KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY,

KUMASI

COLLEGE OF AGRICULTURE AND NATURAL RESOURCES

DEPARTMENT OF HORTICULTURE

EFFECT OF DIFFERENT INDIGENOUS STORAGE STRUCTURES ON THE QUALITY OF COWPEA (*Vigna unguiculata*) GRAINS DURING FIVE MONTHS STORAGE IN THE SAVELUGU / NANTON MUNICIPALITY OF THE NORTHERN REGION

BY

IMORO YAKUBU

MARCH, 2014

EFFECT OF DIFFERENT INDIGENOUS STORAGE STRUCTURES ON THE

QUALITY OF COWPEA (*Vigna unguiculata*) GRAINS DURING FIVE MONTHS

STORAGE IN THE SAVELUGU / NANTON MUNICIPALITY OF THE

NORTHERN REGION

BY

IMORO YAKUBU

THESIS SUBMITTED TO THE SCHOOL OF GRADUATE STUDIES, KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF MASTER OF PHILOSOPHY DEGREE (M. phil. POSTHARVEST TECHNOLOGY)

MARCH, 2014

DECLARATOIN

I hereby declare that this submission is my own work towards the Master of Science degree and that, to the best of my knowledge, it contains no material previously published by another person nor materials which have been accepted for the award of any other degree of the University, except where due acknowledgements have been made in the text.

…. …………………….. …………………………..
Signature DATE
IMORO YAKUBU
(STUDENT)

Certified by:

………………………….. …………………………..
Signature DATE
DR. B.K Maalekuu.
(Main Supervisor)

………………………….. …………………………..
Signature DATE
MR. P.Y Adjei
Co supervisor

………………………….. …………………………..
Signature DATE
DR.BEN K. Banful
(Head of Department)

DEDICATION

This research is dedicated to God Almighty for giving me life and seeing me through all my education, to my lovely mother and wife Memunatu Yakubu and Afishetu Imoro respectively, and my children, Imoro Nashiratu, Imoro Hidri, Imoro Ilham and Imoro Kaisan.

ACKNOWLEDGEMENT

A Special word of thanks goes to my main supervisor, Dr. B. K Maalekuu and my cosupervisor, Mr. P. Y. Adjei for their invaluable comments and assistance. I am also indebted to Mr. Yazid Mumin a lecturer at the University for Development Studies (UDS) for his suggestions, contributions and also analyzing the data. I am forever grateful to Mr. Francis Appiah, a lecturer from Kwame Nkrumah University of Science and Technology Kumasi, for useful suggestions.

My profound gratitude goes to Mr. Nat, a Technician at KWAME Nkrumah University of Science and Technology Food Science Laboratory, for the assistance offered me throughout the laboratory work. Special thanks also go to Mr. Apaliya Tabiru Maurice of Islamic Senior High School, for his suggestions and contributions. Special thanks to my lovely wife, Afishetu Imoro for her encouragement and financial support.

I also want to acknowledge all my friends and colleagues for the good time that we had together throughout the course. I say God bless you all. I also thank the librarians of University for Development Studies, for their immeasurable assistance in lending me all the materials needed for the work. Last but not the least, my special thanks go to my children, Imoro Nashiratu, Imoro Hidri, Imoro Ilham and Imoro Kaisan for their patience and companion throughout the work. May the Almighty God bless all.

ABSTRACT

The effect of different indigenous storage structures on the quality of cowpea (*Vigna unguiculata*) grains was carried out in the Savelugu / Nanton municipality of northern region from November 2012 to May 2013. 50% of total producers, 25 percent of retailers and 25 percent of consumers of cowpea grains in the Savelugu/Nanton municipality were randomly selected and interviewed from communities such as Tampion, Nanton, Savelugu, Pong Tamale, Diary, Zoggu, Nakpanzoo, Yepalsi, Gushei and Kanshegu. The structures used for storing cowpea grains were jute sacks, fertilizer sacks, clay pots, mud silos and cribs. The processing methods were threshing, drying, winnowing, transportation, application of chemicals and storage. The same quantity of grains were put in each of the storage structures and the parameters such as weight retained, temperature, relative humidity, number of insects and damage grains were determined every two weeks for quality analysis. The food nutrients such as carbohydrates, protein, fat, ash, moisture and fibre were analyzed at the Kwame Nkrumah University of Science and Technology Chemistry Laboratory, Kumasi. Finally, relevant conclusion and recommendations were made. Some of the relevant conclusions made were:Crib and clay pot were effective in maintaining the quality of grains in terms of weight retention, germination, insect protection, temperature, carbohydrates and proteins. Fertilizer sack, jute sack and mud silo were ineffective in maintaining the quality of cowpea grains. It was recommended that the crib and clay pot with little modification of fertilizer and jute would be good for cowpea over five month‘s storage.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

ISTA—International Seed Testing Association

USA—United States of America

FAO—Food and Agricultural organization

MOFA—Ministry of Food and Agriculture

CHAPTER ONE

1.0 INTRODUCTION

Cowpea is a traditional legume widely cultivated by small–scale farmers in sub-Saharan Africa. The legume was domesticated either in Southern and Eastern Africa or in West Africa, where a large number of primitive cultivars and semi wild forms can be found (Raemaekers, 2001). It is cultivated in the tropical, sub-tropical and many temperate regions of the world. The main cowpea- producing countries in Africa include Nigeria, Niger, Burkina Faso, Ghana, Kenya, Uganda, Malawi and Senegal (Raemaekers, 2001). The cultivation of cowpea in Ghana is carried out mostly in the transitional and northern guinea savannah zones of Northern, Upper East and Upper West Regions. The major season for cowpea cultivation in the Savelugu/Nanton District is from May to August. However , a few resourceful farmers who can protect their cowpea plants against field pests plant around late July or early August, and harvest in October(personal observation). The most common variety cultivated by farmers in the Savelugu/Nanton Municipality is the local cowpea, which is of two types –the creeping and erect or *bengpulla* and *bengsagla* respectively. However, other varieties such as *ayiyi*, black eye, asontem and *mondoh* are cultivated in small quantities (Lowenberg-DeBoar *et al.* 2003). Cowpea is a major staple food crop in sub-Saharan Africa, especially in the dry savannah regions of West Africa. The seeds are a major source of plant proteins and vitamins for man and his animals, and also a source of income. The young leaves and immature pods are eaten as vegetables. There is a big market for the sale of cowpea grain and fodder in West Africa. In Nigeria, farmers who cut and store cowpea fodder for sale at the peak of the dry season have been found to increase their annual income by 25% (Raemaekers, 2001). Cowpea also plays an important role in providing soil nitrogen to cereal crops (such as maize, millet and sorghum) when grown in rotation, especially in areas where poor soil fertility is a problem.

The cowpea grain harvested at the end of the season is stored over a period of about eight month. However, in anticipation of grain losses during storage, only the seed for planting in the next season is stored by farmers in the district for longer than eight months, and the rest of the crop is sold out at harvest time. Due to the enormous world-wide and nutritional importance of cowpea products, it is critical to recognize the various factors contributing to the deterioration of cowpea. The postharvest storage method practiced in the district by these farmers is the traditional method of mud silos (the most widely used), clay pots, calabashes, cribs and jute sack

A large number of pests and diseases attack cowpea at all growth stages. The pests and diseases constitute, without doubt, the most limiting factors affecting intensive cowpea production in Savelugu/Nanton Municipality as they may cause total loss of the grain. Losses of the grain during the traditional postharvest storage period are very high, leading to serious financial and nutritional losses of the grain to storage pest in the municipality. Singh *et al.* (1997), documented the losses of cowpea grain during traditional postharvest storage in Nigeria. Pods stored for eight months had 50% grain damage by pests, but when stored as grain, 82% of the grain had one or more holes in them. A visit to any village market in the district will reveal that the cowpea grains offered for sale are usually damaged and when the damage exceeds one or two holes per seed, the price is usually lower than the grain without holes or with very few holes in them.

Once the farmer‘s postharvest storage methods are unable to prevent or even reduce the damage caused by pest to storage grain, most farmers have resorted to the use of very dangerous and unapproved synthetic chemicals such as organo-chlorine chemicals for cowpea grain storage. These chemicals are not only expensive, but can cause serious environmental and health hazards or even death to livestock and human beings. As a result farmers‘ interest in cowpea production in the study area has declined. There is therefore the need to critically research into the methods that farmers use in storing their grains and how the methods affect the quality of the grains and possibly suggest a way or two to improve some of them.

Ghana cannot achieve its planned economic growth and poverty reduction without a significant improvement in the performance of the agricultural sector. Storage of food therefore enhances food security through continuous supply of food for processing and distribution. Inadequate, inappropriate, as well as expensive storage facilities are constraints to agricultural production. They contribute to high postharvest losses and low returns for farmers and processors. Minimizing postharvest losses and maintaining high quality of produce are crucial for sustainable and profitable agriculture. The nature of storage structures and the type of storage management practices leave much to be desired. The contribution of cowpea to food and poverty reduction can be substantial in Ghana if both biological and socioeconomic constraints such as storage and marketing are addressed. The demand for cowpea is increasing because of high population growth mainly from the urban areas and also because of poverty and demand for low-cost food (Langyintuo *et al.,* 2003).

Damage and weight loss to stored cowpea are caused by the larvae, which develop inside the grain and consume the seed. Often, farm storage for six months is accompanied by about 30% loss in weight with up to 70% of seeds being infested and virtually unfit for consumption (Murdock *et al.,* 2003). The damage incurred is highly significant as poor quality cowpea commands much reduced market prices.

Research done in the methods used in storing cowpea in the study area with appropriate recommendation will have great benefits especially to the people of Savelugu/Nanton District and Ghana as a whole. The study is likely to bring out some solutions to problems of storing cowpea grains in the area of study. It may provide information for the government, non-governmental organizations, financial institutions and other co-operate bodies who will be interested in agricultural projects/activities.

The main objective of the study is to determine the shelf life of cowpea grains using different indigenous structures of storage. The specific objective is

1. To identify cowpea postharvest practices used in the Savelugu/Nanton Municipality
2. To determine the effects of different structures of storing cowpea in the Savelugu/Nanton Municipality.
3. To determine the best indigenous structures of storing cowpea grains

CHAPTER TWO

LITERATURE REVIEW

2.1 BOTANY

Cowpea is one of common names in English: cowpea, bachapin bean, black-eyed pea, southern, Crowder pea, china pea and cow gram; in Afrikaans: akkerboon, swartbekboon, koertjie; in Zulu: isihlumaya; in Venda: munawa (plant), nawa (fruits) imbumba, indumba; in Shangaan: dinaba, munaoa, tinyawa (Aveling, 1999). It is also known internationally as lubia, niebe coupe or frijol. However, they are all species of *Vigna unguiculata* (L) Walp, which in older reference may be identified as *Vigna sinensis* (L) (Quinn, 1999)

It is an annual herb with a strong principal root and many spreading lateral roots in surface soil. The root system having large nodules is more extensive than those of soybean. *Bradyrhizobiuim spp* are the specific symbiotic nodular bacteria. Growth forms vary and may be erect, trailing, climbing or bushy, usually indeterminate under favourable conditions. Leaves are alternate and trifoliate and usually dark green. The first pair of them is simple and opposite. Stems are striate, smooth or slightly hairy, sometimes tinged with purple (Aveling, 1999).

