COMPARATIVE ASSESSMENT OF SOME STORAGE TECHNOLOGIES USED FOR COWPEA STORAGE IN THE NADOWLI DISTRICT OF THE UPPER WEST REGION OF GHANA

BY

SALIFU MAHAMA

JUNE, 2012

KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

COLLEGE OF AGRICULTURE AND NATURAL RESOURCES

DEPARTMENT OF HORTICULTURE

MASTER OF SCIENCE (POSTHARVEST TECHNOLOGY)

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THESIS SUBMITTED TO THE DEPARTMENT OF HORTICULTURE, KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF

MASTERS OF SCIENCE IN POSTHARVEST TECHNOLOGY

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DECLARATION

I hereby declare that this work presented to the Department of Horticulture, is the result of my own research and that no part of it has ever been presented here or elsewhere. Works done by other authors, which served as source of information, have been duly acknowledged by way of references to the authors.

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DEDICATION

I dedicate this work to my dear mother, Mrs Alimata Salifu for her care, encouragement and support that has led me this far.

ABSTRACT

Pest infestation is the major storage problem in cowpea (*Vigna unguiculata*) storage around the world. The principal postharvest pest of cowpea in Ghana is the cowpea weevil (*Callosobruchus maculatus*). The main objective of the study was to evaluate the common storage methods used in the Nadowli District and their effectiveness in maintaining the quality of cowpea beans during storage. A survey was conducted to identify the major storage technologies and problems in the district. Four storage structures: barns, polypropylene sacks, earthen pots and triple bags and 3 protectants (wood ash, phostoxin, monthly solarisation) with a control were used to store 'ormondoh' cowpea variety. There were monthly data collections on cowpea samples taken from each treatment set up and assessed for quality for three months. Parameters that were determined were percentage weight loss, percentage damage, germination percentage, taste and colour change. Monthly solarisations of beans on all the storage structures proved to be more efficacious by killing all stages of the weevil. Also, triple bags using Purdue Improved Cowpea Storage sacks which use hermetic principle was also more effective when combined with the control or either of ash and phostoxin. The interactions between ash and storage in pots, barns and polypropylene sacks offered lower protection and recorded a high level of damage and loss of other quality parameters. Phostoxin fumigation on polypropylene sack and pot recorded a reduction in grain quality as the storage period increased because the structures were not entirely airtight. The untreated control of the barn, polypropylene sack and pot were highly ineffective in keeping cowpea grain quality. There were losses in taste and colour for all the controls for the various storages technologies with the exception of those kept in the triple bags. Monthly solarisation of cowpea in storage structures did not record any taste or colour change. The study has shown that the use of triple bag treatment with the protectants were more effective in controlling the cowpea weevil (*Callosobruchus maculatus*) which feeding activities cause loss in grain quality. Monthly solarisation in all the interventions should be the method of choice in the absence of triple bags in the district.

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CHAPTER ONE

1.0 INTRODUCTION

1.1. Background

Cowpea (*Vigna unguiculata*) is one of the most versatile food legumes in the tropical and sub-tropical regions of the world where it is cultivated (Brisibe *et al*., 2011). Although indigenous to South-Eastern Africa, cowpea has spread worldwide and it is extensively cultivated and consumed in regions of Asia, South and Central America, the Caribbean, the United States, the Middle East and Southern Europe (Kebe and Sembene, 2011). It is a major grain legume in Sub-Saharan Africa (FCDP, 2005). According to Ocran *et al.* (1998), cowpea is the most widely grown legume in Ghana. Also, cowpea is the most widely consumed legume in Ghana (MOFA, 2010).

Whilst cowpea is grown throughout Ghana, the bulk of production takes place in the three northern regions (Northern, Upper West and Upper East Regions). In northern Ghana, Cowpea forms a major part of the diet, and the majority of farmers cultivate it for home consumption, but some will sell part of the harvest to raise cash to meet costs such as medical expenses and school fees (Golob *et al.*, 1999).

Cowpea consumption is higher than production in Ghana and as a result, it imported 3,380 MT of cowpea grains which supplemented the country's production of 219,300 MT in 2010 (Egbadzor *et al*., 2013).

