CHAPTER ONE

INTRODUCTION

Maize, *Zea mays* L. is believed to have originated from the high Plateau of Central Mexico. Maize is currently the world's most important cereal after wheat and rice, it however ranks second to wheat in terms of total world production (Belfield and Brown, 2008). In Africa, maize is the most important cereal crop both in terms of production and usage (Jean du Plessis, 2003). According to SRID-MOFA, (2004) the total world-wide cultivated maize area in 1973 was 111 million hectares with a total production of 312 million tons, and a total world-wide cultivated area in 2008 was 161,105,730 hectares with a total production of 826,224,247 tons.

Demand for maize is projected to increase from 1995 levels by 50 percent globally by 2020 and the demand in Sub Saharan Africa was projected to increase by 93 percent by 2020 (Rosegrant *et al*., 2001). It is therefore alarming that, although average maize yield in USA and other high income countries is 8.3 tons/ha, most of Africa and large areas of Asia and South America achieve yield below 2.0 tons/ha (Aquino *et al*., 2001).

Part of the yield difference is explained by the use of unimproved varieties. In Africa, about 50 percent of all maize is planted with farm-saved grain (not purchased seed), while 33 percent is planted with hybrids, and 15 percent with improved open-pollinated varieties (Morris, 2001). Ghana has all the potentials in terms of land, climate and human resources to produce maize to meet both internal and external demand but fail to do so due to the use of unimproved varieties and insufficient fertilizer application (Armah *et al*., 2006). Maize is produced over 80 million hectares in developing countries alone under varying climatic conditions (Obeng-Offori, 1998).

The total estimate of maize production in Ghana is 740,000 hectares with a total yield of 1,171,390 metric tons and average yield per hectare of 1.58 metric ton (SRID-MOFA, 2006). According to Dowswell *et al*., (1996) it is cultivated on millions of hectares. In the Northern regions of Ghana, the total estimate of maize production is 91,100 hectares with total average yield of 86,126 metric tons (SRID-MOFA, 2005).

According to MOFA, (2010) the total estimate of maize production in the Upper West region of Ghana in 2010 cropping season was 48,336 hectares with a total yield of 52,995 metric tons. The Sissala East district cultivated 6,763 hectares and total yield was 8,792 metric tons. The Sissala West district cultivated 6,652 hectares and the total estimated yield was 8,554 metric tons.

In past decades, researchers had come up with many production technologies for different cropping systems. The growing of improved varieties, mineral fertilizer use, rotations, and intercrops, have all boosted production considerably. Nevertheless, the gains of technological advancement are threatened by poor post production techniques to process, handle and store the increased production. Due to high levels of investment in crop production, postharvest losses, in the form of quantity or quality should be kept at a minimum (Derera *et al.*, 1996).

According to Derera *et al*., (1996) significant volumes of grains in developing countries are lost after harvest, aggravating hunger and resulting in expensive inputs; such as fertilizer, irrigation water, and human labour being wasted. During postharvest operations, there may be losses of both cereal quantity and quality. Quality postharvest losses can lead to loss in market opportunity and nutritional value; under certain conditions, these may pose a serious health hazard if linked to consumption of afflatoxin-contaminated grain. These causes of loss are many and varied.

Cereals constitute the most important source of carbohydrates in the world, especially in the developing countries of which maize is the most widely used. It is a staple food in many parts of Africa (Owusu 2007). Maize has an average composition of 10.3% of protein, 60.5% starch, 1.2% sugar, 2.5% crude fibre and other substances (Addo-Quaye *et al*., 1993). Because of its low price and world-wide distribution; it has become the most important raw material for animal feed and several industrial processes (SRID-MOFA, 2006). It is a staple food in many parts of the world. It is used to prepare banku, "TuoZafi" or "Gwelli" (TZ), Kenkey, porridge, it is also eaten fresh either boiled or roasted (Addo-Quaye, 1993). In Ghana, it is used in the preparation of major meals such as kenkey, banku and akpele (Owusu 2007). Maize starch is used in the manufacture of ice cream, cooking oil and salad oil (Addo-Quaye *et al*., 1993). It is also served as the main source of energy for livestock after harvest in the form of fodder. The grains are used as feed in the poultry industry. Maize is also used in the making of soap and pharmaceuticals, the husk in making paper for boxes. The cobs and stocks are also used as fuel wood (Addo-Quaye *et al.*, 1993).

Food security exists when all people, at all times have physical, social and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preference for an active and healthy life.

The study on postharvest losses in food grains at different stages of their handling would help assess the extent and magnitude of losses and identify the factors responsible for such losses.

This research will be invaluable to maize farmers and other stakeholders in determining the main causes of postharvest losses in the area of study; it will determine the amount of maize that is lost after harvest up to consumption.

The purpose of the study is to assess the effect of postharvest losses of maize grain on food security in the Sissala East and Sissala West Districts of the Upper West Region of Ghana.

Specifically, the study sought to

1. quantify postharvest losses of maize in the Sissala East and Sissala West Districts of Ghana from production to processing.
2. assess qualitative losses of maize.
3. assess the economic losses attributable to postharvest.

CHAPTER TWO

LITERATURE REVIEW

2.1 ORIGIN, DISTRIBUTION AND HISTORY OF MAIZE

Maize, *Zea* mays is a plant belonging to the tribe *Maydeae* of the grass family (Poaceae). "*Zea*" (zela) was derived from an old Greek name for a food grass. The genius *Zea* consists of four species of which *Zea mays* L. is economically important. The other *Zea* sp., referred to as teosintes, is largely wild grasses native to Mexico and Central America (Doeblay, 1990). Maize is believed to have originated from the Plateau of Central Mexico. It is cultivated globally being one of the most important crops worldwide. Maize is not only an important human nutrient, but also a basic element of animal feed and raw material for manufacture of many industrial products include corn starch, maltodextrins, corn oil, corn syrup and products of fermentation and distillation industries. It is also recently used as bio-fuel (Doeblay, 1990).

Maize is a versatile crop grown over a range of agro climatic zones. In fact the suitability of maize to diverse environment is unmatched by any other crop. It is grown from 58^{o}N to 40^{o}S, from below sea level to altitude higher than 300m, and in areas with 250mm to more than 500mm of rainfall per year (Shaw, 1988; Dowswell *et al*., 1996) and with a growing cycle ranging from 3 to 13 months (CIMMYT, 2000). However, the major maize production areas are located in temperate regions of the globe.

In the Latin America, maize is the central foodstuff of the hearth and household. Because of the broad range of climate, soils and topographic and hydrological conditions under which maize may be cultivated, diverse agricultural methods have evolved to accommodate its cultivation and processing. Maize environments in the third world have been classified into four major types; tropical, sub-tropical, temperate and highlands. As of

1996, tropical environment accounted for 90.6 million acres, or 45% of the total area under cultivation in the developing countries; temperate environments accounted for 55.1 million acres or 27% of the total; sub-tropical environment accounted for 42 million acres or 21% of the total; and highland environment accounted for 15.3 million acres or 7% of the total area under maize cultivation in the developing world (Dowswell, Paliwal, and Cantrell, 1996).

The United States remain the highest producer of maize in the world with around 32 million hectares being grown annually. The other two main producers are China and Brazil, these countries total 52% of the global surface of the area. The European Union is the fifth largest producer after Russia. In 1999, the European Union produced 3,857,000 hectares of grain maize (FAO, 2010).

Approximately 8 million tons of maize grains are produced in South Africa annually on approximately 3.1 million hectares of land. Half of the production consists of white maize for human consumption (Shaw, 1998).

In Nigeria for instance, maize is one of the two major crops that occupy about 40% of the land area under agricultural production and account for about 43% of the maize grown in West Africa (Smith *et al.,* 1997; Philip, 2001). Among different groups, maize is a relatively more important source of both calories and protein for the poorer proportion of consumers, including HIV/AIDS affected families, who cannot afford more expensive foods such as bread, milk and/ or meat (Byerlee and Heisey, 1997).

In Ghana, the total estimate of maize production is about 740,000 hectares with a total yield of 1,171,390 metric tons and average yield per hectare of 1.58 metric tons (SRID-MOFA, 2006).The estimated production of maize in the Northern regions of Ghana is 91,100 hectares with total average yield of 86,126 metric tons (SRID-MOFA, 2005).

2.2 ECONOMIC IMPORTANCE OF MAIZE

Maize ranks second to wheat among world's cereal crops in terms of importance and total production (Obeng-Antwi *et al.*, 2002). The use of maize varies in different countries. In U.S.A., European Union, Canada and other developed countries, maize is used mainly to feed animals directly or sold to feed industry and as raw material for extractive/ fermentation industries (Morris, 1998; Galinat, 1988; Shaw, 1988). In developing countries use of maize is variable. In Latin America and Africa the main use of maize is for food while in Asia it is used for food and animal feed. In fact in many countries, it is the basic staple food and an important ingredient in the diets of people (Morris, 1998). According to Morris (1998) it has been estimated globally that 21% of the total grain produced is consumed as food. Maize is the third most important food grain in India after wheat and rice. In India about 28% of maize produced is used for food purposes, about 11% as livestock feed, 48% as poultry feed,12% in wet milling industry (for example starch and oil production) and 1% as seed (AICRP on maize 2007). In the last one decade, it has registered the highest growth rate among all food grains including wheat and rice because of newly emerging food habits as well as enhanced industrial requirement (Gopalan *et al*., 2007).

Cereals constitute the most important source of carbohydrate in the world, especially in the developing countries of which maize is the most widely used. Maize has an average composition of10.5% protein, 84.0% carbohydrate, 4.2% fat and 1.3% minerals and other substances (Addo-Quaye *et al.*, 1993). In Ghana maize is used to prepare banku, TuoZaafi (T.Z), kenkey and porridge, it is also eaten fresh either roasted or boiled (Addo-Quaye *et al*., 1993).

2.3 MAIZE PRODUCTION IN UPPER WEST REGION OF GHANA

The Upper West Region of Ghana is a maize surplus region though self-sufficient, (Winter-Nelson and Aggrey-Fynn 2008). Yield per hector in the region ranges from 1,500kg per hectare to 2,200 kg per hectare (9 bags of maize per acre) and these variations is due to differences in soil fertility, this implying the requirement of greater use of chemical fertilizer in the region. According to Winter-Nelson and Aggrey-Fynn (2008) the use of improved maize seeds and appropriate soil fertilization could raise maize yields to 4,000 kg per hectare (16 bags per acre). Yields have been found to be average of 1.6 tons per hectare and further interventions could result in an increase of income of up to 250 %.

2.4 POSTHARVEST LOSSES AND CONSTRAINTS IN THE PRODUCTION OF MAIZE

Postharvest losses may occur during harvesting and handling due to grain shattering, spillage during transport and also result from bio-deterioration at all steps in the postharvest chain including storage and processing. The principal agents of bio-deterioration are mould, insect-pests and diseases, rodents and birds.

All succeeding events after harvesting is defined as postharvest, that is, from the time the crop is matured enough for harvesting and processing to the time of consumption (Salunkhe *et al.*, 1985). According to Salunkhe *et al.*, (1985) loss defined by the national academy of science is the reduction in weight, and amount of food available for consumption. Hence postharvest losses can be said to be the amount of commodity which get lost or perish right from harvest till it gets to the final consumer. Thompson (1996) explained postharvest losses as follows: fruit, vegetables and grains are living organisms. Their condition and marketable life are affected by such things as temperature, humidity, the composition of the atmosphere which surrounds them, the level of damage that has been inflicted on them before, during and after harvest and the type and degree of deterioration during storage through loss of moisture, absorption of moisture, loss of stored energy, physical losses through pest and disease attack, loss in quality from physiological disorders etc. Thompson (1996) also said that losses after harvest are a major source of human food loss and can cause scarcity and food insecurity. Insect pest substantially reduce yield of the plant maize. Several insects are considered pest but only a few species are of major importance. These species infest all part of the maize plant at all growing stages and some are vectors of virus diseases (Owusu, 2007). Maize also suffers pest infestation in storage condition in the tropics.

The weevil, *Sitophilus zeamais* is a major storage pest of the stored maize causing both quantitative and qualitative losses. The larvae and the adult feed on grains and can reduce the grains to powder form. It attacks undamaged grains on the field before harvesting. The larvae develop within the grain, leaving a characteristic round hole on emergence (Owusu, 2007).

The larger grain borer, *Prostephanus struncatus* (Horst), (*Coleoptera/Bostrychidea*) is an exotic pest that was accidentally introduced in Africa from South America. It is now the most destructive pest of maize. The larvae and adult cause damage to various commodities especially maize and cassava. Weight losses cause by these pests is 3 to 5 times higher than those caused by other pests (Owusu, 2007).

Augumois moth, *Sitotroga cerealella* feed voraciously on stored maize and contaminate them with their cocoons and extensive webbing. The damage may be more serious on maize stored on the cob. Damage is more limited to shelled grain as the moth does not penetrate more than a few centimetres from the surface. The developing larvae cause all damage as the adult does not feed (Owusu, 2007).

The lesser grain borer, *Rhizopertha dominica* (*Coleoptera; Bostrychidea*) is a major primary pest in the dried tropical regions which attack maize, sorghum and other cereals and cassava. The (*Bostrychidea*) are adapted to boring into hard substances such as wood and capable of attacking previously undamaged grains where they can cause serious damage. Other beetle pest species of maize include flour beetle, *Triblium casteneum* (Horst), flat grain beetle, *Crytolestes pussilus* (Schonh) and saw-toothed grain beetle *Oryzae philussurinamensis* (Linnaeus) (Owusu, 2007).

2.5 POSTHARVEST STAGES OF HANDLING AND ASSOCIATED LOSSES

2.5.1: HARVESTING

Most grains have a single annual harvesting season, although in bimodal rainfall areas there may be two harvesting of maize or rice (e.g. Ghana and Uganda). Africa producers harvest grains crops once the grain reaches physiological maturity (moisture content is 20-30 percent). At this stage the grain is very susceptible to pest attacks. Also, unseasonal rains at this stage can dampen the crop, resulting in mould growth and associated risk of afflatoxin or other mycotoxin contamination. Weather conditions at the time of harvest are a critical factor influencing postharvest losses. More unstable weather condition due to climate change, leading to damper or cloudier conditions, may therefore increase postharvest losses. In most part of Sub-Saharan Africa, harvesting is traditionally the work of men; however, with the rise in single-headed households, the burden between men and women is increasingly shared; (Azu, 2002). Harvesting by hand is traditional method used by small producers in Africa. In principle, hand harvesting is likely to be less wasteful but labour constraints can lead to delays in or failures to harvest; those then can result in significant postharvest losses (Compton, 1992).

Maize losses have been reported to occur at different stages including pre-harvest, during harvesting, during shelling and during storage and transportation. These losses contribute to food insecurity and low farm incomes not only in Sub-Saharan African countries (Compton, 1992; Azu, 2002). Therefore, efficient postharvest handling, storage and marketing can tremendously contribute to social economic aspects of rural communities Komen *et al.*, (2008).

2.5.2 : DRYING

Most farmers in Africa, both small and large, rely almost exclusively on natural drying of maize from a combination of sunshine and movement of atmospheric air through the product. So damp weather at harvest time can be a serious cause of postharvest losses; measured losses in excess of 16 percent in Swaziland (De Lima, 1982). Grains should be dried in such manner that damage to the grain is minimised and moisture levels are lower than those required to support mould growth during storage (usually 13-15 percent). According to De Lima (1982), this is necessary to prevent further growth of a number of fungal species that may be present on the fresh grains. To achieve this, the harvested crop may be left standing in the field, cut and left drying on the ground, or stoked. In some places, the crop may be moved immediately from the field to swept area of ground at the homestead or rocks or cribs that are specifically designed to promote drying (De Lima, 1982).

Two losses are frequently caused by drying; removal of grain or portions of grains from the drying system and damage to the grain leading to a subsequent loss. Grains which are dried in the yard or on warehouse floor would be partially consumed by birds and rodents.

2.5.3 : SHELLING/THRESHING

Stripping of grains from cobs is known as shelling. For some grains, particularly millet and sorghum, threshing may be delayed for several months after harvest and the un-threshed crop stored in opened cribs. In the case of maize, the grain may be stored on the cob with or without sheathing leaves for some months or the cobs may be shelled and grain stored. All grain may eventually be shelled or threshed. For smallholders this is almost exclusively a manual process, except for the few cases in which some groups have access to machinery suitable for small scale operation, such as the maize shellers that some tractors owners may hire out.

Losses may occur during threshing or shelling wherever mechanical shelling or beating by stick is not followed by hand-stripping of the grains remaining on the cob. Certain shellers or some time, beating damage the grains, making insect penetration and absorption of moisture easier and subsequent storage losses higher.

2.5.4: WINNOWING/CLEANING

Winnowing and cleaning of grains is usually done prior to storage, milling or marketing if the grain is to be sold directly. For the majority of smallholder grain, the process is undertaken manually. At home, the hand-cleaning is a combination of hand winnowing with removal of stones, sand, broken cobs and extraneous organic matter. Losses can be very low when carefully done or high when siftings are allowed to scatter on the ground or winnowing done with the same result.

2.5.5: TRANSPORTATION

In Sub-Saharan Africa, there is relatively little access to intermediate means of transport such as bicycles, handcarts, animal-drawn carts or motorcycles (World Bank 2006). For smallholders, the movement of grain from field to farm store is often still by head or bicycle and in some places by animal-drawn carts. For movement from store to market, commercial farmers hire or use their trucks, while smallholders may use bicycle, tractors, trailers, pickups, taxis depending on availability of transport and quantity of grains to be transported. These modes of transport could lead to high postharvest losses as the grain is not properly protected from exposure from elements such as insects, birds and theft as well as losses from spillage due bad roads (De Lima 1982).

2.5.6 : STORAGE

Postharvest losses at storage are associated to the poor storage conditions and lack of storage capacity. Postharvest losses in storage vary widely, with variation by crop, climate, storage structure, grain protection options, and length of storage period. Maize as grain or cob (without large grain borer infestation) typically undergoes 4-5 percent losses in storage (Haile, 2006). If cobs or grains are infested by normal storage pests, not large grain borer, then weight losses typically range from 4-5 percent. When cobs are infested by large grain borers, weight losses can be more than double and if unchecked, may result in the total destruction of the stored grain (Hodges *et al.*, 2008). Shelling grain and storing in sacks (as well as addition of insecticide) are the standard recommendation to reduce losses resulting from large grain borer attack.