Flowers are self-pollinating and may be white, dirty yellow, pink, pale blue or purple in colour. They are arranged in raceme or intermediate inflorescences in alternate pairs. Flowers open in the early day and close at approximately midday; after blooming they wilt and collapse. Pollinating insect activities are beneficial in increasing the number of pod set, the number of seeds per pod or both; however, there are no recommendations for the use of pollinating insects on cowpeas (McGregor, 1999).

Its geographical range is wide, from Warm Temperature Thorn to Moist through Tropical Thorn to Wet Forest Life Zones. It grows best in hot areas and can produce a yield of one ton seed and five tons hay per hectare with as little as 300 mm of rainfall. Long taproot and mechanisms such as turning the leaves upwards to prevent them to become too hot and closing the stomata, give to cowpea an excellent drought tolerance (Van Rij, 1999) Cowpea is considered more tolerant to drought than soybean or mung bean because of its tendency to form a deep taproot. It has a competitive niche in sandy soils, does not tolerate excessively wet conditions, and should not be grown on poorly drained soils.

One of the most remarkable things about cowpea is that it thrives in dry environments; available cultivars produce a crop with as little as 300 mm of rainfall. This makes it the crop of choice for the Sahelian zone and the dry savannahs, though cultivars that flourish in the moist savannahs are available as well as stated by CRSP West Africa Mission (Lowenberg-DeBoar, 1997).

Varieties of cowpea are said to be tolerant of Aluminium and to be adapted to poor soil if pH is between 5.5 and 6.5. On the whole, it is less tolerant of alkaline and salinity condition, but intolerant of excess amount of Boron (Duke (1990). Cowpea crop often responds favourably to added Phosphorus, although there was no significant increase in cowpea grain yield up to Nitrogen application rate of 30 kg/ha (Adejumo *et al*,(2007). Length of growing season varies with type: 100 days in determinate type, 110 days in semi-determinate, 120 days in ranking type. The climate will also have an effect on the length of the growing season: the hotter the weather, the shorter the maturity period (Van Rij, 1999).

2.2 IMPORTANCE OF COWPEA

2.2.1 Social-economic importance of cowpea

Cowpea is a multipurpose crop, providing food for human and feed for livestock and it is a cash generating commodity for farmers, small and medium-size entrepreneurs. It can also be used as cover crop (Langyintuo *et al*. 2003; Timko *et al.* 2008). The very early maturity characteristics of some cowpea varieties provide the first harvest earlier than most other crops during production period. This is an important component in hunger fighting strategy, especially in the Sub-Saharan Africa where the peasant farmers can experience food shortage a few months before the maturity of the new crop. Its drought tolerance, relatively early maturity and nitrogen fixation characteristics fit very well to the tropical soils where moisture and low soil fertility is the major limiting factor in crop production (Hall, 2004; Hall *et al.* 2002).

This crop is grown worldwide with an estimated cultivation area of about 12.5 million hectares annually and an annual worldwide production of over 3 million metric tons. About 70% of the cowpea production occurs in marginal areas of West Central, East and Southern Africa. Nigeria is the largest producer and consumer of cowpea at an estimated annual yield of 2 million metric tons (Timko *et al.* 2008). In Tanzania, cowpea is regarded as a _women‘s crop, because, contrary to other crops, the production process to marketing is often handled by women. Thus, it is among the crops that are generating income to female farmers and traders. Cowpea is among the dominating grain legumes traded almost in all local markets especially in the central, southern and western part of
Tanzania (Timko *et al* 2008).

Significant amount of cowpea is also produced in Peru, northern Brazil, parts of India and the south-eastern and south-western regions of North America Produce about 80,000 mt. The states involved in this production include Tennessee, Missouri, Louisiana, Alabama, Georgia, Texas, California and Arkansas (Fery, 2002).

2.2.2 Nutritional value of cowpea

The protein found in cowpea is similar to the one from other legumes, rich in the essential amino acids lysine and tryptophan (Timko and Singh, 2008). However, the protein nutritive value of these legumes is lower than that of animal proteins because they are deficient of sulfur amino acids and contain non-nutritional factors (phytates and polyphenols), enzymes inhibitors (against trypsin, chymotrypsin and R-amylase) and hemagglutinins. Minerals and vitamins are the other nutritional important constituents of the cowpea seeds. It has been reported that folic acid, a vitamin B necessary during pregnancy to prevent birth defect in the brain and spine content is found in higher quantity in cowpea compared to other plants (Timko and Singh 2008). Total seed protein content in seed ranges from 22% - 24%, carbohydrate 56-66%, crude fibre 5.9-7.3%, ash 3.4-3.9%, fat 1.3-1.5% and moisture 11% of the seed weight (Kay, 1979; Quass, 1995).

The total crude protein in foliage ranges from 14-21% and in crop residues; it is 6-8%. This crop has no toxicity effect on ruminants, however for the monogastrics, trypsin inhibitors and some tannin need to be considered. The presence of high protein in all cowpea parts consumable by human and animal (leaves, stems, pods and seeds), is the key factor in alleviating the malnutrition among women and children and improvement of healthy status of the livestock in resource limited households where regular access to animal protein is limited due to low economic status (Kay, 1979; Quass, 1995).

2.3 METHODS OF STORING COWPEA

Producers and traders usually store cowpea grains through different methods to prevent insect pest damages. Storage is a component within the farming systems, a tradition enterprise or a government policy and may be undertaken because of its contribution to other activities or objectives (Proctor, 1994). The common storage methods used in preserving cowpea grains in the study area includes jute sacks, mud silo, ―kambon‖ and ―pupuri‖, clay pot, plastic containers and gourds.(Proctor, 1994).

2.3.1 Jute sacks

Storage of cowpea grains in jute sacks is widely used in farms, villages' levels and commercial storage centres. The storage sacks are made of woven jute, sisal, local grass and cotton. Jute sacks are inexpensive as they do not often last for more than two seasons, and do not give much natural protection against insects, rodents, and moisture. But jute sacks have some advantages for small scale farmers, bags of cowpea may be piled under any convenient shelter away from weather and predators. Bags can be transported and handled without special equipment. However, both bags and storage space becomes expensive, particularly where manpower is involved costs are high. Also sacks are easy to label, and farmers can label old grain sacks and new grain sacks from other grains. However, cowpeas stored in fibre sacks are easily attacked by insects, moulds and rodents. Often these attacks are worse when a farmer fails to protect his/her grain sacks.

There are few measures that a farmer can take, such as to net proof the walls and the roof of the building where grains are stored. (David, 1978).

Farmers should also stack the sacks on platforms raised off the floor; this keeps stacked grain from taking moisture from the floor. Farmers can make these platforms out of whatever materials they have. If no wood or bricks are available to make a platform, the ground can be covered with plastic sheets. The raised platform is better than plastic because it allows air to flow under the sacked grains (David, 1978).

2.3.2 Mud silo

Mud silo is usually used for storing cowpea grains in Northern region of Ghana due to its long lifespan and insects and pest resistance. According to Stevenson (1999), the Moshe tribe, from Burkina Faso who were trading in various items between Burkina Faso and Ghana, settled in parts of the East Manprusi and Soboba/chereponi districts and introduced this structure to the natives. The structure is spherical in shape and normally built on three or four stones that serve as a base. The carrying capacity of the structure is between 1-4 tonnes. It is normally constructed from termite mound soil. It is claimed that the advent of commercialization has eroded the use of the mud silo and caused the present generation to abandon it (Stevenson, 1999).

2.3.3 Thatch silo

This is a cylindrical structure built on stones of about 0.5 m above the ground. The structure is cladding with zanamats woven from grass (and ropogonspp) and sticks as reinforcement. It is usually about 2m high with the carrying capacity depending on the size and crop to be stored. Apart from cowpea grains this structure can also be used to preserve unshelled maize, unthreshed sorghum and groundnut pods (Fuseini, 2003).

2.3.4 Crib

This is another structure widely used in Northern Region of Ghana for the preservation of cowpea grains due to easy acquisition of materials and requires fewer skills. It is known to be made from spilt guinea corn stalks or shrubs. It is oval in shape, and normally placed on stones or on raised platform. It is also used for the storage of shelled or threshed cereals and pulses. Cow dung or mud is normally smeared over it to seal the spaces between the stalks so as to prevent spillage of grains during storage. Its carrying capacity is about 0.5 to 2 tonnes (Fuseini, 2003).

2.3.5 Clay pot

The structure is commonly used in northern Ghana for the preservation of cowpea grains. It is made from clay. The structure is cylindrical in shape. It is used to store threshed cowpea grains. The carrying capacity of this structure varies depending on the size of the pot (Fuseini, 2003).

2.4 POST HARVEST CONSTRAINTS OF COWPEA

Cowpea, despite its economic importance, is among the many crops that suffer serious postharvest constraints of grain losses, stretching from the time after harvest through processing, transport, storage, marketing and utilization. Reports have shown that these losses occur in the form of weight, quality, nutritional and economic and loss of seed viability (Hall, 1980). Several factors or agents, including infestation and damage by insects, mites and vertebrate (rodents and birds) pests, as well as unfavourable environment, and other factors that may be inherent in the grains are responsible for the high postharvest losses of cowpea. The effects of these factors may increase as a result of inadequate crop husbandry practices in the field and or ineffective storage conditions after harvest. (Hall, 1980).

Cowpea grain loss is a directly measurable reduction of the seed grains which may be qualitative, quantitative or nutritional. Qualitative losses are partly subjective, in that they are assessed according to taste of the consumer, and criteria used by local traders.

Normally they are judged on the bases of appearances, size, shape, smell and flavour (Appert, 1987).

Nutritional losses represent a reduction in the food value of the grain as a result of lowering its protein, carbohydrate and vitamin contents. Many insect pests such as rodents eat the germ, selectively destroying a high proportion of proteins, oil and vitamins and affecting seed germination. The grain weevil, *Callosobruchus maculates*, for instance, eats in to the endosperm, reducing the carbohydrate content of seeds. Weight losses are as a result of evaporation of moisture components of grain being damaged by the pest, birds and rodents, sometimes spillage from the container in which the produce is transported or stored. In some instance, weight loss (due to insects for example) may be converted into a slight grain weight due to re-absorption of moisture from air (Hall,
1980). Losses in seed viability are as a result of failure of seed to germinate. Since seeds are not generally available for consumption, losses in seed viability may only have long term but profound effects.(Hall, 1980).