Cowpea is cultivated for its leaves, green pods, grain and haulm for livestock feed. It is a major source of vegetable protein (Appiah *et al.,* 2011). It contains minerals (such as Calcium and Iron) and amino acids (including lysine, tryptophan and methionine) which improve human nutrition and health status. (FCDP, 2005).

The leaves, immature pods, fresh seeds (Southern peas or “green pods”) and dry grain of cowpea can be eaten or marketed (Kebe and Sembene, 2011). This legume plays an important role in the diet and economy of many small-scale farmers in northern Ghana (FAO, 2011).

According to Brisibe *et al*. (2011), Africa accounts for about 75% of the world cowpea production, with Nigeria and Niger dominating.

According to FCDP (2005) there is the need to combine improved crop production, protection and post-harvest practices. Cowpea beans can be stored short term at around 12% moisture or less, with 8 to 9% recommended for long term storage (Quinn and Myers, 2002).

Recently, post-harvest loss of grain due to insect pest has become a major concern all over the world. Estimated discounts in Senegal, Cameroon, and Ghana ranged from 0.17 to 2.3 percent of the average annual cowpea price per hole (Lowenberg-Deboer and Ibro, 2008). Demand for good quality products, which are free from chemical resources, is high and increasing rapidly (Kashi, 1981).

1.2 Problem Statement

In West Africa, Bruchidae (Coleoptera) are the main pests with great economic impact on the production of cowpea (*Vigna unguiculata*), (Effowe *et al*., 2010). Initially shielded from insects within the harvested pods, the grain becomes more exposed to post-harvest insect pests after threshing, and is vulnerable to these insects throughout subsequent storage (Murdock *et al*., 2003).

According to Dugje *et al*. (2009), damage by insect pests on cowpea can be as high as 80 – 100% if not effectively controlled.

In Ghana, insect damage may amount to more than 30 percent during on-farm storage, but farmers appear to consume or sell their cowpea when losses approach 5 percent by weight (Morris and Tran, 2002).

A visit to any market in the Upper West Region and for that matter, Nadowli District few months after harvest indicate there is a high level of damage by bruchids in cowpea beans. According to Sallam (2008), high losses could be incurred during storage. These damaged beans eventually get to the market attracting lower prices.

Farmers have adopted several storage technologies for storing their cowpea beans. Unfortunately, the effectiveness of these technologies used in the Nadowli District have not been sufficiently reported. This makes it difficult for stakeholders to make appropriate choice of storage technologies. This gap in knowledge therefore needs to be addressed.

1.3 Justification

A preliminary survey indicated most farmers are aware of the Bruchids problem, and often sold their newly harvested grain within few months of harvest, or consume it quickly in order to avoid the post-harvest losses. As stated by Murdock *et al*. (2003), the disadvantage of this was that they sold when the price was near its annual low point but subsequently had to buy cowpeas on the open markets when the price was higher.

While some farmers opted for the "sell or eat" strategy because of the bruchids, others made attempts to prevent bruchids infestations (Murdock *et al*., 2003). Among the preventive/storage methods of pest control used in the Upper West Region are synthetic insecticide (phostoxin, bettalic); treatment with plant products (*lodel*); wood ash, barn (*bogr*), clay pot, polyethylene sacks; and recently introduce in the region which is still not readily available is the triple bagging (Purdue Improved Cowpea Storage [PICS]) sacks.

However, with all these preventive and available storage structures at the disposal of farmers, the problem of bruchid infestation is still a problem to the local farmers in cowpea production and traders of cowpea beans as well.

Without protection, harvest of cowpea beans may be lost quickly and completely (PICS, 2010).

1.4 Objective of the Study

1.4.1 Main Objective

The main objective of the research is to evaluate the common methods of cowpea storage used in the Nadowli district with respect to grain quality.