2.6: POSTHARVEST LOSSES OF MAIZE ON FOOD SECURITY AND LIVELIHOOD

2.6.1 : HOUSEHOLD FOOD SECURITY

A household food security may be defined in terms of consumption or production or production unit as a small residential group of people who live together for the purpose of defense or offence (Miller, 2002). A household is food secured when it has access to the food needed for a healthy life for all its members (Broun *et al.*, 1992). They also stated that, since food security is important for development, such activities should be eligible for credit.

2.6.2: FOOD SECURITY AND LIVELIHOOD

Food security exists when all people, at all times have physical, social and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preference for active and healthy life.

According to this definition, food security has three components;

- Availability- sufficient food to meet fundamental requirement.
- Affordability- potential consumers have enough income to buy food.
- Accessibility, safety and nutritious – potential consumers obtain good quality with better nutrient composition through distribution system.

In recent times postharvest losses have been a major problem in the world especially developing countries (Salunkhe *et al*., 1985). Low income and food deficit countries have become especially concerned about the global and national food situation over the past years. While the proximate cause of the heightened concern was the surge in food prices that began in 2006 and peaked in mid-2008, concerns remain for other reasons, among them the higher market-clearing price levels that now seem to prevail, continuing price volatility, and the risk of intermittent food shortages among repeatedly far into the future.

According to SRID-MOFA, (2009) the following handling losses were deduced for maize; Harvesting**:** 5-8%, storing operation: 15-20%, storage: 5-10% Transport: 10-12%.

That is a theoretical total of 35-50 percent.

Postharvest management in most developing countries are far from satisfactory as losses resulting from inadequate handling, poor storage and improper distribution resulting in diminished returns to producer (Asian Productivity Organisation, 2006). These losses may result in hunger, inability of payment of school fees and purchasing of inputs for cultivation in the next farming season. This may lead to children dropping-out of school and increase the illiteracy rate of the study area.

Postharvest losses are unavoidable due to an acceptable loss rate of 0.75-1% in 9-10 months storage (Asian Productivity Organisation, 2006).The lost rate in commercial sector is usually 0.75%. Below is the trend of maize production for a period of five years (from 2005 to 2009).

Table 2.1: Trend of production of maize in Sissala East District

Year	Area cultivated	Yield (MT/Ton/Ha)	Total Yield (MT/Ton)
2005	5,842	1.55	9073
2006	6,148	1.49	9161
2007	6,763	1.30	8792
2008	6,810	1.40	8879
2009	6,825	1.50	9123

Source: SRID-MOFA (2009)

Table 2.2: Trend of production of maize in the Sissala West District

Year	Area cultivation	Yield (MT/Ton/Ha)	Total Yield (MT/Tom)
2005	4,207	1.58	6,785
2006	4,613	1.49	6,873
2007	4,652	1.50	6,867
2008	4,862	1.59	6,952
2009	4,782	1.52	6,772

Source: SRID-MOFA (2009)

Table 2.3: Financial effect of postharvest losses on commercial cost:

Percentage loss	Kg of food stuff marketed	Cost/kg in US$	Percentage rise in cost
0	1.047	0.65	0
5	0.995	06.8	5
10	0.942	07.2	11
15	0.890	07.6	17
20	0.838	0.81	25

Source: Asian Production Organization (2006).

According to Asian Productivity Organization (2006) the calculated financial effect of postharvest losses on commercial cost is given below;

The lower-income Sub Saharan Africa (SSA) countries, on-going contributing factors may include persistent low productivity, difficulty in adapting to climate change, financial difficulties (inability to handle the burden of high food or fuel prices or credit squeeze), and increase dependence on food aid. Yet there is an additional, often forgotten factor that exacerbates food insecurity; postharvest losses.

The Food and Agriculture Sector Development Policy (FASDEP) report, (2009) indicated that minimizing postharvest losses and maintaining high quality of produce is crucial for sustainable and profitable agriculture.

However, according to Thompson (1996), before an attempt is made to reduce losses, it is advisable to assess what they are and how much they cost. Maize has an average composition of 10.3% protein, 60.5% starch, 1.5% sugar, 2.5% crude fibre and other substances (Addo-Quaye *et al.*, 1993). It is a staple food in many parts of the world. It is the main source of energy for majority of Ghanaian population especially the study area.

Losses are directly measurable in economic, quantitative and qualitative (nutritional) terms. Economic losses are reduction in monetary value of maize grain as a result of physical loss. Quantitative maize loss involves reduction in weight and therefore can be defined and valued. Qualitative maize loss although difficult to assess because it is frequently based on subjective judgments (like damage), can often be described by comparison with locally accepted quality standard (Magan and Alfred, 2007). Such losses could lead to lower levels of food security, hunger and low on-farm incomes. The study on post-harvest losses in food grains at different stages of their handling would help assess the extent and magnitude of losses and identify the factors responsible for such losses.

Food and Agriculture Organization (FAO) defined food security as existing when all people, at all-time have physical, social and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preference for an active and healthy life. In Ghana the Ministry of Food and Agriculture's operational definition of food security is "good quality nutritious food hygienically packaged, attractively presented, available in sufficient quantities all year round and located at the right place at affordable prices" (FASDEP 11, 2009).

The issue of food security has been understood by many development workers as the availability of food in the world marketplace and on the food production systems of developing countries (FASDEP II, 2009).

Ghana faces the challenge of making substantial progress in food security because average yields have remained stagnant. Commercial food imports and food aid have constituted about 4.7 percent of food needs in the last 15 years (FASDEP II, 2009).

According to FASDEP II, Report (2009) food production fluctuates from year to year due to frequent variations in the magnitude of rains during and between growing seasons. This recurrent of climatic stress destroy crop and livestock. Rainfall is a major determinant in the annual fluctuations of households and national output. This creates food insecurity at household levels, which can be transitory in poor communities and chronic in distressed areas. In areas such as Upper East and Upper West Regions, the situation is cyclical and severe for three to five months each year. There is therefore a regional disparity in food insecurity due to seasonal food deficit in the three northern regions (MOFA, 2010).

A significant proportion of food insecurity in Ghanaian households in rural as well as urban localities produced some of the food they consume. For most households, hunger is frequently associated with poor harvests resulting from environmental degradation, poor weather, natural disasters, harvest losses or conflicts. Almost all families supplement their food requirement with significant amounts of purchased staple crops (FASDEP II, 2009).

While Ghana can be classified as generally food secured, pockets of food insecurity populations exist in all regions because of acute resources limitations and lack of alternative livelihood opportunity for some individuals and households to meet their dietary needs with purchased food. Malnutrition is a serious problem among children, adolescents and pregnant women due to insufficient levels of food intake and or diets not providing an adequate nutritional intake (FASDEP II, 2009).

Results from the 2003 Ghana Demographic Health Survey (GDHS) indicated that malnutrition contributes 40 percent to mortality among children less than 5 years. In that survey, 29 percent of this group of children was chronically malnourished, an increase of 3 percent points over the 1998 rate. Seven percent of children were wasted (through acute malnutrition) and this reflected a two percentage point decline from the 1998 level. Twenty-two percent were underweight (with 5 percent severely underweight) in 2003, a decline of three percentage points from 1998.

Basically, there are two forms of food insecurity, namely; chronic and transitory food insecurity. Chronic food insecurity implies a persistent inability on the part of the household to access adequate food. Chronic food insecurity generally arises through inadequate access to resources, and is therefore structural in character. Transitory food insecurity comes about as a result of shocks due to economic failures and human induced as well as natural disasters creating food shortages that affect, temporarily, all or part of the country population. In addition, even in the absence of chronic and transitory hunger, the population may suffer from lack of essential micronutrients. This is often referred to as hidden hunger. According to report released by UNICEF and Micronutrient Initiative, as many as a third of the world's people do not meet their physical and intellectual potentials because of vitamins and mineral deficiencies. The incidence of food insecurity and poverty are particular devastating in the developing countries and a lot of resources are being channeled towards programmes aimed at eradicating food insecurity and poverty by various international organisations and government of the developing nations (Broun *et al.*, 1999)

A district baseline survey conducted in Tolon-Kunbungu district by Broun *et al.*, (1999) indicated that, in 1988, 54.4 percent of the household surveyed did not produce enough food to cover the year, 34.4 percent run out of food before M arch and 83.7 percent June, 94 percent of the households with a significant harvest bought food in 1988 and 75 percent expected a food shortage in their household in 1999. In totality, Broun *et al.*, (1999) realised more than 80 percent of the household had run out of their own produced food by April to June, indicating that period to be lean season (a state of food insecurity).

CHAPTER THREE

MATERIALS AND METHODS

3.1 RESEARCH DESIGN

This chapter discusses the various methods used in carrying out the research from sampling of the study communities through to the collection, presentation of data and findings. The profile of the Upper West Region was also discussed in relation to issues relevant to the topic. The case study approach was used in the study to identify the communities in the Sissala East and West Districts.

3.2 GEOGRAPHICAL LOCATION OF THE RESEARCH AREA

The study was conducted in two districts (Sissala East and Sissala West) in the Upper West Region of Ghana. Sissala East with its capital to be Tumu and Sissala West with its capital to be Gwollu both located in the North- Eastern part of the Upper West region of Ghana. Sissala East falls between longitude 1.300W and latitude 10.000N and 11.000N, whereas Sissala West lies between longitude 2.300W and 2.36W and between latitude 10.000N and latitude 11.000 N (MOFA, 2010).

3.3: SURVEY

A survey on the demographic background of the people involved in harvesting and gathering, shelling and winnowing, transporting, storage and processing/milling was conducted in some selected communities in the Sissala East and West districts of the Upper West region. Semi structured questionnaires aimed at collecting data on sex and other information on postharvest activities of maize from harvesting to processing were issued by trained technical officers of Masara N'Arziki in the Upper West region.

Purposive sampling was used in the selection of ten (10) communities each from Sissala East and West Districts to participate in the research. The communities selected from the

Sissala East are Tarsaw, Kroboi Sakai, Bandei, Kulfuo, Challu, Pieng, Sakalu, Nankpawie and Nganduonu. In the Sissala West the communities selected are Jawia, Buoti, Jeffisi, Duwie, Sobbelle, Pulima, Kupulima, Desime, Jitong and Kusali. However, random sampling was used to select ten (10) farmers from each community selected for the research.

3.4: SAMPLE SIZE

3.4.1: Determination of Harvesting Losses

A total of ten (10) farmers were selected from each community to participate in the research. Five acres each from the selected farmers' fields were marked out and harvested as practiced by the farmer during harvesting. Gleaning (second harvesting) was done afterwards, left over maize cobs on the harvested field (both on the ground and on the un-harvest standing plants) were thoroughly collected and carefully shelled/threshed by hand. This was used to estimate the quantity of maize lost during harvesting.

According to MOFA (2010), averagely fifteen (15) maxi bags (1500kg) of maize grains are often gotten from one acre of maize field.

Therefore, the calculation of the total loss of maize from the farmers' field according to this research was;

The total loss= total harvested (1st harvest + gleaned quantity) -1st harvest.

3.4.2: Determination of Shelling/ Winnowing Losses

Total of ten (10) farmers each were randomly selected for the research from both districts.

Two different types of shelling/ threshing methods, as practiced by the farmers, were used as the produce were in larger quantity, these were machine shelling/threshing and or bag beating.

The "bag beating" method, un-husked cobs were put in bags, beaten and poured on to the ground then the cobs and chaff were separated and winnowed, then subsequently bagged in sacks for transportation to the house for storage.

The machine threshing/shelling, un-husked maize cobs were fed into a tractor mounted machine (sheller) and the threshed/shelled grains were collected, winnowed and bagged.

In both methods, losses were determined by collecting the cobs and chaff after the first threshing/shelling and carefully hand threshed/shelled by picking the grains and also carefully winnowed the chaff.

The total produce collected after (both the first and second) threshing/shelling represented the estimated quantity of grains gotten during entire threshing/shelling process.

Therefore, to determine the losses during threshing/shelling, the quantity of grains received during second threshing/shelling was subtracted from the entire produce received after the threshing/shelling of the maize.

Threshing/Shelling Losses = Entire produce after threshing/shelling - First round threshing/shelling.

3.4.3: Determination of Losses during Transportation

Ten (10) farmers from ten (10) communities from each district were duly sampled randomly to carry out this research.

Farmer's way of conveying produce from field to the house for storage was considered. This was done in various ways and included the use of head pans, donkey/bullock carts, bicycle, motor bike, tractors.

Assessment was done by first weighing the maize on the farm to know the quantity to be transported. The transported produce was reweighed at home to know the quantity lost through transportation. The quantity lost was determined by deducting reweighed figure from the total quantity that was weighed earlier.

3.4.4: Determination of Losses during Storage

Ten (10) farmers were selected purposively from each of the districts. Each of the farmers were made to store four (4) bags (100Kg) maize in the farmers' own way for a period of four months, from 8th November, 2011 to 8th March, 2012. At the end of each month a sample of Fifty (50) grams of grains was collected from each of the bags from the top, middle and bottom portion to determine the following:

1. Number of grains that made up of fifty (50) grams
2. Number of grains with holes in fifty (50) grams
3. Number of weevils present in fifty (50) grams of grains.

Periodically, the stored grains were examined for mouldiness.

At the end of the four months period (120 days) the pre-weighed bags of grains were re-weighed. Storage losses were calculated by subtracting the final weight of maize from the initial weight. This gave the quantity lost during storage.

3.4.5: Determination of Losses during Milling/ Gridding

Ten (10) corn mills in each district were selected to participate in this research.

At the close of each day, a form was filled by the corn mill operators to indicate the quantity of maize milled in each of the selected corn mills. Rubber tarpaulins were used to collect maize that fell on the ground. This was weighed daily for a period of Five (5) days, that is from Monday to Friday. This quantity of maize collected and weighed represented the losses during milling/gridding.

3.5: STATISTICAL ANALYSIS

Data collected were subjected to analysis, using Statistix 8 statistical software. Two sample t-tests were used to determine the difference in the districts. For the communities analysis of variance (ANOVA) was performed and the differences among the communities determined using Least Significant Difference Test (Lsd) at P=0.05. Differences between the two districts were ascertained using the Student t-test.

CHAPTER FOUR

RESULTS

4.1 GENDER OF FARMERS

Figure 4.1 shows the gender of respondents. Out of the respondents, 64% were females while 36% were males.

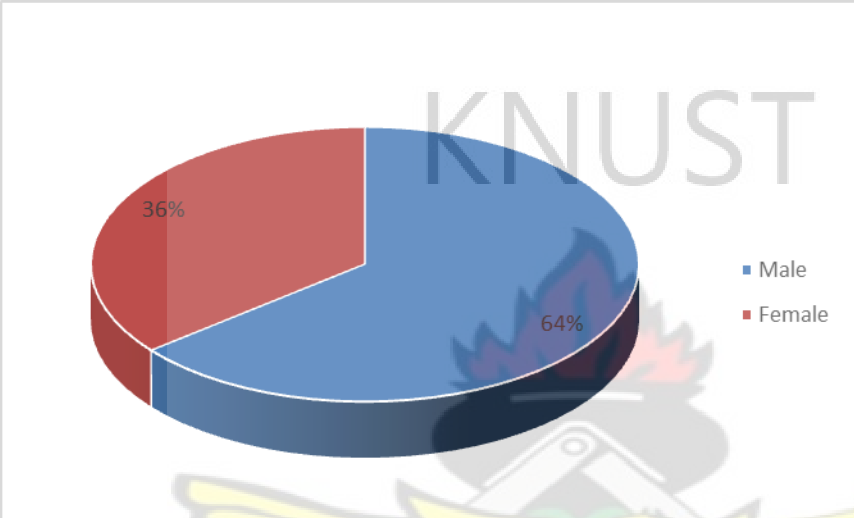

Figure 4.1: Gender of farmers

4.2 MARITAL STATUS OF FARMERS

From figure 4.2, 99% of the respondents were married while 1% were not married (single).

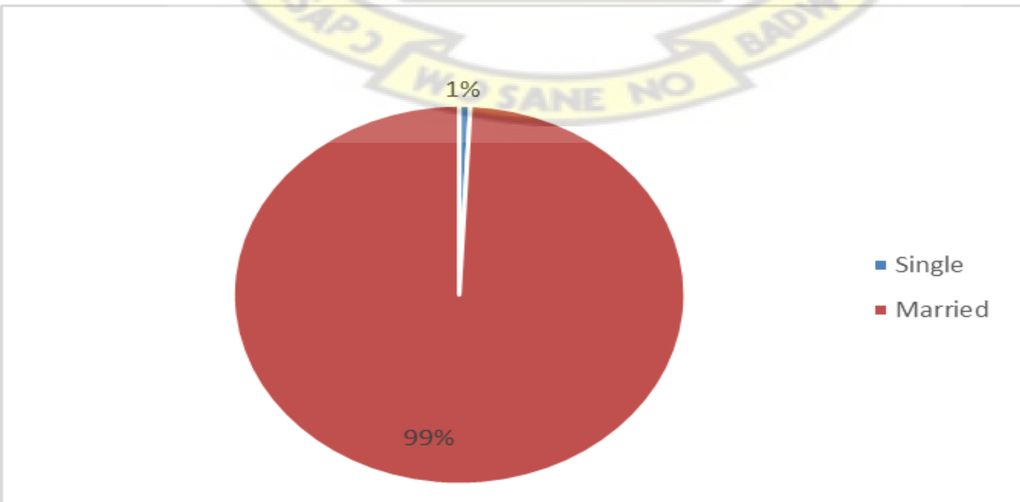

Figure 4.2: Marital status of respondents

4.3 EDUCATIONAL LEVEL

From the study, 83% of the respondents had formal education and 17% had no formal (informal) education (Figure 4.3).