The major damage of cowpea grains is done by the larva feeding inside the seed which can cause 70% loss in weight of seed stored for six months. Yield losses caused by

Callosobruchus maculate and other storage pests in Nigeria are estimated to be 30 million Naira annually (Caswell, 1973).

2.5 MAINTENANCE OF STORE HYGIENE

The ideal method of preventing stored cowpea from damage is to keep the store as clean as possible. Practical hygiene control measures vary with different kinds of storage. It is only when good and adequate drying, disinfestations and storage practices are combined with good hygiene that satisfactory results can be achieved (Taylor, 1976). In bag storage stores, all stacks should be built in floor areas which has been swept and heavily dusted with 1% lindane dust. At the farm level, farmers should clean out their stores before harvest and then spray with Malathion to reduce insect infestation in stored cowpea grains (Taylor, 1976).

2.6 POST HARVEST PRACTICES

2.6.1 Threshing

Threshing is the process of loosening the edible part of cereal grain (or other crop) from the scaly, inedible chaff that surrounds it. It is the step in grain preparation after harvesting and before winnowing, which separates the loosened chaff from the grain.

Threshing does not remove the bran from the grain. Threshing of cowpea may be done by beating the grain using sticks. Another traditional method of threshing is to make donkeys or oxen walk in circles on the grains on a hard surface. A modern version of this in some areas is to spread the grain on the surface of a country road so the grains may be threshed by the wheels of passing vehicles. However, in developed areas it is now mostly done by machine, usually by a combine harvester, which harvests, threshes, and winnows the grain while it is still in the field. (Adejumo, and Raji, 2007).

2.6.2 Drying

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 lower (Adejumo, and Raji, 2007).

2.6.3 Winnowing

This is a process of separating a heavier and a lighter component. This is done by throwing it from a height. The lighter material is blown away by the wind and the heavier component goes or falls down (Thamaga-Chitja *et al*., 2004).

2.6.4 Storage

Storage is a way or process by which agricultural products or produce 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. For small scale farmers in Africa, the main purpose of storage is to ensure household food supplies (reserves) and seed for planting (Adetunji, 2007). The stored crop is gradually released to the market during off-season periods, which also stabilizes seasonal prices (Adejumo and Raji, 2007).

Harvested green cowpeas will "heat" resulting in spoilage unless kept cool. Postharvest facilities have to provide shade and adequate ventilation on the way to the cooler. Cowpeas cooled below 45^o F may show chilling injury (Davis, *et al*., 1991). 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 higher moisture, such as 18 percent and trucked directly from the field to the processor (Quinn, 1999).

2.6.5 Seed Germination

Although seed dormancy is common among species in a wide range of plant families, it has largely been overcome, with some notable exceptions, in most important commercial crops (Villiers, 1972). In the absence of dormancy, the basic germination requirements for crop species are simple: adequate temperature, water, and a favourable gaseous environment (Hegarty, 1984). When any of these basic requirements become limiting in seedbed, seeds may fail to germinate. Seed quality determines the ability of seed to cope with these sub-optimal conditions and to compete with soil micro-organisms for resources (Telcrony and Egli, 1991). Thus, germination is defined by the International Seed Testing Association (ISTA, 1985) as the emergence and development of the seedling to a stage

where the aspects of it essential structure indicate whether or not it is able to develop further into a satisfactory plant under favourable conditions in the soil
(ISTA, 1985).

2.6.6 The Relevance of Germination Test

The ultimate objective of testing for germination is to gain information with respect to the field planting value of the seed (ISTA, 1985). Field emergence ability is the major aspect of seed quality of concern to growers (Pieta-Filho and Ellis, 1991). The second objective of germination test is to provide results which can be used to compare the values of different seed lots (ISTA, 1985). Germination test result in conjunction with the analytical purity result provides the principal data upon which the seed traders buys, markets and sells seeds nationally and internationally (Hampton and Coolbear, 1990). The third objective of germination test pertains to storage. Germination testing and seed moisture content is traditionally used to provide the data upon which storage decision is based. Thus, a seed store manager would correctly conclude that a seed lot with germination of 95% should be able to store longer under the same conditions of temperature and humidity than a seed lot of the same species and cultivar with a germination of 75% (Hampton and Coolbear, 1990).

2.7 STORAGE WEEVIL

The cowpea weevil, *Callosobruchus maculatus* (Fabricius) is the most important postharvest storage pest of cowpea. The weevils occur wherever the cowpea is grown. The adult beetle are small (3 mm long) and orange-brown with dark markings. The adult lays eggs on the pods that are at maturity stage in the field, and on hatching the larvae bore the pod wall and seed coat and enter the seed. The adult emergence occurs after harvest and in the store, where real destruction happens due to re-infestations and easiness of larvae penetration into the seed, because usually the seeds are stored after shelling (Booker, 1967).

Re-infestation occurs repeatedly during storage period. In store, each female lays 40-60 white flat eggs and glues it on the seeds surface; on hatching the larva bore into the seed, where it feeds, grow and pupate before emerging as adult out of the seed after about 3-4 weeks. A single seed can be infested with multiple larvae (Fox, 1993; Giga and Smith, 1983). It is reported that about 8-10 or more larvae can be found in a single seed. Thus, heavily damaged seeds show many exit holes (Ofuya and Agele 1990). Both sexes can mate soon after emergence and they require neither food nor water to reproduce and can mate several times during their life time. The beetle longevity is slightly affected by relative humidity (Giga and Smith, 1983). Both sexes live an average of 7 days (Fox 1993). The complete life cycle takes about five weeks; this means that a new generation rises every month during storage. An infestation of up to 100% of the stored seeds has been reported within 3 to 5 months under farmer‘s storage conditions (Redden *et al*., 1984). The reduction in seed weight is directly proportional to the number of exit holes on the seeds, thus the yield losses can be easily estimated for different accession. A single beetle is able to cause a weight loss of grain of up to 3.5% (Booker, 1967).

CHAPTER THREE

MATERIALS AND METHODS

3.1 STUDY AREA

The study area was Savelugu/Nanton Municipality in the Northern Region of Ghana. The municipality shares boundary with other four districts such as Kumbugu in the western part, Karaga in the eastern part, Tamale metropolis in the southern and West Mampurugu in the north. The study area (Savelugu/Nanton Municipality) has a population of about 139,283people (2010 population and housing census) based on Ghana Statistics Service (2010). It is about 24 kilometres from Tamale. The major occupation of the people in the study area is farming; common crops cultivated include: rice, yam, groundnuts, soybeans, cowpea and maize as the main crops cultivated. The farmers also grow some vegetables such as pepper, tomatoes and okra at their back yard during the raining season. The scale of farming is usually subsistence. Almost every household rear domestic fowl with few others engaged in the rearing of goats, sheep, cattle and pigs.

The area has short raining season (April to September) with long period of dry season (October to March). The vegetation of the area is classified as guinea Savannah. The soil type is generally clay and sandy. The sandy soils easily dry up if there is any short drought. The clay soil on the other hand becomes very wet and sticky at the peak of the raining season. The commonest land holding system among the inhabitants is inheritance though sections of the populace do engage in lease and share cropping system.

3.2 STORAGE METHODS SELECTION

Five indigenous storage methods such as mud silo, crib, clay pot, fertilizer sack and jute sacks were selected for the study and monitored over five months. This was an intensive method of sampling in the sense that the five methods selected represent the main indigenous storage structures used by farmers in the area. A total of twenty-five (25) samples were taken during the period with five samples from each storage method.

3.3 SAMPLING FREQUENCY

Cowpea grains were taken from all the five storage methods on a monthly basis starting from November 2012 to April, 2013. Sampling of grains was done with the assistance of the farmers, retailers or consumers. To ensure accuracy and to avoid bias, the same variety of cowpea grains in the study area and the same processing methods were adopted to process the grains before storing. Grains weight, number of insects, moisture content, temperature, relative humidity and number of damage grains were determined during sampling to assess losses. Proximate analysis was also done to ascertain the food nutrients content in the grains from each structure after storage.

3.4 SOCIO-ECONOMIC AND QUALITY SURVEY.

A cross sectional socio-economic and quality survey was carried out by administering questionnaires in the Savelugu/Nanton municipality (local dialect) to assess the qualities of cowpea grains. The questionnaire was also designed to elicit responses on the traditional methods used in storing cowpea and the postharvest qualities of the grain regarding its shelf life, absence of defects, size, and weight. The questionnaire also sought information on handling practices after harvesting such as drying, threshing, winnowing and storage.

The questionnaire included open and close-ended questions about the occupation, family size, source of cowpea grains, use of chemicals, storage methods and pests etc.

Ten major communities producing cowpea were selected in the study area randomly and five producers were selected in each of the selected communities to constitute the total sample size of 50 producers. The sampling techniques used were cluster random sampling and simple random sampling. With the cluster random sampling the municipality was divided on the basis of communities whereas a sampling frame was constructed and used in the selection of producers randomly. These random sampling techniques were used because they provided the respondents equal chances of being selected. The ten communities are as follows: Tampion, Savelugu, Nanton, Zoggu, Nakpanzoo, Pong-Tamale, Gushei, Diare, Kanshegu and Yepalsi. The questionnaires were also administered at random to target retailers and consumers in the open market. In all 25 retailers and 25 consumers were contacted and interviewed.

3.5 DETERMINATION OF QUALITY PARAMETERS

The quality characteristics data that were determined included the following:

3.5.1 Determination of insects

This was done by pouring the grains from each storage structure in a container, and by using a sieve the numbers of insects within the grains were counted manually and recorded every two weeks for five months.

3.5.2 Determination of damage grains in each storage structure:

This was done by randomly counting 200 grains from samples of each method and manually counting the number of damage grain in each storage structure every two weeks for five months.

3.5.3 Determination of temperature and relative humidity

These two parameters were determined by putting certify hydrometer and temperature indicator (Sufft, SEEBURO, made in Germany) in the grains of each storage structure for about 30minutes every two weeks. Before putting the metre into the grains, the temperature and the relative humidity of the surroundings were determined by hanging the metre indicator in the room to study the conditions outside the grains. Both temperature and relative humidity data were recorded.