1.4.2 Specific Objectives

1. To assess the effectiveness of various technologies against storage pest incidence.
2. To assess the effect of different storage technologies on germinability of stored cowpea beans.
3. To assess the effect of the various technologies on some sensory quality of cowpea beans.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Introduction

Cowpea is one of the most ancient crops known to man. It is now a broadly adapted and highly variable crop, cultivated around the world primarily for bean, but also as a vegetable (for leafy greens, green pods, fresh shelled green peas, and shelled dried peas), a cover crop and for fodder (Quinn and Myers, 2002).

Cowpea has a number of common names, including Crowder pea, Black-eyed pea and Southern pea. It is known internationally as lubia, niebe, coupe or frijole. However, they are all the species *Vigna unguiculata* (L.) Walp., which in older references may be identified as *Vigna senensis* (L.) (Quinn and Myers, 2002).

More than 5.4 million tons of dried cowpeas are produced worldwide, with Africa producing nearly 5.2 million. Nigeria, the largest producer and consumer, accounts for 61% of production in Africa and 58% worldwide. Africa exports and imports negligible amounts of cowpea (IITA, 2009).

Cowpea is the main edible leguminous plant which is cultivated all over West of Africa (Mondedji *et al*., 2002). It is an important component of sustainable cropping systems in Ghana (FCDP, 2005).

2.2 Uses of Cowpea

Cowpea seed is a nutritious component in the human diet, as well as a nutritious livestock feed (Davis *et al*., 1991).

Cowpea leaves can be used as spinach. The grain can be boiled and eaten with stew. The flour can be used to prepare *koose, tubani* and fortified foods (e.g. porridge) for adults and children (FCDP, 2005). An added advantage of cowpea is that the plants can be harvested as fodder for livestock (Kebe and Sembene, 2011).

It can fix up to 120 kg N per ha and offers strong residual benefits to following crops, particularly from the longer duration, trailing varieties (Woomer, 2010).

2.3 Nutritional Value of Cowpea

Cowpea is considered nutritious with a protein content of about 23%, fat content of 1.3%, fiber content of 1.8%, carbohydrate content of 67% and water content of 8-9% (Quinn and Myers, 2002). It also contains B vitamins such as folic acid which is important in preventing birth defects and essential micronutrients such as iron, calcium and zinc (Kebe and Sembene, 2011).

Although a significant amount of cowpea is commercialised, it plays a critical subsistence role in the diets of many households in Africa, Latin America and Asia, providing nutrients that are deficient in cereals (Kebe and Sembene, 2011). Cowpea seeds contain most of the amino acids necessary for human feeding, except the sulphured amino acids (Smart, 1964). Similar to other grain legumes, cowpea contains trypsin inhibitors which limit protein utilization (Davis *et al.*, 1991).

2.4 Cowpea storage protectants

During storage, heavy damage is caused by insect pest, which can destroy the entire harvest (Tran, 2001). Cowpeas are particularly susceptible to damage in storage, mainly by cowpea bruchids, (*Callosobruchus maculatus*). Entomologists had hypothesized that African consumers were willing to tolerate up to one bruchid hole per grain before they demanded a discount.

Cowpea storage is a big business in Kano. It is also indicated that most merchants who store cowpea beans for extended periods use storage chemicals (Lowenberg-Deboer and Ibro, 2008).

To protect their stored crops against pests, farmers introduced into their storage structures inert substances such as ash and sand (Chinwada and Giga, 1997), vegetable oils (Credland, 1992) or presumed insecticidal aromatic plants and/or insect repellents (Golob and Webley 1980; Ketoh *et al*., 2006). In order to preserve significant quantities of cowpea, farmers have turned to the use of synthetic insecticides, the majority of which are not intended for Bruchidae. The misuse of these insecticides inevitably has harmful consequences on the health of the users, the consumers and the environment (Effowe *et al*., 2010). In addition, the widespread use of these synthetic insecticides could lead to pest resistance (Effowe *et al*., 2010).

An alternative to chemical methods is the use of a biological agent to control the beetle population and consequently their damage to stored seeds (Amevoin *et al*., 2007). Studies of insect population dynamics on cowpea in field and granaries lead to the identification of a solitary ectoparasitoid of larvae and nymphs of Bruchidae, *Dinarmus basilis* Rond (Hymenoptera: Pteromalidae) (Effowe *et al*., 2010).