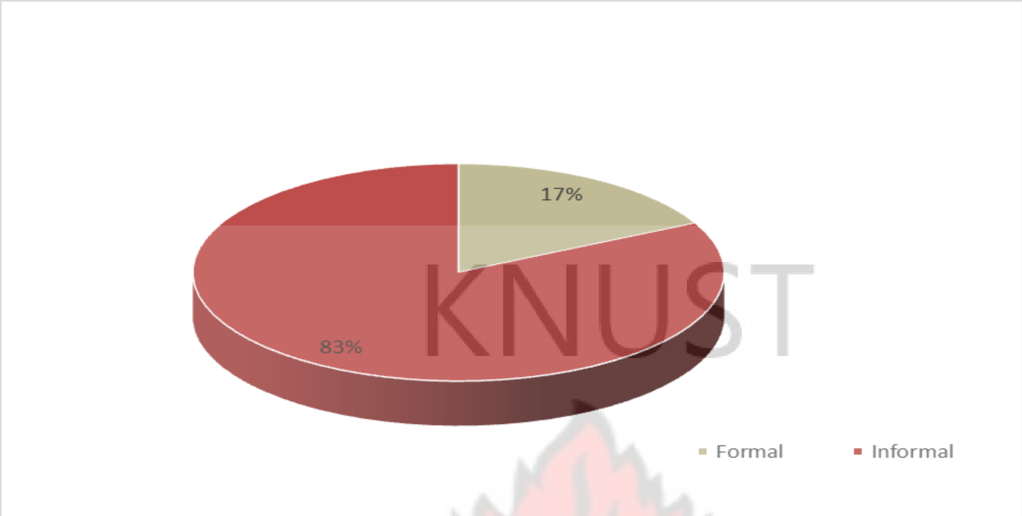

Figure 4.3: Educational level of Farmers

4.4 HOUSEHOLD SIZE OF FARMERS

Farmers were asked the number of people in their homes. Figure 4.4 showed that 0.8% of farmers had 1-2 people in their homes, 15% had 3-5 people in their homes while 84.2% had 6 and more people in their homes.

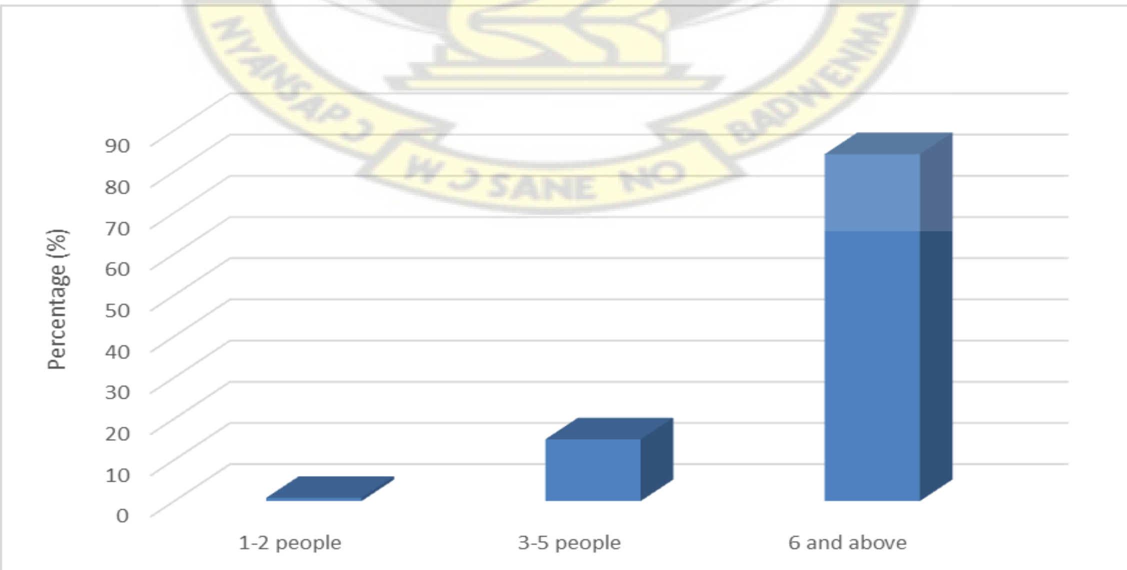

Figure 4.4: Household size of farmers

4.5 HARVESTING METHODS USED BY FARMERS

Farmers were asked the methods they use during harvesting of their maize cobs. From figure 4.5, 97% of the farmers used their hands in harvesting their maize while 3% used machines.

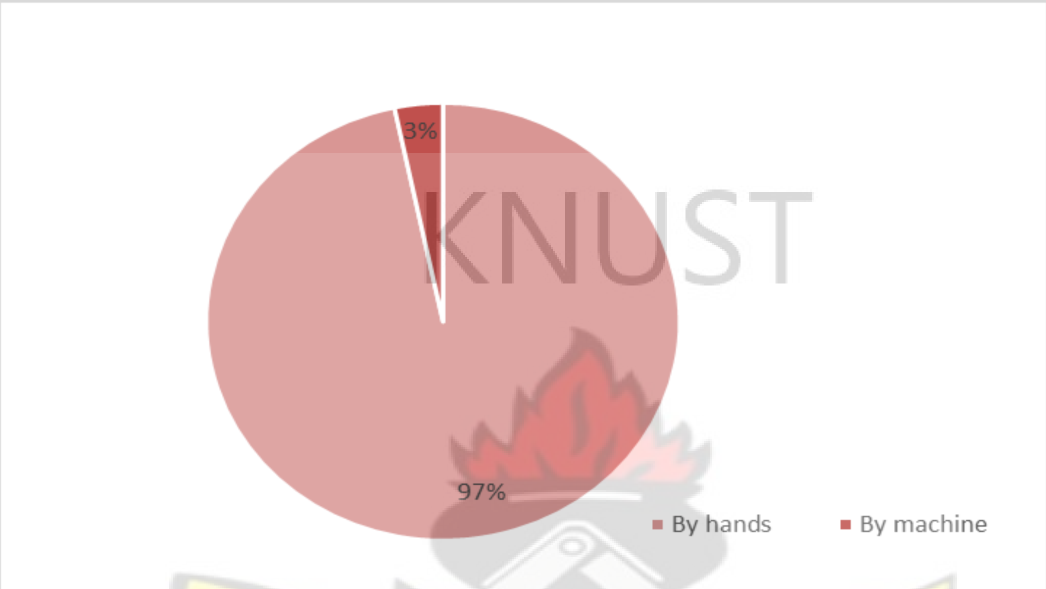

Figure 4.5: Harvesting methods used by farrmers in harvestring their maize cobs

4.6 AVAILABLILITY OF LABOUR

Form the stusdy, 4.2% of farmers employed 1-5 people to harvest their maize cobs, 95% empolyed 6-10 people while only 0.8% employed 11 and more people to harvest their maize cobs (Figure 4.6).

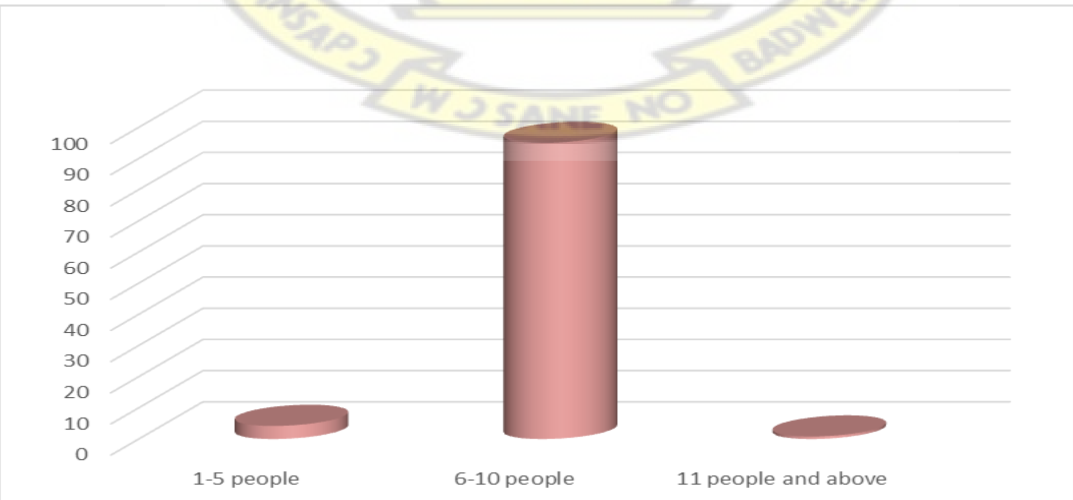

Figure 4.6: Number of people used for harvesting of maize cobs

4.7 STAGE MATURITY OF HARVESTED MAIZE

Farmers were asked the stage of maturity at which they harvest their maize cobs. Figure 4.7 showed that 1% of farmers harvested the cobs when it was 1-4 weeks matured and 99% harvested the cobs when it was 5-6 weeks matured (thus when leaves begin to turn brownish.

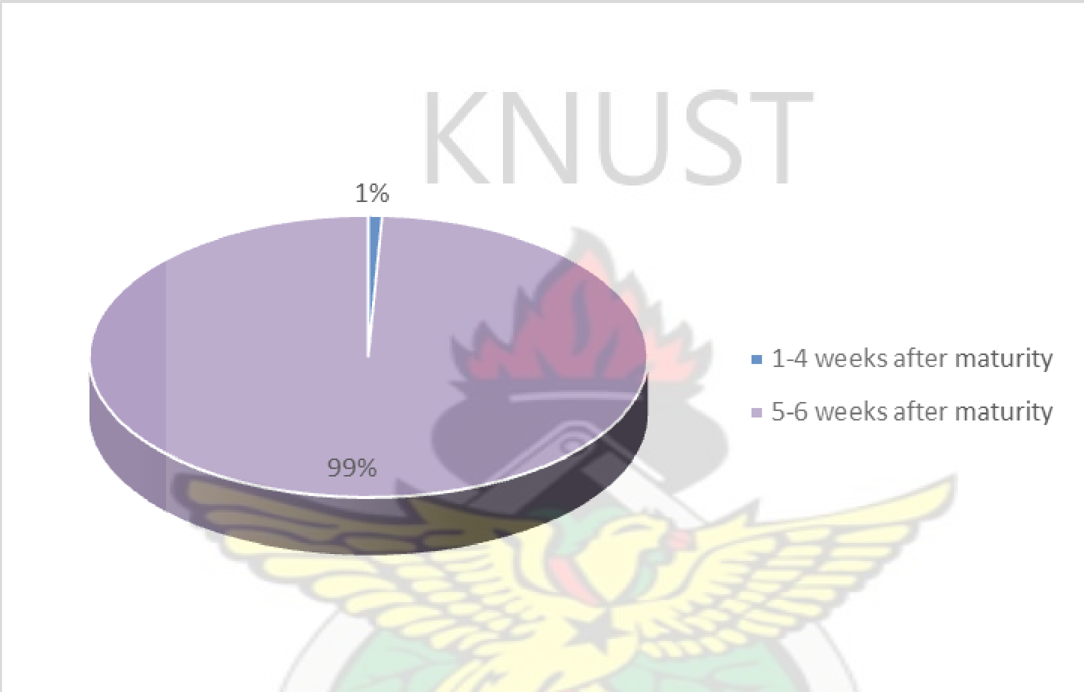

Figure 4.7: Stage of maturity of harvested maize cobs

4.8 WEED CONTROL

From the figure 4.8, majority (85%) of farmers did not control weeds before harvesting while 15% indicated they did although not cocistently.

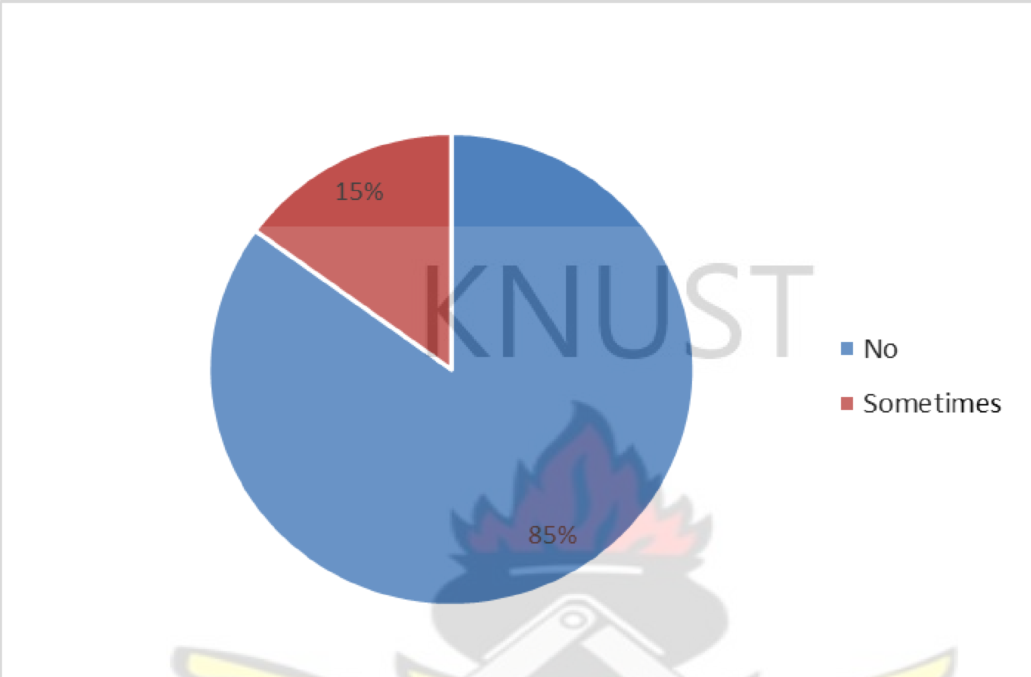

Figure 4.8: Do farmers control weeds of maize before harvesting?

4.9 HIRED LABOUR

Majority (59%) of farmers intervewed did not hire labour during harvesting of maize cobs while 41% hired labour during harvesting of maize cobs.

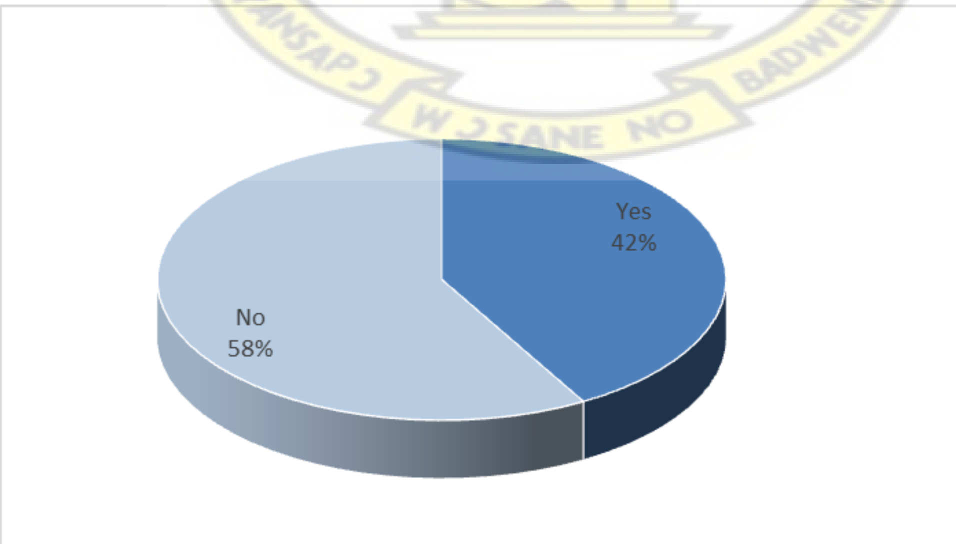

Figure 4.9: Do farmers hire labour during harvesting?

4.10 GATHERING METHODS USED BY FARMERS

From figure 4.10, 50% of farmers gathered their maize cobs by throwing to a central point while the other 50% carry the maize cobs in basins to a central point.

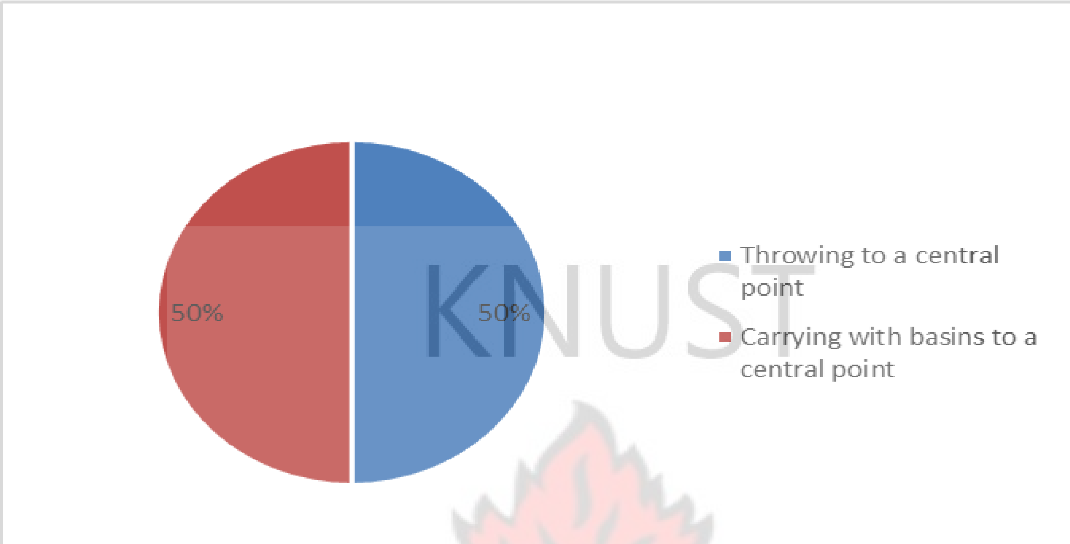

Figure 4.10: Gathering methods usd by farmers

4.11 DURATION OF COB ON FIELD BEFORE BEING SHELLED

The study showed that, 1.7% of farmers left their cobs on the field 1-7 days before shelling them, 25% left the cob on the field 8-14 days while 73.3% left the cob on the field 15 days and more before shelling them.

