KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY,

KUMASI

COLLEGE OF AGRICULTURE AND NATURAL RESOURCES

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DEPARTMENT OF HORTICULTURE

EVALUATION OF STORAGE FACILITIES FOR GROUNDNUT AND COWPEA IN THE ZABZUGU AND SABOBA DISTRICTS IN THE NORTHERN REGION OF GHANA

BY

MOHAMMED ABDUL-RAHIM

MARCH, 2014

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(BSC AGRICULTURE TECHNOLOGY)

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MARCH, 2014

DECLARATION

I hereby declare that this work is the result of my research work conducted. Apart from books, references and ideas or support from able people made leading to the production of this piece of work, no part or whole of this work is a production or duplication of any work presented to any institution/ university for any degree elsewhere. Works of authors used in the thesis have duly been acknowledged. I am solely responsible for all errors in this work.

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DEDICATION

This research is dedicated to God Almighty Allah for giving me life and seeing me through all my education, to my parents, Mr. and Mrs. Mohammed, to my lovely wife, Adam Rukaya and daughters, Nadrah Abdul-Rahim Timtooni and Husna Abdul-Rahim Timalma for their love, care and commitment that I should become a leader of good will. I love them so much and may the Almighty Allah grant them long life

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ABSTRACT

Three storage containers; clay pot, jute and polypropylene sacks were evaluated for postharvest losses of groundnut and cowpea in the Zabzugu and Saboba Districts in the Northern Region. The survey revealed that 60% of the respondents were males while female farmers represented 40%. The age range of respondents from 38 to 47 years (35%) formed the largest group in groundnut and cowpea farming. Out of the 100 respondents 35 farmers representing 35% had no formal education, and 32% who had only basic education. Only 18% and 14% had secondary and tertiary education respectively. The survey also revealed lack of labour as the main constraint to the cultivation of the pulses. It also showed that, a considerably high loss occurred at harvest through pod stripping, mechanical damage, self-explosion and pest attack. Jute sack, crib, clay pot, mud silo and polypropylene sack were used by farmers with mud silo used to store for long term. A storage experiment showed a significant ($p<0.05$) and severe pest damage of cowpea in jute sack as a result of very high level pest infestation. Similarly, pest damage on groundnut was significant ($p<0.05$) among the storage containers with high level detected in jute sack while low but significant equal counts were detected in clay pot and polypropylene sack. Amount of undamaged cowpea grains were significantly not different ($p>0.05$) in the storage containers but different ($p<0.05$) with groundnut whole grains count. The analysis showed that, temperature within the storage containers for which the pulses, groundnut and cowpea were stored varied slightly between the two pulses with temperature range of 30.17 – 31.27ºC with significant difference ($p<0.05$) recorded. But there was no significant difference ($p>0.05$) was recorded among the storage containers on moisture and humidity. The storing cowpea and groundnut for longer periods reduce their capacity to germinate. As seen in Figures 18 and 19, all the three

treatments decreased, with time, in germination percentage. This goes to support the claim by Ripp *et al* (1984) that the seeds must not be stored too long, since in course of time they lose the capacity to germinate. The cowpea weevil, the notorious cowpea post harvest pest and groundnut beetles, if not handled with prudent post-harvest management techniques, can destroy a granary full of cowpea and groundnut within four or five months, as in this study there was much loss of grain in the jute sack by the first month of storage Regardless of the poor performance of jute sack with reference to pest infestation and damage, it performed best in preserving and retaining the highest protein, fat, fibre and moisture level except carbohydrate and ash content of cowpea. No significant differences were recorded among the storage containers on nutritional composition of the groundnuts.

Early maturing, drought and pest resistance and good yielding varieties of groundnut and cowpea could help increase production and minimize losses.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

Legumes, which belong to the family *Leguminoseae* or *Fabaceae* are subsistence crops in tropical Africa with more than 30 species of grain legumes are grown across the tropics for food security, income, improved nutrition extraction of oil, feed and helping to maintain soil fertility (Abate *et al.*, 2012).

The most important grain legumes cultivated in Ghana are groundnut (*Arachis hypogaea* Linn) and cowpea (*Vigna unguiculata* (L.) Walp) with much concentration in the north. The need for money forces many farmers to sell pulses soon after harvest to traders who then take on the responsibilities of storing through the remaining period of the year. These farmers often store pulses before sale and can generally afford reasonable storage facilities and appropriate protective mechanisms (Brice *et al*., 1996; Golob *et al*., 1996; Gudrups *et al*., 1997).

Storage is a way or process by which agricultural produce or products are kept for future use, it is an interim and repeated phase during transit of agricultural produce from producers to processors and its products from processors to consumers (Thamaga-Chitja *et al*., 2004). Grains need to be stored from one harvest to the next in order to maintain its constant supply all year round and to preserve its quality until required for use.

A wide variety of containers used for seed or grain storage include pots, tins and baskets, but the most common is the jute bags/sacks or polypropylene sacks. With respect to groundnut, smallholder farmers store it in-shell in earthen pots, mud bins, jute sacks or plastic bags and bamboo baskets. Generally, postharvest losses are more with cowpea than with groundnut and explain why many producers tend to produce and also store less of cowpea than groundnut at the present level of storage technologies that are available to them.

The annual grain losses of over 50% (Abraham and Firdissa, 1991) in cereals and up to 100% (Boeke, 2002) in pulses have been reported, although the average stands at 20% (Youdeowi and Service, 1986; Philips and Throne, 2010).

The study of food security situation in the Northern parts of Ghana examined has shown how farmer households cope during food insecure periods as farmers cultivate purposely for household consumption and sell the surplus. Food is not available throughout the year in the farmer households. On the average, staple foods produced, last for about seven months.

There are many different kinds of traditional storage facilities in northern Ghana depending on the ethnic groups and the location. The lack of suitable storage facilities for cowpea and groundnut and absence of management technologies often force the smallholders to sell their produce immediately after harvest. Several investigations have been carried on methods of harvesting, moisture migration, physiochemical properties, nutritional composition and forms of storage of legumes. Researchers have demonstrated that there are several reasons that lead to postharvest losses which include time of harvest, methods used, amount of drying and the storage facilities for groundnut and cowpea.

However, comparisons of various storage facilities for legumes to determine the best facilities in order to maintain grain quality and quantity have not been much addressed. It is thus necessary for this study to show how various storage facilities affect both the quantity and quality of legumes in order to eliminate or reduce postharvest losses and increase their usable value.

It has been predicted that the World population will reach 9.1 billion by 2050 and this will require a 70% increase in food production and availability. Almost all of this growth will occur in less developed countries including Africa. However, Africa is suffering from 20-30% postharvest losses valued at 4 billion dollars annually.

The lack of appropriate storage structures and technologies has forced farmers to sell grains when prices are low. This implies that the storage sector needs to adopt appropriate structures and techniques that will help cut down postharvest losses. There is therefore the need to carry out this research in the area.

The main objective of this research is to identify and examine the performance of storage facilities for cowpea and groundnut for the reduction of postharvest losses in the Northern Region.

The specific objectives include:

- To identify the storage facilities available for legumes storage in the selected areas.
- To identify the problems encountered by smallholder farmers with the use of each storage facility.
- To determine the efficiency of each storage facility for groundnut and cowpea in the study area.

CHAPTER TWO

2.0 THE REVIEW OF LITERATURE

2.1 GENERAL INFORMATION ON LEGUMES

2.1.1 Groundnut

The peanut (*Arachis hypogaea*) better known worldwide as groundnut and to a lesser extent as earthnut, monkey-nut, and goobers is not a true nut but rather an annual legume much like the bean or a pea (Nwokolo, 1996). The plant originated from South America and it is unusual because it flowers above ground and pods containing one to five seeds are produced underground. The cultivated groundnut plant is an erect or prostrate, usually 15 to 60 cm tall. It is sparsely hairy and has a well-developed tap root system with many lateral roots. Roots are usually devoid of hairs, and a distinct epidermis. A unique characteristic of the groundnut plant is the nyctinastic movements of the leaflets. Flowers are borne on inflorescence located in the axils of the leaves. Flowers are never at the same node as vegetative branches, although very short internodes on some plants may make it appear that they are (Coffelt, 1989).

The groundnut is one of the world's most popular and universal crops, cultivated in more than 100 countries in all six continents (Nwokolo, 1996). All parts of the plant can be easily utilized. The vines with leaves provide excellent high protein hay for horses and ruminant. The shells or pods can be used as feed for livestock, burned for fuel, made into particle board, and many other uses. The peanut is grown mainly for human consumption of the seed. The seed can be used directly for food and crushing to produce oil and a high protein meal. Nearly two thirds of all groundnuts produced are crushed for oil (Bunting *et al*., 1985). Peanut oil can be used in cooking, lighting, fuel and as food constituent. The oil has better keeping quality than soybean, corn and safflower oils and is a good source of vitamin E. The multiple uses of the peanut make it an excellent cash crop for domestic market as well as foreign trade.

2.1.2 Cowpea

Cowpea (*Vigna unguiculata* L. Walp.), an annual legume, is also commonly referred to as southern pea, blackeye pea, Crowder pea, lubia, niebe, coupe or frijole. Cowpea originated in Africa and is widely grown in Africa, Latin America and South-East Asia as well as in the Southern United States. It is chiefly used as a grain crop, for animal fodder, or as a vegetable. The history of cowpea dates to ancient West African cereal farming, 5 to 6 thousand years ago, where it was closely associated with the cultivation of sorghum and pearl millet (Davis *et al*., 1991). It is a subsistence crop, often intercropped with sorghum, maize and pearl millet. The grain provides valuable protein and the leaves are used as a nutritious vegetable. (IPM CRSP, 2000). It serves as the major source of protein in the absence of sufficient animal protein for the population. The nutritional value of cowpea thus lies in its protein content which is nearly double that of cereals (FAO, 1970).

Millions of African farmers grow cowpea; some two hundred million Africans consume cowpea, many, maybe a majority of these farmers are women. Cowpea grain, nutritious and inexpensive, serves as a source of cheap protein for both rural and urban consumers. The cowpea grain contains about 25 percent protein and 64 percent carbohydrate (Bressani, 1985). Even the goats and the cattle benefit from cowpea, this genuinely African crop, for the hay left over after the grain is harvested as a high-value nutritious forage (ABIOTECH, 2002).

Cowpea is an indigenous crop that has evolved from the native wild types and its genetic diversity is greater than that of any other crop in the dry African savannah (IFAD, 2000). In semi-arid zones of West and Central Africa, farmers traditionally cultivate two main types of cowpea: early maturing varieties grown for grain and late maturing varieties that are grown for fodder production (Inaizumi *et al*., 1999).

There are three recognized specific groups of cultivated cowpeas. Two of these are grown in Australia with most varieties grown for grain, forage and green manure. The other type, the yard-long bean, is a minor vegetable (Imrie, 2000)

2.2 IMPORTANCE OF LEGUMES

2.2.1 Groundnut

The seed has several uses including as a whole seed or processed to make groundnut butter, oil and other products. The most common method of preparation for human consumption of whole seeds is dry roasting the seed (Coffelt, 1989). The vast food preparations incorporating groundnut to improve the protein level has helped in no small way in reducing malnutrition in the developing countries. The special taste and flavour of foods containing groundnut is important in the acceptance of these food preparations (Asibuo *et al*., 2008). The lack of colour, bland flavour and low concentration of flatulence-producing carbohydrates in peanuts make it a more desirable choice of food supplements than other plant proteins (Conkerton and Ory, 1976). The seeds of most groundnut cultivars contain about 50 % oil (Worthington and Hammons, 1971), and therefore the quality of the oil and groundnut products depend to a large extent on the oil fraction. The oil content of groundnut differs in quantity, the relative proportion of fatty acids, geographical location, seasons and growing conditions (Holaday and Pearson, 1974; Young *et al*., 1974; Brown *et al*., 1975).

2.2.2 Cowpea

Cowpea is the most economically important indigenous African legume crop. (Langyintuo *et al*., 2003). Cowpeas are of vital importance to the livelihood of several millions of people in West and Central Africa. Rural families that make up the larger part of the population of these regions derive from its production, food, animal feed, alongside cash income.

Food habits in West and Central Africa are mainly based on tuber crops (cassava, yam) and cereal (maize, rice, millet). Although they have a high nutritional value, grain legumes are a minor component of food diet. That is the reason why tentative efforts have been made to introduce soybean in African food habits and farmer activities, but with little success because of its undesirable taste and cooking difficulty. Unlike soybean, cowpea is appreciated and different traditional African meals and seasonings are prepared from cowpea, among them homemade weaning food (Lambeth, 2002).

Cowpea is a most versatile African crop: it feeds people, their livestock and the next crop. In the Americas, also known as "black-eyed peas", cowpea is a high protein food, and very popular in West Africa. The plant itself can be dried and stored until needed as fodder for livestock. As a nitrogen-fixing legume, cowpea improves soil fertility, and consequently helps to increase the yields of cereal crops when grown in rotation.

2.3 NUTRITIONAL COMPOSITION OF GROUNDNUT

The composition of food is fundamental factor for theoretical and applied investigations in food science and technology. This is often the basis for establishing the nutritional value and overall acceptance of the food from consumers' standpoint (Wilson, 1979).

Abbey *et al*. (2001) indicated that groundnut has the following proximate composition: 26% protein, 10% carbohydrate, 6% moisture, 44% lipid, 50% Calcium (mg/100g), 2% Iron (mg/100g) and 2344Kj Energy. USDA (2009) gave the proximate composition of groundnut nutrient value for standard Reference. The information is shown in the table below:

Table 2.1: Nutritional Value of groundnut of all types per 100g

Principle	Nutrient Value	Percentage Of RDA
Energy	567kcal	29
Carbohydrate	16.13g	12
Protein	25.80g	46
Total fat	29.24g	16.5
Cholesterol	0mg	0
Dietary fibre	8.5g	22

Source: US Department of Agriculture, Agricultural Research Service. 2009. USDA.

Thomas, (2003) also indicated that, nutrient content of cowpea is about 23% protein, 1.3% Fat, 1.8% Fibre, 67% Carbohydrate and 8-9% Water content. It further stated that, cowpea can be stored for short term at moisture content of 12% or less and 8-9% for long term storage. According to Bressani (1985), nutrient content of mature cowpea seed (average of eight varieties) is shown as follows: protein- 24.8%, Fat- 1.9%, Fibre- 6.3%, Carbohydrate – 63.6%, Thiamine – 0.00074%, Riboflavin – 0.00042% and Niacin – 0.00281%.