Under natural conditions of infestation of cowpea seeds in the field, the numbers of this natural enemy are low so it does not provide an effective control of the beetle population (Amevoin *et al*., 2006). Biological control of natural enemies can represent an interesting alternative for low-income small-scale producers in West Africa (Huis, 1991). Studies carried out under different experimental conditions in different climatic zones of West Africa showed that introduction of *Dinarmus Basalis* adults at the beginning of storage could effectively control bruchid populations and conserve good quality of seeds after 6 months of storage (Glitho *et al*., 1998; Amevoin *et al*., 2006).

2.5 Pest of Cowpea

Possible insects are Mexican bean beetle, bean leaf beetles, cowpea curculio, aphids, green stink bag, lesser cornstalk borer and weevils (when in storage) (Quinn and Myers, 2002). The main problem that farmers face is the conservation of the cowpea crops because 80 to 100% of beans are destroyed by two bruchid species namely *Bruchidius atrolineatus* (Pic) and *Callosobruchus maculatus* (Fab), in a period of 2 to 3 months after storage (Ndoutoume-Ndong and Rojas-Rousse, 2008). Cowpea storage bruchid eats cowpea grain making distinctive round holes (Kebe and Sembene, 2011). The infestation of cowpea pods by these insects begins in the fields when the cowpea plant starts producing pods (Kebe and Sembene, 2011). The eggs are laid on the cowpea pods and then hatch within 5 to 7 days for both species in the best conditions (Djossou, 2006); Damage is apparent about 2 to 3 months after harvest and virtually all of the grain may have holes by 6 months (Kebe and Sembene, 2011).

The larvae of the bruchid beetle penetrate the seeds and their entire development occurs inside (Effowe *et al*., 2010). At the time of harvest, approximately 0.5% of cowpea seeds contain larvae and nymphs that will continue their development in granaries, thereby causing very significant post-harvest crop losses (Huignard *et al*., 1985).

An individual cowpea weevil female can reproduce herself twenty to forty (20-40) folds, and she is ready to mate and lay eggs immediately after emerging from the seed in which she developed. Egg hatchings can produce reproductively active adults in as short a time as 3 weeks if temperatures are favourable. When a gravid female finds herself in a granary full of newly threshed seeds the stage is set for potentially disastrous losses. (Murdock *et al*., 2003).

2.6 Storage of Cowpea

2.6.1 Drum Storage

The technique developed by Dr. Dogo Seck and others (Seck and Gaspar, 1992) involves storing the cowpea grain in sealed metal drums. Sixty litres drums whose tops are fitted with 6-7cm diameter screw-type plastic lids are filled to the top with dry threshed grain. Each drum holds about 45-55kg, depending upon seed size. The filled container is sealed, with peanut or other cooking oil used to lubricate the edges of the closure to ensure an airtight seal. The oil also makes it easier to remove the lid after months of storage. The filled drums can be stored for 6 months with minimal losses to cowpea bruchids (Seck and Gaspar, 1992). The protective action during drum storage is likely due to depletion of oxygen and elevation of carbon dioxide concentration (Seck *et al*., 1996) that results from respiration of insects living in the grain at the time of storage, and to respiration of the grain itself. According to Murdock *et al*. (2003) good quality used metal drums are relatively expensive in much of Africa and hard to find in many places; this may limit the spread of the drum technology. Air leaks lower the value of drum storage and farmers have to be encouraged not to open the drums too soon after initiating the storage, for this admits air and allows surviving insects to resume feeding and development (Murdock *et al*., 2003).

2.6.2 Improved Ash Storage

In many parts of sub-Saharan Africa, farmers often mix their cowpea grain with sieved ash from cooking fires, or with sand, in the hope of protecting their grain from bruchids (Golob and Webley, 1980). Survey of cowpea storage by CSRP scientists in northern Cameroon confirmed that ash usage is common there, but farmers differed widely in the way they used ash, especially in the proportions of ash to grain. Some dusted their cowpeas lightly with ash, others used a large excess of ash over the grain, while still others used alternate layers of cowpeas and ash (Wolfson *et al*., 1991).