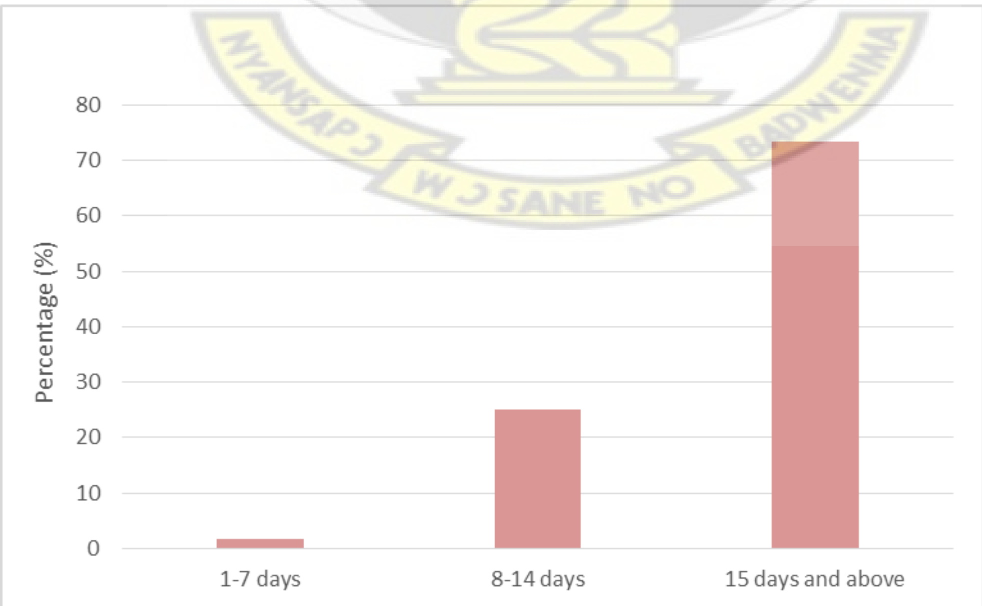

Figure 4.11: Number of days cob stays on the filed before being shelled

4.12 SORTING OF COBS

Majority (55%) of the farmers sorted their cobs during gathering while 45% did not sort their cobs during gathering.

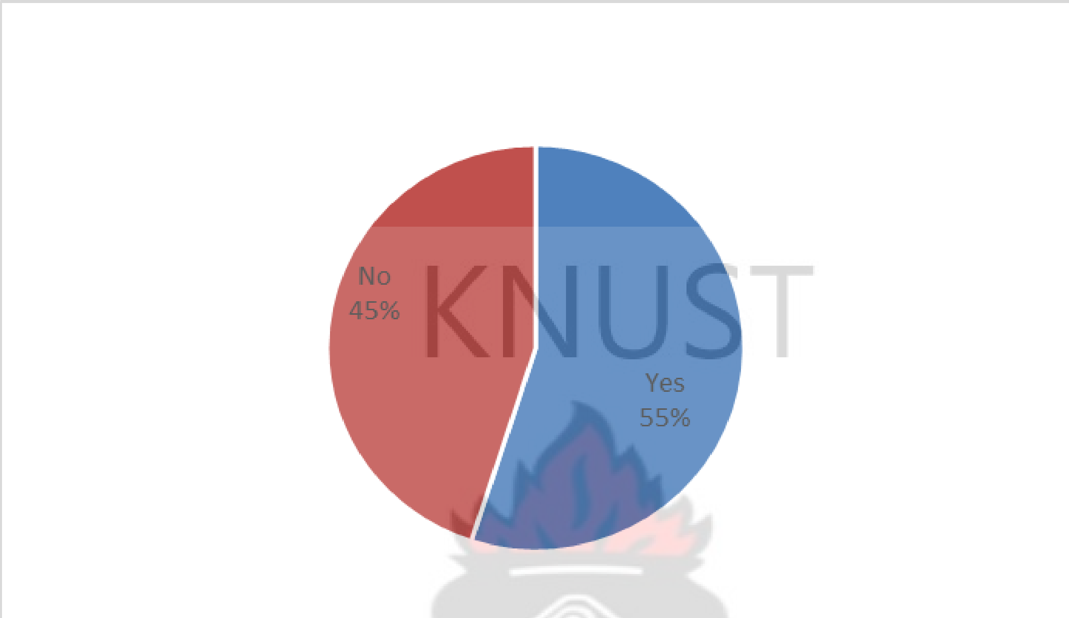

Figure 4.12: Sort cobs during gathering?

4.13 SHELLING METHODS

From the interview, 99% of the farmers used machines to shell their maize while only 1% used sticks to beat the maize cobs as a shelling method (figure 4.13).

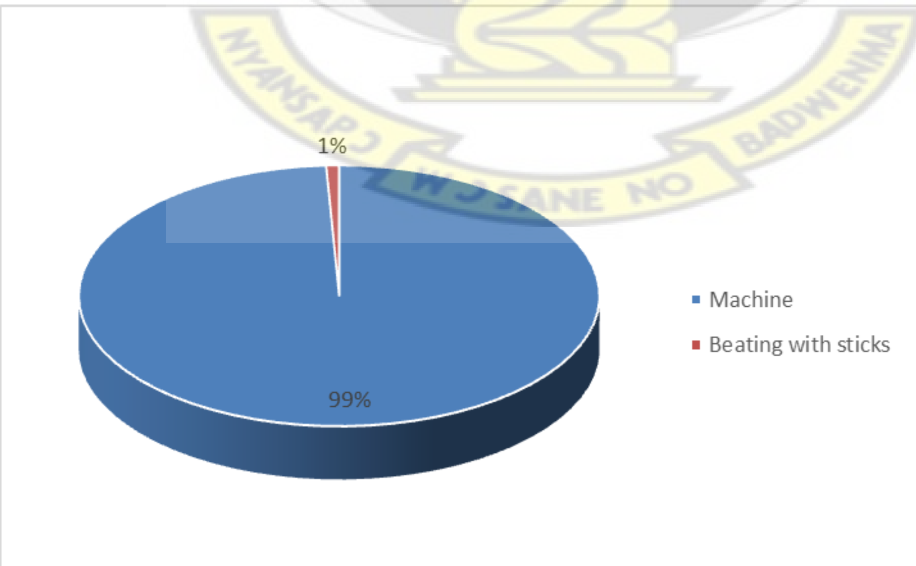

Figure 4.13: Shelling methods used to shell maize cobs

4.14 PERCENTAGE OF BROKEN GRAINS AFTER SHELLING

Figure 4.14 shows that 98% of farmers recorded below 50% of broken grains after shelling while only 2% recorded 50-60%.

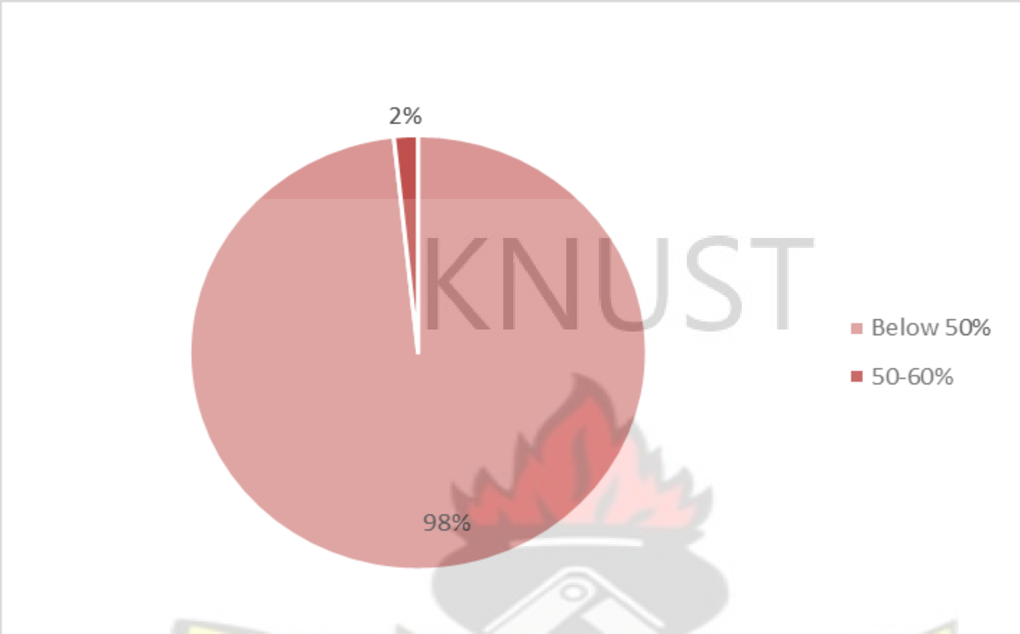

Figure 4.14: Percentage of broken grains after shelling

4.15 PROBLEMS ENCOUNTERED DURING SHELLING

Problems encountered by farmers during shelling were poor state of shellers, high cost of shelling and late arrival of shellers (20.8%), late shelling due to lack of machines (33.3%), high cost of shelling and difficulty in getting shellers (9.2%), high cost of shelling and ineffective shellers (14.2%), late arrival of shellers (14.2%), difficulty during beating (5.8%), high cost of hiring shellers (0.8%), insufficient shellers (1.7%) and high charges for shelling (13.3%).

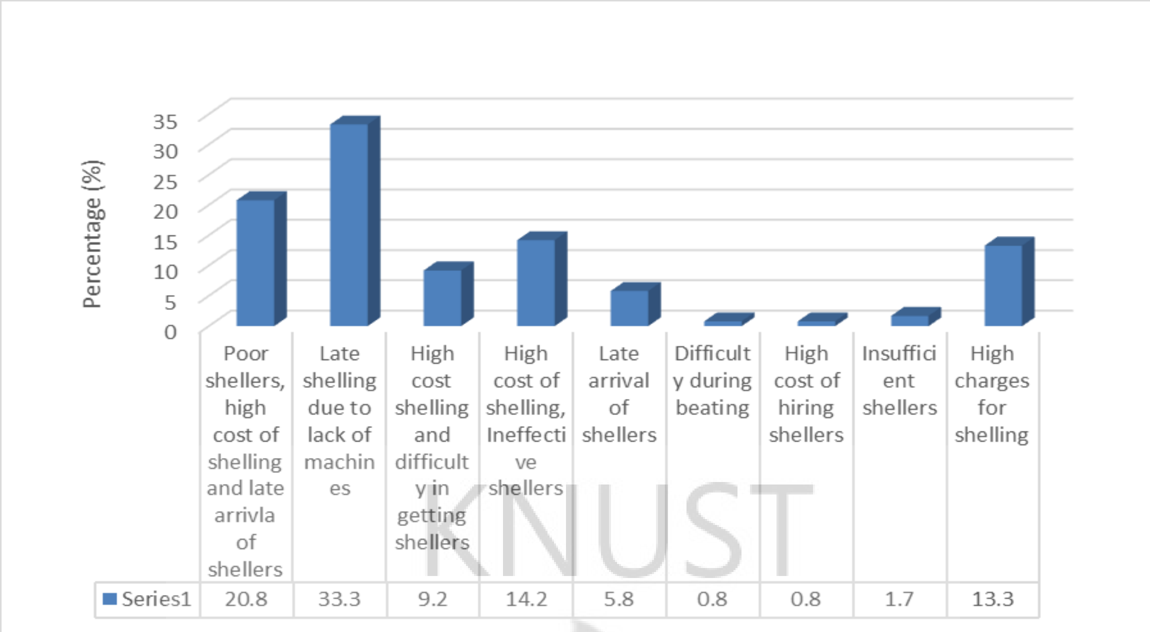

Figure 4.15: Problems Encountered during Shelling

4.16 WINNOWING METHODS

Winnowing methods used by farmers were by win (99%) and by machine (1%) as shown in figure 4.16.

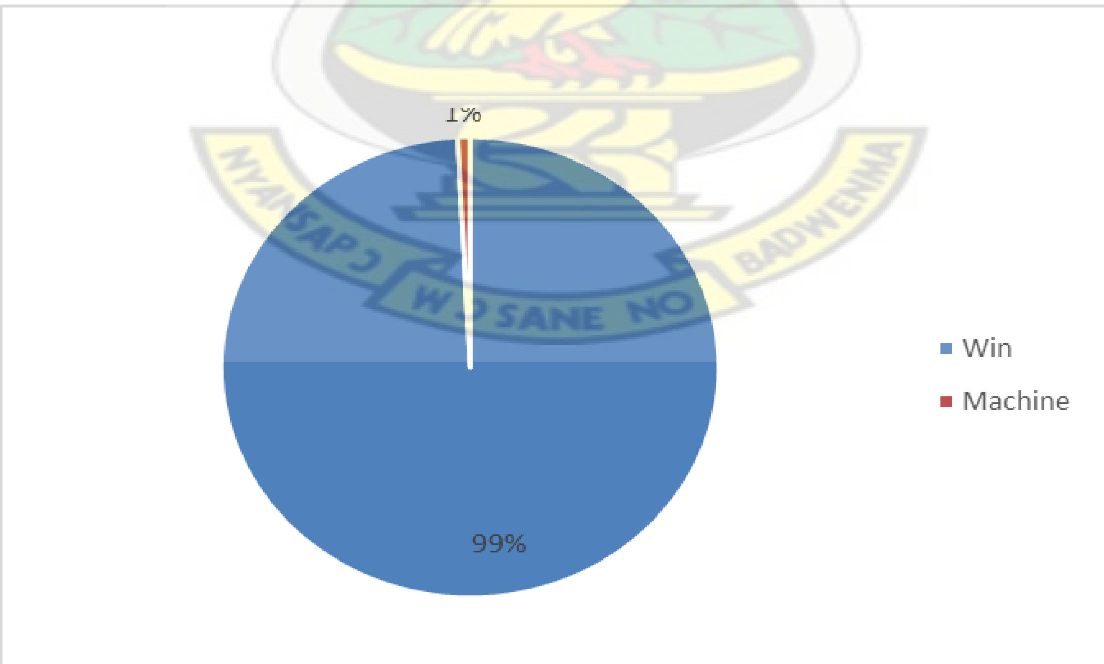

Figure 4.16: Winnowing methods used by farmers

4.17 CHALLENGES ENCOUNTERED DURING WINNOWING

Lot of chaff (41.7%), poor cleaning due to much chaff (25.8%), improper shelling leading to grain-fall-off (20.8%), lot of labour during winnowing (3.3%), difficulty due to large quanity of maize (5%), difficult due to poor shelling (0.8%) and delay of work due to wind disturbances (2.5%) were challenges encountered by farmers during winnowing.

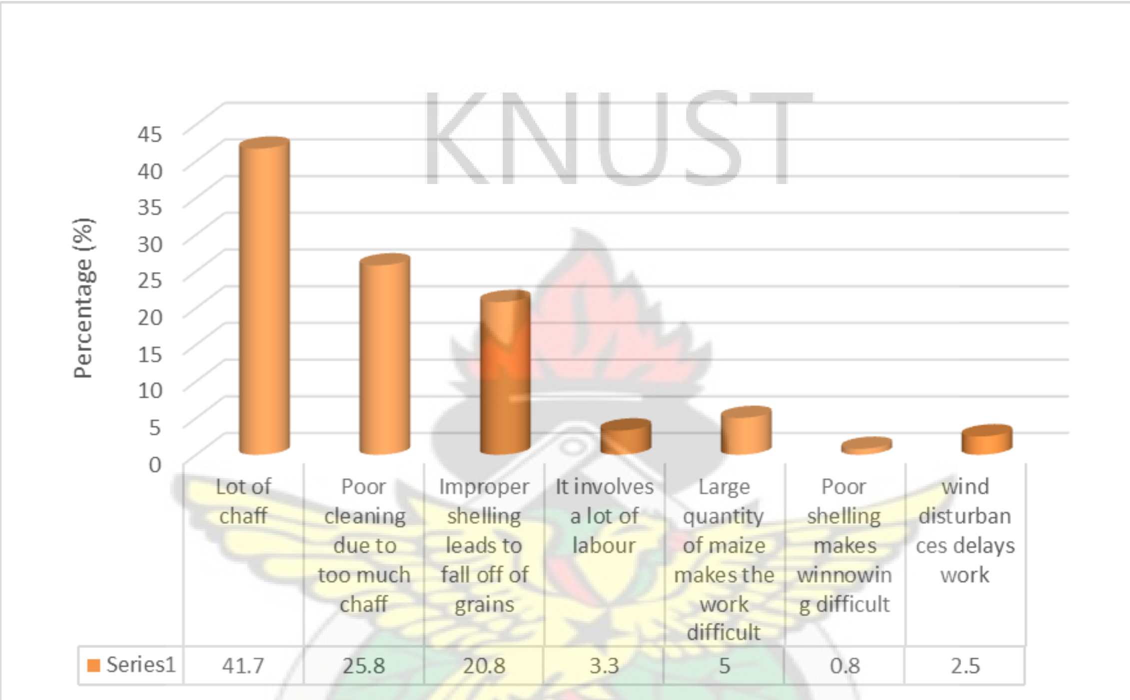

Figure 4.17: Challenges encountered by farmers during winnowing

4.18 TYPE OF PACKAGING METHODS USED BY FARMERS

Majority (53%) used fertilizer sack as a packaging material for the grains while 47% used jute sack as a packaging material (figure 4.18).