3.5.4 Assessment of loss

This was done by weighing the grains before storing them, and weighed the same grains monthly for five months, using electronic balance. Using the difference between the initial weights and the final weights, losses in each structure were then assessed. A sieve (mesh size) was used to clean the grain to remove insects and other fine material. During the cleaning, some dead insect parts were also removed. The formula for calculating the percentage weight losses below was used:

$$\text{Weight loss (\%)} = (WB-WA)/WB \times 100$$

Where WB = weight of grains before storage and WA = weight of grains after storage

3.5.5 Determination of percentage germination in each method

This was done by randomly counting 100 grains from each structure. The samples were then planted, and germination percentage was taken after 7 days when all grains would have germinated. This test was done to select the storage structure with high percentage of germination.

3.5.6 Proximate analysis of food samples

Proximate analysis from each storage structure were analysed at the Kwame Nkrumah University of Science and Technology Biological Laboratory, to ascertain the basic chemical composition of food samples. These components were fundamental to the assessment of the nutritive quality of the food being analysed. The following determinations were made on each food sample: protein, carbohydrates, moisture content, fat, ash and fibre. The results were recorded and averages were also determined.

3.5.7 Experimental design and analysis

The data obtained from the survey was analysed using a statistical analysis package;

SPSS 17 and Microsoft Office Excel 2010.The experimental design for the storage of cowpea was completely randomized design (CRD) with 3 replicates. Data on measure parameters was analysed using Statistix 9 and means separated at Lsd of 5%.

3.5.8 Analysis of Best Storage Structures

This was done by using Kendall's coefficient of concordance (W) to establish whether there is agreement or disagreement among ranks of structures by quality indicator. With this, best quality is ranked from the very efficient to very inefficient where storage structure with the least mean rank score is the most efficient and the one with the highest mean rank score is the least efficient. Table 3.1 represents storage structures and their mean ranks and ranks as it will appear in the analysis.

Table 3.1: Storage Structures and Ranks

Structures	**Mean rank**	**Ranking**
Jute sack	XX	1st
Fertilizer sack	XX	2nd
Crib	XX	3rd
Clay pot	XX	4th
Mud silo	XX	5th
Kendall's W	XX	
Chi-square and Probability	XX	

Source: Field Survey, 2012.

The range of (W) cannot exceed one (1) and cannot be lower than zero (0). One (1) means perfect agreement and zero (0) means perfect disagreement. In this regard, there is the need to test hypothesis to establish the significance of the (W).The hypothesis was;

H_o**:** There is no agreement among ranks of storage structures.

H_1: There is agreement among ranks of storage structures.

This hypothesis was tested using the chi-square test and the asymptotic significance was used in making the decision. If the probability value is less than 5 per cent, then the null hypothesis will be rejected in favour of the alternative hypothesis and the vice versa.

CHAPTER FOUR

PRESENTATION OF RESULTS

4.1 INTRODUCTION

This chapter presents the results of the studies conducted. The first section constitutes the socio-demographic characteristics of respondents. Section 4.2 presents results on the postharvest practices by producers. Effects of storage structures are contained in section 4.3. Finally section 4.4 represents the results of the rankings of storage structures in terms of efficiency.

4.2 SOCIO-DEMOGRAPHIC CHARACTERISTICS OF RESPONDENTS

The socio-demographic characteristics presented here are gender, age and educational status of producers.

4.2.1 Gender backgrounds of respondents

The research revealed that out of 100 respondents who were interviewed 65% were males whiles 35% were females. Those sampled were producers, retailers and consumers of cowpea in the Savelugu/Nanton Municipality.

Table 4.1: Gender distribution of the respondent

Gender	**Frequency**	**Percentage (%)**
Male	65	65
Female	35	35
Total	**100**	**100**

Source: Field work, April, 2013

4.2.2 Age of Respondent

The age distribution of respondents in the study area is shown in Table 4.2. The Majority of the respondents were within the age group of 31-40 years. This represents 44% of the respondents.

Table 4.2: Age distribution of respondents

Age	Frequency	Percentage (%)
21--30	16	16
31--40	44	44
41--50	30	30
Above 50	10	10
Total	**100**	**100**

Source: Field work, April, 2013

Thirty (30) respondents, representing 30% fall within the age group of 41-50 years whereas 16% of the respondents are between the ages 21-30 years. However, only ten (10) of the respondents representing 10% are above 50 years.

4.2.3 Educational Background

From Table 4.3, out of hundred (100) respondents, fifty one (51) of them which represent 51% had no formal education, 25% of the respondents had basic education. 16% had secondary education and only 8% of them had tertiary education.

Table 4.3: Educational background of respondents

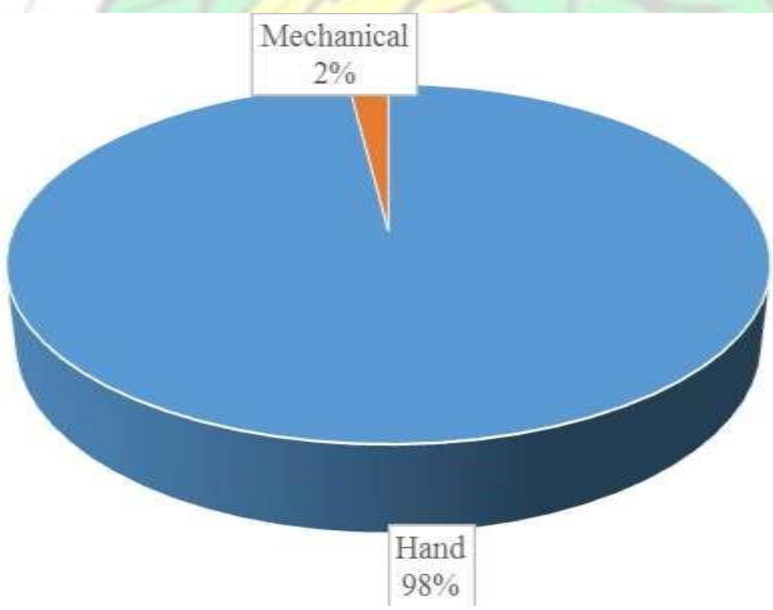
Education of respondents	Frequency	Percentage
No formal education	51	51
Basic education	25	25
Secondary	16	16
Tertiary	8	8
Total	**100**	**100**

Source: Field work, April, 2013

4.3 COWPEA POSTHARVEST PRACTICES USED IN THE SAVELUGU / NANTON MUNICIPALITY

4.3.1 Winnowing

Figure 4.1 shows the results of methods used by respondents in winnowing. Most of the farmers, constituting 98% carry out this activity by hand whereas mechanical winnowing is done by only 2% of the farmers interviewed.



Source: Field work, April 2013.

Figure 4.1: Method of Winnowing

4.3.2 Threshing

The main method of threshing cowpea grains in the study area is hand threshing. 90% of the respondents used their hands to do the threshing. Respondents who thresh with mechanical means (that is running over the dried pods by a tractor) constitute 8% and only 2% of the respondents used explosive method of threshing (that is allowing the dry grains to crack and come out). This is shown in Table 4.4.

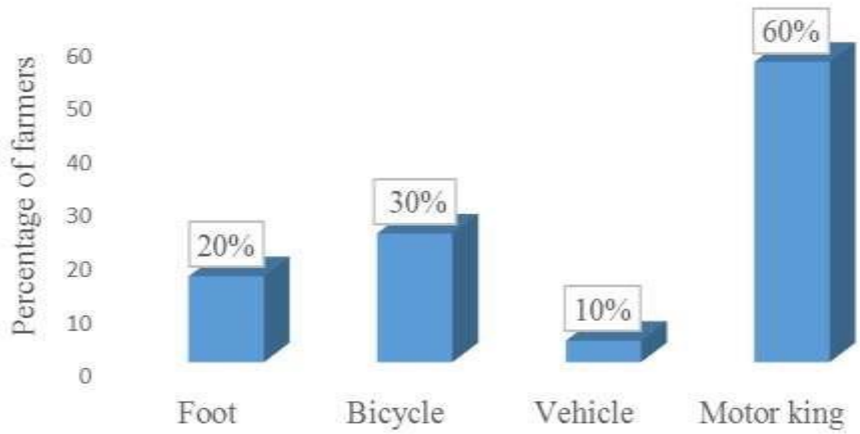
Table 4.4: Methods of threshing

Method	Frequency	Percentage (%)
Hand threshing	45	90
Mechanical	4	8
Self-explosive	1	2
Others	0	0
Total	**50**	**100**

Source: Field work, April 2013.

4.3.3 Transportation

Transportation is another major important postharvest activity which is prominent among all the farmers. Figure 4.2 represents the results of the various modes of transportation used in carting cowpea grains in the study area. 60% of the respondents used motor king, 30% used bicycle, 20% and 10% used their foot and vehicle respectively.

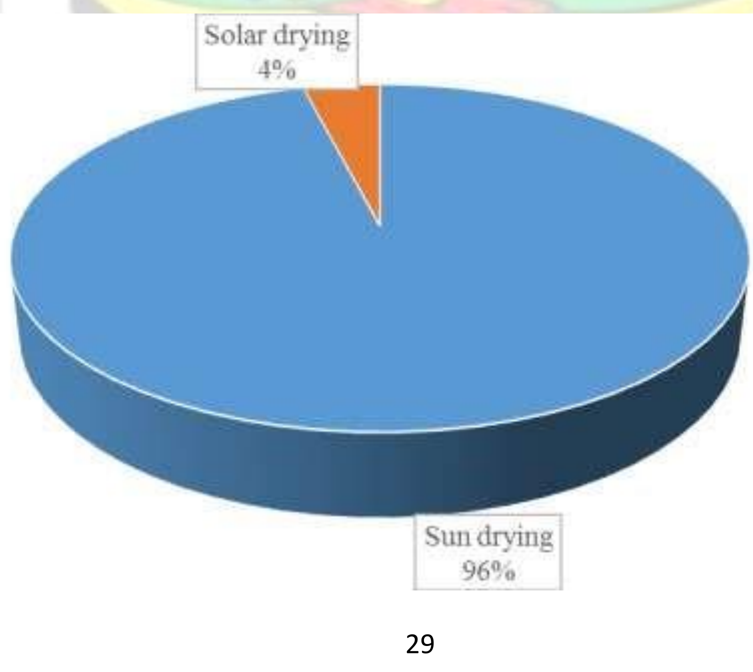


Source: Field work, April 2013.

Figure 4.2: Mode of Transportation

4.3.4 Drying

Figure 4.3: shows that the main source of drying the cowpea grains in the municipality is sun drying. This was observed to be practiced by 96% of the respondent. Four percent (4%) of the respondents used solar dryers.



Source: Field work, April 2013.