2.4 PRODUCTION TRENDS

2.4.1 Groundnut

Groundnut is the most widely grown major legume worldwide cultivated in 118 countries and occupies more than 22.6 million ha that account for about 36.4 million MT, with average yield of about 1600 kg per ha. World groundnut production has shown a steady pace over the years whereas the area expansion grew at a slower rate and somewhat levelled off since the 1990s. Average rate of growths for area, yield and production are estimated at 1%, 1%, and 2.9% respectively. India has the largest area but China is the highest producer because of better yields per unit area (FAOSTAT 2010).

An estimated 18.3 million households (86.6 million people) grow groundnut in South Saharan Africa (SSA) on more than 9 million ha (40% of world total) with average yield of about 1000 kg per ha. Top ten producing countries out of the 44 in SSA are Nigeria, Sudan, Senegal, Ghana, Chad, Democratic Republic of Congo (DRC), Tanzania, Guinea, Mali and Burkina Faso. The average productivity grew by about 1.3% whereas faster growth rates have been registered in Cameroon (5.6%) and

Guinea (4.8%). Sierra Leone, Tanzania, Ghana, and Nigeria registered growth rates in area ranging between 9.8% and 6.6% whereas annual increases in production of 9.7% to 8.3% have been registered in Niger, Tanzania, Sierra Leone, Nigeria and Guinea. The South Asia (SA) region occupies more than 7 million ha (31% of world total); nearly 83% of this is in India. The average area in SA declined by about 1.1% per annum whereas yield and production increased by about 1% and 0.2% respectively. The fastest growth in yield (2.2%) has been registered for Myanmar. About 6.7 million households (26.6 million people) grow groundnut in SA. It has been projected that production in SSA will jump from about 10.4 million MT in 2010 to nearly 13 million MT in 2020, with Nigeria, Sudan and Senegal as largest producers. In a similar fashion, there would be demand for nearly 12 million MT in 2020, compared with about 10 million MT in 2010. Estimated production and demand for SA in 2020 are about 9.8 million MT and 11 million MT respectively (FAOSTAT 2010).

Annual groundnut import trade values for SSA and SA are estimated at about US$ 54 million and US$ 5 million respectively. By contrast, SSA export stands at US$ 42 million whereas that for SA is nearly US$ 184 million. Projections show that SSA would have net surplus trade of nearly 957,000 MT by 2020. Senegal, followed by South Africa, Sudan, Cameroon, Ghana, Gambia, Nigeria and Ivory Coast would be by far the largest exporters. By contrast, all SA countries would continue to have net deficit trade of about 951,000 MT by 2020 (FAOSTAT, 2010).

2.4.2 Cowpea

Cowpea is grown in 45 countries across the world. An estimated 14.5 million ha of land is planted to cowpea each year worldwide; total annual production is approximately 6.2 million MT. The current average yield is estimated at about 454 kg per ha. This is the lowest among the six tropical legumes; this crop is mainly grown under subsistence conditions where the environment is harsh because of frequent droughts and excessive heat, and the soils are marginal. World cowpea area, yield and production grew at an annual rate of 4.5%, 1.4% and 5.9% respectively (Abate *et al.*, 2012). Cowpea is primarily an African crop. Nine of the top ten cowpea-producing countries are found in SSA. Approximately 38 million households (194 million people) grow cowpea in this region. SSA accounts for about 84% and 83.4% of the world's area and production respectively. Yields are comparable to the world average of 454 kg per ha. Cultivated area grew at a much faster pace than productivity, especially starting in the mid-1980s. The rate of growth (ROG) for total area was 4.4% whereas the yield and production grew at the rate of 1.5% and 5.9%, respectively. Nigeria and Niger each cultivate well over 4 million ha and account for more than 45% and nearly 15% respectively, of the total world production. Burkina Faso stands a distant third, with 6.1% of the world's total production. Other important producers in SSA include Cameroon, Ghana, Benin, Mali, Uganda, Kenya, Senegal, Tanzania, and DRC. Malawi, Sudan, Mauritania, South Africa, Madagascar, Swaziland, Guinea-Bissau and Zimbabwe also grow cowpea. The average area under cowpea in the SSA region is estimated at a little more than 0.27 ha per rural household. More than 38 million households (194 million people) grow cowpea each year in the SSA region (FAOSTAT, 2010).

The total area planted to cowpea in SA is about 159,000 ha; with annual production of 154,000 MT. Myanmar and Sri Lanka are the only two countries that produce significant amounts of cowpea in the SA region. Cowpea area and production in Sri Lanka have declined at the rate of approximately 5% and 4.4% respectively. By contrast, Myanmar has registered annual growth rates of more than 12% in area and nearly 15.9% in production over the 20 years between 1985-87 and 2005-07. The rate of growth (ROG) for yield in this country for the same period was 3.9% while Sri Lanka registered only 1% ROG. The total area and production of cowpea in Myanmar are not very large but the growth patterns (especially starting in the early 1990s) show an ideal situation whereby increases in production are obtained more from the increases in productivity rather than area expansion. Cowpea yields in this country showed consistent and significant increases starting in the early 1990s. The current average yield for Myanmar is over 966 kg per ha (FAOSTAT, 2010).

2.5 ENVIRONMENT REQUIREMENTS

2.5.1 Climate

Groundnut is essentially a tropical plant and requires a long and warm growing season. The favourable climate for groundnut is a well-distributed rainfall of at least 500 mm during the crop-growing season, and with abundance of sunshine and relatively warm temperature. Temperature in the range of 25 to 30ºC is optimum for plant development (Weiss 2000).

Once established, groundnut is drought tolerant, and to some extent it also tolerates flooding. A rainfall of 500 to 1000 mm will allow commercial production, although crop can be produced on as little as 300 to 400 mm of rainfall. Groundnut thrives best in well-drained sandy loam soils, as light soil helps in easy penetration of pegs and their development and their harvesting. The productivity of groundnut is higher in soils with pH between 6.0 - 6.5(Weiss 2000).

Cowpea is a warm-season crop well adapted to many areas of the humid tropics and temperate zones. It tolerates heat and dry conditions, but is intolerant of frost. Germination is rapid at temperatures above 65ºF; colder temperatures slow germination. Cowpeas are grown under both irrigated and non-irrigated regimes. The crop responds positively to irrigation but will also produce well under dry land conditions. Cowpea is more drought resistant than common bean. Drought resistance is one reason that cowpea is such an important crop in many underdeveloped parts of the world. If irrigation is used, more vegetative growth and some delay in maturity may result. Application rates should insure that the crop is not overwatered, especially in more northern latitudes, as this will suppress growth by lowering soil temperatures. The most critical moisture requiring period is just prior to and during bloom (Davis *et al.*, 1991).

2.5.2 Soil

Cowpea performs well on a wide variety of soils and soil conditions, but performs best on well-drained sandy loams or sandy soils where soil pH is in the range of 5.5 to 6.5 (Davis *et al.,* 1991). Soil for peanut production should be a light-coloured, light textured with good drainage, and moderately low amounts of organic matter. Such soil is preferred since it is usually loose and friable, permitting easier penetration of roots and pegs, better percolation of rainfall, and easier harvesting. Light-coloured soils reduce staining of pods which ensures greater eye appeal when the crop is used for unshelled nuts. Well-drained soils provide proper aeration for the roots and nitrifying bacteria that are necessary for proper mineral nutrition of the plant. Medium to heavy soils or those with high clay content should also be avoided due to excessive loss of pods when harvesting peanuts (Weiss, 1983).

Organic matter should be maintained at a level of 1 to 2% to improve water-holding capacity of the soil and supply plant nutrients. Peanut grows best in slightly acidic soils with a pH of 6.0 to 6.5, but a range of 5.5 to 7.0 is acceptable. Saline soils are not suitable since peanut has a very low salt tolerance (Weiss, 1983).

2.6 HARVESTING

The optimum time for harvesting is when most pods have a veined surface, seed coats are coloured, and 75% of pods show darkening on the inner surface of the hull. However, peanut does not reach this stage in Minnesota, so immature pods are removed in the threshing, drying, and cleaning operations. Harvesting in northern areas should begin after the first killing frost if soil moisture is at a level suitable for cultivation since wet soil sticks to pods (Putnam *et al.*, 1991).

Harvesting usually starts with clipping or coultering. Rotary mowers remove up to half of the top growth when plant growth is too great for efficient harvesting. A killing frost may make this step unnecessary, since most of the leaves may have already fallen off the plant. Varieties with prostrate growth may overlap between rows and a coulter makes the vertical cut between rows. The next operation frequently uses a digger-shaker-windrower. Dig deep enough to prevent cutting pegs. Windrow-inverting attachments orient plants as they leave the shaker so pods are primarily on the top of windrows to permit more air circulation and exposure to sunlight for a shorter drying time (Putnam *et al.*, 1991).

Windrowed peanut may be combined-harvested wet (35 to 50% moisture), semidry (18 to 25%), or dry (8 to 10%). These peanuts may reach the semidry condition (seeds rattle in pods) 1 to 3 days after digging. Drying in the windrow to a moisture level of 8 to 10% requires 5 to 10 days of good drying weather. However, peanut remaining in windrows for several days is more susceptible to weather damage than when freshly dug. Combining wet (green) or preferably semidry peanut, followed by artificial drying, may result in better quality nuts. Adjust combines regularly to give more picking action when vines are tough, and reduce picking action when vines are dry, to obtain good picking efficiency and minimize mechanical damage to peanut hulls.

White and Roy (1982) reported that, an once-over harvester used for peanut variety Valencia gave 50% more total harvested yield than conventional digging and combining methods. Percentage of loose, shelled seeds was reduced from 10 to 1%, and subsequent germination improved from 45 to 86%. An once-over harvester developed in Canada had less than 3% loss and 1% mechanical damage while maintaining high viability of seed. Certain cultural practices were recommended to make once-over harvesting easier and more efficient than use of a digger-shaker-windrower.

The harvesting process of cowpea will be determined by cultivar choice. Ranking types are harvested in windrows and threshed while determined types are harvested by pulling and threshing the same day. Hand harvesting is recommended for small areas. (Rij, 1999). If the harvest is mechanized and combine is used, a low drum speed is required to avoid splitting and cracking of seeds or grains. Cowpea can be threshed manually by beating the plants or bagged pods with sticks once they are dry enough. Whatever the method is used, cowpea seed can be easily injured if threshed too roughly or when too dry. Injured seed when planted will produce weak, stunted plants and other abnormalities.

For the cowpea seed market, quality of seed is important, so care in harvest and postharvest handling may be important to avoid cracked or split seed. The grain can be stored short term at around 12% moisture or less, with 8 to 9% recommended for long term storage. Since the pods are relatively long, some will touch the ground or be close to it, making it important to run the grain table close to the ground. Some buyers will want the seed cleaned and bagged, while others will take the grain in bulk form and clean it themselves. For some markets, the cowpeas must be harvested at higher moisture, such as 18%, and trucked directly from the field to the processor (Rij, 1999).

2.7 DRYING AND STORAGE

The two most important operations in handling groundnut after harvest are cleaning and drying to safe moisture content (5 to 10%). Pods should be kept dry and protected against infestation from insects or rodents, as well as from loss of natural colour and flavour, and prevention of the development of off-flavours and rancidity. Artificial drying of wet or semi dry groundnut should start immediately after combining to prevent mould growth and aflatoxin formation. Presence of aflatoxin is a concern in groundnut production states with warmer climates. However, cool September and October temperatures in Minnesota should minimize this problem when proper drying and storage practices are followed (Davis, *et al.*, 1991).

Unheated air may be used for drying when relative humidity is below 65%. Besides removal of water, drying causes physical and biochemical changes that can be harmful or beneficial to flavour and quality. Groundnut seed should not be heated above 95°F to avoid off-flavours, and the drying rate should not exceed 0.5% per hour. Safe storage of groundnut requires an atmosphere with low relative humidity (60 to 70%). Robinson (1984) reported that groundnut maintains moisture content of about 7% at a relative humidity of 65 to 70%.

Groundnut saved for seed must be protected from insect pests and rodents as well as from high temperatures and high relative humidity (70%). Groundnut is usually stored in the form of unshelled nuts. Seven to eight month storage is usually required for groundnut used as seed, and those intended for food uses can be stored until the start of next harvesting season. Seed harvested from Minnesota research plots usually tested over 90% germination. Seed retained viability longer when stored in the pod than when shelled. Seed stored with 5% moisture content lost viability more slowly than seed with 8% moisture, but relative humidity must be less than 50% to maintain such a low moisture level. In a storage trial in Minnesota, shelled seed maintained viability for three years when kept frozen (32°F) and for one year in a heated (68°F) office (Putnam *et al.,* 1991).

Most seed sold to growers is treated with fungicides to prevent damage from seed-rotting and damping-off fungi in the soil. Germination and emergence of hand-shelled seed was also improved when treated with fungicides.

Harvested green cowpeas will "heat" resulting in spoilage unless kept cool. Post-harvest, provide shade and adequate ventilation is necessary on the way to the cooler. Cowpeas cooled below 45ºF may show chilling injury. Dry cowpea seed is cleaned, graded, fumigated and packed in small plastic bags for sale to consumers (Davis, *et al.*, 1991).

Cowpea is considered nutritious with a protein content of about 23%, fat content of 1.3%, fibre content of 1.8%, carbohydrate content of 67% and water content of 8-9%. As in most legumes, the amino acid profile complements cereal grains (Thomas, 2003).

2.8 POSTHARVEST LOSSES

Losses in food crops, occurring during harvesting, threshing, drying, storage, and transportation etc. have been estimated to be between 30 and 40% of all food crops in developing countries. If postharvest losses are reduced, the world supply can be increased by 30-40 % without cultivating additional hectares of land or increasing any additional expenditure on seed, fertilizer, irrigation and plant protection measure to grow the crop. To this end, post-production losses and deterioration of food quality are areas of major concern in many developing countries of the world, Backhop (1980).

Harries and Lindbled (1978), defined losses as any change in the ability, edibility, wholesomeness or quality of food that prevents it from being consumed by people. Food losses may be direct or indirect. The direct loss is the disappearance of food by spillage, or consumption by insects, rodents and birds. The indirect loss is the lowering of quality to the point where people refuse to eat it. They also identified three periods of time, pre-harvest, harvest and post-harvest, during which food may be lost and stated that each period has its own characteristic problems and means of overcoming these problems. Pre-harvest losses are those, which occur before the process of harvesting begins, for example, losses in a growing crop due to insects, weeds and rusts. Harvest losses occur between the onset and completion of the process of harvesting, for example, losses due to shattering during harvesting of grain.