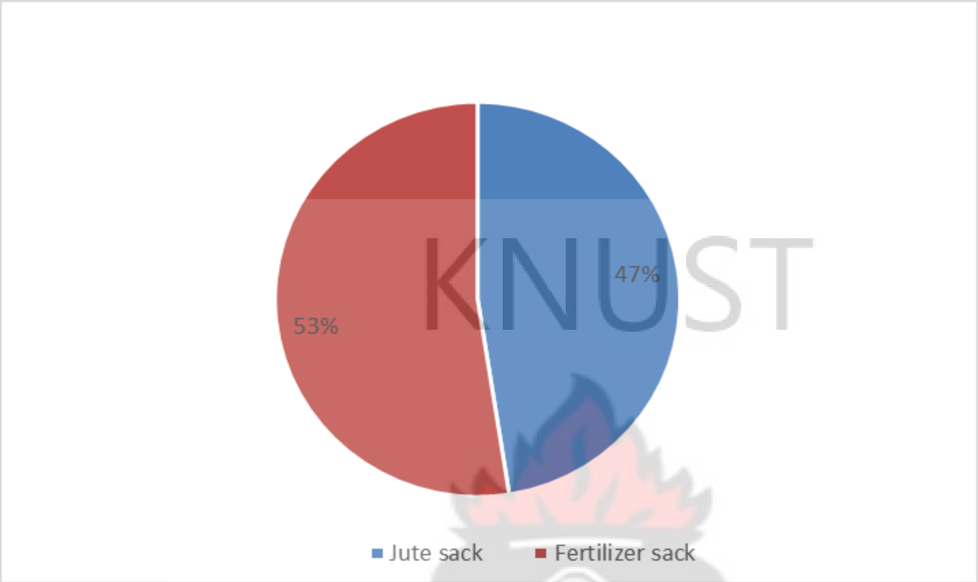

Figure 4.18: Type of packaging material used to bag grains

4.19 TRANSPORTATION METHODS

Framers were asked the methods used to transport grains to their house.Response in Figure 4.19 showed that 0.8% used head pan or basins, 62.5% used donkey or bullock carts, 0.8% used bicycle or motor bikes and 35.8% used cars or tractors to transport maize grains to their house.

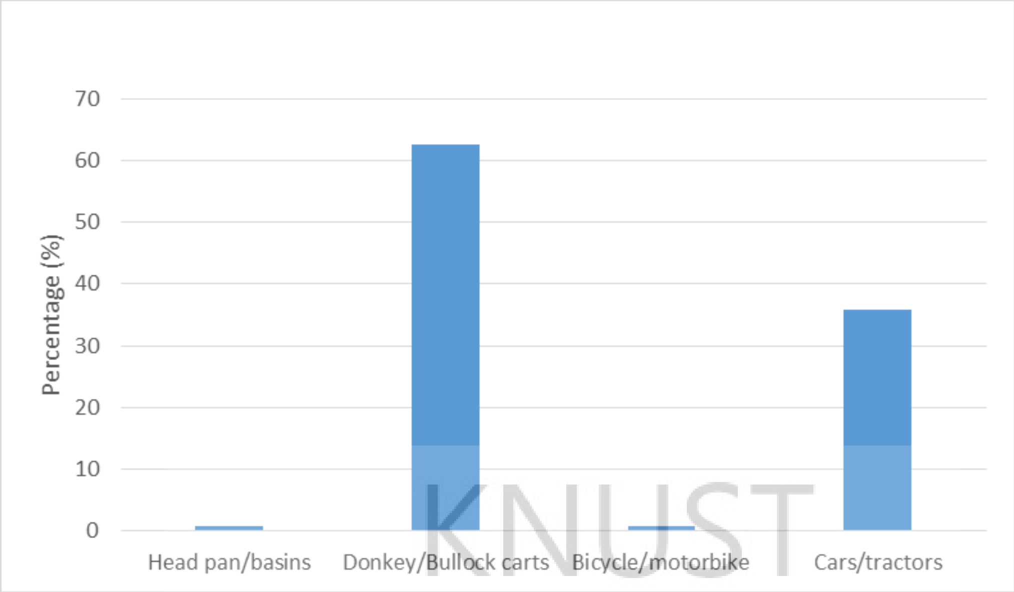

Figure 4.19: Methods used by farmers to transport grains to their house

4.20 NATURE OF TRANSPORTATION ROADS

From figure 4.20, few of the farmers (37%) responded that the nature of their roads were rough while majority (63%) of the farmers used footpaths.

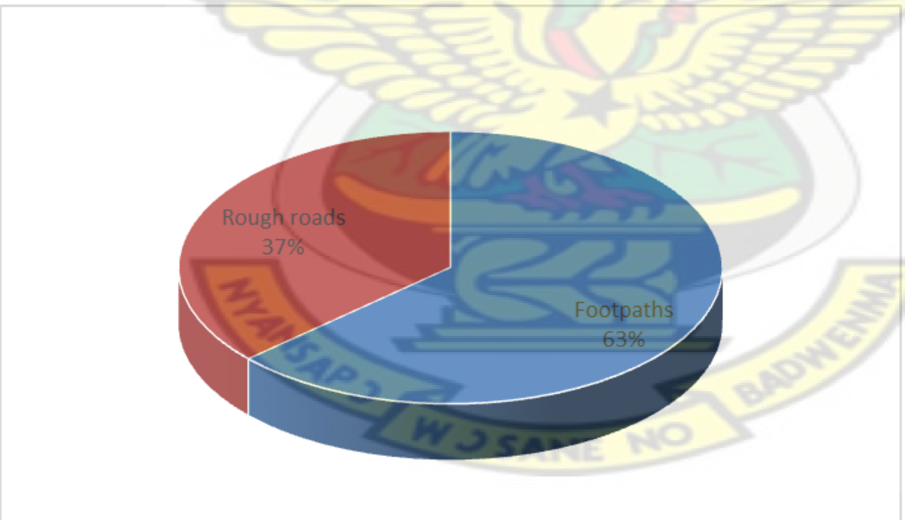

Figure 4.20: Nature of roads used by farmers

4.21 STORAGE METHODS

Storage methods used by farmers to store their grains were thatch uncemented floors (93%) and silos (7%).

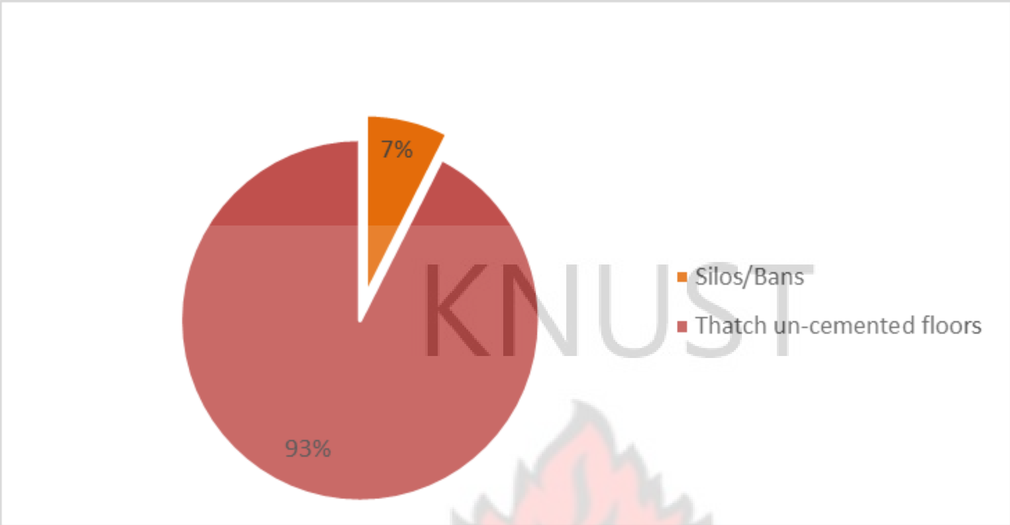

Figure 4.21: Storage methods used by farmers to store their grains

4.22 FUMIGATE OR TREAT GRAINS BEFORE STORAGE

Manjority (97%) of the farmers responded they do not fumigate their grains while only 3% responded they did.

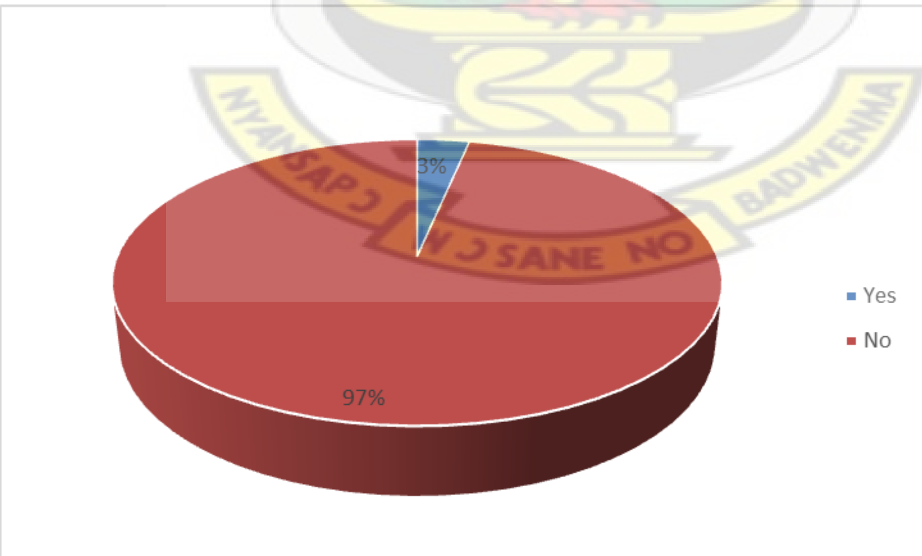

Figure 4.22: Do farmers fumigate or treat their grains before storage?

4.23 SOLARIZE GRAINS BEFORE STORAGE

A few (33%) of the farmers solarized their grains while 67% did not.

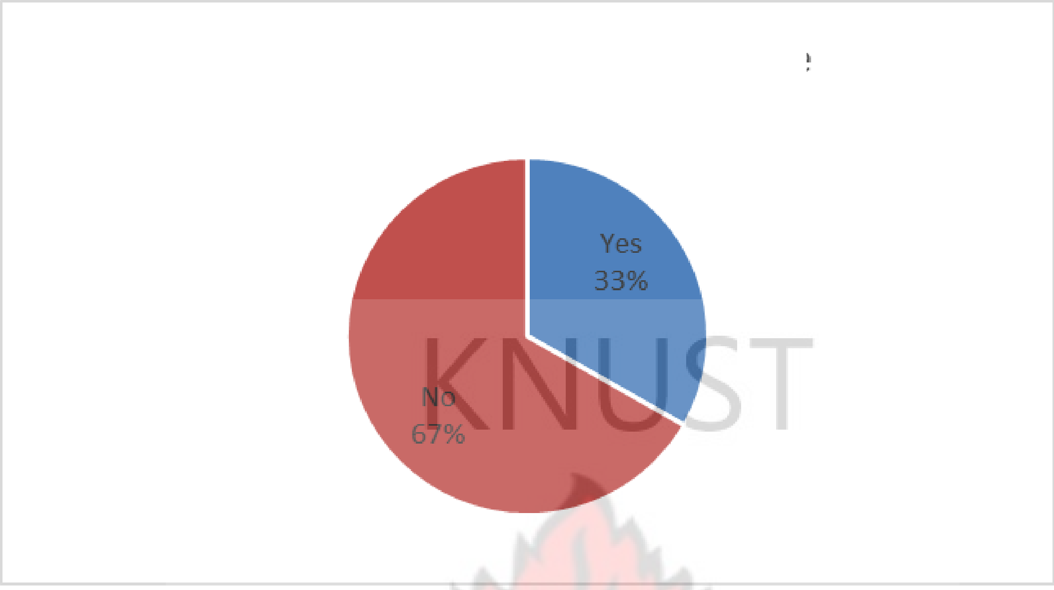

Figure 4.23: Do farmers solarize their grains before storage?

4.24 STORAGE DAYS OF GRAINS

From the interview, 91% of farmers stored their grains for more than 3 months while only 9% stored their grains for 1-2 months (figure 4.24).

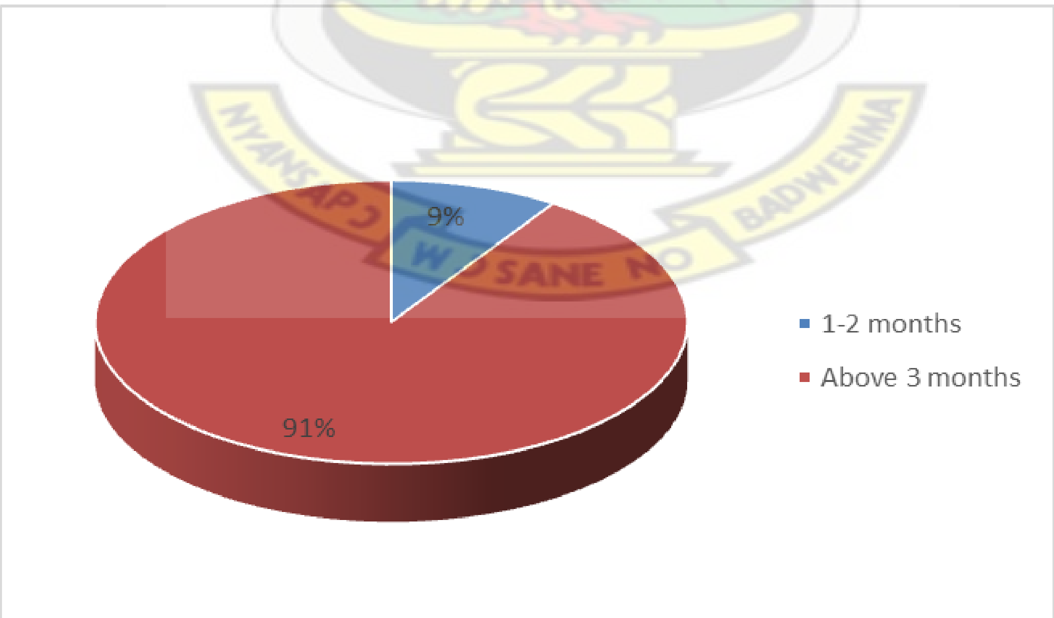

Figure 4.24: How long farmers store their maize grians

4.25 HOW LONG FARMERS HAVE BEEN MILLING MAIZE GRAINS

Figure 4.25 shows that 98% of farmers had been milling their maize grains for more than one year while 2% of them have been milling their maize grains for only one year.

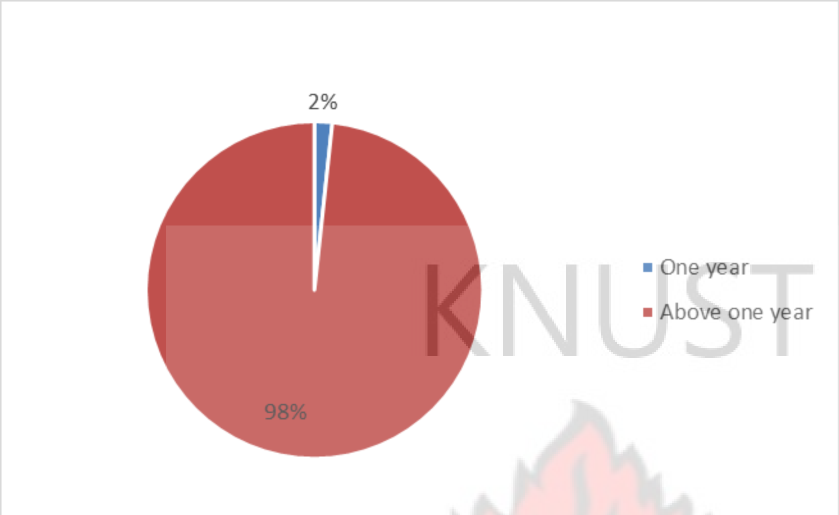

Figure 4.25: How long farmers have been milling maize grains

4.26 QUANTITY OF GRAINS MILLED PER DAY BY MILLERS

Out of the millers interviewed (figure 4.26), 2.5% of them milled less than a bag (100kg) of maize per day, 0.8% milled one bag of maize per day while 96.7% milled more than one bag of maize per day.

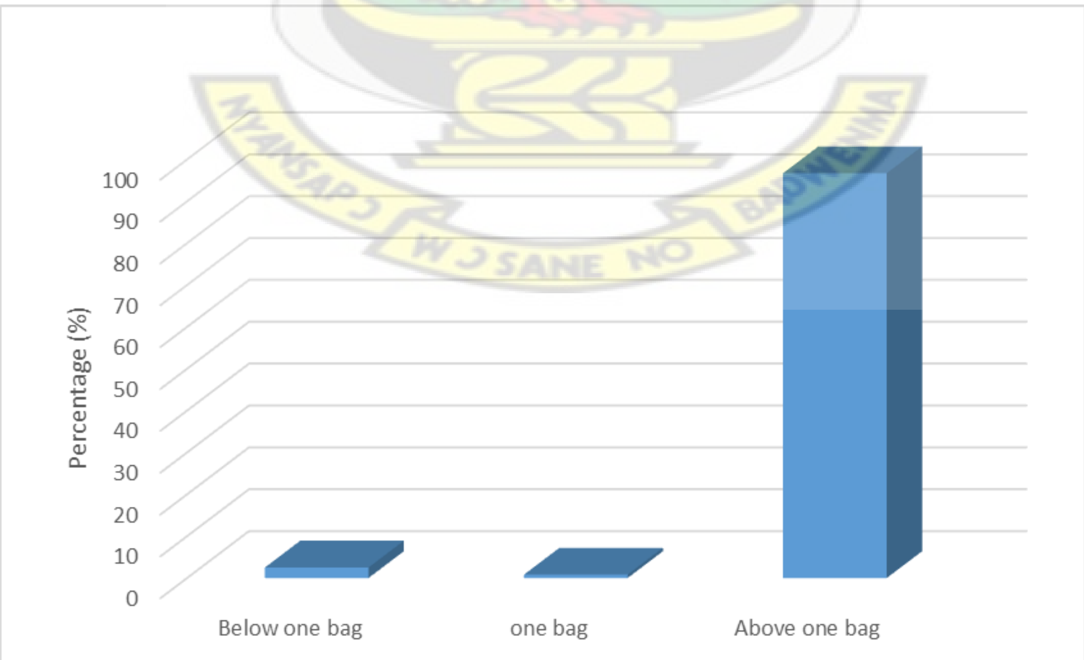

Figure 4.26: Quantity of grians milled by millers per day (one bag=100kg)

4.27 QUANTITY OF GRIANS COLLECTED ON THE GROUND PER DAY BY MILLERS

From figure 4.27, 61.7% of millers collected less than a bag of maize from the ground per day, 15.8% collected just a bag of maize while 22.5% collected more than one bag per day.