Figure 4.3: Cowpea drying methods

4.3.5 Storage

Table 4.5 shows the storage structures and technologies used in storing cowpea grains in the study area. Out of fifty respondents, sixty-six percent (66%) used sacks for storage. Twenty percent (20%) of the respondents used cribs. Four percent (4%) used mud silos or clay pots. Only six percent (6%) were found to use thatch silos in storing their cowpea grains.

Table 4.5: Storage structures used by producers

Structure	Frequency	Percentage (%)
Bagging	33	66
Cribs	10	20
Thatch silos	3	6
Mud silos	2	4
Clay pots	2	4
Total	**50**	**100**

Source: Field work, April 2013.

4.4 EFFECTS OF STORAGE STRUCTURES ON THE QUALITY OF COWPEA

4.4.1 Effect of Storage Structures on Weight loss, Germination, Insect Infestation and Storage condition of Cowpea

Table 4.6 depicts the results of the effects of indigenous storage structures used by producers on the quality of cowpea grains in the study area. The results suggest varying degrees of advantage of each storage structure depending on the indicator of quality that is concerned.

Table 4.6: Indigenous storage structures and quality of cowpea grains

Structure	Weight retained %	Germination %	Insect count	Temperature (°C)	Humidity (%)
Jute sack	95.2 c	40 d	74 b	30.90 b	87.9 b
Fertilizer sack	86.1 e	22 e	89 a	31.30 a	88.0 b
Crib	87.8 d	78 a	18 e	31.10 ab	88.9 a
Clay pot	96.2 a	73 b	33 d	30.15 c	88.6 a
Mud silo	95.7 b	68 c	43 c	31.05 ab	88.9 a
Lsd (0.05)	0.27	3.04	2.57	0.28	0.41
CV	0.16	2.98	2.75	0.50	0.26

Source: Field work, April 2013.

There was a significant effect of the storage structures (treatments) on the weight of the stored grains. Thus the level of weight loss suffered from the various storage treatments varied significantly at $p<0.05$. In decreasing order of weight retention capability, Clay pot performed best in retaining significantly the highest grain weight (96.2%), followed by Mud silo (95.7%), Jute sack (95.2%), Crib (87.8%) and the least, recorded by Fertilizer sack (86.1%).

The effect of the treatments on the viability of the grains shown by the germination percentage also proved a high significant level. Thus, germination percentages of the stored seeds or grains were significantly different ($p<0.05$). Grains stored in the Crib recorded the highest germination percentage of 78% while the grains in Fertilizer sack after storage had least number of germinated seeds (22%). Clay pot, Mud silo and Jute sack had 73%, 68% and 40% in decreasing order.

The level of insect count within the storage structures during the storage were also significantly different ($p<0.05$). The Crib structure proved most efficient in recording the least count of insects (18) over the storage period. Fertilizer sack had the highest insect count (89), followed by Jute sack (74), Mud silo (43) and Clay pot (33) in decreasing order. Temperature variations within the storage structures were significantly different ($p<0.05$). It ranged from 30.15 – 31.30ºC, the lowest and highest were recorded in clay pot and fertilizer sack respectively. The average readings in Crib and Mud silo were significantly not different from the rest except that recorded by the Clay pot. With regard to humidity levels, the Jute and Fertilizer sacks recorded an equal percentage of humidity but were significantly different ($p<0.05$) from Crib, Clay pot and Mud silo which also performed equally.

4.4.2 Effect of storage structure on the proximate analysis of cowpea

Table 4.7 shows the results of laboratory analysis of nutritional quality of stored cowpea by the indigenous structure. The qualities analysed were carbohydrate, protein, moisture, ash, fibre and fat contents.

Table 4.7: Laboratory analysis of nutritional quality of stored cowpea by structure

Storage structure	Carbohydrate %	Protein %	Moisture %	Ash %	Fibre %	Fat %
Jute Sack	63.15 b	20.48 c	7.58 b	3.68 c	2.03 c	3.10 a
Fertilizer sack	61.60 d	23.14 a	7.43 c	4.59 b	2.10 c	1.15 b
Crib	64.24 a	21.49 b	7.32 d	3.13 d	2.73 b	1.10 b
Clay Pot	62.81 bc	18.35 e	7.80 a	4.50 b	3.29 a	3.25 a
Mud Silo	62.67 c	19.23 d	7.83 a	5.43 a	3.38 a	3.32 a
Lsd (0.05)	0.44	0.24	0.09	0.19	0.11	0.26
CV	0.38	0.64	0.65	2.45	2.27	6.08

Source: Field work, April 2013.

The carbohydrate content of stored cowpea grains from the five storage structures were significantly different ($p<0.05$). Grains from the crib had the highest carbohydrate content of 64.24% while those sampled from fertilizer sack recorded the least (61.60%). Cowpea stored in jute sack, clay pot and mud silo recorded 63.15, 62.81 and 62.67 per cent of carbohydrate respectively.

Similarly, the storage structures caused a varying level of protein in the stored cowpea grains and were significantly different ($p<0.05$). In order of decreasing protein content, cowpea stored in fertilizer sack had the highest (23.14%), followed by crib (21.49%), jute sack (20.48%), mud silo (19.23%) and the least, recorded by clay pot (18.35%). Moisture content of the stored grains were significantly also different ($p<0.05$). The mud silo and clay pot significantly had an equal moisture composition and were different from those from jute sack, fertilizer sack and crib with 7.83%, 7.80%, 7.58%, 7.43% and 7.32% respectively in decreasing order.

Differences in ash content of the stored cowpea from the five storage structures were also significant ($p<0.05$). Grains from the mud silo recorded the highest ash content (5.43%) and was significantly different from the rest. The ash content from the fertilizer sack and clay pots were not reduced significantly but different from jute sack and crib stored cowpea respectively.

With regard to Fibre content, cowpea stored in mud silo and clay pot statistically had an equal fibre content of 3.38% and 3.29% respectively and were different ($p<0.05$) from the rest. Crib stored cowpea had 2.73% fibre reserved and was also different from 2.10% and 2.03% fibre contained in cowpeas stored in jute and fertilizer sack respectively. Both were also statistically not different.

The influence of mud silo, clay pot and jute sack on the fat content of the stored cowpeas with 3.32%, 3.25% and 3.10% respectively were significantly not different but were different ($p<0.05$) against 1.15% and 1.10% fat recorded by fertilizer and jute sack stored cowpeas that were equally not different.

4.5 EFFICIENCY OF INDIGENOUS STRUCTURES IN STORING COWPEA GRAINS

Table 4.8 shows the ranking of indigenous structures of storing cowpea grains in terms of efficiency using 8 indicators namely; weight retention, germination of seeds, insect protection, carbohydrate content, protein content average, moisture, average temperature and average humidity.

Table 4.8: Efficiency of indigenous structures in storing cowpea grains

Indigenous structure	**Mean Rank**	**Rank**
Crib	2.38	1st
Clay pot	2.56	2nd
Jute sack	2.81	3rd
Mud silo	3.50	4th
Fertilizer sack	3.75	5th
Diagnostic statistics		
N (Number of indicators)	8	
Kendall's W	0.144	
Chi-square and Probability	4.667	0.323

Source: Field work, April 2013

The results of the Kendall's analysis, as shown in Table 4.8, suggest no agreement among the ranks and the Kendall's Coefficient (W) of 0.1444 is also weak. These can be explained by the fact that the samples are not very related since independent indicators and tests were performed to obtain the values. However, the Table still presented a valid ranking of the indigenous structures in terms of efficiency in a structure fulfilling all or most of the desired condition(s) for the indicators. Crib appeared first, followed by clay pot and the least ranked structure was the fertilizer sack.

CHAPTER FIVE

DISCUSSIONS

5.1 INTRODUCTION

This chapter presents the discussions of the results of the study and it is organized into four sections including section 5.1. Section 5.2 dwells on discussions on post-harvest practices. Discussions on effects of storage structures are presented in section 5.3 and section 5.4 sheds light on the ranking of best storage structures in the study area.

5.2 COWPEA POST-HARVEST PRACTICES USED IN THE SAVELUGU / NANTON MUNICIPALITY

Postharvest is a major farming stage which involves several practices in the area. These practices include winnowing, threshing, drying, transportation and storage. Winnowing is a major practice among all the producers because it is a way of ensuring the quality of the grains harvested. Generally, the method of winnowing predominantly used by producers was by hand, this could be as a result of abundant winds in the area that may easily separate the grains from the chaff and only a few make use of mechanization; which may be as a result of the high cost of machines. This does not only suggest the laborious nature of winnowing in the area but also indicates the rudimentary and inefficiency that may be involved in winnowing in the area.

Threshing is the next postharvest practice in the area and the predominant practice there is labour intensive. Basically, hand threshing, mechanical threshing and self-explosive were the methods of threshing cowpea in the area. Threshing was a very important postharvest practice because it determines the quality of cowpea grains, the extent of postharvest losses and the efficiency and quality outcomes of grains stored. All these advantages will require that threshing should be fast, timely and properly done which were observed to be inadequately realized in the study area. The reason was that most of the farmers (Table 4.1) were observed to be practicing this by hand which is devoid of speed and as such sometimes lead to inefficiency and poor quality of grains before and after storage. Majority of the farmers depended on hand threshing. This may be reserved for women in the area for their livelihood. Only a few, constituting 8% were found to be threshing cowpea mechanically which has also proven to be efficient and effective in terms of time and quality but due to the cost involved a lot of the farmers could not afford to use it. Self-explosive was the least prominent method used but it is essentially inefficient because it has a high probability of leading to postharvest losses.

The next major practice was the transportation of harvested cowpea to the needed destination. Four modes of transportation were observed to be used by producers in the area. These were by means of motor king (motor cycle with a trailer), bicycle, carry the load on the head and other vehicles. Motor king is a new and relatively efficient way of carting the produce because it ensures efficiency by being fast in carrying cowpea to destinations and has a higher carrying capacity and as such has come to remain the predominant form of transporting cowpea by producers. Discussions with producers also indicated that using motor king enables them to be able to cart their produce with minimal labour input and reduces the risk of postharvest losses resulting from transportation rigidities. The other form of transportation usually patronized by farmers was by bicycle because this was the form of transportation owned by most farmers.

Although this is not very efficient compared to the motor king and other vehicles, it has become very necessary to use by some farmers due to financial constraints in accessing motor king or vehicle and cultural traits where they believe bicycle is what they have been using for years even when motor king was not there.

Producers who cannot afford the services of motor king, and other vehicles, carry their grains on their heads to their homes or storage facilities. However, producers mentioned that this was very difficult especially when the farm is far and, it was also not very effective and efficient. There are times they are not able to carry the produce for days due to tiredness and other health reasons. The least form of transportation is by means of other vehicles and this is mainly through the tractor. Producers mentioned that this comes closer to motor king but the reasons for the low patronage of it was due to inadequate tractor supply for this services in the area and also the financial limitations to renting or buying a tractor.