According to Hall (1980), Postharvest loss is any part of the harvested produce that is desired but failed to reach its point of utilization, or if utilized fails to yield its fall value. These postharvest losses occur in the form of weight loss (quantity) quality, nutritional, economic (market value) and loss of seed viability.

Grains and legumes may be lost in the pre-harvest, harvest and postharvest stages. Pre-harvest losses occur before the process of harvesting begins, and may be due to insects, weeds and rusts. Harvest losses occur between the beginning and completion of harvesting, and are primarily caused by losses due to shattering. Postharvest losses occur between harvest and the moment of human consumption. They include on-farm losses, such as when grain is threshed, winnowed and dried, as well as losses along the chain during transportation, storage and processing. Important in many developing countries, particularly in Africa, are on-farm losses during storage, when the grain is being stored for auto-consumption or while the farmer awaits a selling opportunity or a rise in prices (Hall, 1980).

Reducing postharvest losses for fresh produce, reported to be in the 30 to 50% range, has been demonstrated to be an important part of sustainable agricultural development efforts meant to increase food availability (Kader, 2005) but during the past thirty years less than 5% of the funding provided for horticultural development efforts has gone toward postharvest areas of concern, while more than 95% has gone toward trying to increase production (Kader and Rolle, 2004). The problems associated with postharvest losses of crops are many and varied. Losses may occur for two main reasons; during harvesting, handling, processing and transport grain may be scattered, dispersed or crushed. Alternatively, the grain may be subject to bio-deterioration. Postharvest losses due to bio-deterioration may start as the crop reaches physiological maturity, i.e. when grain moisture contents reach 20 - 30% and the crop is close to harvest. It is at this stage, while the crop is still standing in the field, that storage pests may make their first attack and when unseasonal rains can dampen the crop resulting in some mould growth. A key issue is the weather conditions at the time of harvest. All small-scale African farmers rely on sun drying to ensure that their crop is sufficiently dry for storage. If weather conditions are too cloudy, humid or even wet then the crop will not be dried sufficiently and losses will be high. Climate at the time a crop should be drying is key to understanding the potential losses of durable crops. However, successful drying alone is not a remedy against all postharvest losses since insects, rodents and birds may attack well dried grain in the field before harvest and/or invade drying cribs or stores after harvest (Hodges, 2006).

2.9 SOME COMMON INSECT PESTS OF STORED GRAIN

Pulses are attacked by a family of primary pests, the Bruchidae or bruchids. There are three common species: *Acanthoscelides obtectus*, the bean beetle, *Zabrotes subfasciatus,* the bean weevil and *Callosobruchus maculatus*, the cowpea beetle. The first two mostly attack beans, particularly of the Phaseolus family, such as common beans, haricot beans and lima beans, whereas Callosobruchus attacks small grain pulses such as lentils, grams and cowpeas (FAO, 2009).

2.10 PESTS AND DISEASES DAMAGE OF COWPEA AND GROUNDNUT

2.10.1 Cowpea

Most cowpea farmers in sub-Saharan Africa are confronted with low yields, caused by insect pests and diseases. Cowpeas are susceptible to a wide range of pests and pathogens (e.g., insects, bacteria, viruses, fungi and weed) that attack the crop at all stages of growth. Some 40 species of fungi are cowpea pathogens. In the Northern Ghana, *Maruca vitrata* damage is most significant in areas where maize is a major component of the farming system. In areas where sorghum and millet are cropped extensively, pod-sucking bugs occur much earlier in cowpea pod development. Cowpea weevils, *Callosobruchus maculatus* (Fabricius) and bruchids are major pests on cowpea in Africa and attack dried cowpeas and other related stored seeds. They are mainly found on cowpea grains in storage and may be the main constraint to increased cowpea production (Bediako *et al*., 2009).

2.10.2 Groundnut

The losses during storage are mainly due to drying loss and through damage by rodents and pests. the peanut growing areas and may produce aflatoxin in peanuts when conditions are favourable to fungal growth (Bediako *et al*., 2009).

Groundnut is prone to attack by pests such as foliar fungal diseases, leaf spot, rust, collar rot, stem rot and dry root rot. With regards to insect pests, a wide range of pests like leaf miner, white grub, jassids, thrips, aphids, red hairy caterpillar and termite cause serious damage Damage also occurs due to dampness which develops the moulds, leading to contamination with Aflatoxin. Peanuts are particularly susceptible to contamination during growth and storage. Poor storage of peanuts can lead to an infection by the mould fungus *Aspergillus flavus*, releasing the toxic and highly carcinogenic substance aflatoxin. The aflatoxin-producing moulds exist throughout to groundnut crop (Basu, 1995).

2.11 CONTROLLING INSECTS IN STORED PULSES

For convenience, control methods can be divided into two groups: non-chemical and chemical. Non-chemical methods of insect control are broadly considered to include any method that does not involve the use of conventional insecticides. They include traditional techniques employed by farmers and their forebears and may also involve the use of chemical substances other than the conventional insecticides specifically recommended for application to grains. Many farmers use conventional chemical insecticides. Several chemicals are available which are approved for use as grain protectants by international organizations, such as the FAO. For application to grain, these chemicals are available as dusts or liquids sold under various brand names. It is absolutely essential to follow the application instructions on the container to ensure that the chemical is used safely and effectively (FAO, 2009).

2.11.1 Control of Cowpea Storage Pests and Disease

2.11.1.1 Use of good storage structures

The following structures are recommended for cowpea storage:

A. Earthenware

These are adapted for the storage of un-threshed cowpea. There are two types of rombus namely,

i. Grass rombus

The grass rombus is usually a temporary storage structure often used where mud is scarce. The structure is cheap and easy to build and permits rapid drying of stored cowpea. Its use is however restricted to areas with low rainfall.

ii. Mud rombus

The mud rhombus is built from clay used with straw to strengthen it. It is rounded or oval in shape and usually supported at the base with large stones. The wall of the rombus should be smooth with no cracks or crevices where insects can take refuge. Rombus may require periodic application of insecticide as they are not completely air-tight. The capacity ranges from 1.0-5.0 metric tonnes of grains (Adejumo and Raji, 2007).

B. Steel drums/Tins

Cowpea storage in steel drums and tins is a form of hermetic storage where the storage structures are air-tight. Since air (oxygen) is essential for the development and multiplication of stored produce insect pests, the air-tight container deprives the pests of air leading to their death by asphyxiation. The use of steel drums/tins is suitable for storage of threshed cowpea. The method is not hazardous since no chemical treatment is required (Adejumo and Raji, 2007).

C. Polythene bags

This is another form of hermetic storage, with the polythene bags designed to be air-tight. They are suitable for the storage of threshed cowpea over a long period. The use of cotton liner enhances the air-tightness. The method like other hermetic storage structures may require no chemicals (Adejumo and Raji, 2007).

D. Silos

Butyl rubbers or aluminium silos may be used. These are suitable for large scale storage of threshed cowpea and are recommended mainly for companies, ministries and co-operatives. Cowpea stored in silos may be fumigated every three months starting from two or three weeks of storage (Adejumo and Raji, 2007).

E. Pit Method

Cowpea can be stored in pits usually measuring 4x4x2m. The floor of the pit is cemented to prevent moisture from entering the pit. This method is suitable for storage of threshed cowpea but is however restricted to areas with low annual rainfall. The pit is normally covered with polythene sheet or mat and then covered with soil. The major problem with this device is usually in the wall lining, which may be eaten up by termite, and the structure is not rodent proof. Maintenance is usually done by cleaning and replacement of the wall lining. Maintenance cost is dependent on the locality and availability of material (Adejumo and Raji, 2007), but it is generally affordable to the rural poor farmers.

2.11.1.2 Use of conventional insecticides

Where grains are already infested by insect pests, it often becomes necessary to apply insecticides for their control. The recommended insecticides for storage of cowpea include:

A. Actellic 25 EC

The application of Actellic 25 E.C to cowpea is recommended where there is bulk storage over a long period. Application of Actellic 25 E.C should be at 10-20 ml in 1-2 litres of water per 100 kg cowpea using a suitable nozzle as the grain is fed into the store. It is essential to cover the store as the fumigant action of Actellic will help in the control of insects in the store by making the store air-tight for the gas to penetrate and remain in the commodity for long enough to kill all stages of the insects present in or amongst the grains (Adejumo and Raji, 2007).

B. Actellic 2% dust

Apply 25-50 g dust to a layer of 50-100 kg of unthreshed cowpea. Application of Actellic dust on threshed cowpea has to be at about 10-12 ppm rate which is the FAO recommendation. Dusts usually work at higher dosage to control cowpea bruchids but make the grains unsafe for human consumption. The application should be repeated after 2-3 months of initial treatment (Adejumo and Raji, 2007).

C. Phostoxin (Aluminium phosphide) tablet

This should be applied at the rate of 1 tablet per 100 kg cowpea in an air-tight container. Place the tablet in a paper envelops or wrap securely in tissue paper. After four days, remove and bury the paper and its contents. Phostoxin tablets may be used at the rate of 1-3 tablets per ton. The treatment should be repeated after 4-6 months (Adejumo and Raji, 2007).

Precautions

- The fumigated grains should be maintained in insect proof containers to prevent re-infestation.
- All fumigants must be handled with care because of the hazards to man if inhaled.
- Application should be away from living houses and domestic animals.

2.11.1.3 Use of plant Materials

Several plant materials have been found to be effective in controlling insect pests of stored cowpea. Neem kernel powder applied at 5-10 g per 100 g seed has been found to be effective in protecting stored cowpea from insect attack (Sowunmi and Akinnusi, 1983; Oparaeke *et al*., 1998). Similarly, powders of Eucalyptus, guava, and lemon grass leaves as well as orange and grape peels applied at similar rates can adequately control the insect pests on stored produce. *Sesamum indicum, Capsicum frutescens* (L.), *Ocimum basilicum* and ash have been used by farmers to control stored cowpea insect pests. Groundnut oil at 5-10 ml per kg, palm oil, palm kernel oil and castor oil at 6 ml per kg cowpea seed have also been used to control insect pests of stored cowpea. Most plant materials have repellant, anti-feedant and insecticidal properties. Some also interfere with normal activities of the pests preventing their multiplication. The plant materials are cheap, easily available and easy to use. They have low mammalian toxicity, are non-persistent and most do not affect seed viability and palatability (Sowunmi and Akinnusi, 1983; Oparaeke *et al*., 1998).

2.12 HARVEST, DRYING AND STORAGE

The crop (groundnut) is mainly harvested manually. Plants are pulled out by hand at the time of maturity. Occasionally hoes and bullock-drawn diggers are also used to dig plants out. In the case of small holdings, the pods are stripped off the plants soon after harvest and carried home for drying. In the case of large holdings, plants are either left in windrows or in small heaps for sun drying before stripping off pods by mechanical threshers. Proper drying of groundnut produce is very important. The moisture content in pods should be brought down to around 8% before storage since higher moisture levels in the produce are congenial for the production of aflatoxin by yellow mould (*Aspergillus flavus*). The produce from the post-rainy/summer crop in India is reported to have lost viability quickly when dried under direct sunlight because of high temperatures prevailing at the time of harvest. To avoid this, the following procedure is recommended (Basu and Reddy 1989).

1. Tie the harvested plants into small bundles and keep them in a single layer with pods upward under shade. In the summer season, due to the natural movement of hot air, pods dry quickly.

2. When the bundles are dried, the pods may be detached from the plants and spread in a thin layer under shade for further drying. The following simple

tests help to determine the correct stage for storage: the well-dried pods rattle upon shaking: when a seed is pressed between thumb and index finger it easily splits into two cotyledons; and when the surface of the seed is rubbed hard a portion of the testa comes off.

3. When the pods are thoroughly dried as indicated by the above tests, they should be stored in polythene- lined gunny bags along with commercial grade calcium chloride at 300 g for each 40 kg bag. The calcium chloride should be placed in a wide-mouthed plastic bottle with pores in its upper portion. The bottle is covered with thin muslin cloth and kept at the central portion of the bag containing the pods.

The above procedure maintains viability up to 80% for a period of 10 months. Experimental results in Bangladesh revealed that seeds with 9% moisture packed in polythene bags and stored in gunny bags retain their viability up to 90% for a period of 7 months. Development of a viable storage technique for deltaic farmers is one of the future research thrusts in Myanmar (Abate *et al*., 2012).

Excessive moisture content levels lead to deterioration of cowpea and make them more susceptible to infestation by insect pests and infection by fungi. At harvest, cowpea should be left to dry for some time to reduce the moisture content to safe levels. The safe moisture content level for cowpea is 13% or lowers (Bawa *et al*., 2012).

2.13 THE ECONOMIC IMPORTANCE OF MOULDS

There are two important types of storage moulds, Aspergillus and Penicillium. Another common mould is Fusarium, which attacks the plant in the field but, if the moisture content of the grain remains high, may be carried over into the store after harvest. All of these moulds produce harmful mycotoxins. Moulds multiply by releasing spherical spores. These germinate, producing elongated projections known as hyphae. Hyphae multiply and branch and form a mass of fungal tissue, the mycelium, at which stage it is recognizable as mould by its colour (FAO, 2009).

2.13.1 Factors that Affect Mould Growth

- Moisture content of the grain; moulds require water for growth, so if the crop is well dried (below 13% for cereals and 7% for groundnuts), moulds will not be able to grow;
- Climatic conditions; hot and humid conditions promote mould growth. Under such conditions, extra attention must be paid to drying the crop well;
- Field damage caused by insects, birds, rodents, and poultry (moulds can quickly infect grain through holes and cracks made by pests);
- Plant stress caused by drought, infertile soil and even untimely or excessive fertilizer application (allows plants and seed to crack and become exposed to invading moulds and insects);
- Maize cobs, sorghum and millet heads and pods of pulses that fall to the ground and come into contact with mould spores that live in the soil;

- Repeated planting of a crop in the same field may increase the risk of infection by mould;
- Poor handling at harvest, during drying, threshing and transportation can cause damage to grain, rendering it susceptible to attack by mould spores; and
- Insect infestation in store (insect respiration produces water, which raises the moisture content of the grain allowing moulds to develop) (FAO, 2009).

2.13.2 Prevention and Control

The most effective way of preventing mould growth is to dry the grain as quickly as possible to a moisture content that is low enough for safe storage. Safe storage is achieved when moulds cannot develop. For cereals and pulses in tropical and subtropical countries this point is achieved when the moisture content is below 13-14 percent, for groundnuts and other oilseeds below 7 percent. Once the grain is dry it must be kept dry while in store (FAO, 2009).