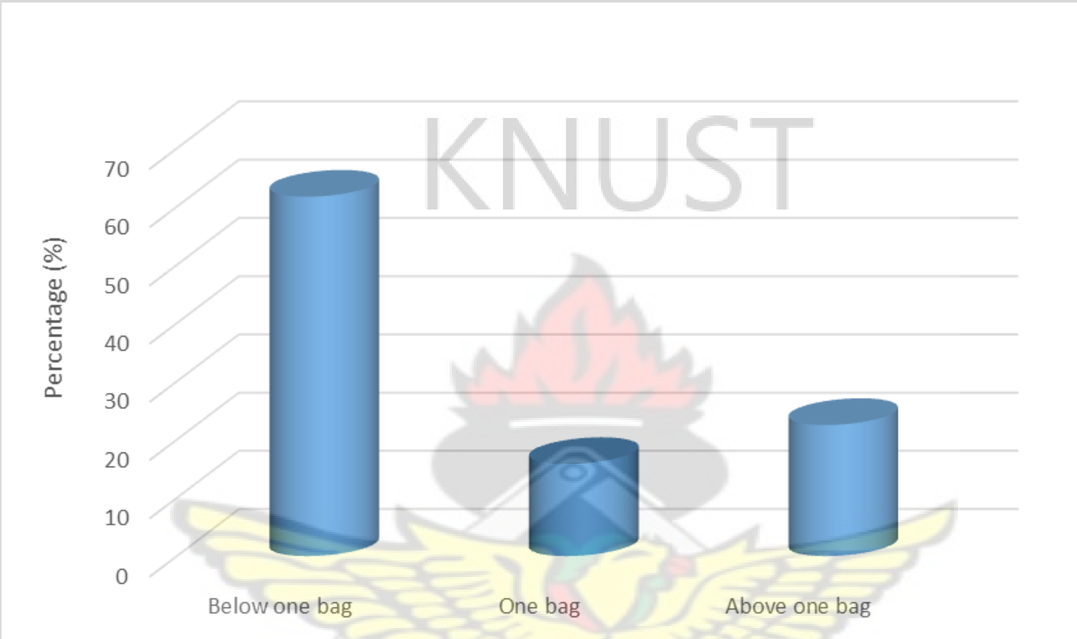

Figure 4.27: Quantity of grains collected on ground per day (one bag= 100kg)

4.28 HARVEST LOSSES

4.28.1: Gender, civil status and other activities performed by people involved in the harvesting.

Figure 4.28: Harvesting and gender in Sissala East District

Figure 4:28 shows the gender balance among the people involved in the harvesting of maize interviewed in the Sissala East district. Out of the 60 people interviewed 40 of them were males which represented 66.7% and 20 were females which also represented 33.3%.

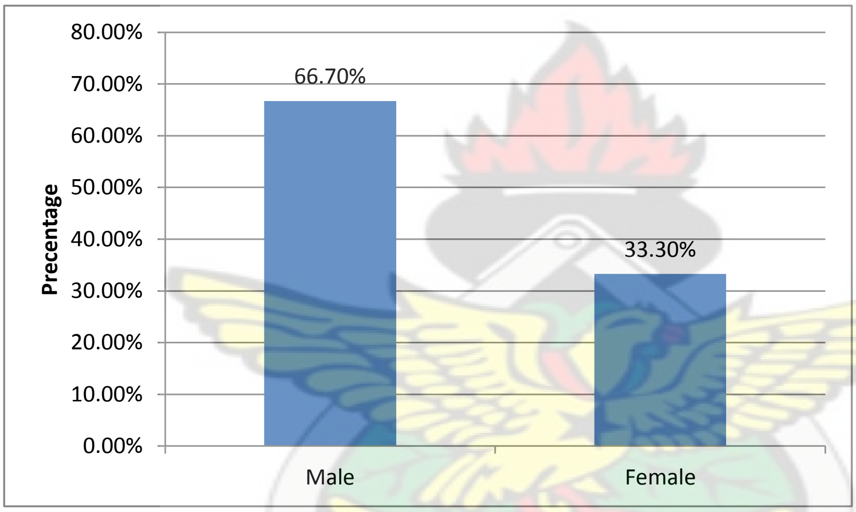

Figure 4.28 Percentage of sex distribution of people involved in harvesting of maize in Sissala East.

4.28.2 Harvesting and Gender in Sissala West District

Of the sixty (60) people interviewed in the Sissala West district, 66.7% and 33.3% were males and females respectively. Figure 4.28 below shows the sex distribution of the people interviewed in the Sissala West district**.**

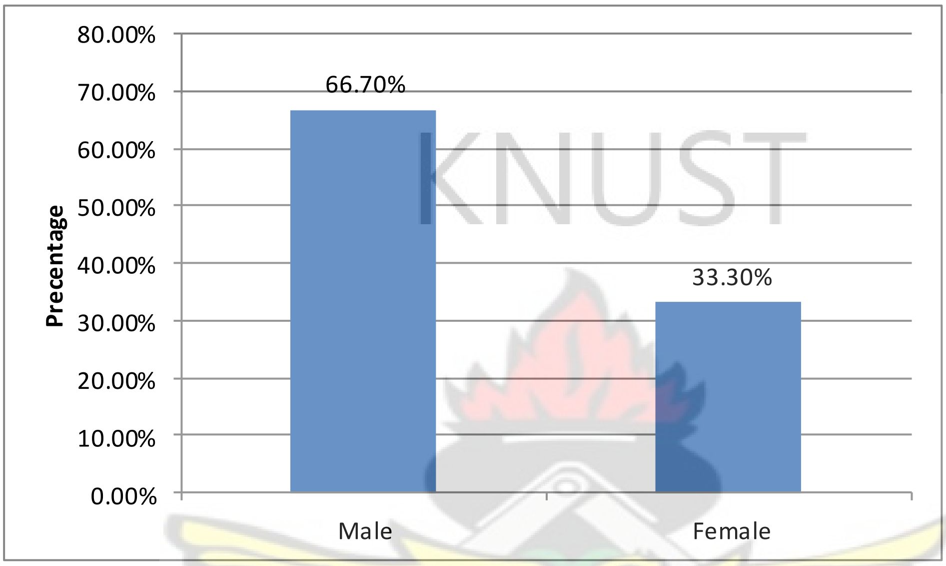

Figure 4.29: Percentage of sex distribution of people involved in harvesting of maize in Sissala West

Results for harvesting losses in the two districts have been presented in Tables 4.1 and 4.2 respectively. Harvest losses for Sissala East District significantly ($P<0.05$) varied between the communities. Whereas Sakalu recorded the least loss of maize (170.75kg/ha) for each hectare of maize field, Pieng however had the highest loss of 281kg/ha.

Table 4.1 Harvesting losses in selected communities in Sissala East District

Community	Harvest loss (kg/ha)
Bandei	216.90
Tarsaw	243.00
Kulfuo	236.50
Sakai	219.75
Pieng	281.00
Challu	178.50
Sakalu	170.75
Nankpawie	200.75
Nganduonu	177.50
Kroboi	207.75
Mean	213.24
Lsd	1.70
CV	0.47

Similarly, differences (P<0.05) were observed among communities in the Sissala West District. Whereas Jawia had the least loss of grains (154.65kg/ha), Pulima recorded the highest being 286.75 kg/ha (Table 4.2).

Table 4.2 Harvesting losses in selected communities in Sissala West District

Community	Harvest loss (kg/ha)
Jawia	154.65
Kusali	233.50
Duwie	180.00
Jefisi	233.00
Pulima	286.75
Desime	178.00
Sobelle	185.75
Kupulima	204.00
Bouti	178.50
Jiton	219.00
Mean	**205.32**
Lsd	3.41
CV	0.97

Although, significant differences in harvesting losses were observed among communities in each of the districts, the differences between the district means were not significant

(Table 4.3). Sissala East (213.24 kg/ha) was only marginally higher than Sissala West which had losses of 205.32 kg/ha.

Table 4.3: Harvesting losses of maize in Sissala East and Sissala West Districts.

District	Harvest loss (kg/ha)
Sissala East	213.24 ± 33.05
Sissala West	205.32±37.32
P	0.258

4.29 SHELLING AND WINNOWING LOSSES

Within the Sissala East District shelling and winnowing losses varied significantly ($P<0.05$) among the communities. Pieng had the highest losses of 249.50 kg/ha (Table 4.4). This was 158% higher than the least (Tarsaw) which recorded 158 kg/ha.

Table 4.4: Shelling and Winnowing losses the selected communities in Sissala East

Communities	Shelling and winnowing losses (kg/ha)
Bandei	209.00
Tarsaw	158.00
Kulfuo	206.00
Sakai	242.90
Pieng	249.50
Challu	235.50
Sakalu	221.00
Nankpawie	161.25
Nganduonu	174.80
Kroboi	199.50
Mean	**207.91**
Lsd	40.36
CV	0.51

With respect to Sissala West District, Buoti recorded the least (154.00 kg/ha) (Table 4.5). This was about 183% lower than what was observed in Jefisi (281.5 kg/ha) which had the highest.

Table 4.5: Shelling and Winnowing losses in the selected communities in Sissala West District

Communities	Shelling and winnowing loss
Jawia	197.30
Kusali	184.00
Duwie	209.00
Jefisi	281.50
Pulima	215.25
Desime	193.75
Sobelle	197.25
Kupulima	169.75
Bouti	154.00
Jitong	172.25
Mean	**197.41**
Lsd	1.7032
CV	16.28

Variation in shelling and winnowing losses in each district did not result in differences in the district means as no differences (P>0.05) were observed between Sissala East and West (Table 4.6).

Table 4.6: Shelling and winnowing losses of maize

District	Shelling and winnowing losses (kg/ha)
Sissala East	207.9±32.21
Sissala West	197.41±33.74
P	0.402

4.30 TRANSPORTATION LOSSES

Communities within the Sissala East District recorded varying (P<0.05) transportation losses. Transportation losses ranged between 0.35 and 1.00 Kg/ha (Table 4.7). Sakalu recorded the highest while Sakai had the least being 286% lower than that of Sakalu.

Table 4.7: Transportation Losses among communities in the Sissala East district

Community	Transport losses (kg/ha)
Bandei	0.85
Tarsaw	0.65
Kulfuo	0.45
Sakai	0.35
Pieng	0.65
Challu	0.55
Sakalu	1.00
Nankpawie	0.75
Nganduonu	0.66
Kroboi	0.65
Mean	**0.66**
Lsd	0.02
CV	1.52

Similarly, variation was found in transportation losses in the Sissala West district. Sobelle had the highest loss of 0.95 kg/ha with Duwie having the least (0.45 kg/ha) (Table 4.8).

Table 4.8: Transportation Losses among communities in the Sissala West district

Community	Transport losses (kg)
Jawia	0.64
Kusali	0.75
Duwie	0.45
Jefisi	0.60
Pulima	0.55
Desime	0.75
Sobelle	0.95
Kupulima	0.70
Bouti	0.49
Jitong	0.70
Mean	0.66
Lsd	0.03
CV	3.04

Although differences were found in the communities, for each district no significant difference (P>0.05) was observed in the district means for Sisala East (0.656 kg/ha) and Sisalla West (0.658 kg/ha) (Table 4.9).

Table 4.9: Transportation losses of Maize

District	Transportation losses (kg/ha)
Sissala East	0.656±0.18
Sissala West	0.658±0.14
P	0.106

4.30.1 STORAGE LOSSES

There were no significant differences between the two districts in terms of storage losses over the four month storage period. There was an 11.2% (Fig. 4.1) loss in weight of maize in the first month of storage for Sissala East as compared to 11.00% for Sissala West (Figure 4.1). Loss in weight continued through to the fourth month of storage. By the end of the second month of storage Sissala East had recorded marginal increase in weight loss to 22.2%. At the end of the 4th month of storage the loss stood at 40.3%. On the other hand, cumulative weight loss in Sissala West increased to 39.6% during the same period.

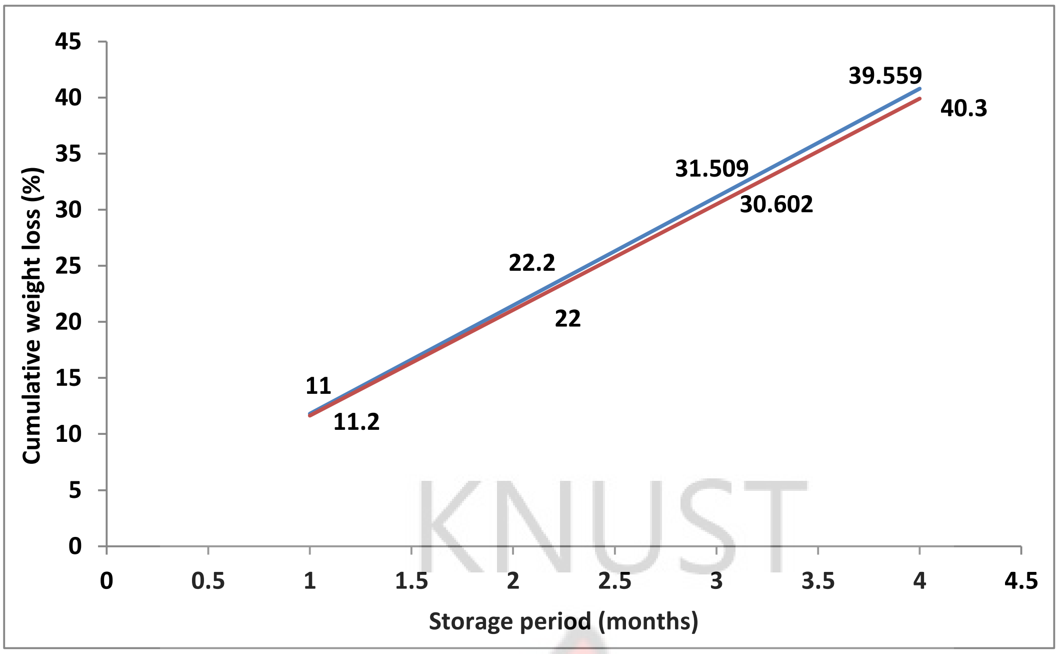

Figure 4.30 Cumulative weight loss of maize during storage.

Table 4.10 presents losses incurred during storage and their corresponding economic loss during the four month duration of storage. The study revealed that potential money lost as a result of loss in weight of maize for the first month of storage was GH₵ 4.5 for Sissala East and GH₵ 4.39 for Sissala West. These values increased to up GH₵ 24.19 and GH₵ 23.73 for Sissala East and Sissala West districts respectively at the end of the fourth month of storage.

Table 4.10: Economic Effect of Storage Losses.

Months of Storage	Sissala East		Sissala West	
	Quantity loss (Kg)	Economic loss (GH₵)	Quantity loss (Kg)	Economic loss (GH₵)
One	11.22	4.49	10.99	4.40
Two	22.41	12.33	22.20	12.21
Three	31.51	17.33	30.60	16.83
Four	40.32	24.19	39.56	23.74

4.30.2 WEEVIL INFESTATION

Significant differences ($P<0.05$) were observed in the extent of weevil infestation in the stored maize grains within the Sissala East District as far as the communities were concerned. The number of weevils per 50grams of grains ranged between 32.5 and 42.5 (Table 4.11). Bandei had the least weevil infestation as against Kulfuo which had the highest.

Table 4.11:Weevil infestation within Sisalla East District.

Communities	Number of weevils	Transformed
Bandei	32.5	5.75
Tarsaw	37.5	6.18
Kulfuo	42.5	6.55
Sakai	37.5	6.18
Pieng	35.0	5.96
Challu	37.5	6.18
Sakalu	37.5	6.18
Nankpawie	37.5	6.18
Nganduonu	37.5	6.14
Kroboi	35.0	5.96
Lsd		0.020
Cv		0.19

Similarly, significant differences existed between communities within the Sissala East District. Whereas Desime had the highest weevil infestation (47.5), Duwie had the least (37.5) (Table 4.12).

Table 4.12: Weevil infestation within Sisalla West District.

Community	Number of weevils	Transformed
Jawia	42.5	6.56
Kusali	42.5	6.56
Duwie	37.5	6.16
Jefisi	40.0	6.36
Pulima	42.5	6.56
Desime	47.5	6.93
Sobelle	42.5	6.56
Kupulima	45.0	6.72
Bouti	45.0	6.75
Jitong	40.0	6.36
Lsd		0.039
CV		0.19

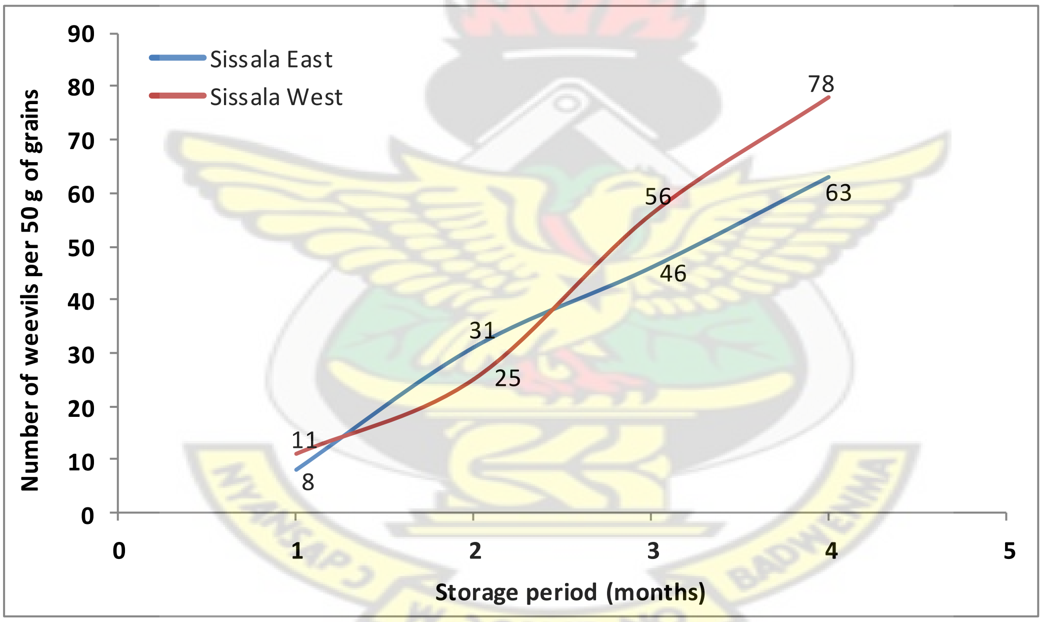

Figure 4.31 Weevils population in maize grains

The two districts, namely Sissala East and Sissala West, showed no differences (p>0.05) in terms of the number of weevils present (Table 4.13). Both Sissala West and Sissala East districts recorded similar means of 37 weevils per 50 grams of grains. Over the period, the were increases in weevil infestation in storage (Figure 4.3).