Given the uncertainty about the effectiveness of ash as a grain protectant, systematic experiments were carried out at Purdue to determine whether ash was actually protective and to optimize the proportions of ash to grain required for protection (Murdock *et al*., 2003). It was found that ash can indeed protect cowpea grain from runaway losses to cowpea weevil, but with some restrictions (Wolfson *et al.*, 1991). One caveat is that any cowpea seed that already has a cowpea bruchid larvae developing inside it at the time the seed is mixed with ash will eventually have an emergence window or even hole (Murdock *et al*., 2003).

As recommended by CRSP Scientists in Cameroon, Murdock *et al*., (2003) reported that equal volume of sieved ash and cowpea grain are mixed, placed in a container and cover the ash/grain mixture with a 3 cm layer of ash. Golob *et al*., (1999) indicated that, in pots, only the admixture of ash at 1:1 by volume proved to be effective at controlling damage and loss on cowpea and bambara: weight loss on cowpea goes from almost 7% on the control, to below 3% with ash (1:1).

2.6.3 Hermetic Control (Triple Bagging)

The principle of the triple bag technology allows less air exchange with the outside world. The bruchids consume the little oxygen available, while emitting the CO_2 and returning to quiescence to die later. It is therefore established in a few hours a low oxygen environment and enriched CO_2 and stopping the bruchid from causing the damage. (PICS, 2010).

According to Murdock *et al*. (2003), systematic studies by CSRP researchers confirmed that merely confining infested grain in multiple tightly closed plastic sacks, one enclosed within the other, is sufficient to arrest a cowpea bruchid infestation. On-farm tests with Cameroon villagers validated the effectiveness of this methodology, called “triple plastic bagging”. The recommended procedure consists of filling a plastic bag with infested cowpea grain, tying the mouth of the bag shut, enclosing this bag completely within a second one, and tightly securing that, then repeating the procedure using a third bag (Murdock *et al*., 2003).

2.7 Solar Disinfestation

All insects have thermal death points, a temperature at which they are unable to survive (Murdock *et al*., 2003). In the case of the cowpea bruchid this is 57^{o}C, with all life stages of the insect (egg, larvae, pupa and adult) killed when exposed to this temperature for 1 hour (Murdock and Shade, 1991).

To achieve this temperature, and thus disinfest cowpeas, Murdock and Shade (1991) used plastic sheeting to enclose and heat the cowpea grain. Black plastic sheeting (woven wicker mats can serve nearly as well) was laid upon the ground, and then covered to a depth of 1-2 cm with infested cowpea grain. A second, translucent plastic sheet was used to cover the lower sheet and grain, then the edges of the two plastic sheets are sealed by folding the upper sheet under the lower one and securing the envelope so formed with small stones laid around the edges. When exposed to the sunlight, the temperature within the envelope rises rapidly thanks to solar energy passing through the translucent upper sheet and being absorbed by the cowpea grain and the underlying black plastic sheet. Within 15 -30 minutes the temperature within the cowpea grain typically rises to 60 – 70^{o}C, more than adequate to kill all stages of the cowpea weevil (Murdock and Shade, 1991)

2.8 Fumigation

Stored grain pest infestation is controlled by various methods among them, fumigation is one of the most effective method in which insect pests are exposed to a poisonous gaseous environment, produced by applying a grain fumigant (Upadhyay and Ahmad, 2011). Fumigation kills insects inside beans with phosphine gas (Golob, 2009). Fumigation is not effective unless the storage to be treated is well sealed and the grain temperature is well above 50 degree F (Upadhyay and Ahmad, 2011). Phosphine, although readily available and cheap is much too toxic to recommend to farmers to use (Golob *et al*., 1999).

Fumigation with phosphine gas is done at the rate of 1 – 2 tablets/100kg of seeds. The phostoxin tablet is wrapped in a piece of cloth or tissue paper or perforated envelope before placing it inside the container. The fumigated cowpea seeds are stored in jute or polypropylene bags with polythene inner liner or triple bagging. (Dugje *et al*., 2009).