2.14 STORAGE STRUCTURES

According to Proctor (1994), storage is a component within the farming system, trading enterprise or a government policy practices for its contribution to other activities or objectives. It is a repeated interim phase in the complex logistics of many grains from producers to processers and grain products from processers to consumers (Anderson, 1973).

Originally storage structures in the continent were made of only plant materials and mud. This trend is changing as a few farmers have replaced or are replacing mud rombus with metal silos and plant material-woven cribs with those built of timber and corrugated iron roof. Most research in the late 1960s to the 1970s was focused on assessment of the prototypes of storage structures (Gilman and Boxall, 1974). Later research to date, have focused on improving traditional granaries for better durability and airtightness (Adetunji, 2007). Post-harvest facilities have to provide shade and adequate ventilation before sent on the way to the cooler not below 45ºF especially for cowpeas storage (Davis *et al*., 1991) in modern storage facility.

In the United States, it is recommended the grain be stored short term at around 12 percent moisture or less, with 8 to 9 percent recommended for long-term storage. Some buyers will want the seed cleaned and bagged, while others will take the grain in bulk form and clean it themselves. For some markets, the cowpeas must be harvested at a higher moisture, such as 18 percent and trucked directly from the field to the processor (Quinn, 1999)

An ISRA survey conducted in June 1996 indicates that the metal drum storage technology is used by most of the farm households (over 80 percent) and that it is used for the quasi-totality of the cowpea stored (95 percent).

As with almost every agricultural technology, farmers have introduced their own modifications of the drum storage method. In particular, many of them put insecticide in the drum. The insecticide may be a form of insurance that protects stored cowpeas even if the drum has unknown air leaks and/or it may limit re-infestation if the drum is opened regularly to obtain cowpea for family use. (Lowenberg-DeBoer, 1995; 1997).

In Africa, cowpea and groundnut storage are done in a variety of traditional structures. They are stored in cribs, polyethylene sacks, plastic bags, clay pots, jute bags, calabashes (gourds), small mud silos, baskets plastered with cowdung or wood ash and oil metal drums.

2.14.1 Jute Sacks

Jute sacks are widely used in the farm, village and in storage centres by grain dealers for storage of legumes. The sacks are made of woven jute, sisal, local grass and cotton. Jute sacks are relatively expensive. They do not give much natural protection against insects, rodents and moisture (Ali, 2008). However, jute sacks are easier to label, hence farmers are able to label old and new sacks to keep them separated from others. They are portable and may be used, as needed (David, 1978). Stored grains in jute sacks are easily attacked by insects, rodents and fungi (moulds) and these can be more serious because a farmer might not have done all he could to protect his grains sacks (David, 1978).

2.14.2 Polyethylene sacks

Storage of legumes in polyethylene sacks have become the widely adopted system of storage at both village level and in market stores they are made of woven nylon (plastic polymer of ethylene) with cotton threads at the lateral ends. Polyethylene sacks are relatively cheaper to buy than jute sacks and have relative airtight atmosphere. However, polyethylene sacks are liable to sweat (produce heat) under high storage temperatures thereby causing moisture build-up in the grain leading to moulds infestation of the grain.

2.14.3 "Naporku" (crib)

It is a cylindrical structure on stones or stick-erected platform of about 0.6m above the ground level. It is built with "zana" mats woven from grass (*Andropogon spp*) and reinforced by sticks at sides tired with rope to keep it firm. Naporku is normally built to about 2.5m high with its carrying capacity depending on the size. Conically woven thatch roofing is provided above it to protect its content from rain, birds and sunlight.

2.14.4 "Kruchun"

This is an oval-shape structure made from shrubs or split guinea corn stalks and placed on raised platform made of sticks. The outer walls of the structure are smeared with cowdung to seal spaces between the woven stalks so as to prevent spillage of grains during storage. It is another structure in the Northern Ghana for the storage of shelled or threshed cereals and pulses due to easy acquisition of materials requires less skill in building it. A standard "krunchun" has a carrying capacity between 0.5-2.0 tonnes (Andan, 2003).

2.14.5. Mud silo (locally called "Bondo")

It is an important structure used for storing pulses and cereals in the Northern Ghana due to its long lifespan and insect resistance. Grain at 28-32% moisture level can be stored suitably in an airtight silo with no problem (Darrel and Donald, 1980). According to Stevenson (1999), the Moshi tribe from Burkina Faso and Ghana settled in parts of the East Mamprusi and the Saboba/Chereponi districts and introduced this structure to the native inhabitants. It is constructed from termite mound soil with a carrying capacity between 1 – 4 tonnes (Ali, 2008).

Many traders store grain legumes for up to seven months in structures they either own or hire. Produce is held in jute or polypropylene sacks in store rooms located either in or close to the market, although traders holding only very small quantities may store within the home. None of the stores is large, the maximum capacity is about 2,000 bags (200 tonnes), but larger traders maintain several stores. Store rooms are often totally inadequate for storage purposes, frequently being simply large enclosures constructed from wooden planking and corrugated iron sheeting with cement rendered floors. The structures are often flimsily built, poorly maintained and infrequently cleaned. Good storage management is very difficult to practice and pest control operations difficult to adapt to maintain effectiveness.

2.15 STORAGE PROTECTION

Throughout the areas of Northern Ghana, farmers in general do not take any precautions to prevent pest damage during storage, other than to place the commodity in the sun. In some villages, such as Zinindo, Galiwei and Gushiegu in the Northern Region, farmers are unaware of any traditional methods for protecting stored crops against insect infestation. In other villages, including some in Upper East, less than 5% are aware of traditional practices, but even, they did not necessarily apply the methods themselves, though they knew of others in the village who did. These methods are not used because they are thought to be ineffective. Villagers believed too much protectant is needed to be effective and so its use is impractical. However, farmers who use storage protectants use them on pulses rather than on any other crop (Golob *et al.*, 1996).

2.16 MAINTENANCE OF STORAGE STRUCTURES (STORAGE HYGIENE)

To prevent damage of legumes in storage, it is ideal to keep the storage structures strong and as possible. Practical hygiene control measures may vary from one type of structure to the other. Basically, it is necessary in all cases to always remove all dirt, rubbish, webbing and refuges or old unwanted products from structures. According to Taylor (1976), it is only when good and adequate drying, disinfection and storage practices are combined with good hygiene that satisfactorily results can be obtained. It stores containing bags, all sacks should be built in a floor area which has been swept and well dusted with 1% Lindane dust (Ali, 2008). For farm level storage farmers should clean out their stores before harvest and the spray with Malathion to reduce insect pest infestation in stored grains (Ali, 2008).

2.17 STORAGE LOSSES

Storage losses are categorized in four different types: weight loss, quality loss, nutritional loss and loss of seed viability (Hall, 1980). Golob *et al*. (1996) found damage to Bambara groundnut to be 14-100% after 6-8 months storage. Likewise, Caswell (1968) in Nigeria and Golob (1996) in Ghana found damage to stored cowpea to be 14-37% and 15-94% respectively, for which the latter was assessed after 7-9 months in store.

The cowpea weevil multiplies very fast in storage, giving rise to a new generation every month (Ouedrago *et al*., 1996). Infestations on stored grains may reach 50% within 3-4 months of storage (Pascual-Villalobus and Ballesta-Acosta, 2003). In Ghana, many of the resource-poor farmers do not treat their harvested grains with insecticides before storing them. Thus cowpea harvested and stored by these farmers becomes heavily infested with *C. maculatus* a few months in storage resulting in economic losses to the farmer.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1. THE STUDY AREA

3.1.1 Regional Profile

The Northern Region has a total of about 70,384 square kilometres, which is 29.5% of the land area and 1,820,806 representing 9.6% of the population of Ghana (GSS, 2010). It is located between latitude 80 30" and 100 31" N and lies completely in the savannah zone. It has Togo and Cote D'Ivoire to the East and West respectively as its international boundaries. Further north in the country, it shares boundaries with the two Upper Regions and to the south with Brong Ahafo and Volta regions. It is currently divided into twenty- seven (27) political/administrative districts.

3.1.2 District Profile

The study areas were Saboba and Zabzugu districts in the Northern Region of Ghana. Saboba District has a population of about 65,706 and about 95miles (152km) away from the Tamale Metropolis and 32miles (51km) from Yendi town and located at 90 433"N 001920"W. Zabzugu District (as was Zabzugu-Tatale) had a population of about123,854 and about 90miles (144km) away from Tamale and 27miles (43km) from Yendi. It is located at latitude 90 17"N 0022"E.

The vegetation in these areas is the Guinea Savannah woodland with tall grasses interspersed with deciduous trees such as dawadawa, shea and baobab trees. Majority of the people are peasant farmers and they produce to feed their families and sell the remaining surplus to make money (Ghana Statistical Service (GSS) 2010).

3.2. METHODOLOGY

A preliminary survey was conducted to get first-hand information about cowpea and groundnut production trends from the Extension Officers in the selected districts. This led to identification of major areas (communities) that grow the crops in the selected districts of the region. Based on the information, relevant ideas were obtained in the identified producing communities through a survey. The survey focussed on the production, harvesting methods, processing and storage facilities that either reduce the problems of food insecurity or enhance food security in the areas.

The research explored both primary and secondary sources of data in the collection process. In both cases, quantitative and qualitative methods were employed to provide varied, sufficient and reliable data. The selection and distribution of sampling and target population were based on stratified random sampling, purposive random sampling and simple random sampling. The stratified sampling was used to group the communities into producing and non-producing communities. Purposive sampling was also employed to select the communities storage normally occurs.

Primary data was collected using participatory rural appraisal tools to get first-hand information on the topic through interviews, observations, focus group discussion and key informants interviews ordered to achieve the objectives of the study.

3.2.1 Interviews

A structured questionnaire was designed to assess the relevant data needed. Some of the areas considered were; information of about respondents, location of farm, number of acreage of the farm, pre-planting and post-planting operations, storage facilities and other postharvest operations as well as farmers' knowledge about importance of storage facilities of legumes and their effects on stored produce in references to food security, income generation and required nutrients of the produce.

It is believed that the best way to get what people have in their minds is by listening to what they say. This technique is regarded easy to be used with all kinds of people- literates, illiterates and physically challenged people. The researcher therefore employed it to facilitate greater interaction with community members.

3.2.2 Observations

Direct observation was adopted to assess the kinds of storage facilities and their distribution in the communities. This was necessary because it gave the researcher the quick insight into the existing situations of storage in the study communities.

3.2.3 Focus Group Discussion (FGD)

The study adopted the focus group discussion method to "extract" information on the views of the old and the young on facilities and problems encountered in using each facility in the communities. This method gave community members the opportunity to freely express on the topic under study. Alternatively, a check list was prepared and used as a guide during the discussion process. The technique aided the researcher to acquire an insight into the effectiveness of the methods used in storage management. This constituted the basis for the qualitative analysis of issues relating to the topic.

Data were also collected from the schools' libraries, journals, the District Assemblies, the District Agricultural Offices, Non-Governmental Organisations (NGOs) and the internet. Information about storage management practices and production of legumes were gathered from District Assemblies, Seed Company Limited, MoFA and Gunda Produce Company.

3.3 QUESTIONNAIRE ADMINISTRATION

The questionnaire was administered to both farmers and traders of cowpea and groundnut at the producing areas. Fifty (50) open-ended questionnaires were administered to forty (40) randomly selected farmers (Producers) and ten (10) traders in two selected communities of each of the two districts. In all, hundred (100) questionnaires were administered.

3.3.1 Data Limitations

Though a lot of methods were employed, the following were encountered. Some respondents refused to answer questions on the fact that they must be paid for. Proximity of experimental sites from point collection of measuring gadget made it difficult for data readings with regard to accessibility to moisture metre due to sample size. All the containers were checked weekly for the data determination, but the clay pot containers could not be opened and sealed back without oxygen penetration into them.

3.4 EXPERIMENTAL DESIGN

The experimental design was randomized complete block design (RCBD) with 3 treatments and 3 replications each. The treatments were clay pot, jute sack and polypropylene sack.

3.5 RESEARCH MATERIAL/CROP

The research materials were cowpea and groundnut grains, varieties known as black eyed and Chinese respectively which were among the preferred varieties in the Northern Region.

3.6 EQUIPMENT

The equipment used to take data included a sieve, a weighing scale (Camry, made in China), hygrometer and temperature indicator (Sufft, SEEDBURO, made in Germany), HE *life* moisture meter (PFEUFFER, made in U.S.A) and DOLE E.T.N moisture meter (Model 400), made in Germany..

3.7 STORAGE METHOD

Five (5) kilograms of the cowpea and groundnut were stored in each of the containers and the open-end of the clay pots were sealed with white thick polythene sheets and lids, ropes used to tie the jute and polypropylene sacks. Chemical or any treatment was not applied to any container or produce, as this is a practice of farmers. All the storage containers filled with cowpea and groundnut were placed in well ventilated rooms. One kilogram of seed was taken out weekly from each of the containers for the determination of relevant parameters.

3.8 DETERMINATION OF QUALITY CHARACTERISTICS

The quality characteristics data that were determined included:

1. **Weekly moisture content, temperature and relative humidity**: The moisture content of cowpea was taken by using the HE life (PFEUFFER) moisture meter and a DOLE E.T.N moisture meter (Model 400) was used to determine the moisture of groundnut grains before and during storage in each treatment.

2. **Live and dead insects**: This was done by taking samples of one kilogram from each treatment and sieved and count the numbers of dead and live insects manually and recorded.

3. **Number of holed bored by insects on grains in treatment containers**: This was done by randomly counting 200 grains from samples of each treatment, and manually counting the number of holes in each grain, in order of zero hole, one hole, two holes, and three holes after sorting them out according to the number of holes.

4. **Percentage germination in each treatment**: this was done by randomly counting 100 grains from each treatment. The samples were sown, and germination percentages were taken after 7 days when all grains would have germinated.

3.9 Laboratory analysis

3.9.1 Proximate nutrients determination

The samples were milled with laboratory miller (Cyclotec 1093 Sample Mill, Tecator, Sweden) and proximate analysis (in triplicates) performed on each sample.

3.9.1.1 Moisture content

Moisture content was determined by the method of the Association of Official Analytical Chemists' (AOAC, 1984) by drying the sample in an oven until a constant weight was obtained. Five grams of the sample was accurately weighed into a previously cleaned, dried and weighed glass dish. The dish with its content was put into a thermostatically controlled oven (Gallenkamp, model OV 880, England) at 105˚C for five hours. The sample was then cooled in a desiccator and weighed. The process was repeated until a constant weight was reached. The loss in weight expressed as a percentage of the initial weight of sample gave the percent moisture content using the formula in appendix B 1.