Drying was a key postharvest practiced but it is a major challenge to producers as they rely largely on nature which is very unpredictable. Sun drying was the major source of drying cowpea in the area and up to 96% of producers were found to be using this method. Producers also mentioned that the limitation of inadequate drying imposed by weather variations sometimes account for high moisture found in stored grains and also the premature germination of stored cowpea grains. Hence, drying is very essential in enhancing the quality of stored cowpea grains and producers need to resort to other means of drying to support the use of the sun. Currently the use of solar drying is very minimal and is being practiced by very few of the producers as shown in Figure 4.3.

Storage was the next but most important postharvest practice because it is probably the most important means of determining postharvest losses, when handling excess grains to take advantage of market situations when prices improve and securing their seeds for the next cropping season. Bagging, which constitute jute and fertilizer sacks, were found to be the main storage methods (structures) used by producers and this was used by 66% of the farmers. Although bagging is the predominant way, it was however mentioned by producers as being less effective because it exposes the grains to moisture, humidity and intense high temperatures and all these were said to have adverse effect on the quality of cowpea grains stored. Also, apart from the risk of being worn-out, producers expressed the fear of insect attacks and premature germination when bagging was used. These assertions by the farmers have been confirmed by my findings as the bagging methods of storage have been ranked 5th base on the parameters adopted especially the fertilizer sack (Table 4.8).

The next form of storage facility used by cowpea producers in the area was the crib. This was observed to be more effective in the sense that it was able to protect the grains from several risk factors including insect and weather elements. This was observed to be used by 20% of the producers. The use of silos (consisting of thatch and mud silos) was found among 10% of the producers and only 4% used clay pots. It can be inferred from the discussions on storage structures that producers of cowpea in the study area mainly rely on indigenous storage structures in storing their produce. It also came out from the farmers that for small scale farmers in Africa, the main purpose of storage is to ensure household food supplies (reserves) or security and seed for planting (Adetunji, 2007).

5.3 EFFECTS OF STORAGE STRUCTURES ON THE QUALITY OF COWPEA

The effectiveness of the indigenous storage structures was assessed on the basis of the ability of these structures to retain the best of the qualities of 8 indicators. The first indicator is the ability of the structure to retain the weight of the stored cowpea grains. With respect to this indicator, almost all the storage structures were able to retain up to more than half of the 8 quality indicators in the stored grains. However, on individual basis, clay pot was found to have had the highest positive effect because it was able to retain up to 96.2% of the weight of cowpea grains stored. The nature of the pot was probably able to insulate the grains from adverse weather factors and farmers also mentioned that the clay pot was easy to manipulate in terms of changes in location and/or removing the grains when it is found to be under threat of insects and weather. This was followed by mud silo and jute sack in terms of efficacy in retaining the weight of the stored grains. Jute sack was also said to be relatively flexible to handle whereas mud silo was able to provide relatively a warm environment for the stored grains. The structures found to retain the least of the weights of cowpea grains were the crib and fertilizer sacks. The next indicator was the ability to ensure high rate of germination of stored seeds by the structure. This indicator was observed to have shown varying levels of efficacy of the structures. Crib appeared the most effective because it was able to guarantee up to 78% cent of the grains to germinate after storage. The crib was observed to be able to contain the grains in such a way that it was not easy for the grains to be exposed to the risk factors that kill the germination capacity of the grains because the crib was also smeared with cow dung, and so insect attacks may also have been low. This was followed by clay pot and mud silo which were able to produce more than 50% of germination rate of stored grains. These two structures have features similar to that of crib and are also able to insulate the grains but not as very effective as compared to the crib. Fertilizer and jute sacks were less effective in ensuring good germination rate of stored grains. This could be due to their exposure to the variety of weather and insects through the perforated holes in them. These suggest that to ensure good rates of seed germination, producers need to consider storing grains in crib, clay pot or mud silo.

Insects were mentioned by producers as a major threat to their ability to successfully store and retrieve quality grains. Most farmers complained of high insect attack to the grains when stored and this is attributable to the fact that most of the farmers store their cowpea grains in bags (i.e. jute and fertilizer sacks) which are very ineffective in preventing insects. From the experiment, it was revealed that the most effective of the storage structures that protects cowpea grains against insect attack is the crib because this had the least insect count of 18 during the study period. This resilient nature of crib against insects may be that the cow dung that had been smeared around the crib served as a repellent to drive away insects. This was followed by clay pot and mud silo which reported insect counts of 33 and 43 respectively during the same period. The high insect count detected in the fertilizer and jute sack was due to the fact that, both do not give much natural protection against insects, rodents and moisture (Ali, 2008).

Weather factors such as temperature, humidity and moisture were some of the factors that storage structures are expected to protect the seeds against. Temperature varied and ranged from 30.15 – 31.30ºC within all the storage structures with a relatively high humidity levels above the recommended range of 60 - 70% (Robinson, 1984) reported for the storage of legumes (Table 4.6). This suggests limitation in the ability of these structures to completely protect cowpea grains against weather over a period of storage. Yet, moisture content of the stored grains from the various structures (7.32% – 7.83%) shown in table 4.7 were all within the recommended range (8 – 9%) required for long storage of grains indicated by Quinn (1999) and Thomas (2003).

The nutritional content of stored grains was analysed on the basis of carbohydrate, protein, ash, moisture content, fibre, and fat content retained after storage. Whereas crib yielded the highest carbohydrate retention, fertilizer sack had the highest retention in terms of protein. Even though there are some minimal variations in the levels of nutrients retained by the specific structures, almost all the structures proved very effective in retaining more than 50% of carbohydrates of stored cowpea grains and the figures also fall within the expected range of 56% to 66% (Kay, 1979; Tindall, 1984; Quass, 1995). However, when this is related to protein, only fertilizer sack was able to retain protein content up to the range within the expected of 22% to 24% whereas almost all other indigenous structures proved ineffective in maintaining the protein deposits of cowpea grains after storage. Hence, to improve on the protein content of cowpea after storage, producers need to consider other modern storage structure and means to realize this.

5.4 EFFICIENCY OF INDIGENOUS STRUCTURES FOR STORING COWPEA GRAINS

Crib was the first ranked indigenous structure and hence represents the best structure in terms of efficiency (Table 4.8). It was realized that crib was the structure that proved very efficient in fulfilling four out of the eight indicators. Storing cowpea in cribs was able to retain the quality of the seed during the period to ensure high rates of germination compared to the other structures. Seventy-eight percent (78%) of cowpea grains stored in cribs was observed to be germinable. This structure also proved to be the most efficient in protection against insects and moisture. Crib had the least insect count of 18 insects, as observed over the study period this may be as a result of smearing it with cow dung that could repel insects, and also ensure low moisture content.

These may be explained by the fact that the crib was able to protect the quality of cowpea by insulating the grains from insect attack for relatively longer periods and kept moisture very low to prevent fungi infections and premature germination compared to the other forms of indigenous storage structures. High levels of carbohydrates were also retained when cowpea was stored in cribs because the laboratory analysis shows that this structure was able to maintain up to 64.23% of the carbohydrate ingredients. Hence, this does not only prove very efficient in retaining high carbohydrate levels after storage but also appeared efficient in ensuring appreciable levels of protein contained in the cowpea (Table 4.8). This is possible because cribs have the ability of repelling insects from entering into the structure to destroy the grains. This structure does not also absorb moisture and air from the atmosphere that will aid insect activities (Fuseini, 2003).

Crib was followed by clay pot because storing in clay pot appeared to be very efficient in retaining the weight and providing favourable temperature to cowpea grains as well as proven efficient in high rates of germination and insect protection. This storage structure was able to retain up to 96.2% of cowpea weight after storage making it possible for farmers to get relatively better weights even after storing the grains for some time. Low temperature levels have been argued to be good for grains underscoring the relevance of clay pot storage in this sense. Clay pot had the least average temperature of 30.15ºC. Discussions with farmers suggested that high temperature encourage weight loss because of high evaporation rates and at the same time able to shield grains against insects' attacks. This was consistent with the observation made regarding clay pot being next to crib (efficiency) in insect prevention and promotion of high rates of germination. Jute sack was ranked third (Table 4.8) because it proved very efficient in maintaining low humidity; efficient in retaining high carbohydrates and average temperature, and moderately efficient in maintaining high weights; the weight loss might be as a result of insect attack or perforated bags during grain handling, protein and low moisture. This may be that the materials used in constructing jute do not absorb air and moisture from the atmosphere (David, 1978). It was observed that this structure is inefficient in terms of germination and insect protection which is not good in terms of ensuring good grains after storage. This may be because most farmers in the area rely on stored harvest to be used as seeds for the next cropping season thereby making the need for high germination and insect protection very necessary. This also implies that jute sacks need to be used with a complement such as the use of chemicals to cater for germination and insect attack which may prove less cost effective.

Mud silo was fourth which was observed to be efficient in retaining the weight of the grains and moderately efficient in terms of germination, insect protection and ensuring relatively low temperatures. Contrary to these positives is its inefficiency in maintaining low humidity, high carbohydrate and protein contents as well as being very inefficient in keeping moisture low. Finally, fertilizer sack was the least ranked structure despite the fact that also it was very efficient in retaining only protein and efficient in moisture and humidity containment. Apart from this, using fertilizer sack to store cowpea appeared to be very inefficient in maintaining its weight and carbohydrates, promoting high number of seeds germination, protection against insect as well as ensuring favourable temperature. It also had good ability to maintain a good amount of protein.

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.1 CONCLUSION

The findings of the study indicated that postharvest practices that were adopted and used by farmers and retailers in cowpea were hand threshing with the use of sticks by women, sun drying, hand winnowing, the use of motor king for transportation and the use of chemicals during storage. However, because the grains undergo a series of different operations in the course of preparations, quantitative and qualitative losses occurred.

The storage structures used by the farmers in the study area were jute sacks, fertilizer sacks, clay pots, mud silos and cribs depending on the purpose of the storage. A lot of farmers treated their grains with chemicals before storage. They (especially consumers) also agreed that the use of chemicals had some effects in the body and on the environment.

There was no clear cut storage structure that was best for all the quality indicators used in this exercise but crib and clay pot were the best among the other structures, in terms of protection from insects, high germination, moisture retention and high levels of carbohydrates. The fertilizer sack was efficient as far as protein level was concerned.

Storing cowpea for longer periods reduced its capability to germinate. As was noted all the five structures, caused a decreased with time in germination percentages. The cowpea weevil, the notorious cowpea postharvest pest, if not handled with prudent postharvest management techniques, could destroy a lot of cowpea grains within six or nine months, as study showed.