Phosphine is characterized as a slow acting fumigant to which insects can develop resistance and so, an imperfect fumigation increases the risk of development of resistance by the insects. Three gram phostoxin tablet emits one gram phosphine gas. (Allahvaisi *et al.*, 2010).

2.9 Cowpea Storage Losses

Cowpea is usually stored in sacks or in some indoor structure that is specifically dedicated to cowpea storage and usually stored for up to 2 to 3 months. Wholesalers often hold cowpea stocks for extended periods waiting for higher prices. (Bean/Cowpea CRSP West Africa, 1998).

Cowpea suffers substantial damage and loss of quality as a result of infestation by members of the Bruchidae family, *Callosobruchus maculatus* (F) and *C. subinnotatus* (Pic) (Golob *et al.*, 1999).

Singh and Jackai (1985) noted that, on-farm storage of cowpeas for 6 months is accompanied by about 30% loss in seed weight, with about 70% of the seeds being damaged and virtually unfit for consumption. Cowpea suffer heavy insect damage, more than 30% whilst stored on the farm, losses can exceed 10% by weight (Golob *et al*., 1999). Insect damage is clearly substantial during storage both on-farm and at the market ranging from 2.6% to 70% on average (Golob *et al*., 1999).

Grain of high quality fetches a premium both for the local trader and for the farmer, particularly as insect-undamaged grain is difficult to find. However, whilst remaining in the trader's store insect damage increases significantly; it is not unusual to see grain with more than 50% damage. (Golob *et al*., 1999).

Under traditional storage conditions, 100% infestation of cowpea occurring within 6 months or more often within 3 to 5 months of storage is common (Booker, 1967; Caswell and Akibu, 1980; Seck, 1993). The cowpea bruchid causes substantial quantitative and qualitative losses manifested by seed perforation and reduction in weight, market value and germinability of seeds (IITA, 1989; Adetuntan and Ofuya, 1998). The larval stages of bruchids develop inside the beans; damage and weight loss are caused by larvae consuming the seed (Golob *et al*., 1999).

2.10 Determination of Percentage Weight Loss

Adams and Schulten (1978) recommended that a sample of 100 – 1,000 beans should be used in calculating percentage weight loss of grains due to insect attack.

According to Olakojo *et al.* (2007), to test the efficacy of some storage methods currently used by farmers, data were collected from the experiment for 18 months which include; Initial seed weight (g), number of seed damaged (number perforated by beetles), number of undamaged seed (number not perforated by beetles), remained seed weight (g) [weight of seed after the experiment], seed weight loss (g) [Initial seed weight – Final seed weight], percentage weight loss [Initial seed weight – Final seed weight/Final seed weight × 100] and emerged insect population.

Boxall (1986) recommended the working sample of approximately 500 beans via the Count and Weigh method.

Boxall (1986) reported that, the Commission for Evaluation of Losses published a formula which incorporated the calculation of the reduction in average grain weight due to insect attack, and the percentage of damaged beans. (Adams and Schulten, 1978):

$$\frac{UNd - DNu}{U(Nu + Nd)} \times 100 = \% weight\ loss$$

Where

U= weight of undamaged beans

D= weight of damaged beans

Nu= Number of undamaged beans

Nd= Number of damaged beans

% damaged (hollowed) beans was determined at the same time, using the formualar:

$$\% \ damage = \frac{Nd}{Nu + Nd} \times 100$$

2.11 Germination Test

Germination percentage is a very important quality attribute of seeds because it indicates their viability potential (Kaaya and Kyamuhangire, 2010). A germination test will tell you how healthy your seeds are (FCDP, 2005).

To ensure good plant stand, always conduct germination test before planting as follows:

- Pick 100 seeds at random from the lot.
- Make a shallow trench 1 – 2 meters long.
- Place the seeds evenly in the shallow trench.
- Cover with 3 – 5 cm of soil and water well (do not saturate the area).
- Observe regularly and water when necessary.
- Count the number of seedlings that emerge one week after planting.