3.9.1.2 Ash content

Ash was determined by the method of the Association of Official Analytical Chemists' (AOAC, 1990). A 2.00g sample was weighed into a previously dried and weighed porcelain crucible. The crucible with its content was placed in a Muffle furnace (Muffle furnace size 2, England) preheated to 600˚C for 2 hours. After this period the crucible with its content was removed and cooled in a desiccator and weighed. The weight of the ash was expressed as a percentage of the initial weight of the sample using the formula in appendix B2.

3.9.1.3 Crude protein content

Crude protein was determined by the method of the Association of Official Analytical Chemists' (AOAC, 1990). Two grams (2.0g) of the sample was weighed into a digestion flask and half grams of selenium-based catalyst tablets and few anti-bumping agents were added. Twenty five (25) ml of concentrated H_2SO_4 was added and the flask was shaken to mix the contents. The flask was then placed on a digestion burner for 8 hrs and heated until the solution turned green and clear and cooled to room temperature. The sample solution was then transferred into a 100 ml volumetric flask and made up to the mark with distilled water. Twenty five milliliters (25ml) of 2 % boric acid was pipetted into a 250 ml conical flask and 2 drops of mixed indicator (20ml of bromocresol green and 4 ml of methyl red) solution added. Into the decomposition chamber of the distillation apparatus was added about 15-20ml of 40 % NaOH solution. Ten milliliters (10 ml) of the digested sample solution was then introduced into a Kjedahl flask. The condenser tip of the distillation apparatus was then dipped into the boric acid contained in the conical flask. The ammonia in the sample solution was then distilled into the boric acid until it changed completely to bluish green. The distillate was then titrated with 0.1 N HCl solution until it became colourless. The percent total crude protein was calculated using the equation in appendix B3.

3.9.1.4 Crude fat content

Crude fat was determined based on the Sohxlet extraction method of AOAC (1990). A 250 ml quickfit round bottom flask was washed and dried in an oven (Gallenkamp, model OV 880, England) at 100˚C for 25 minutes and allowed to cool to room temperature before it was weighed. Five grams (5.00g) of the sample was weighed into a muslin thimble. This was inserted into the extraction column with the condenser connected. One hundred and fifty milliliters (150 ml) of petroleum spirit at boiling point 60-80˚C) was poured into the round bottom flask and fitted into the extraction unit. The flask was then heated with the aid of electrothermal heater at 60˚C for 2 hours. Losses of solvent due to heating were checked with the aid of the condenser so that it cooled and refluxed the evaporated solvent. After extraction, the thimble was removed and the solvent recovered by distillation. The flask containing the fat and residual solvent was placed on a water bath to evaporate the solvent followed by a further drying in an oven (Gallenkamp, model OV 880, England) at 103˚C for 30 minutes to completely evaporate the solvent. It was then cooled in a desiccator and weighed. The fat obtained was expressed as a percentage of the initial weight of the sample using the formula in appendix B 4.

3.9.1.5 Crude fibre content

Crude fibre was determined by the method of the Association of Official Analytical Chemists' (AOAC, 1990). The defatted sample (from crude fat determination) was transferred into a 750 ml Erlenmeyer flask and 0.5 g of asbestos was added. Two hundred milliliters (200 ml) of boiling 1.25% H_2SO_4 was added and the flask was immediately set on a hot plate and condenser connected to it. The content was brought to boil within 1 minute and the sample was digested for 30 minutes. At the end of the 30 minutes, the flask was removed and the content was filtered through a linen cloth in a funnel and subsequently washed with boiling water until the washings were no longer acidic. The sample was washed back into the flask with 200 ml boiling 1.25% NaOH solution. The condenser was again connected to the flask and the content of the flask was boiled for 30 minutes. It was then filtered through the linen cloth and thoroughly washed with boiling water until the washings were no longer alkaline. The residue was transferred to a clean crucible with a spatula and the remaining particles washed off with 15 ml ethanol into the crucible. The crucible with its content was then dried at 100°C for an hour and cooled in a desiccator and weighed. The crucible with its content was then ignited in a furnace (Muffle furnace size 2, England) at 600˚C for 30 minutes, cooled and reweighed. The loss in weight gave the crude fibre content and was expressed as a percentage of the initial weight of the sample using the formula in appendix B 5.

3.2.1.6 Carbohydrate content

Total percentage carbohydrate was determined by the difference between 100 and the sum of crude protein, crude fat, crude fibre, moisture and ash constituents of the sample. The value obtained is the percentage carbohydrate constituent of the sample. The formula for the calculation of percentage carbohydrate is shown in appendix B6.

3.10 DATA ANALYSIS

The data obtained were analysed using Microsoft Office Excel 2007 for the survey data. Data on measure parameters were analysed using Statistix 9 and means separated at Lsd of 5%. The results were presented in charts and tables.

CHAPTER FOUR

4.0 RESULTS

4.1 SURVEY

The field survey showed the socio-demographic characteristics of respondents such gender, age and educational background of respondents and as well as evaluation of the storage facilities, causes of postharvest losses of cowpea and groundnut presented charts and tables and how they can be managed in the Northern Region of Ghana.

4.1.1 Gender Backgrounds of Respondents

In table 4.1, the research revealed that out of 100 respondents who were interviewed 60% were males whiles 40% were females. Those sampled were farmers and traders of cowpea and groundnut production in four communities in the Zabzugu and Saboba Districts of Northern Region.

Table 4. 1: Sex of Respondent

SEX	FREQUENCY	PERCENTAGE (%)
MALE	**60**	**60**
FEMALE	**40**	**40**

Source : Field survey 2013

4.1.2 Age of Respondents

The age distribution of respondents in the study areas revealed the economic age group who are into production of the pulses are within ages from 18 – 57 years. The majority, 35% of the producers were within the ages of 38 – 47 years, followed 28 –

37 age range represented by 32%, then 28% (18 – 27) and the least participated age group, 5% were those of 48 – 57 years.

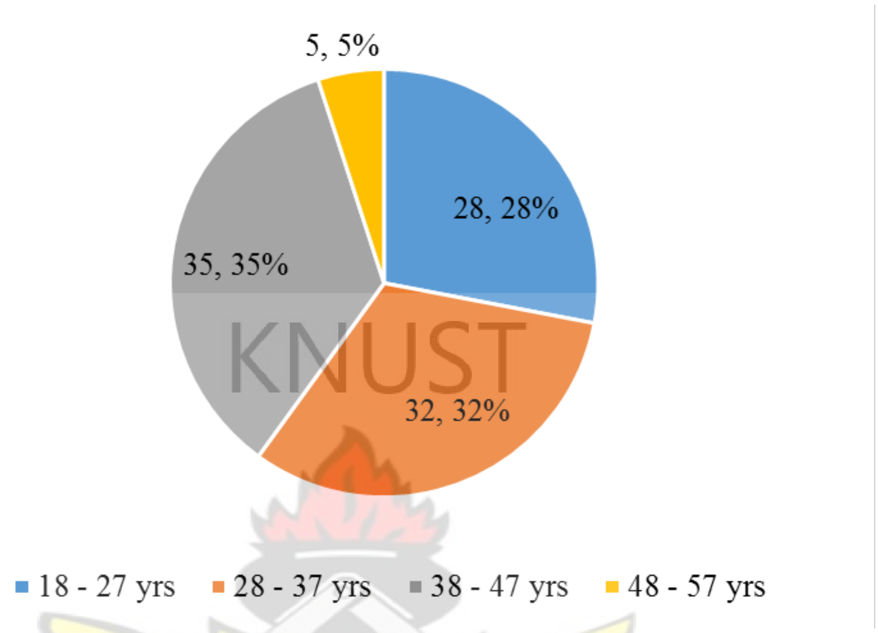

Figure 4.1 Age profile of respondents

4.1.3 Educational Levels of Respondents

From Table 4.2, out of hundred (100) respondents thirty-five (35) farmers representing 35% had no education and 32% represented by 32 respondents have had basic education. Also, 18 respondents representing 18% had attained secondary education, 14% had tertiary education and 1%, non-formal education.

Table 4.2: Educational levels of respondents

Educational Level	Frequency	Percentage (%)
Basic	32	32
Secondary	18	18
Tertiary	14	14
None	35	35
Non formal education	1	1
Total	100	100

4.1.4 Some Benefits Derived from Legume Cultivation

The survey revealed a majority of the producer, 33% derive more than one benefit such as income, food, oil and employment from cowpea and groundnut production in figure 4.2. This was followed by income generation, oil extraction, employment and food representing 26%, 21%, 13% and 7% respectively as some benefits derived from legume cultivation.

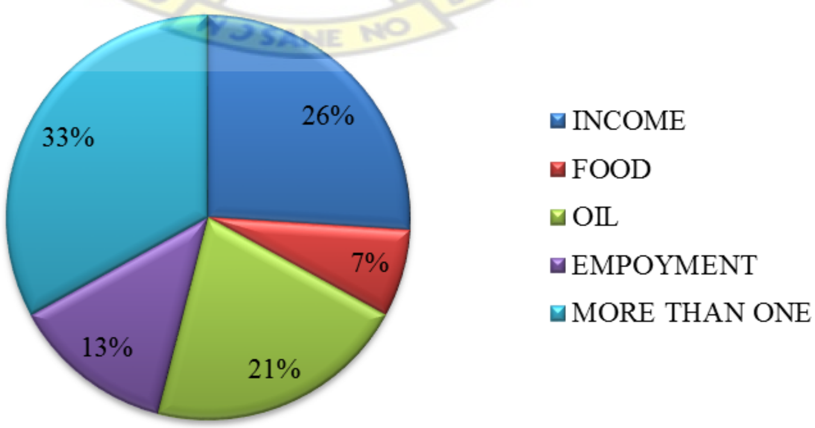

Figure 4.2: Benefits from legumes

4.1.5 Problems Farmers Encounter in Cowpea and Groundnut Production

From table 4.3, thirty-eight percent (38%) of the farmers attributed their problems to lack of adequate labour force for cultivation and harvesting. Fifteen percent (15%) of the farmers indicated that, their problems were as a result of lack of labour, cost farming failure of rains and wrong time of harvesting. Twelve (12%), ten (10%) and seven percent (7%) of farmers indicated that, their problems were as a result of inadequate tractors during tilling, low capital to farm and failure of rains in the area in northern Ghana respectively.

Table 4.3: Problems farmers encounter in cowpea and groundnut production

PROBLEM	PERCENTAGE (%)
LACK OF LABOUR	38
TRACTOR	12
RAIN FAILURE	**7**
COST OF FARMING	10
MORE THAN ONE	15

4.1.6 Stages of Postharvest Lossess in Cowpea and Groundnut

The survey showed that 32% of the respondents attributed losses to more than one of the factors mentioned in figure 4.8. This was followed by 26%, 14%, 11% and 8% in storage, threshing, drying and transporting respectively. The least in losses were recorded during winnowing and shelling which represented 6% and 3%.

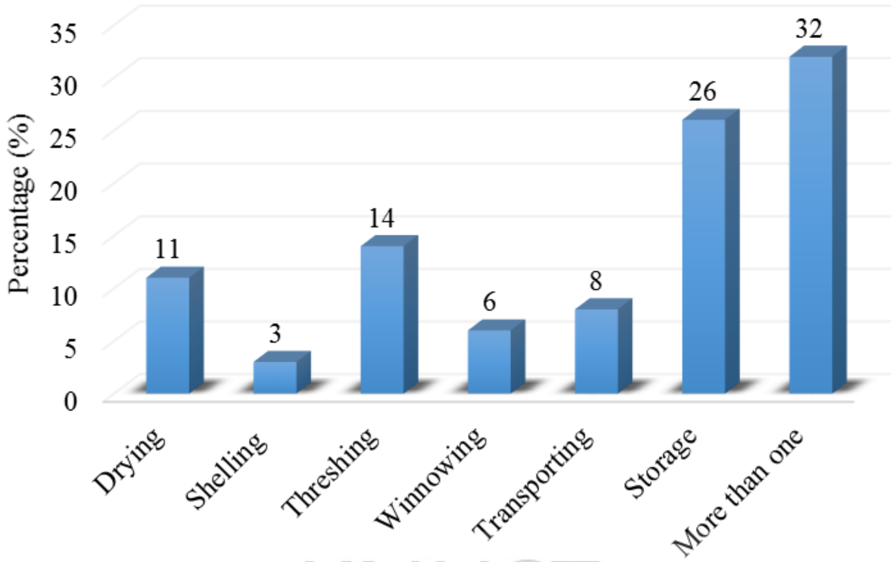

Figure 4.3: Stages of postharvest lossess

4.1.7 Duration of Storing Produce before Marketing

From Table 4.4, it is clear that a few farmers store their produce between two and five months where ten (10) farmers each representing 10% of all respondents were recorded. Also most of the farmers in the survey area store their produce in three and six months representing 28% and 22% respectively. While fourteen and sixteen farmers representing (14%) and (16%) harvested in four and one months.

Table 4.4: Duration of storage

NUMBER OF MONTH	FREQUENCY	PERCENTAGE (%)
One month	16	16
Two months	10	10
Three months	28	28
Four months	14	14
Five months	10	10
Six months	22	22

4.1.8 Best facilities for Storing Groundnut and Cowpea

The research revealed mud silo (32%) as the best storage facility, followed by crib (24%) and polypropylene sack (24%). Eleven (11) and nine (9) farmers representing 11% and 9% mentioned jute sack and clay pot as facilities for storing cowpea and groundnut.