6.2 RECOMMMENDATION

Farmers and cowpea dealers should adopt the crib and the clay structures for storing cowpea for a better keeping quality. Government, Non-governmental Organinazations (NGOs) and other related Agencies should educate farmers and the general public on dangers of using chemicals in storing their cowpea grains. Further research on type of insects that damage grains, comparison of traditional structures and modern storage facilities, use of Thousand Grain Mass (TGM) to determine the damage grains and the effects of temperature and relative humidity on the shelf life of stored grains should be carried out.

REFERENCES

Adejumo, B. A. and Raji, A. O. (2007). Technical Appraisal of Grain Storage System in the Nigerian Sudan Savannah. Agricultural Engineering International: *The e-Journal Invited Overview 11*. Vol. IX September, 2007.

Adetunji, M.O. (2007). Economics of maize storage techniques by farmers in Kwara state, Nigeria. *Pakistan Journal of Social Sciences* 4, pp. 442-450.

Ali, I. (2008). Storage systems of Cowpea and their implications for pests' management in the Tamale Metropolis, BSc. Dissertation, UDS, Tamale; pp. 43-49.

Appert, J. (1987). The Tropical Agriculturist: The Storage of Food Grains and Seeds. CTA Macmillan Publications London and Basingstore.

Aveling, T., (1999). Cowpea pathology of postharvest research Analysis of Postharvest Systems; The Sub-Saharan Africa: The case of a new variety of cowpea around the Agricultural Research Station of Cinzanz, Mali. Msc. thesis, Michigan State University, East Lansing, Michigan, USA.

Booker, R.H. (1967). Observation on three bruchids associated with cowpea in Northern Nigeria. *Journal of Stored Products Research* 3: pp. 1-15.

Caswell, G.H. (1973). The impact of infestation on commodities. Tropical Stored Products Information. Nigeria.

David, D. (1978). Workbook for East African. Or Training Course on improved from and Village-Level Grain Storage Methods.

Davis, D.W, Oflke, E.A, Oplinger, E.S., Doll, J.D., Hanson, C.V. and Putnam, D.H. (1991). Cowpea. University of Wisconsin-Madison. United States.

Duke, J.A. (1990). Introduction to Food legumes

Fery, F.L. (2002). New opportunities in Vigna. In: Janick, J. and Whipkey (eds), Trends in New Crops and New Uses. ASHS Press, Alexandria, VA.

Fox, C.W. (1993). Multiple mating, lifetime fecundity and female mortality of the Bruchid beetle, *Callosobruchus-maculatus* (*Coleoptera*, *Bruchidae*). *Funct Ecol 7*: pp. 203-208

Fuseini, H.A. (2003). Evaluation of the mud silo as long-term grain storage for farmers in Northern region of Ghana, M.phil. Thesis, Greenwich University.

Ghana Statistical Service (2010). Population and Housing Census. Available online at; www.statsghana.gov.gh or www.citypopulation.DE.

Giga, D.P. and Smith, R.H. (1983). Comparative life-history studies of 4 *Callosobruchus* species infesting cowpeas with special reference to *Callosobruchus-rhodesianus* (pic) (*Coleoptera, Bruchidae*). *Journal of Stored Products Research, 19*: pp. 189-198

Hall AE (2004) Breeding for adaptation to drought and heat in cowpea. Eur J Agron 21:447–454

Hall AE, Ismail AM, Ehlers JD, Marfo KO, Cisse N, et al. (2002) Breeding cowpeas for tolerance to temperature extremes and adaptation to drought. In: Fatokun CA, Tarawali SA, Singh BB, Kormawa PM,MTamo (eds) Challenges and Opportunities for Enhancing Sustainable Cowpea Production. Intl Inst Tropical Agric, Ibadan, Nigeria, pp. 14–21

Hall, D.W. (1980). Handling and storage of food grains in tropical and subtropical areas, 1980. FAO, Rome, Italy. ISBN: 92-5-100854-X; pp. 350

Hampton, J.G, and Coolbear, P. (1990). Potential versus actual seed performance - can vigour testing provide an answer? *Seed Science and Technology*. 18: 215-228.

Hegarty, T.W. (1984). The influence of environment on seed germination. *Aspects of Applied Biology, 7*: pp. 13-31.

ISTA, **(1985)**. International Rules for seed testing. *Seed Science and Technology*. 21 Suppl Seed prod, 6: pp. 57-84.

Kay, D.E., (1979). Food Legumes. Tropical Development and Research Institute, London. Pp. 48-71.

Langyintuo, A.S., Lowenberg-DeBoer, J., Faye, M., Lambert, D., Ibro, G., Moussa, B., **Kergna, A., Kushwaha, S., Musa, S & Ntoukam, G. (2003).** Cowpea supply and demand in West and Central Africa. *Field Crop Research 82*: pp. 215-231.

Lowenberg- DeBoer J., Mbene F., Saket K., Joan F., Germain I. and Langyintuo A. **(2003)**.Determination of the Demand and Market Opportunities for Cowpea Grain and Processed Products in West Africa).

Lowenberg-DeBoer, (1997). Bean/Cowpea CRSP West Africa, FY 96 Annual Report.October,1995–April,1997.Available online at; www. Entm.purdue.edu/entomologyresearch/cowpea/economic%20pages/impac.htm.

McGregor, S. E. (1976). Insect pollination of cultivated crop plant. USDA.

Murdock, L. M., Seek D., Ntoukam, G., Kitch, l., Shale, R.E.,(2003). Preservation of Cowpea grain in Sub-Saharan Africa-Bean/Cowpea CRSP Contributions. Field crops Research. 28: 168-178

Ofuya, T.I., Agele, S.O. (1990). Ability of ovipositing *Callosobruchus-maculatus*

(Fabricius) (*Coleoptera, Bruchidae*) females to discriminate between seeds with differing numbers of emergence holes. *Journal of Stored Products Research 26*: pp. 117-120.

Pieta-Filho, C, and Ellis, R.H., **(1991)**. The development of seed quality in spring barley in four environments on germination and longevity. *Seed Science Res*. 1: 163-177.

Proctor, D.L. (1994). Grain storage techniques: Evolution and trends in developing countries, 1994**,** *FAO Agricultural Service Bulletin* No: **109**: p. 277. FAO, Rome. Italy. ISBN: 92-5-1 03456-7.

Quass, C.F., (1995). Guidelines for the Production of Cowpea. National Development of Agriculture, Pretoria, pp. 263.

Quinn, J. (1999). *Cowpea, a versatile legume for hot, dry conditions*. Thomas B. Jefferson Institute. Columbia, USA. Available online at; www.hort.purdue.edu/new crop articles/ji-compea html.

Raemaekers, R.H. (ed.) (2001). Crop Production in Tropical Africa. Directorate General for International Cooperation, Ministry of Foreign Affairs, External Trade and International Cooperation, Brussels, Belgium; p. 1549.

Redden RJ, Singh SR, Luckefahr, M.J. (1984). Breeding for cowpea resistance to bruchids at IITA. *Protection Ecology 7*: pp. 291-303

Robinson, R.G. (1984). Peanut: A food crop for Minnesota**.** University of Minnesota *Agric. Expt. Sta. Bultn. AD-SB*-**2478**.

Singh, B.B., Chambliss, Q.L. and Sharma, B. (1997). Recent advances in cowpea breeding.

Stevenson, S. (1999). Report on participatory Rural Appraisals on mud silos in Northern Ghana. NRI report Type written; p. 69.

Taylor, T.A. (1976). Tropical Storage Entomology and the small farmer. Proceedings XV International Congress Entomology Washington 1976. *Vices Bulletin* **109**; pp. 673-679.

Telcrony, D.M. and Egli, D.B., **(1991)**. Relationship of seed vigour to crop yield. A review. *Crop Science*. 31: 816-822

Thamaga-Chitja, J.M., Henddriks, S.L., Ortmana, G.F. and Green, M. (2004). Impact of maize storage on rural household food security in Northern KwaZulu-Natal. *Journal of Family Ecology and Consumer Sciences* 32, pp. 8-15

Thomas, J. **(2003)**. Thomas Jefferson Agricultural Institute 601 West Nifong Blvd. Suite 1D Columbia, MO 65203. 573-449-3518.; p. 21. Available online from; info@jeffersoninstitute.org

Timko, M.P. and Singh, B.B., (2008). Cowpea, a multifunctional legume, in: Moore, P.H., Ming, R. (Eds.), Genomics of tropical crop plants. Springer, New York, pp. 227-257.

Tindall, H.D., (1983). Vegetables in the Tropics. Macmillan Press, London, pp. 533.

Van Rij, N. (1999). Production of cowpea in Kwazulu-Natal. Agri Update; p 4. Available online at; www.agriculture.kzntl.go.za/agri-update/1999/update-5asp.

Villiers, T.A., **(1972)**. Seed Dormancy. *In Seed Biology.* Vol. 11, Ed Kozlowski, T.T New York. Academic Press; pp. 220-281

APPENDIX I

Questionnaire for the Assessment of Effect of different indigenous storage structures on the quality of cowpea grains during five months storage in the Savelugu / Nanton Municipality

A. Personal information

1. What is the name of this village……………………………………………………………………?
2. Sex: A. Male [ ] B. Female [ ]
3. How old are you...................................?
4. What is your main occupation? A. Farming [ ] B. Others…………
5. Are you married? A. Yes [ ]