(Source: FCDP, 2005)

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study Area

The study was conducted in Nadowli District. Nadowli District is located in the heart of the Upper West Region of Ghana. It lies between latitude 11° 30` and 10° 20`.The district has a mean annual temperature of 32°C and a mean monthly temperature ranging between 36°C in March to 27°C in August. The district lies within the Tropical Continental Zone and annual rainfall is confined to 6 months that is from May to October and is also unevenly distributed.

Mean annual rainfall is about 1100mm with its peak in August. Between October and March there is virtually no rain and this long dry season is made harsh by the dry North-Easterly harmattan winds. Relative humidity is between 70% and 90% during the rainy season but is as low as 20% during the long dry season.

Nadowli District lies within the Tropical Continental or Guinea Savannah woodland characterized by shrubs and grassland with scattered medium sized trees. Some economic trees found in the district are kapok, shea, baobab, mango and dawadawa and these are resistant to both fire and drought.

3.2 Methods

3.2.1 Questionnaire Design

A baseline survey was carried out in five (5) communities (Serekpere; Daffiama; Chakale; Kojokpere and Issa) in the district through the administration of questionnaire to identify three of the most widely used structures in the district. Ten (10) questionnaires were administered in each community to cowpea farmers through purposive sampling.

The parameters that were used in the design of the questionnaire were social background of the respondents, storage of cowpea (method and duration), constraints face in the use of the preferred method.

3.2.2 Experimental Design

The experimental design was four by four (4 × 4) factorial in a completely randomized design. Treatments were three protectants (solarisation; phostoxin and wood ash) and a control. Three of the most popular structures used in the district which were identified through the questionnaire administered were Barns (*Bogre*); Earthen Pots and Polypropylene sacks. Each of these storage structures were treated with wood ash, fumigation and solarisation. Also, the triple bag or PICS sack (which is a new technology introduced in the district and uses the principle of modified atmosphere package) was also applied with wood ash, fumigation and solarisation to each. Each of these four storage structures had a control to which no protectant was applied. In addition, each of the setup was filled with 10 kg of the local cowpea variety, '*Ormondoh*'. The cowpea variety was obtained from one farmer to eliminate variability as a result of different production and handling methods. The local structures were conducted under farmer's practices at Serekpere, a selected community within the district. The triple bags setups were conducted at the office of the Ministry of Food and Agriculture, Nadowli District Agricultural Development Unit. The setups period was for three (3) months.

3.2.3 Baseline Information

Before the setup, three samples of 500 each of the cowpea beans were randomly picked from the experimental material for percentage weight determination, germination percentage, percentage damage (through perforations as a result of field infestation by bruchids), and colour. These were used as baseline information for comparison with changing parameters with monthly samples for a period of three months.

3.2.4 Monthly Data Reading

500 beans were sampled out from the top, middle and bottom of each of the four triple bags, four polypropylenes, four pots and four barns (*bogre*) for parameters determination.

3.2.5 Storage Methods

Ten kilograms (10 kg) of cowpea was put in each of the four triple bags. The first was without any treatment which served as the control. The second bag was solar dried once every month for a period of 2 hours and tied back. The third bag was mixed with sieved wood ash in the ratio 1:1 by volume. Phostoxin (0.6 g) tablet was wrapped in a piece of cloth and placed inside the bag.

The steps of tying the triple bags were as follows;

1. Small amount of cowpea was poured into the inner bag, starting gently.
2. Putting the three bags together (one inside the other), the rest of the cowpea was poured into the inner bag.
3. Twisting the lip of the first bag tightly shut, folded it over and tied firmly with a heavy string at the base of the twist and over the folded twist.
4. Pulling the middle bag up over the first one so that it completely surrounded it. Twisting the lip shut, fold over and tied, as before.
5. The same steps were followed for the outer bag.

(See Appendix I-a for triple bag plate)

Ten kilograms (10 kg) of cowpea was put in each of the four polypropylene bags. The first bag was without any protectant and was used as the control. The second bag cowpea was always solar dried once every month for 2 hours and tied back. The third bag grain was mixed with sieved wood ash in the ratio 1:1 by volume. The fourth bag was treated with phostoxin tablet where 0.6 g of the phostoxin was wrapped in a piece of cloth and placed inside the bag and tied.