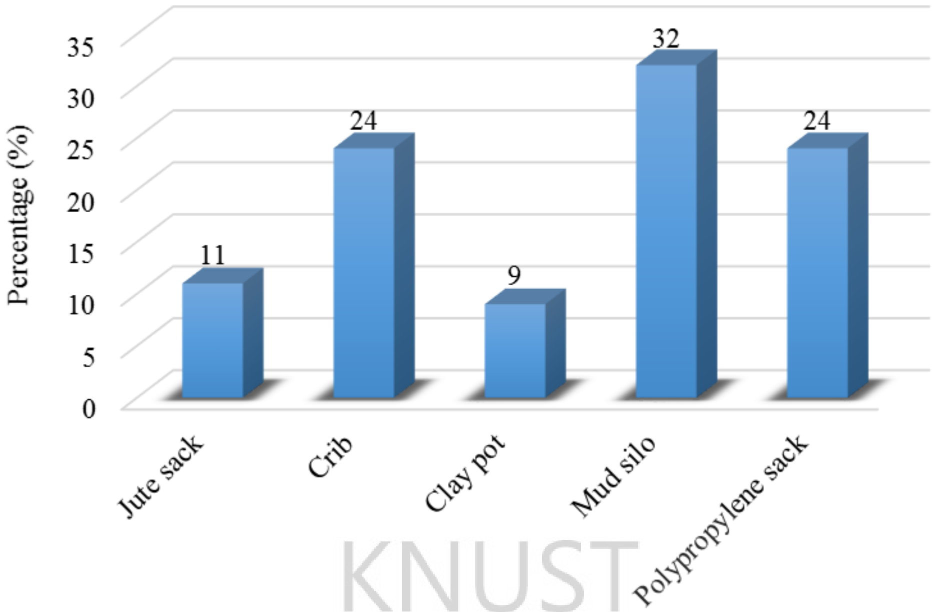

Figure 4.4: Facilities for storing

4.1.9 Pests and Diseases Encountered during Storage

Majority of the farmers (71%) sampled mentioned beetles such as bean beetle, bean weevil and cowpea beetle and groundnut bruchids as pests encountered during storage. Eighteen percent (18%) of the respondents named rodents such as rats and mice which destroy jute sacks while 11% of farmers talked about mouldy growth caused by fungi that leads to release of aflatoxin substance in groundnut.

Table 4.5 Pests and diseases in storage

PEST/DISEASE	FREQUENCY	PERCENTAGE (%)
Bruchids	71	71
Moulds	11	11
Rodents	18	18

4.1.10 Ways of Reducing Postharvest Losses during Handling

The results of the survey as shown in Figure 16 revealed that thirty-four (34) farmers making up 34% of the respondents indicated that the use of good facilities was important to reducing or avoiding postharvest losses. Thirty-three (33%) of the respondents claimed that proper drying enhances postharvest handling of cowpea and groundnut in reduction of postharvest losses of the crop, whereas 7%, 6% and 5%% of farmers were of the view that use of resistant varieties, proper use of chemicals and good training on losses respectively greatly reduce postharvest losses in cowpea and groundnut. Only fifteen (15%) of the farmers mentioned more than one ways of reducing postharvest losses.

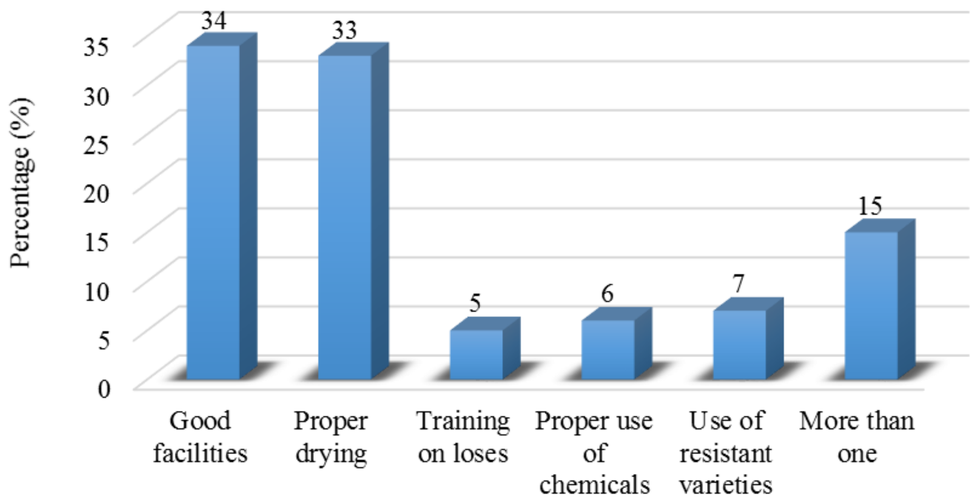

Figure 4.5: Reduction of postharvest losses

4.2 POSTHARVEST STORAGE CONDITION

This section of the result presents the average of temperature, humidity and moisture recorded weekly for a period of two (2) months in the storage containers. The temperature readings varied slightly between the cowpea and the groundnut with regard to the containers used. Tables 4.4 and 4.5 show the storage conditions within the storage containers used.

4.2.1 Mean Temperature, Humidity and Moisture within containers used for Groundnut Storage

Table 4.6: Influence of storage containers on mean temperature, humidity and moisture of stored groundnut

Container	Temp (^{0}C)	Humidity (%)	Moisture (%)
Pot	31.27 a	86.73 a	8.51 a
Jute Sack	30.47 b	87.46 a	8.65 a
Polypropylene sack	30.39 b	87.44 a	8.68 a
Lsd (0.05)	0.47	1.00	0.20
CV	0.68	0.51	1.00

4.2.1.1 Temperature within storage containers

Temperature within the storage containers used to the groundnuts was significantly different ($p<0.05$). Significantly high temperature on the average was recorded within the pot compared to the jute and polypropylene sacks which had statistically an equal average temperature variation over the storage period.

4.2.1.2 Humidity within the storage containers

Unlike temperature, humidity levels within the storage containers were significantly not different ($p>0.05$). Thus, they had a similar range of humidity recorded among the storage containers over the storage period.

4.2.1.3 Moisture within the storage containers

The level of moisture within the storage containers was significantly not different ($p>0.05$). Thus, the moisture level on the average was significantly equal among the grains in the storage containers.

4.2.2 Mean Temperature, Humidity and Moisture within Containers used for Cowpea Storage

Table 4.7: Influence of storage containers on mean temperature, humidity and moisture of stored cowpea

Container	Temp (^{0}C)	Humidity (%)	Moisture (%)
Pot	30.21 a	88.27 a	8.27 a
Jute Sack	30.33 a	87.92 a	8.30 a
Polypropylene sack	30.17 a	88.42 a	8.37 a
Lsd (0.05)	1.1	0.91	0.64
CV	1.61	0.46	3.41

4.2.2.1 Temperature within the storage containers

The temperature variation on average within the storage containers over the study period was significantly similar ($p>0.05$) and within the same range.

4.2.2.2 Humidity within the storage containers

Similarly, the average humidity levels recorded among the storage containers were significantly not different ($p>0.05$) and fell within the same range over the storage period.

4.2.2.3 Moisture level within the storage containers

Moisture level within the storage containers were significantly not different (p>0.05) from one another. They all recorded the same average moisture level over the storage period.

4.3 POSTHARVEST PEST AND DAMAGE LEVEL

Table 4.8 and 4.9 show the level of insect count per every 5 kilogram of grains of cowpea and groundnut stored separated with the storage containers taken weekly for 2 months period.

4.3.1 Level of Pest Count in Stored Groundnut

Table 4.8: Percentage of dead and live insects per 5kg of groundnut stored with the storage containers

Container	Dead	Live	Total
Pot	1.00 a	15.67 ab	16.67 ab
Jute Sack	1.00 a	24.33 a	25.33 a
Polypropylene	0.00 a	6.67 b	6.67 b
Lsd (0.05)	1.60	14. 27	15.59
CV	106.07	40.46	42.39

4.3.1.1 Dead insects screened from groundnut

There was a very low level of dead insect count detected in groundnuts stored in the three storage containers. These counts were significantly not different (p>0.05) with zero (0) count of dead insect in polypropylene sack and one (1) count each in jute sack and pot per 5kg stored groundnut.

4.3.1.2 Live insects screened from groundnut

Except for the number of live insect count (16) in pot storage container, the level of count in the jute and polypropylene sacks was significantly different ($p<0.05$) from each other with 24 and 7 live insects per 5kg stored groundnut.

The total of dead and live insects detected in the various storage containers also showed a significant difference between jute sack and polypropylene sack, and were significantly similar to that in the pot. They had 25, 7 and 17 insect count respectively.

4.3.2 Level of Pest Count in Stored Cowpea

Table 4.9: Percentage of dead and live insects per 5kg of cowpea stored with the storage containers

Container	Dead insect	Live insect	Total
Pot	48.00 a	25.33 a	73.33 a
Jute Sack	436.33 a	178.33 a	614.67 a
Polypropylene	270.00 a	97.00 a	367.00 a
Lsd (0.05)	597.50	184.03	765.75
CV	104.82	81.00	96.05

4.3.2.1 Dead insects screened from cowpea

The amount of dead insect count was significant not different ($p>0.05$) within the containers, though relatively, jute sack comparatively had a highest count of approximately 436 dead insect in 5kg weight of cowpea grains than the rest. The lowest dead insect count of 48 in 5kg weight of cowpea grains was found in cowpea stored in the pot container.

4.3.2.2 Live insects screened from cowpea

Similarly, there was no significant difference ($p>0.05$) in number of live insects screened from the cowpeas from the storage containers. Like the dead insects found in the cowpea, jute sack relatively had the highest count of live insect of 178 per 5kg of cowpea while the pot storage container had the lowest live insect count of 25 per 5kg weight of cowpea.

In total, a relatively high count of insects on the average were detected in jute sack (615 insects), followed by polypropylene sack with 367 insects and the least, in pot which had appropriately 73 insect count.

4.3.3 Quality Loss due to Pest Damage

The results showed in tables 4.8 and 4.9 show the level of pest damage of the groundnut and the cowpea respectively. The level of damage was comparatively higher in cowpea than groundnut under the same storage conditions. The outcome on quality loss due to pest damage is reported in average percentage of holes (1, 2 and 3) bored by the insects detected on every 200 grains sampled per week over the storage period from the 5kg cowpea and groundnut.

4.3.3.1 Pest damage on groundnut

Table 4.10: Level of pest damage (holes) recorded on stored groundnut in storage containers

Container	1 hole	2 hole	Total	Whole grains
Pot	0.88 b	0.04 a	0.92 b	99.09 a
Jute Sack	1.56 a	0.29 a	1.86 a	98.15 b
Polypropylene	0.98 b	0.00 a	0.98 b	99.02 a
Lsd (0.05)	0.19	0.39	0.53	0.53
CV	7.19	155.70	18.55	0.24

Amount of grains showing 1 bored hole were significantly equal ($p>0.05$) in pot and polypropylene sack but was different ($p<0.05$) from that recorded in Jute sack, the highest recorded on the average over the storage period. No significant difference was recorded among the storage containers with regard to 2 bored holes on grains of groundnut. There were no counts of 3 bored holes by insects on the groundnuts in all the three storage containers.

In all, an average of 1.86 % of groundnuts were affected with insect attack in jute sack different from both polypropylene sack and pot which had 0.98 and 0.92 percent respectively in order of decreasing.

In contrast to the total, both the pot and polypropylene sack significantly recorded a higher level of whole grains while the jute sack had the least count of whole grains of 99.09, 99.02 and 98.15 percent respectively in order of decreasing.

4.3.3.2 Pest damage on cowpea

Table 4.11: Level of pest damage (holes) recorded on stored cowpea in storage containers

Container	1 hole	2 hole	3 hole	Total	Whole grains
Pot	6.46 b	0.17 a	0.00 a	6.63 b	93.38 a
Jute Sack	36.19 a	2.15 a	0.31 a	38.65 a	66.48 a
Polypropylene sack	19.38 ab	1.27 a	0.13 a	20.77 ab	79.23 a
Lsd (0.05)	28.95	2.66	0.41	31.82	33.79
CV	61.76	98.40	123.72	63.76	18.70

A significant difference ($p<0.05$) was recorded among the cowpea grains with 1 bored hole counted. Grains sampled from jute sack recorded the highest while pot recorded the least. The amount of grains showing 2 and 3 holes in the various storage containers were significantly not different ($p>0.05$).

And the total average number of grains attacked by insects showed significant higher percentage detected in jute sack (38.65%) and the least (6.63%) in pot while polypropylene had 20.77% per 200 grains.

No significant difference ($p>0.05$) was recorded among the grains that showed no sign of pest attack (wholegrain). Relatively, pot container recorded the highest whole grain, followed by polypropylene sack and the least by jute sack with 93.38, 79.23 and 66.48 percent respectively

4.4 Percentage Germination

4.4.1 Average percentage germination of cowpea

The field work revealed that jute sack performed the least in germination percentage as in Figure 18. The initial germination test before storage was 92% whilst the last germination test after the last week were 70.7%, 70.7% and 56% in Clay pot, Polypropylene sack and Jute sack respectively.

Table 4.12: Average percentage germination

CONTAINER	PERCENTAGE (%)
CLAY POT	70.7
JUTE SACK	56.0
POLYPROPYLENE SACK	70.7

4.4.2 Average percentage germination of groundnut

It was observed that the difference in germination percentage between the Polypropylene sack and the Clay pot representing 80% and 78% was not much, with Jute sack performing the least as seen from Table 4.10. The difference in percentage germination from the germination test before storage (90%) and the germination test after the last week was 10% in the polypropylene sack, clay pot 12% and jute sack 31%.

Table 4.13: Average percentage germination of groundnut

CONTAINER	PERCENTAGE (%)
CLAY POT	**78**
JUTE SACK	**59**
POLYPROPYLENE SACK	**80**

4.5 NUTRITIONAL COMPOSITION

4.5.1 Nutritional Composition of Groundnut

Table 4.14: Effect of storage containers on nutritional composition of groundnut

Container	Ash	Moisture	Protein	Fat	Fibre	Carbohydrate
Pot	2.82 a	5.28 a	25.76 a	43.72 a	4.26 a	18.16 a
Jute Sack	3.11 a	5.64 a	25.87 a	43.72 a	4.86 a	16.78 a
Polypropylene sack	3.19 a	5.36 a	26.25 a	44.39 a	4.69 a	16.11 a
Lsd (0.05)	0.44	0.41	1.19	3.15	0.95	3.84
CV	14.65	7.64	4.69	7.34	21.19	23.06

No significant difference ($p>0.05$) was recorded among the grains stored in the three storage containers with regards to their effects on the nutritional composition of groundnut.

4.5.2 Nutritional Composition of Cowpea

Table 4.15: Effect of storage containers on nutritional composition of cowpea

Container	Ash	Moisture	Protein	Fat	Fibre	Carbohydrate
Pot	3.78 a	10.68 b	21.04 b	2.56 b	3.08 b	58.87 a
Jute Sack	3.76 a	11.19 a	22.70 a	3.67 a	3.72 a	54.96 b
Polypropylene sack	3.96 a	11.11 a	22.05 ab	2.61 b	2.99 b	57.28 a
Lsd (0.05)	0.61	0.33	1.08	0.67	0.64	1.94
CV	16.16	3.11	5.04	23.34	20.08	3.47

4.5.2.1 Ash content of cowpea

The storage containers had no significant effect ($p>0.05$) on the stored groundnut and thus caused no changes in the ash content.

4.5.2.2 Moisture content of cowpea

The moisture content of the stored cowpea was significantly affected ($p<0.05$) by the type of storage. Cowpea stored in the jute (11.19%) and polypropylene (11.11%) sacks had similar moisture, higher and different from that recorded by those stored in pot storage which had the least (10.68%) in order of decreasing.