   B. No [ ]

   C. Widow [ ]

   D. Widower [ ]
6. Have you being to school?

   A. Yes [ ]

   B. No [ ]
7. If yes what is your educational level?

   A. Primary [ ]

   B. J H S [ ]

   C. Secondary/ S H S [ ]

   B. Tertiary [ ]

   E. Others……………………………………………

B **FARMERS/PRODUCERS**

8. How did you prepare the land(s) on which you farmed cowpea?

A. Hoeing [ ]

B. Bullock ploughing [ ]

C. Tractor [ ]

D. Others…………………………………………………

9. What is the source of your planting materials?

A. Self [ ]

B. Ministry of Agric. [ ]

C. Friends [ ]

D. Seed Growers [ ]

E. Others……………………………

10. Do you use recommended spacing?

A. Yes [ ]

B. No [ ]

C. Others…………………………………………

11. Do you apply fertilizer to your cowpea plants?

A. Yes [ ]

B. No [ ]

12. If yes what type of fertilizer did you use?

A. Organic [ ]

B. Inorganic [ ]

C. Both [ ]

13. How did you control weeds in your farm before harvesting?

A. Weeding [ ]

B. Weedicides [ ]

C. Both [ ]

D. Others………………………………………………………

14. Do you control pests and diseases?

A. Yes [ ]

B. No [ ]

15. If yes what methods did you use?

A. Cultural [ ]

B. Physical [ ]

C. Chemical [ ]

D. Others………………………………………

B. POSTHARVEST PRACTICES

16. What methods did you use to harvest?

A. Uprooting [ ]

B. Use of hoe [ ]

C. Picking daily [ ]

D. Mechanical [ ]

E. Others……………………………………

17. How did you remove the grains?

A. Self-explosive [ ]

B. Threshing by hand [ ]

C. Mechanical threshing [ ]

D. Others…………………………………………

18. Where did you remove the grains?

A. in the field [ ]

B. in the home [ ]

19. If in the field how did you convey the grains to the house?

A. Bicycle [ ]

B. Head [ ]

C. Motor king [ ]

D. Vehicle [ ]

E. Others………………………………………..

20. If in the house how did you convey the pods to the house?

A. Bicycle [ ]

B. Head [ ]

C. Motor king [ ]

D. Vehicle [ ]

E. Others …………………………………………

21. When did you dry your beans? A. Before removing the grains [ ]

B. After removing grains [ ]

C. Both [ ]

22. Which method do you use in drying your beans?

A. Sun drying [ ]

B. Kill drying [ ]

C. Others…………………………

23. Where do you dry your beans?

A. On concrete floor [ ]

B. Above the ground [ ]

C. Others……………………………………………

24. State two problems you face in drying your grains.

A. ……………………………………………………

B. …………………………………………………

25. What method do you use in winnowing your grains?

A. By hand [ ]

B. Mechanical [ ]

C. Both [ ]

26. When do you do winnowing?

A. After drying [ ]

B. Before drying [ ]

C. After storage [ ]

27. Did you face any problems during winnowing?

A. Yes [ ]

B. No [ ]

28. If yes state two problems you face during winnowing

A. ……………………………………………………………

B. ……………………………………………………………

D. STORING OF PODS/GRAINS

29. Do you store your grains after drying?

A. Yes [ ]

B. No [ ]

30. If yes what method did you use?

A. Bagging [ ]

B. Mud silo [

C. Thatch silo [ ]

D. Crib [ ]

F. Others…………………………………………………

31. In which form did you store your cowpea grains?

A. Pods [ ]

B. Grains [ ]

C. Both [ ]

32. Do you see pests in your grains?

A. Yes [ ]

B. No [ ]

33. If yes when did you see them?

A. Before storage [ ]

B. After storage [ ]

C. Both [ ]

34. Mention two examples of the pests you see.

A. ………………………………………………………

B. ………………………………………………………

35. Did you treat your grains with chemicals before storage?

A. Yes [ ]

B. No [ ]

36. If yes what is the form of the chemicals?

A. Powder [ ]

B. Liquid [ ]

C. Granular [ ]

D. Others………………………………

37. How long did you store your cowpea grains?

A. 1----4 months

B. 4-----6months

C. 6-----8 months

D. Others…………………………………

38. Do you think the method of storage affects postharvest quality of cowpea?

A. yes [ ]

B. No [ ]

39. If yes give one reason.

……………………………………………………………………………

40. Which method would you have choosing if you had the chance?

A. Bagging [ ]

B. Mud silo [ ]

C. thatch silo [ ]

D. Crib [ ]

E. Others…………………………………………………………

E. CONSUMERS

41. Do you like the type of grains in the market?

   A. Yes [ ]

   B. No [ ]

   C. Others……………………………………

42. If yes why……………………..if no why………………………………..

43. Where do you buy your grains from?

   A. Producers [ ]

   B. Middlemen [ ]

   C. Market [ ]

   D. Others……………………………………………

44. Does the grains you buy have holes in them?

   A. Yes [ ]

   B. No [ ]

   C. Others……………………………………

45. Do you think the storage method affect the quality of grains?

   A. Yes [ ]

   B. No [ ]

C. Others……………………………..

46. What is the commonest method of storing cowpea grains?

A. Crib [ ]

B. Mud silo [ ]

C. Jute sack [ ]

D. Others…………………………………………….

47. Do you like the appearance of the grains you buy?

A. Yes [ ]

B. No [ ]

C. Others…………………………………………………………

48. Do you like the taste of the grains you eat?

A. Ye [ ]

B. No [ ]

C. Others……………………………………………

49. Does the grains you buy have deferent colours?

A. Yes [ ]

B. No [ ]

C. Others……………………………………………

50. Do you feel any stomach discomfort after eating cooked cowpea grains?

You buy?

A. Yes [ ]

B. No [ ]

C. Don‘t know [ ]

D. Others…………………………………………………..

APPENDIX II

Number of insects

Every fortnight	Jute sack	Fertilizer sack	crib	Mud silo	Clay pot
0	0	0	0	0	0
1	5	4	0	0	0
2	6	7	0	0	0
3	7	9	0	5	3
4	9	13	4	12	5
5	12	29	10	12	8
6	16	32	12	13	15
7	25	41	13	25	16
8	34	57	13	26	27
9	46	66	14	27	28
10	67	82	16	27	39
TOTAL	74	89	18	33	43

Sources; field work, May, 2013

LABORATORY ANALYSIS REPORT

SAMPLE: COWPEA

sample cowpea	Carbohydrate %	protein %	moisture %	ash %	fibre %	fat %
fertilizer sack	61.60	23.14	7.42	4.59	2.09	1.15

jute sack	63.14	20.47	7.57	3.67	2.03	3.10
crib	64.23	21.49	7.32	3.12	2.73	1.10
clay pot	62.81	18.35	7.80	4.50	3.29	3.25
mud silo	62.67	19.23	7.83	5.43	3.38	3.32

Sources; field work, May, 2013

Average Storage Temperature

Forth nightly	Jute sack	Fertilizer sack	crib	Clay pot	Mud silo
1	30	31	29	30	30
2	32	30	31	31.5	31
3	34	32	30	32	31.5
4	29	29	28	28	33
5	31	30	33	30	29
6	31	34	31	32	32
7	29	31	34	28	33
8	30	32	30	30	30
9	31	33	32	31	31
10	32	31	33	29	30

Sources; field work, May, 2013 **Average Relative Humidity**

Forth nightly	Jute sack	Fertilizer sack	Crib	Clay pot	Mud silo
1	90	89	90	88	89
2	88	91	91	89	88
3	86	87	87	87	88
4	88	89	89	88	87
5	87	86	86	86	89
6	86	88	87	87	88
7	90	89	91	91	90

8	89	90	90	90	91
9	88	86	87	89	88
10	87	85	91	91	90

Sources; Field work May,2013.

Weight of cowpea grains

Structure	Weight of grains before storage (g)	Weight of grains after storage (g)	weight loss (g)	Percentage weight loss (%)
Jute sack	2420.5	2304.1	116.4	4.8
Fertilizer sack	2420.5	1842.2	578.3	23.9
Crib	2420.5	2124.6	295.9	12.2
Clay pot	2420.5	2329.3	91.2	3.8
Mud silo	2420.5	2315.7	104.8	4.3

Source: Field work, May, 2013

Average number of damage grains

Every fortnight	Jute sack	Fertilizer sack	Crib	Mud silo	Clay pot
0	**0**	**0**	**0**	**0**	**0**
1	**7**	**8**	**2**	**1**	**4**
2	**14**	**28**	**7**	**12**	**10**
3	**29**	**50**	**18**	**18**	**20**
4	**36**	**67**	**20**	**22**	**24**
5	**41**	**79**	**24**	**23**	**25**

6	**46**	**90**	**30**	**26**	**30**
7	**61**	**105**	**33**	**29**	**35**
8	**105**	**125**	**41**	**33**	**39**
9	**127**	**142**	**46**	**39**	**40**
10	**168**	**163**	**52**	**44**	**41**

APPENDIX III: ANOVA Tables

Weight retained, Germination, Insect count, Temperature and Humidity

Completely Randomized AOV for weight Loss

Source	DF	SS	MS	F	P
Structure	4	887.460	221.865	13866.6	0.0000
Error	10	0.160	0.016		
Total	14	887.620			

Grand Mean 9.8000 CV 1.29

Completely Randomized AOV for germ

Source	DF	SS	MS	F	P
Structure	4	6986.40	1746.60	623.79	0.0000
Error	10	28.00	2.80		
Total	14	7014.40			

Grand Mean 56.200 CV 2.98

Completely Randomized AOV for Insect count

Source	**DF**	**SS**	**MS**	**F**	**P**
Structure	4	10347.6	2586.90	1293.45	0.0000
Error	10	20.0	2.00		
Total	14	10367.6			

Grand Mean 51.400 CV 2.75

Completely Randomized AOV for Temperature

Source	**DF**	**SS**	**MS**	**F**	**P**
Structure	4	2.35500	0.58875	24.19	0.0000
Error	10	0.24340	0.02434		
Total	14	2.59840			

Grand Mean 30.900 CV 0.50

Completely Randomized AOV for Humidity

Source	**DF**	**SS**	**MS**	**F**	**P**
Structure	4	2.79600	0.69900	13.44	0.0005

Error	10	0.52000	0.05200
Total	14	3.31600	

Grand Mean 88.460 CV 0.26

Proximate Analysis ANOVA Tables of Cowpea

Completely Randomized AOV for Carbohydrates

Source	**DF**	**SS**	**MS**	**F**	**P**
Structure	4	10.7948	2.69869	46.36	0.0000
Error	10	0.5821	0.05821		
Total	14	11.3769			

Grand Mean 62.893 CV 0.38

Completely Randomized AOV for Protein

Source	**DF**	**SS**	**MS**	**F**	**P**
Structure	4	42.5360	10.6340	610.21	0.0000
Error	10	0.1743	0.0174		
Total	14	42.7103			

Grand Mean 20.537 CV 0.64

Completely Randomized AOV for Moisture

Source	DF	SS	MS	F	P
Structure	4	0.60436	0.15109	62.61	0.0000
Error	10	0.02413	0.00241		
Total	14	0.62849			

Grand Mean 7.5907 CV 0.65

Completely Randomized AOV for Ash

Source	DF	SS	MS	F	P
Structure	4	9.48004	2.37001	217.57	0.0000
Error	10	0.10893	0.01089		
Total	14	9.58897			

Grand Mean 4.2647 CV 2.45

Completely Randomized AOV for Fibre

Source	DF	SS	MS	F	P
Structure	4	4.87251	1.21813	321.69	0.0000
Error	10	0.03787	0.00379		
Total	14	4.91037			

Grand Mean 2.7053 CV 2.27

Completely Randomized AOV for Fat

Source	DF	SS	MS	F	P
Structure	4	15.9304	3.98259	189.47	0.0000
Error	10	0.2102	0.02102		
Total	14	16.1406			

Grand Mean 2.3840 CV 6.08