Table 4.13:Number of weevil per fifty gram of maize within the districts.

DIST	Mean	Transformed
Sissala East	37.00	6.13
Sissala West	37.00	6.13
P		1.00

4.4.2 HOLED GRAINS

Within the Sissala East District, the communities had significantly varied number of grains with holes (Table 4.14). Sakalu, Challu and Pieng were similar (42.5 holed grains/50g grain) but higher than the rest. However, Tarsaw had the least (27.5 holed grains/50g grain).

Table 4.14: Grains with holes per fifty gram of maize within the communities

Community	Holed grains	Transformed
Bandei	32.50	5.75
Tarsaw	27.50	5.29
Kulfuo	35.00	5.95
Sakai	37.50	6.16
Pieng	42.50	6.56
Challu	42.50	6.56
Sakalu	42.50	6.56
Nankpawie	35.00	5.96
Nganduonu	37.50	6.16
Kroboi	37.50	6.16
Lsd		0.024
CV		0.23

Significant differences ($P<0.05$) were observed between the communities within the Sissala West District with respect to holed grains. The number of holed grains ranged between 35.0/50g (Duwie) and 45.0/50g (Jefisi and Kupulima) (Table 4.15).

Table 4.15: Grains with holes per fifty gram of maize within the Sissala West District

Community	Holed grains	Transformed
Jawia	42.50	6.56
Kusali	40.00	6.36
Duwie	35.00	4.96
Jefisi	45.00	6.75
Pulima	42.50	6.56
Desime	42.50	6.56
Sobelle	40.00	6.36
Kupulima	45.00	6.75
Bouti	40.00	6.36
Jitong	42.50	6.56
Lsd		0.012
CV		0.11

Table 4.16: Number of grains with holes

District	Mean	Transposed
Sissala East	36.85±1.29	6.112
Sissala West	36.85±1.03	6.112
P	0.104	1.00

Regarding the mean of the two districts (Sissala East and West), no significant differences ($p>0.05$) were observed (Table 4.16). By the end of the 4th month of storage, Sissala West had recorded 44.4 holed grains/50g of grains whereas 40.8 holed grains /50g grains were recorded in the Sissala East (Figure 4.2).

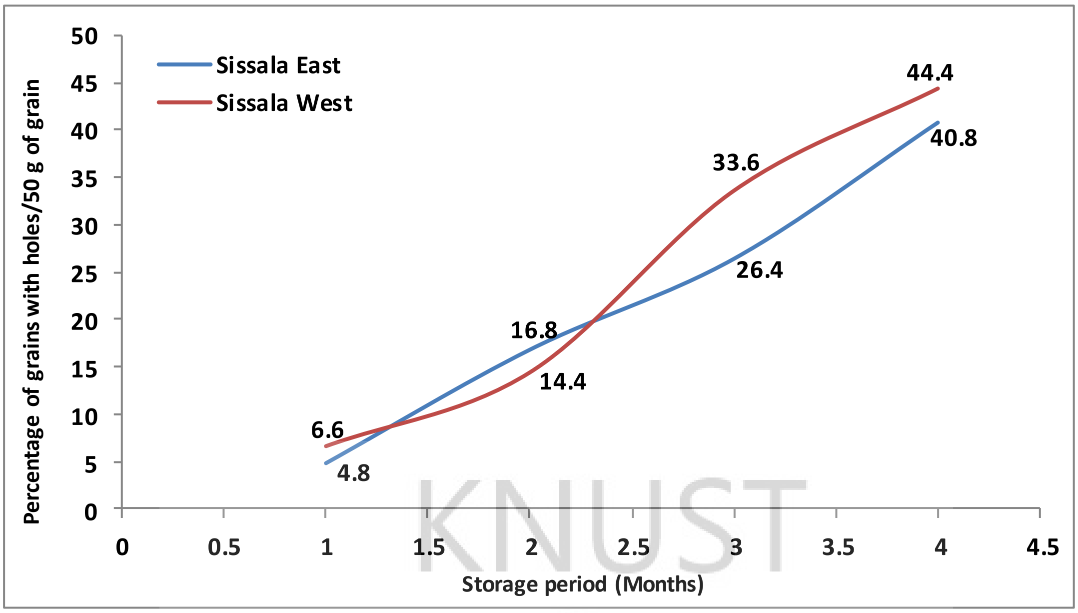

Figure 4.32: Number of grains with holes over four months of storage

4.5 PROCESSING LOSS

The processing losses in the communities within the Sissala East varied significantly ($p>0.05$). Bandei and Sakalu recorded the highest loss of 4.25 kg/bag whereas Nankpawie had the least loss, being 2.88 kg/bag (Table 4.17).

Table 4.17: Processing losses in Sissala East District

Community	Processing loss (kg)
Bandei	4.24
Tarsaw	3.35
Kulfuo	3.61
Sakai	3.69
Pieng	4.19
Challu	3.47
Sakalu	4.25
Nankpawie	2.88
Nganduonu	3.83
Kroboi	3.65
Mean	**3.72**
Lsd	0.85
CV	13.46

Similarly, significant differences ($P<0.05$) were observed between communities within the Sissala West District. Processing losses varied between 5.67 and 8.46 kg/bag (Table 4.18). Jawia scored the highest for processing losses while Desime had the least.

Table 4.18: Processing losses in Sissala West District

Community	Processing loss (kg)
Jawia	8.46
Kusali	6.66
Duwie	6.40
Jefisi	4.52
Pulima	6.63
Desime	5.67
Sobelle	7.04
Kupulima	7.48
Bouti	6.66
Jitong	6.66
Mean	**6.62**
Lsd	1.02
CV	9.07

Overall, significant differences ($p<0.05$) were observed in processing losses between the means of Sissala East and West districts. Higher processing losses were found in Sissala West (6.62kg per bag of maize weighing 100kg) compared to Sissala East which recorded about 50% less loss (3.72kg per 100kg bag) (Table 4.19).

Table 4.19: Processing losses of Maize in the Sissala East and West

District	Processing loss (kg/100kg)
Sissala East	3.72±0.59
Sissala West	6.62±1.12
P value	0.001

Table 4.20: Quantitative losses in the Sissala East and Sissala West Districts

District	HL	shelling loss	THH	TY	QM/day	PL	PL (kg)/ha	TL (kg)	SL/ (%)	SL (kg)/ ha	Total loss (kg)/ha	% Total Loss	R.Y(bagS)/ha	R.Y (kg)/ ha	%loss for not using RP
SN	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
S East	213.26	207.9	3177.77	3598.93	100	3.72	118.21	0.679	40.32	1281.28	1706.84	47.19	37.5	4.03	3.546507
S West	205.32	197.41	3240	3642.73	88.89	6.62	214.49	0.637	39.56	1281.71	1694.28	46.76	37.5	2.86	3.38752
	0.258	0.402	0.106												

HL: Harvesting Loss, THH: Take Home Harvest, TY: Total Yield, QM: Quantity Milled, PL: Processing Loss, TL: Transport Loss, SL: Storage Loss, RY: Recommended Yield, RP: Recommended Practice

TY= SN1+2+3;   Total loss = SN1+2+3+6+8;   % Loss = [(SN 14-4)/SN4]*100

Table 4.21: Economic losses in GH₵ at different stages of the Postharvest maize value chain.

District	Harvesting loss	Shelling and winnowing loss	Processing loss	Storage loss	Total loss	Weevil infestation	Holes in grain
Sissala East	149.28	149	82.75	896.90	1287.461	20-40% less	20-40% less
Sissala West	143.72	136.65	150.14	187.20	1315.42	20-40% less	20-40% less

Price as at 30th August, 2012:

Wholesome grains weevil infested grains

100kg = GH₵ 70 a bag (100kg) =GH₵49

1kg = GH₵ 0.7

Table 4.20 depicts the economic effect of the losses in Table 4.19. It was observed that total loss of up to 47.19 % recorded in the Sissala East translated in to an amount of GH₵ 1,277.93 whilst 46.76 % recorded in the Sissala West represent GH₵ 617.97. The study revealed that losses as a result of weevil infestation and holes in grains resulted into 20-40% reduction in the market value of grains.

CHAPTER FIVE

DISCUSSION

5.1 FIELD SURVEY

From the survey, most of the farmers (84%) had household size of 6 or more people probably contributing to majority of the farmers (59%) not using hired labour. However, the household size was not enough to efficiently harvest maize on the farm and Compton (1992) stated that labour constraints could lead to delay or failure in the harvest, which could lead to significant postharvest losses.

It was observed that majority of the farmers (97%) harvested their maize cobs by hand. This practice leads to oversight and sometimes negligence. Maize cobs were also harvested 5-6 weeks after maturity, which implied the maize cobs overstayed on the farm, which leads to pest infestation. Infested pest stored increased losses in storage as found in quantitative assessment (Table 4.1) and it corroborates a report by Owusu (2007),which stated that insect pest substantially reduce yield of maize. Farmers are therefore advised to harvest their maize cobs early and if possible consider mechanized method of harvesting their maize.

Losses of maize have been reported to occur at different stages including at pre-harvest, for instance if fields have poor sanitation prior to harvest (Compton, 1992). It was therefore worrying when the survey showed that most of the farmers did not control weeds on their farmers. This practice could lead to poor field sanitation and haboured pest would cause farm infestation. Infested maize grains may be carried into storage and this could cause reduction in maize quality.

The responses showed that assembling of harvested maize was done by throwing of the maize cobs to central locations. There was high possibility of not gathering all the harvested maize cobs and could be a reason why high harvest losses were in Table 4.1. Again, harvested maize cobs were held longer on the field and this allowed for pest and mould infestation. Thompson (1996) reported that losses after harvest are a major source of human food loss and can cause scarcity and food insecurity.

Shelling is a method of stripping of the grains from cobs and most of the farmers (98%) reported less than 50% of maize loss when this was done. However, quantitative loss recorded showed higher levels of losses 9 (Table 4.4) and this is as a result of the inefficient shelling machine used by farmers.

The survey showed that most of the farmers did manual winnowing and challenges they encountered were high levels of chaff. This was as a result of inefficient winnowing done farmers and it reduced quality of stored maize grains as well as price of the grains. There were significant losses as corroborated by the quantitative loss assessment (Table 4.4). the losses of grains can be very low when winnowing is carefully done.

It was observed that farmers (93%) mostly stored their grans on thatch un-cemented floors and 97% of them did not treat or fumigate their grains storage. Storage of grains on un-cemented floors without fumigation allows pest infestation in grains which leads to postharvest losses. This confirms a report from Adegoke *et al.,* (1996) which indicated that poor maize storage conditions usually favour insect and fungi proliferation and lead to reduction in viability of seed stocks.

Grains should be dried to minimize grain damage and moisture levels lowered so as not to support mould growth during storage. Farmer (66%) interviewed, however did not solarize their grains during storage. Thus, pest attack of grains could be high as well as mould growth during storage and this also caused postharvest losses (Table 4.9).

The results showed that most of the farmers (98%) had milling experience for more than one year. Thus, they were expected to have more experience in milling which could consequently lead to reduced postharvest losses. However, the inefficient milling machines caused high levels of postharvest losses as shown in Table 4.17.

5.2: HARVESTING LOSS

The results showed that high levels of harvesting losses occurred in both Sissala West and East Districts. The losses that occurred ranged between 205 and 213 kg/ha. This represents at least 2 bags (200kg) of maize per hectare of maize field. Harvesting was done by hand by the family members and sometimes with help from friends. Cobs were harvested from the main plant and thrown to a central location where they were gathered. According to Mangan and Aldred (2007), during this process maize cobs were lost through stovers, as was observed in the study.

The study showed that harvesting losses were mainly due to un-harvested maize left either standing or lodging on the ground. Other losses were due to cobs left on the plant during harvesting. 85% of the farmers interviewed said they do not control weed before harvesting as such this impede the visibility of those harvesting and contribute to the losses. According to Vishwanatha (2005) the magnitude of losses at this segment is influenced by the time of harvesting, weather conditions, harvesting practices (especially referred to by hand and machine) and field exposure which affects subsequent storage quality of the grain. Also, 50% of the farmers interviewed throw their cobs to a central point during gathering and this practice also contribute to losses because cobs may fall at points that may not be seen and picked.

Pulima recorded the highest harvesting losses in the Sissala West District While Pieng had the highest in the East. During the study it was observed that in the Sissala East District Sakalu which had more available labour had the least harvesting losses compared to Pieng which had insufficient farm labour. On the other hand, in the Sissala West District Pulima which was nearer Tumu (the District Capital) had their labour force migrate to Tumu. This resulted in unavailable labour for harvesting in Pulima, which resulted in the high harvesting losses compared to Jawia (which was further away from Tumu). It was also realised that most of the farms had a lot of weeds which made harvesting difficult.

As regards the district means the study found the losses to be similar. This was not surprising as generally, similar harvesting cultures and challenges were found in each district.

Komen *et al*., (2008) reported that losses at harvest also depended on supervision and experience of the workers. This implied that proper supervisions could reduce post-harvest loses during harvesting.

Vishwanatha (2005) reported harvesting losses of 20.46 kg/ha which was lower than what was found in the two districts.

FASDEP report by MoFA (Ghana), in 2009 indicated that minimizing postharvest losses and maintaining high quality of produce is crucial for sustainable and profitable agriculture.

5.3: SHELLING AND WINNOWING

Threshing or shelling consists of separating the grains or the kernels in the case of maize from the portion of cob that holds them (Vishwanatha, 2005). Threshing constitutes a major operation in maize production. According to Komen *et al*., (2008) threshing has been considered for a long time as the last step in production, it must rather be approached as the first one in the post-production system after harvest because of its influence on subsequent processing and preservation of the product. The difficulty of kernels separation depends on the maize variety. According to Vishwanatha (2005), the losses in shelling operations are proportional to the moisture content of the grain and depend on the type of threshing method used. Compton (1992) reported that traditional shelling of maize, thus by hands, cause minimum losses. Use of flails to beat the grain off of the cobs can damage the kernel and the un-separated grain of the cob can be lost with the chaff. Modern equipment, not properly used can also cause damage to kernels. In case of hand shelling in maize, an average loss of grains is 1% as compared to machine shelling losses from 2% to 5% by considering broken kernels and grain lost with chaff into the soil (Vishwanatha, 2005). The share of losses during other threshing operations such as cleaning/ winnowing was estimated to be 8.75% by the author.

The findings of the study revealed that Tarsaw in the Sissala East District which had good and efficient shelling machines had the least shelling losses compared to Pieng. On the other hand, the absence of shelling machines in Jefisi in the Sissala West District contributed to the loss in the community.

In this study, the observed winnowing and shelling losses (198-204kg/ha) represent 2 maxi bags (100kg) that could have been available for food or income if not lost.

The observed losses were attributable to broken and un-threshed grain during mechanical shelling in the threshing machines. In contrast, hand threshing resulted in being left on the cobs (which usually found on upper part of cobs). The shelling and winnowing losses obtained in the two districts was mainly due to higher amount of broken and un-threshed grain losses as compared to low grain losses during manual shelling in traditional threshing methods by human labour in the study area.

Cleaning (winnowing) losses ranged between 195.21- 212.87kg/ha in traditional threshing methods and accounted for 10.3 to 11.5 per cent of the total post-harvest losses. This was due to cleaning/ winnowing operation in the un-mechanized traditional methods causing more grain losses in the chaffy materials as a result of blowing of air through it. The unacceptably high levels of losses recorded in the communities of the two districts indicate that more efficient shelling and winnowing methods need to be introduced to curtail and salvage these grains that could otherwise be sold to increase income and standard of living or be kept to increase the families' food buffer stock increasing food security.

5.4: TRANSPORT LOSSES

Vishwanatha (2005) reported that, losses due to transportation of the crop within and off-farm depends on type of transport facility used, efficiency of transport facility, quantity of crop transported, ground conditions and surface of the terrain. According to the author, transportation losses are generally small and ranging from 1 to 2%. According to World Food Programme (2012) 9.1metric ton was the quantity of loss that arose from transportation of maize alone in Ghana. The results obtained in this study however showed a negligible amount of losses as a result of transportation with values falling below 1kg/ha in the Sissala East and West Districts.

From the interview conducted, 62.5% of farmers used donkey and bullock carts and 63% of them transport their produce on paths. These contribute to losses though not so much.

Transportation is identified as an integral component of agricultural development towards ensuring efficient marketing of produce, access to inputs, reduction in storage losses, better pricing and the related increased production amongst others. Transportation is done by head loads by women and children (Osei *et al.*, 2010), carts pulled by donkeys and bullocks (World Bank 1996) and sometimes tractors by those who can afford it.

The transportation losses recorded in this study suggest that in the Sissala East District, Sakalu had higher transportation losses than the rest. This could be attributed to the nature of roads interspersed with rivers and streams. It was observed that the roads were poor. The donkey-carts used were not enough to prevent spillage.

5.5: STORAGE LOSSES

Excess harvested produce are stored for future use. Winter-Nelson and Aggrey-Fynn (2008) reported that, storage facilities not only offer the opportunity to reduce hunger but farmers are possibly able to improve farm incomes by storing crops and selling at premium prices when demand outstrips supply later in the post-harvest period.

It has been hypothesized that maize farmers would only store maize grains if and only if their storage benefits outweighed their costs or future prices rise enough to cover storage costs (Komen *et al.*, 2008).