4.5.2.3 Protein content of cowpea

The storage containers influenced a significant difference among the stored cowpea. And except for cowpea grains in polypropylene sack, the grains in jute sack recorded significantly higher protein content than grains stored in pot storage with 22.05, 22.70 and 21.04 percent respectively.

4.5.2.4 Fat content of cowpea

The fat content of cowpea grains in jute sack contained a significant higher fat (3.67%) than that contained in those stored in polypropylene sack (2.61%) and pot (2.56%).

4.5.2.5 Fibre content of cowpea

Similarly, cowpea stored in jute sack had the highest fibre content and was significantly different ($p<0.05$) from that stored in polypropylene sack and pot which were statistically similar with 2.99 and 3.08 percent respectively.

4.5.2.6 Carbohydrate content of cowpea

A significant difference ($p<0.05$) was recorded among the cowpea grains in the storage containers. Cowpea grains stored with pot and polypropylene sack significantly recorded an equal level of carbohydrate content of 58.89 and 57.28 percent respectively. Both were however different from carbohydrate content recorded in cowpeas stored in jute sack (54.96%).

CHAPTER FIVE

5.0 DISCUSSION

5.1 SURVEY

The survey revealed male as the dominant sex group who were into cultivation of the cowpea and groundnut for the fact that the production is energy demanding. The most economic working age group were those aged from 18 to 37 years and hence, show a youthful class are the major producers of the pulses at the study areas. A relatively low number of the producers, 35% have not had any form of education.

Income generation, food, oil extraction and employment are the main benefits that drive the farmers into cowpea and groundnut cultivation. Yet, they are faced with a number of constraints such as lack of labour, insufficient and failure of rains, accessibility and availability of tractors and high cost of production. According to the farmers, lack of labour is the major constraint for the cultivation of the pulses. There has not been a lasting solution to the constraints, testified by 63% of farmers (respondents).

Losses incurred before harvests were attributed to problem in identifying and selecting good quality varieties, wrongly use or misapplication of chemical, inappropriate cultural practice and the major factor, harsh or poor climatic conditions. Major harvest periods take place from September to November yearly and often done with both hoe and hands for uprooting and plucking. A greater number of loss occurring during harvest through pods stripping, mechanical damage, self-explosions of bean and millipedes attack. Modes of transporting of their produce were by use of cargo cars, motor bike, bicycles and on heads.

Postharvest losses occur at four main stages of the postharvest chain, namely during storage, threshing, drying and transporting as well as winnowing and shelling in a decreasing order of severity. Normally, the producers keep their harvested groundnuts and cowpeas for a period of 1 – 6 months either in crib, polypropylene sack, jute sack or clay pot based preference and availability.

The majority of the farmers (70%) identified insects like bean beetle, bean weevil and cowpea beetle as well as the groundnut bruchids as the main pests that damage and cause diseases to cowpea and groundnut at storage while rodents and fungi are regarded to cause a minimal damage by a few farmers. Pests and diseases are vastly controlled by periodic drying of the produce in the sun and use of wood ash while chemicals and traps are rarely used. Mud silo is regarded by farmers as best storage facility that prevents and minimizes the prevalence of pests and diseases to a great extent during storage than crib, polypropylene sack, clay pot and jute sack.

5.2 POSTHARVEST STORAGE

5.2.1 Temperature, Humidity and Moisture within Storage Containers

Some major storage factors which influence the longevity of produces at storage are temperature, humidity and moisture level under which the produces are stored. The study showed that, temperature within the storage containers for which the pulses, groundnut and cowpea were stored varied slightly between the two pulses with temperature range of 30.17 – 31.27ºC. A significant difference ($p<0.05$) was recorded among the sacks and the clay pot storage used to store groundnut seeds while cowpeas stored in the same storage containers were within the same storage temperature influences ($p>0.05$). The sacks (jute and polypropylene) used for groundnut storage showed a similar temperature but were different from clay pot due to clay pot able to maintain a uniform temperatures longer.

It is well documented that, an excessively high humidity level within storage area of grains often account for high build-up of moulds (fungi) and consequently, the release of toxic substances due to the fungi growth. Humidity levels of the storage containers within which the pulses were stored were significantly not different ($p>0.05$). Thus, the three storage containers had an equal humidity effect on the stored groundnuts and cowpeas. The relative humidity levels were above the recommended range (60 – 70%) (Robinson, 1984) deemed safe for the storage of the legumes.

Often a time, moisture level of stored produces is positively correlated to humidity level. And like the humidity level, no significant difference ($p>0.05$) was recorded among the storage containers within which the pulses were stored. Thus, the moisture level of groundnut in clay pot, jute and polypropylene sacks were significantly equal likewise the cowpeas. The moisture levels ranged from 8.30 to 8.68% were within the recommended 8 – 9% moisture level required for long storage of grains as indicated by Quinn (1999) and Thomas (2003). However, a high moisture level, 12% and above (Quinn, 1999:Thomas, 2003) of stored grains is likely to lead to fungi growth that releases toxic substances due to dampness and in the case of groundnut, Aflatoxin (Bediako *et al.*, 2009) which contaminates the grains. Besides, excessive moisture level may lead to deterioration of cowpeas.

5.2.2 Postharvest Pest and Damage

Insect pests' infestation and their damage is one major problem that affects grains at storage and account for a high percentage of losses prior to and at storage. Level of infestation and damage is often observed and reported to be greatly high in cowpeas comparative to groundnuts. This unchanging outcome could be due to repellent properties of groundnut with relatively higher oil content. The result as shown on Table 4.6 and 4.7 proved a relatively high pest infestation in cowpea than groundnut with regard to the total amount of insects (both dead and live) detected in the containers used for the storage of the pulses. With regard to groundnut storage, a significant difference ($p<0.05$) in the level of pests were recorded between the jute sack and polypropylene sack with high (25) and low (7) counts per 1kg grains respectively on the average but both were not different from that recorded in the clay pot storage. The difference could be as a result of the ability of the polypropylene sack to keep the content air-tight and hence, forced a low rate in breeding than jute sack.

The extent of damage caused by the pests on the groundnuts was minimal though the level of damaged grains (rated by bore holes on grains) per every 200 grains count on average, detected in jute sack (1.86%) was significantly ($p<0.05$) higher than polypropylene sack (0.98%) and clay pot storage (0.92%) that significantly recorded the same ($p>0.05$) level of grains damage. Similarly, the whole grains in contrast, showed a significant difference among the storage containers. The high insects count in the jute sack is due to the fact that it does not give much natural protection against insects, rodents and moisture (Ali, 2008). Similarly, David (1978) earlier stated that, stored grains in jute sacks are easily attacked by insects, rodents and fungi and becomes serious when the grains are well protected in the grain sacks.

No significant difference ($p>0.05$) on insect count in cowpea was however recorded among the storage containers. This could be due to the fact that, cowpea is highly prone to insect attack especially cowpea weevils that have high breeding at storage. It is confirmed by Ouedrago *et al.* (1996) that, cowpea weevils multiplies very fast in storage and gives rise to new generation every month. Most often cowpea weevils attack the pods on the field and at transit and oviposit through the pod before getting into storage. Level of damage caused by the insect pests on cowpea was relatively higher compared to groundnut and the counts were significantly different ($p<0.05$) among the storage containers. And the capability of the storage containers to hold and minimize the extent of damage caused by the insects on cowpea was better in clay pot storage, which recorded the least percentage of 6.63% but higher in jute sack with a total of 38.65% on the average due to a relatively high count of insects in jute sack. The highest level of damage recorded for the two months period fell within the range reported by Golob (1996) who said, damage to stored cowpea is at 15 – 94% for a period of 7 – 9 months in Ghana. On contrary to the level of damage, the amount of cowpea whole grains (not attacked by insects) in all the storage studies were significantly not different ($p>0.05$).

5.2.3 Percentage Germination

It was observed that the both clay pot and polypropylene sack showed 70.7% germination of cowpea after storage at a reduction in germination percentage, as seen from Figure 18. The jute sack recorded 56% germination which could be attributed to serious destruction of the germ layer by insects. There were significant differences between the initial germination percentage (92%) and the final germination of each container. It was observed that there was no much difference in germination percentage between the Polypropylene sack and the Clay pot representing 80% and 78% respectively as seen in the Jute sack against 90% for groundnut.

This could be due to persistent increase in insects' population in the facilities. It might also be due to changes in the moisture content level temperature of the product and its environment inside the containers as the containers were very permeable to atmospheric moisture.

5.3 NUTRITIONAL COMPOSITION

Legumes are an important economical crops considered to provide high amount or level of nutritional values when consumed as food and feed. Yet, the levels could be affected in terms of loss if not stored well. The proximate analysis of groundnut and cowpea showed a varying level of ash, moisture, protein, fat, fibre and carbohydrate in high quantities. The result has shown that, while cowpea is relatively high in the level of ash, moisture and carbohydrates, groundnut is very rich in protein, fat and fibre content in comparison.

The storage containers showed no significant influences on the ash component of the groundnut and cowpea. Similarly, the storage of groundnut in the pot, jute and polypropylene sacks performed and maintained a significant equal level of moisture, protein, fat, fibre and carbohydrate. Thus all the storage containers have the capability of retaining the same level of nutritional value under the same storage condition. The compositions were within the standard reported by US Department of Agriculture, Agricultural Research Service (2009).

The moisture level of cowpea varied significantly ($p<0.05$) with pot stored cowpeas recording the least level of moisture content compared to jute and polypropylene sacks which performed equally. This outcome means the pot's cowpeas may store longer than those stored in sacks due to an increase in moisture level as a result of heat build-up. Yet, the moisture contents were within the recommended rates for short term storage of cowpea and long term storage of groundnut (Thomas, 2003).

Protein of cowpeas stored with jute sack recorded significantly ($p<0.05$), a higher protein than clay pot. Similarly, the jute sack's stored grains had the highest level of fat and fibre than those stored with pot and polypropylene sack which performed equally. The clay pot and polypropylene sack's stored cowpeas equally had higher carbohydrate content different from that of jute sack's grains. Carbohydrate content of the stored cowpeas in the storage containers showed a significant difference ($p<0.05$) with jute sack's grains recording the least compared to clay pot and polypropylene sack that were significantly not different. The difference could be due to varying rate of respiration of the stored cowpeas in the various containers. This confirms the findings of Passem *et al.* (1978) who stated that, respiration result in a steady loss of carbohydrate in the form of carbon dioxide and water.

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATION

6.1 CONCLUSION

The survey revealed lack of labour for pulse production as the major constraints faced by farmers while insect pest infestation and damage has become difficult to control at storage without a chemical treatment. A great deal of loss occurs at harvest through pod stripping, mechanical damage, self-explosion (in the case of beans) and pest attack.

The outcome of storage experiment showed pest infestation and damage as the main cause of postharvest loss. The Loss of cowpea is comparatively higher than groundnut at storage. This was as a result of the high pest infestation recorded in cowpea. For groundnut, pot storage performed equally to the jute and polypropylene sack but the latter two showed a difference. The highest pests count was detected in jute sack. Similarly, pest damage on cowpea was significant and severe in the jute sacks but low in pot storage container. Also, damage to groundnuts in the storage containers was minimal yet significant among the storage containers. High counts of affected groundnuts were detected in jute sack while low but significant equal counts were detected in pot and polypropylene sack.

Regardless of the high damage on cowpeas, the whole grains count showed no significant difference among the containers. The whole grains counted were different among the containers for the storage of groundnut.

Against the odds of jute sack with reference to pest infestation and damage, it performed best in preserving and retaining the highest protein, fat, fibre and moisture level except carbohydrate and ash content of cowpea. No significant differences were recorded among the storage containers with regard to levels of ash, moisture, protein, fat, fibre and carbohydrate content of groundnuts.

6.2 RECOMMENDATION

Since the nutritional composition is within a recommended rate, producers may rely on any of the three storage containers tested for the storage of cowpea on the short term due to proneness to pest attack.

The clay pot storage containers performed best against the level of pests attack and damage on groundnut and hence, could be considered for the storage of groundnut without chemical application and achieve a good result since nutritional composition of groundnut stored with the containers had the same levels.

Selection of early maturing, drought and pest resistance and good yielding varieties of groundnut and cowpea could help increase production and minimize losses.

Further studies should be researched on the types of insects, their mode of infestation and control or preventive measures on groundnut and cowpea as they were the challenges. Also, comparisons of the traditional methods and conventional methods of controlling insects should be carried to enhance both quantity and quality of food as the people health is concerned.

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APPENDICE

Appendix A: Sample of questionnaire used for the survey

QUESTIONNAIRE ON EVALUATION OF STORAGE FACILITIES FOR GROUNDNUT AND COWPEA IN THE ZABZUGU AND SABOBA DISTRICTS OF THE NORTHERN REGION OF GHANA

A: BIODATA

1. Name of District---

2. Name of Community--

3a. Sex of Respondent------------------------------ 3b. Age------------------------

4. Educational level; A. None B. Basic C. Secondary D. Tertiary E. Others ----------------------------

5. Household status --------------------------------

B: SURVEY DATA

1. Do you engage in crop cultivation? YES NO

2. If yes, name some of the crops you cultivate.

3. Which of the following legumes do grow?

A. Soya beans B. Groundnuts

C. cowpea D. Pigeon peas

E. Others, specify-------------------------------------

4. How long have you been growing it/them? --

5. How large is your field in acres for cowpea? --

6. How large is your field in acres for groundnut? -------------------------------------

7. What variety or varieties of cowpea do you grow? -------------------------------

8. What variety or varieties of groundnut do you grow? -------------------------------

9. Which of the farming systems do you practice in cowpea or groundnut cultivation?

----

10. Why ---

11. What benefits do derive from cowpea or groundnut cultivation?

12. What are the problems you encounter during the cultivation of cowpea or groundnut? --

13. Have there been any solutions to the problems? YES NO

14. If yes, how were they solved? --

15. What factors cause losses of cowpea or groundnut during the pre-harvest stage?

A. Variety of crop

B. Climate

C. Types of chemicals used

D. Others, specify--

16. Do you leave your crops till maturity before you harvest them? YES NO

17. If NO, why---

18. When do you harvest your crop? --

19. How do you harvest? Describe ---

20. Do you experience harvesting losses? YES NO

21. If YES, how? ---

22. What harvesting method(s) do you use? A. Manual

B. Tractor drawn implement.

C. Combine Harvester

23. Do you own / use any postharvest equipment or machines? YES NO

24. If yes, which one(s)

A. Dryers B. Sorters

C. thresher D. Others or more than one----------------------------

25. Do you experience any postharvest losses? YES NO

26. If yes, when? During --

A. Drying B. Shelling or threshing

C. Winnowing D. Transportation

E. Storage F. All the above---

27. What threshing method do you use?

A. Manual B. Machine.

28. What is/are your perception(s) of postharvest losses of cowpea or groundnut in general? Give estimation. -------------------------

29. How do you dry your cowpea or groundnut?

A. Sun B. Solar

C. Oven D. Air

30. Do you store your produce after harvesting? YES NO

31. If YES, how long do you store your produce before marketing?

A. 2 weeks B. 1 month

C. 3 months. D. 6 Months.

E. More than above, specify------------------- F. None ---------------------------------

32. Which form do you store your produce?

A. Pods

B. Grains

33. Do you have difficulties in storing the produce? YES NO

34. If yes, what are the difficulties you have in storing them?

----

35. Which of the following facilities do you store your produce?

A. pots B. Sacks C. Cribs D. Silos

E .Calabashes F. Others, specify---

36. Are the storage facilities available at your use? YES NO

37. If NO, then how do you manage the produce? --

38. Which of the above facilities best stores the produce for long time without spoilage?

A. Pots B. Sacks

C. Cribs D. Calabashes

E. Silos F. Others, specify--

39. How long can it store the produce?

A. Weeks----------------------

B. Months---------------------

40. Do you treat your produce with chemicals during storage? YES NO

41. If yes, what type of chemicals? -------------------------------

42. Why do you treat the produce with the chemicals?

A. Prolong shelf life B. Control pest and disease

C. Other reason -------------------------------

43. What type of pests or diseases do you encounter during storage?

44. How do you control any pests or diseases found in your produce? --------------------
----

45. Which of the storage facilities prevent(s) the prevalence of pests and diseases?

Why? ---
----

46. Which facility is the poorest in storing food stuffs? -------------------------------------

47. Rank the storage facilities available in the area in order of maintaining quality of produce.

48. Have you received any training on methods of storing your produce?

YES NO

49. If yes, from which organizations?

A. MOFA

B. NGO’S

C. Other bodies, specify----------------------------

50. Do you have ready market for your produce?

YES NO

51. If yes, how do you transport your produce? By ---------

A. Head B. Cargo car C. Bicycle D. Motor bike

52. What do you think can be done to reduce postharvest losses of cowpea or groundnut from harvesting to final use? ----------------------------------

Appendix B: FORMULAE USED IN CALCULATIONS

B1. Moisture content determination

$$\% \text{ Moisture} = \frac{\text{Weight of moisture}}{\text{Weight of wet sample}} \times 100 = \frac{W2 - W3}{W2 - W1} \times 100$$

Let W1= weight of the empty glass dish
W2= weight of the empty glass dish + wet sample
W3= weight of the empty glass dish + dry sample

B2. Total Ash determination

$$\% \text{ Ash} = \frac{\text{Weight of ash}}{\text{Weight of sample}} \times 100 = \frac{W3 - W1}{W2 - W1} \times 100$$

B3. Crude protein determination

$$\% \text{ Total Nitrogen} = \frac{(100 \times (Va - Vb) \times NA \times 0.01401) \times 100}{W \times 100}$$

Where Va = volume (ml) of HCl used in the sample titration
Vb = volume (ml) of HCl used in the blank titration
N = Normality of HCl
W = weight of sample (g)
% Crude protein = %N × F

B4. Crude fat determination

$$\% \text{ Crude fat} = \frac{\text{Weight of fat} \times 100}{\text{Weight of sample}} = \frac{A}{M} \times 100$$

A : Mass(g) of the extracted matter
B : Mass (g) of the tested sample

B5. Crude fibre determination

$$\% \text{ Crude fibre} = \frac{\text{Weight of crude fibre}}{\text{Weight of sample}} \times 100 = \frac{W2 - W3}{W2 - W1} \times 100$$

Let W1= weight of the empty crucible
W2= weight of the empty crucible + wet sample
W3= weight of the empty crucible + ash sample

B6. Carbohydrate determination

% Carbohydrate = 100 – (% moisture + % ash + protein + % fat + % fibre)

$$\text{Or, } \%\text{Carbohydrate} = \frac{(100 - Mc) \times Y}{100}$$

Appendix C: ANOVA Tables

Temperature, Humidity and Moisture ANOVA Tables of Groundnut

Randomized Complete Block AOV Table for Temperature

Source	DF	SS	MS	F	P
BLK	2	0.06003	0.03002		
Container	2	1.40524	0.70262	16.12	0.0122
Error	4	0.17434	0.04359		
Total	8	1.63962			

Grand Mean 30.710 CV 0.68

Randomized Complete Block AOV Table for Humidity

Source	DF	SS	MS	F	P
BLK	2	1.08594	0.54297		
Container	2	1.03385	0.51693	2.66	0.1846
Error	4	0.77865	0.19466		
Total	8	2.89844			

Grand Mean 87.208 CV 0.51

Randomized Complete Block AOV Table for Moisture

Source	DF	SS	MS	F	P
BLK	2	0.02542	0.01271		
Container	2	0.04667	0.02333	3.13	0.1518
Error	4	0.02979	0.00745		
Total	8	0.10187			

Grand Mean 8.6125 CV 1.00

Dead, Live and Total Insect ANOVA Table of Groundnut

Randomized Complete Block AOV Table for Dead

Source	DF	SS	MS	F	P
BLK	2	2.00000	1.00000		
Container	2	2.00000	1.00000	2.00	0.2500
Error	4	2.00000	0.50000		
Total	8	6.00000			

Grand Mean 0.6667 CV 106.07

Randomized Complete Block AOV Table for Live

Source	DF	SS	MS	F	P
BLK	2	137.556	68.778		
Container	2	468.222	234.111	5.91	0.0639
Error	4	158.444	39.611		
Total	8	764.222			

Grand Mean 15.556   CV 40.46

Randomized Complete Block AOV Table for Total

Source	DF	SS	MS	F	P
BLK	2	160.889	80.444		
Container	2	523.556	261.778	5.54	0.0704
Error	4	189.111	47.278		
Total	8	873.556			

Grand Mean 16.222   CV 42.39

Insect Damage - One, Two, Three and Total holes and Whole Grains ANOVA

Randomized Complete Block AOV Table for One

Source	DF	SS	MS	F	P
BLK	2	0.66462	0.33231		
Container	2	0.82776	0.41388	61.37	0.0010
Error	4	0.02698	0.00674		
Total	8	1.51936			

Grand Mean 1.1422   CV 7.19

Randomized Complete Block AOV Table for Two

Source	DF	SS	MS	F	P
BLK	2	0.04247	0.02123		
Container	2	0.14820	0.07410	2.53	0.1953
Error	4	0.11733	0.02933		
Total	8	0.30800			

Grand Mean 0.1100   CV 155.70

Randomized Complete Block AOV Table for Total holes

Source	DF	SS	MS	F	P
BLK	2	0.96127	0.48063		
Container	2	1.64407	0.82203	15.20	0.0135
Error	4	0.21627	0.05407		
Total	8	2.82160			

Grand Mean 1.2533 CV 18.55

Randomized Complete Block AOV Table for Whole Grains

Source	DF	SS	MS	F	P
BLK	2	0.98216	0.49108		
Container	2	1.65616	0.82808	15.00	0.0138
Error	4	0.22084	0.05521		
Total	8	2.85916			

Grand Mean 98.752 CV 0.24

Proximate Analysis ANOVA Tables of Groundnut

Randomized Complete Block AOV Table for ash

Source	DF	SS	MS	F	P
BLK	2	3.60525	1.80263		
Container	2	0.69103	0.34551	1.74	0.1992
Error	22	4.37344	0.19879		
Total	26	8.66972			

Grand Mean 3.0426 CV 14.65

Randomized Complete Block AOV Table for moisture

Source	DF	SS	MS	F	P
BLK	2	1.30889	0.65444		
Container	2	0.64320	0.32160	1.87	0.1779
Error	22	3.78438	0.17202		
Total	26	5.73647			

Grand Mean 5.4289 CV 7.64

Randomized Complete Block AOV Table for Protein

Source	DF	SS	MS	F	P
BLK	2	3.1152	1.55760		
Container	2	1.2100	0.60499	0.41	0.6693
Error	22	32.5499	1.47954		
Total	26	36.8751			

Grand Mean 25.961 CV 4.69

Randomized Complete Block AOV Table for fat

Source	DF	SS	MS	F	P
BLK	2	0.389	0.1944		
Container	2	2.667	1.3333	0.13	0.8802
Error	22	228.611	10.3914		
Total	26	231.667			

Grand Mean 43.944 CV 7.34

Randomized Complete Block AOV Table for fibre

Source	DF	SS	MS	F	P
BLK	2	0.8976	0.44880		
Container	2	1.7490	0.87449	0.92	0.4140
Error	22	20.9552	0.95251		
Total	26	23.6018			

Grand Mean 4.6063 CV 21.19

Randomized Complete Block AOV Table for carbohydrate

Source	DF	SS	MS	F	P
BLK	2	9.042	4.5212		
Container	2	19.616	9.8082	0.64	0.5384
Error	22	338.827	15.4012		
Total	26	367.486			

Grand Mean 17.016 CV 23.06

Temperature, Humidity and Moisture ANOVA Tables of Cowpea

Randomized Complete Block AOV Table for Mean Temperature

Source	DF	SS	MS	F	P
BLK	2	0.14149	0.07075		
Container	2	0.04514	0.02257	0.10	0.9109
Error	4	0.94444	0.23611		
Total	8	1.13108			

Grand Mean 30.236 CV 1.61

Randomized Complete Block AOV Table for Mean Humidity

Source	DF	SS	MS	F	P
BLK	2	0.08681	0.04340		
Container	2	0.39670	0.19835	1.23	0.3845
Error	4	0.64757	0.16189		
Total	8	1.13108			

Grand Mean 88.201 CV 0.46

Randomized Complete Block AOV Table for Mean Moisture

Source	DF	SS	MS	F	P
BLK	2	0.11010	0.05505		
Container	2	0.01531	0.00766	0.10	0.9110
Error	4	0.32083	0.08021		
Total	8	0.44625			

Grand Mean 8.3125 CV 3.41

Dead, Live and Total Insect ANOVA Tables on Cowpea

Randomized Complete Block AOV Table for dead

Source	DF	SS	MS	F	P
BLK	2	2623.34	1311.67		
Container	2	2277.54	1138.77	1.64	0.3020
Error	4	2778.83	694.71		
Total	8	7679.70			

Grand Mean 25.144 CV 104.82

Randomized Complete Block AOV Table for live

Source	DF	SS	MS	F	P
BLK	2	569.06	284.528		
Container	2	351.60	175.801	2.67	0.1836
Error	4	263.60	65.899		
Total	8	1184.26			

Grand Mean 10.022 CV 81.00

Randomized Complete Block AOV Table for Total

Source	DF	SS	MS	F	P
BLK	2	5576.2	2788.12		
Container	2	4406.2	2203.10	1.93	0.2589
Error	4	4564.0	1141.01		
Total	8	14546.5			

Grand Mean 35.167 CV 96.05

Insect Damage - One, Two, Three and Total holes and Whole Grains ANOVA

Randomized Complete Block AOV Table for one hole

Source	DF	SS	MS	F	P
BLK	2	704.21	352.106		
Container	2	1333.32	666.662	4.09	0.1079
Error	4	652.18	163.045		
Total	8	2689.72			

Grand Mean 20.674 CV 61.76

Randomized Complete Block AOV Table for two holes

Source	DF	SS	MS	F	P
BLK	2	4.1311	2.06554		
Container	2	5.9019	2.95095	2.14	0.2338
Error	4	5.5252	1.38129		
Total	8	15.5582			

Grand Mean 1.1944 CV 98.40

Randomized Complete Block AOV Table for three holes

Source	DF	SS	MS	F	P
BLK	2	0.20573	0.10286		
Container	2	0.14844	0.07422	2.28	0.2184
Error	4	0.13021	0.03255		
Total	8	0.48438			

Grand Mean 0.1458 CV 123.72

Randomized Complete Block AOV Table for Total holes

Source	DF	SS	MS	F	P
BLK	2	842.17	421.084		
Container	2	1544.95	772.477	3.92	0.1141
Error	4	788.03	197.006		
Total	8	3175.15			

Grand Mean 22.014 CV 63.76

Randomized Complete Block AOV Table for whole Grains

Source	DF	SS	MS	F	P
BLK	2	634.27	317.136		
Container	2	1086.05	543.026	2.44	0.2025
Error	4	888.64	222.160		
Total	8	2608.96			

Grand Mean 79.694 CV 18.70

Proximate Analysis ANOVA Tables of Cowpea

Randomized Complete Block AOV Table for ash

Source	DF	SS	MS	F	P
BLK	2	0.48139	0.24069		
Container	2	0.22312	0.11156	0.29	0.7508
Error	22	8.45217	0.38419		
Total	26	9.15667			

Grand Mean 3.8352 CV 16.16

Randomized Complete Block AOV Table for moisture

Source	DF	SS	MS	F	P
BLK	2	1.38130	0.69065		
Container	2	1.35294	0.67647	5.77	0.0097
Error	22	2.57808	0.11719		
Total	26	5.31232			

Grand Mean 10.993 CV 3.11

Randomized Complete Block AOV Table for Protein

Source	DF	SS	MS	F	P
BLK	2	26.8979	13.4489		
Container	2	12.6148	6.3074	5.17	0.0144
Error	22	26.8324	1.2197		
Total	26	66.3451			

Grand Mean 21.929 CV 5.04

Randomized Complete Block AOV Table for fat

Source	DF	SS	MS	F	P
BLK	2	1.7222	0.86111		
Container	2	7.0556	3.52778	7.47	0.0033
Error	22	10.3889	0.47222		
Total	26	19.1667			

Grand Mean 2.9444 CV 23.34

Randomized Complete Block AOV Table for fibre

Source	DF	SS	MS	F	P
BLK	2	1.4935	0.74677		
Container	2	2.8284	1.41418	3.30	0.0559
Error	22	9.4352	0.42887		
Total	26	13.7571			

Grand Mean 3.2615 CV 20.08

Randomized Complete Block AOV Table for carbohydrate

Source	DF	SS	MS	F	P
BLK	2	29.245	14.6226		
Container	2	69.498	34.7491	8.85	0.0015
Error	22	86.344	3.9247		
Total	26	185.088			

Grand Mean 57.037 CV 3.47