The study showed that as much as 40% (40kg/100Kg maize) of stored maize is lost due to weevil attack in the 4 month storage period. According to MOFA (2010), this was higher than the per capital consumption in the Upper West region. The lost maize grains (40kg per every 100kg stored) during the 4 month storage was sufficient to meet the maize requirement of an adult in the region. The losses could be attributable to the fact that no protection against storage pests were usually carried out by farmers.

Though there was an increase in price over the storage period from GHC40 to GHC60 the increase in price did not compensate for the weight loss as well as the cost of storage during this period. These losses undermined stake holders' effort to attain food security as well as reducing rural poverty level of these farmers as the moneys lost on a bag could have been used to better their livelihood (MOFA, 2010).

5.5.1 WEEVIL INFESTATION AND HOLED GRAINS

Weevils, *Sitophillus* spp, are known storage pest of cereals especially maize (Owusu, 2007). Their infestation depends on the moisture level of grains as well as storage conditions. According to Hodges (2008) maize cobs are most often left on the field for about 2 to 3 weeks to dry to the recommended moisture levels of 15-18 percent. It is at this stage that insect pest such as weevil bore, feed and lay their eggs in the cobs (Hodges, 2008). These eggs then hatch in storage feeding on the grains, boring holes in to them. Weevil infestation has been associated with grains weight loss as they feed on grains turning them in to weightless powder.

During the study, 73.3% of the farmers alluded to the fact that they leave their cobs on the field over 15 days before shelling. It was observed that farmers left their maize for similar periods as corroborating the report of Komen *et al.*, (2008). According to the authors, maize was traditionally left to dry in the fields prior to harvesting through stoking for about 2-4 weeks and it is at this point that insect infest cobs. This probably accounted for the high levels of weevils and resultant holes in them. The study revealed that more than 40% of the maize by the 4th month of storage develops holes. This significantly reduced the quality leading to loss of income and food.

In Duwie the observed lower level of weevil infestation was found to have reflected in reduced number of holed grains.

The observed higher storage losses at Kulfuo and Desime could be traced to longer periods of maize remaining on the field when ready for harvest. This probably allowed on-field weevil attack which was carried into storage. It is important that the holding time on the field prior to harvest be reduced. The use of protectants would be very essential in storage.

5.6: PROCESSING LOSS

Processing of maize is an age- old practice that is very necessary if one wants to prepare a meal from it. Grinding is the most common form of processing carried out in the two districts. This is because Tuo Zaafi (T.Z) which is the indigenous food is prepared from maize flour and this is achieved by grinding the maize into powder. Traditionally, this practice use to be carried out on stones until the introduction of grinding mills. The grinding mill provides a fast and more efficient way of processing maize in to flour. 22% of the millers interviewed collect over 100 Kg of maize from the ground daily. This sums up to be high loss per a week.

The results obtained showed significant differences between the two districts. Sissala East recorded the least loss of 3.72kg whilst Sissala West recorded the highest processing loss of 6.62kg. The observed difference could be attributed to the fact that the operators at the West were inexperienced compared to those in the East. Until recently, the people of the West sent their grains to the East for processing. The operators at the East had developed their skills and as such were able to salvage spill over grains, hence, reduced the loss that could have occurred by almost half. According to Winter-Nelson and Aggrey-Fynn (2008), reduction of post-harvest losses and improvement in processing quality could enhance the maize systems.

5.7: PERCENTAGE TOTAL LOSS

Sissala West recorded the highest loss of 46.76% whilst Sissala East recorded 47.19% total losses. These values indicate that more than half of what was produce was lost from harvest to processing. Though this values fall in the range proposed by Winter-Nelson and Aggrey-Fynn, these values are unacceptable in the sense that the time and the resources wasted could have been used for other purpose.

Osei *et al*. (2010) reported the postharvest loss for maize in Ghana to be approximately 18 percent in the major season and 10 percent in the minor season. A draft report in 2008 on Maize Value Chain Study in Ghana: Enhancing Efficiency and Competitiveness reported that postharvest losses ranged from 5 – 70 % depending on the practices of each individual farmer in Ghana. In the present study, the results suggest that more than 50% of maize is lost between harvesting, shelling, winnowing, transportation, storage and milling. This is unacceptable, particularly in the face of high poverty levels and low income of farmers for the districts.

Qualitative losses results in reduced revenues due to loss of quality and market opportunity losses. It also resulted in the losses of nutritional value of grains and have resulted in adverse effects on the health of populations consuming unsafe food, notably those contaminated with aflatoxins.

In the light of the soaring prices and the risk of food shortages in the future, investments in reducing post-harvest losses are seen as a potentially cost-effective and environmentally sustainable option to enhance food security of especially vulnerable populations

CHAPTER SIX

6.1 CONCLUSION

Most of the farmers (84%) had household size of 6 or more people probably contributing to majority of the farmers (59%) not using hired labour. Harvesting of maize cobs was also done by hand which contributed to oversight and sometimes negligence. Maize cobs were also harvested 5-6 weeks after maturity which implied the maize cobs were kept longer on the farm which led to pest infestation. Harvested maize was assembled by throwing of the cobs to a central location which led to the high probability of not gathering all the harvested maize cobs. Again, harvested maize cobs were held longer on the field and this allowed for pest and mould infestation. Manual winnowing led to high levels of chaff from harvested grains. Storage of grains on un-cemented floors without fumigation allows pest infestation in grains which leads to postharvest losses

Postharvest losses of maize in Sissala East and West districts were generally high at different stages of the value chain. From the results obtained, it can be concluded that, total losses for the two districts about 50% of total production meaning, half of whatever is produce end up as losses. In quantity wise, nearly 20 bags of maize per hector was loss in the Sissala East and Sissala West districts. Avoidance of this loss implies that maize which is a staple in these districts could double the period of food availability.

Except for transportation loss which was negligible for Sissala East and West respectively, Harvesting loss, shelling and winnowing losses, processing and storage losses were very high accounting for more than 98% of the total losses occurred along the value chain. Shelling and winnowing loss was 2.12 bags (212.0kg) for Sissala East whilst almost 2 bags/ hector were recorded at the Sissala West. Processing loss recorded 118.84kg (1.18 bags) for Sissala East and 214.49kg (2.14 bags) for Sissala West. Storage losses alone accounted for about 70% of the total loss along the value chain of maize in the two Districts. Loss during storage increases by 10 percent with each month of storage. At the end of four months of storage, Sissala East recorded 1,281 kg/hector equivalent to 12.8 bags whilst Sissala West recorded 1,281.71 kg (12.8 bags). Whilst it was difficult to place monetary value or qualitative loss, it was observed that weevil infested and grains with holes received 20 to 40 percent less the prevailing market price for wholesome grains depending on the severity of infestation.

Economic losses as a result of quantitative losses varied at the different stages of the value chain with a total monetary loss of up Gh ₵ 1,277.93 per hector of land cultivated which when saved could improve the living standard of the farmers. Generally, Sissala West showed higher losses than the East. Maize losses in the district were at unacceptably high levels and all effort should be taken to reduce it.

6.2 RECOMMENDATIONS

Mechanization could be a solution to some of the harvesting losses incurred during harvesting. However, for mechanized harvesting to be possible, farmers need to invest in sowing to have crops sown in rows to enhance mechanize harvesting.

Farmers must solicit for programmes aimed at teaching them on proper maize storage and post-harvest handling to reduce food losses.

Storage interventional activities must be provided to farmers and traders to reduce maize grain losses for enhanced food security.

For the unacceptably high levels of losses recorded in the communities of the two districts, more efficient shelling and winnowing methods needs to be developed to curtail and salvage these grains that could otherwise be sold to increase income and standard of living or be kept to increase the families' food buffer stock increasing food security.

Further work on this topic could be carried out to confirm or reject the findings that came out from this work.

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APPENDICES

APPENDIX A: QUESTIONNAIRE FOR SURVEY

SECTION A: DEMOGRAPHIC BACKGROUND OF THE RESPONDENT

A1. Sex of the respondent 1. Male 2. Female

A2. Type of education of the respondent. 1. Formal 2. Informal

A3. Marital status 1. Single 2. Married 3. Divorce

A4. Household size, 1. 1-2 2. 3-5 3. 6 and above.

A5. How many years have you been in maize production? 1.Below one. 2. More than one

B. HARVESTING INFORMATION

B1. What method do you use during harvesting? 1. By hands 2.By machine. 3.By cutlass

B2. How many people harvest your maize? 1. 1-5, 2. 6-10, 3.11 and above.

B3. What stage of maturity do you harvest your maize? 1.1-4 weeks after maturity, 2. 5-6 weeks after maturity, 3. Over seven weeks after maturity.

B4. Do you control pest eg. weevils, before harvesting? 1. Yes 2. No. 3.Sometimes.

B5. Do you hire labour during harvesting? 1. Yes 2. No

C. GATHERING INFORMATION

C1. What method do you use to gather your maize after harvesting? 1. Throwing to a central point, 2. Carrying with basins to a central point. 3. Others.

C2. How many days do the cobs stay on the field before shelling? 1. 1-7 days, 2.8-14, 3.15 days and above.

C3.do you sort the cobs during gathering? 1. Yes 2. No 3. Others

D. SHELLING INFORMATION

D1. What method of shelling do you use? 1. Machine 2. Beating with sticks, 3.Hand shelling.

D2. What is the percentage of broken grains after shelling? 1.Below 50% 2. 50-60%, 3.Above 60%.

D3. What are the problems you encounter during shelling?

E. WINNOWING AND BAGGING

E1. What method do you use during winnowing of the maize after shelling? 1. Win, 2.Machine, 3. Others.

E2. What challenges do you encounter?

E3. What type of sack do you use to bag the grains? 1. Jute sack, 2. Fertilizer sack 3. Others

F. TRANSPORTATIONS INFORMATION

F1. What method do you use to transport your grains to the house? 1. Head pan/basins, 2. Donkey/bullock carts. 3. Bicycle/motorbike, 4 Cars/tractors, 5. Others

F2. What is the nature of the road on which you transport the grains? 1. Footpaths, 2.Rough roads, 3.Tarred road, 4.Others.

G. STORAGE INFORMATION

G1. What method do you use to store your grains? 1. Silos/Bans, 2.Thatch un-cemented floors, 3.Cemented floor. 4. Others.

G2. Do you threat/fumigate the grains before storage? 1. Yes 2. No 3.Others.

G3. Do you solarize the grains during storage? 1. Yes. 2. No.

D4. For how long do you store your grains? 1 Below 1 month, 2. 1-2 months, 3.Above 3 months

H. PROCESSING/MILLING INFORMATION

H1. How long have been milling maize? 1.Below one year, 2.One year 3.Above one year

H2. What type of mill do you use? 1. Local mill, 2. Engine/electricity powered mill, 3.Others.

H3.What quantity of grains do you mill a day. 1.Below one bag, 2.One bag, 3.Above one bag. 4

H4. What quantity of grains do you collect on the ground per each day? 1.Below one bag, 2.one bag, 3.Above one bag.

APPENDIX B: ANOVA TABLES

Sissala East Communities

Completely Randomized AOV for grains with holes

Source	DF	SS	MS	F	P
trt	9	1.43226	0.15914	3078.92	0.0000
Error	20	0.00103	0.00005		
Total	29	1.43329			

Grand Mean 6.4771   CV 0.11

Completely Randomized AOV for harv

Source	DF	SS	MS	F	P
trt	9	31648.9	3516.54	3516.54	0.0000
Error	20	20.0	1.00		
Total	29	31668.9			

Grand Mean 213.24   CV 0.47

Completely Randomized AOV for number of weevils

Source	DF	SS	MS	F	P
trt	9	1.28774	0.14308	270.72	0.0000
Error	20	0.01057	0.00053		
Total	29	1.29831			

Grand Mean 6.5518   CV 0.35

Completely Randomized AOV for processin

Source	DF	SS	MS	F	P
trt	9	5.1211	0.56901	2.28	0.0603
Error	20	5.0000	0.25000		
Total	29	10.1211			

Grand Mean 3.7160   CV 13.46

Completely Randomized AOV for shell

Source	DF	SS	MS	F	P
trt	9	18846.6	2094.06	3.73	0.0068
Error	20	11233.8	561.69		
Total	29	30080.4			

Grand Mean 207.91   CV 11.40

Completely Randomized AOV for transport

Source	DF	SS	MS	F	P
trt	9	0.93672	0.10408	1040.80	0.0000
Error	20	0.00200	0.00010		
Total	29	0.93872			

Grand Mean 0.6560   CV 1.52

Sissala West Communities

Completely Randomized AOV for grains with holes

Source	DF	SS	MS	F	P
trt	9	1.43226	0.15914	3078.92	0.0000
Error	20	0.00103	0.00005		
Total	29	1.43329			

Grand Mean 6.4771   CV 0.11

Completely Randomized AOV for harv

Source	DF	SS	MS	F	P
trt	9	40311.8	4479.09	1119.77	0.0000
Error	20	80.0	4.00		
Total	29	40391.8			

Grand Mean 205.32   CV 0.97

Completely Randomized AOV for number of weevils

Source	DF	SS	MS	F	P
trt	9	1.28774	0.14308	270.72	0.0000
Error	20	0.01057	0.00053		
Total	29	1.29831			

Grand Mean 6.5518   CV 0.35

Completely Randomized AOV for processin

Source	DF	SS	MS	F	P
trt	9	29.0021	3.22245	8.95	0.0000
Error	20	7.2000	0.36000		
Total	29	36.2021			

Grand Mean 6.6180   CV 9.07

Completely Randomized AOV for shell

Source	DF	SS	MS	F	P
trt	9	32998.5	3666.50	3666.50	0.0000
Error	20	20.0	1.00		
Total	29	33018.5			

Grand Mean 197.41   CV 0.51

Completely Randomized AOV for transport

Source	DF	SS	MS	F	P
trt	9	0.57829	0.06425	160.64	0.0000
Error	20	0.00800	0.00040		
Total	29	0.58629			

Grand Mean 0.6575   CV 3.04

SISSALA EAST AND SISSALA WEST DISTRICTS

Two-Sample T Tests for grains by District

District	N	Mean	SD	SE
east	30	20.954	1.2986	0.2371
west	30	21.948	1.0249	0.1871
Difference		-0.9942	1.1698	0.3020

T-Tests for Mean Difference
Null Hypothesis: difference = 0
Alternative Hyp: difference <> 0

					95% CI for Difference	
Method	**Variances**	**DF**	**T**	**P**	**Lower**	**Upper**
Pooled	Equal	58	-3.29	0.0017	-1.5988	-0.3896
Satterthwaite	Unequal	55.0	-3.29	0.0017	-1.5995	-0.3889

Homogeneity of Variances	DF	F	P
Folded F Test	29,29	1.61	0.1042

Cases Included 60   Missing Cases 0

Two-Sample T Tests for harv by District

District	N	Mean	SD	SE
east	30	213.24	33.046	6.0333
west	30	205.32	37.320	6.8138
Difference		7.9250	35.248	9.1010

T-Tests for Mean Difference
Null Hypothesis: difference = 0
Alternative Hyp: difference <> 0

					95% CI for Difference	
Method	**Variances**	**DF**	**T**	**P**	**Lower**	**Upper**
Pooled	Equal	58	0.87	0.3875	-10.293	26.143
Satterthwaite	Unequal	57.2	0.87	0.3875	-10.298	26.148

Homogeneity of Variances	DF	F	P
Folded F Test	29,29	1.28	0.2583

Cases Included 60   Missing Cases 0

Two-Sample T Tests for num by District

District	N	Mean	SD	SE
east	30	21.038	1.7654	0.3223
west	30	22.110	1.0568	0.1930
Difference		-1.0719	1.4549	0.3756

T-Tests for Mean Difference

Null Hypothesis: difference = 0
Alternative Hyp: difference <> 0

Method	Variances	DF	T	P	95% CI for Difference Lower	Upper
Pooled	Equal	58	-2.85	0.0060	-1.8238	-0.3200
Satterthwaite	Unequal	47.4	-2.85	0.0064	-1.8274	-0.3164

Homogeneity of Variances	DF	F	P
Folded F Test	29,29	2.79	0.0036

Cases Included 60   Missing Cases 0

Two-Sample T Tests for processin by District

District	N	Mean	SD	SE
east	30	3.7160	0.5908	0.1079
west	30	6.6180	1.1173	0.2040
Difference		-2.9020	0.8937	0.2307

T-Tests for Mean Difference

Null Hypothesis: difference = 0
Alternative Hyp: difference <> 0

Method	Variances	DF	T	P	95% CI for Difference Lower	Upper
Pooled	Equal	58	-12.58	0.0000	-3.3639	-2.4401
Satterthwaite	Unequal	44.0	-12.58	0.0000	-3.3670	-2.4370

Homogeneity of Variances	DF	F	P
Folded F Test	29,29	3.58	0.0005

Cases Included 60   Missing Cases 0

Two-Sample T Tests for shell by District

District	N	Mean	SD	SE
east	30	207.91	32.206	5.8801
west	30	197.41	33.743	6.1605
Difference		10.505	32.984	8.5163

T-Tests for Mean Difference

Null Hypothesis: difference = 0
Alternative Hyp: difference <> 0

Method	Variances	DF	T	P	95% CI for Difference Lower	Upper
Pooled	Equal	58	1.23	0.2224	-6.5422	27.552
Satterthwaite	Unequal	57.9	1.23	0.2224	-6.5430	27.553

Homogeneity of Variances	**DF**	**F**	**P**
Folded F Test	29,29	1.10	0.4018

Cases Included 60   Missing Cases 0

Two-Sample T Tests for transport by District

District	**N**	**Mean**	**SD**	**SE**
east	30	0.6560	0.1799	0.0328
west	30	0.6575	0.1422	0.0260
Difference		-1.50E-03	0.1622	0.0419

T-Tests for Mean Difference

Null Hypothesis: difference = 0

Alternative Hyp: difference <> 0

Method	**Variances**	**DF**	**T**	**P**	**95% CI for Difference Lower**	**Upper**
Pooled	Equal	58	-0.04	0.9715	-0.0853	0.0823
Satterthwaite	Unequal	55.1	-0.04	0.9715	-0.0854	0.0824

Homogeneity of Variances	**DF**	**F**	**P**
Folded F Test	29,29	1.60	0.1055

Cases Included 60   Missing Cases 0