Ten kilograms (10 kg) of cowpea was put in each of the four barns ("Bogre"). The first barn was without any protectant added which served as the control. The second barn was solar dried once every month. The third barn cowpea was mixed with sieved wood ash in the ratio 1:1 by volume with 0.6 kg of phostoxin tablet wrapped in a piece of cloth put inside the barn. The openings to the barns were closed with lids and the edges sealed with mud. (See Appendix I-b for barn plate)

Also, 10 kg of cowpea were put in each of the four pots. The first pot was without any protectant which served as the control. The second pot content was always solar dried once every month. In the third pot cowpea was mixed with sieved wood ash in the ratio 1:1 by volume and the fourth pot cowpea was treated with phostoxin, 0.6 g tablet was wrapped in a piece of cloth and placed inside the pot. The openings of the pots were always covered with lids and the edges sealed with mud. (See appendix I-c for pot plate)

3.2.6 Solar Drying Procedure

Solar drying was carried out monthly using the following procedure;

1. Rice straw was spread on the ground to serve as insulator between the ground and the black polyethylene sheet
2. A black polyethylene sheet was spread over the straw
3. The grain was spread uniformly on the plastic material
4. The grain was covered with a translucent plastic material with similar size as the black polyethylene

5. The edges of the two plastic sheets were folded and secured with stones
6. The materials were left in the sun for two hours.

   [Source: FCDP, 2005]

(See Appendix I-d for solar drying plate)

3.2.7 Determination of Weight Loss caused by insects

The setups were opened monthly and samples of 500 beans were picked from the top, middle and bottom of storage structures and separations of damaged (perforated) or otherwise infested beans were made from the undamaged ones. The samples were then sieved to remove insects in beans. The weight of both the damaged beans and undamaged beans were calculated from the monthly samples using Salter Brecknell Electronic Balance scale. (See Appendix I-e for Brecknell Electronic Scale plate)

Percentage weight loss was calculated using the following formula:

$$\frac{UNd-DNu}{U(Nu+Nd)} \times 100 = \%\ weight\ loss\ caused\ by\ insects \quad \text{...(1)}$$

Where:

U= weight of undamaged beans

D= weight of damaged beans

Nu= Number of undamaged beans

Nd= Number of damaged beans

Percentage damaged (hollowed) beans was determined as:

$$\%\ damage = \frac{Nd}{Nu+Nd} \times 100 \quad \text{..(2)}$$

(Source: Boxall, 1986)

3.2.8 Determination of Germination Percentage

The procedure recommended by FCDP (2005) was used to determine the percentage germination. 100 seeds were selected from top, middle and bottom of each lot. Shallow trenches of 5 cm deep and 2 meters long were made. The seeds were evenly placed in the shallow trenches and covered with 5 cm of soil and watered well (not to saturate the area). Observations were made regularly and plots watered when necessary. One week after planting number of seedlings that emerged were counted. (See Appendix I-f for germination test plate)

Germination Percentage was then computed using the formula:

Germination %= $\frac{Ng}{Np} \times 100 \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (3)$

Where

Ng = number germinated

Np = number planted

3.2.9 Determination of Colour Change

Colour changes were monitored using a colour chart. This was done during monthly data collection from the samples picked.

3.2.10 Determination of Change in Taste

Samples were picked at the end of the each month from the 16 setups and cooked and sensory panel were set to taste and determine whether changes had occurred as a result of the method of storage.

3.3 Treatments

The treatments that were applied to the storage structures were:

1. Wood ash: this was applied to each of the three most widely used structures (barn, pot and polypropylene) in the district and triple bag.
2. Synthetic chemical (Phostoxin): this chemical was applied to the three most widely used structures (barn, pot and polypropylene) in the district and triple bag.
3. Solarisation: this was applied to the three most widely used structures (barn, pot and polypropylene) in the district and triple bag. Solarisation was repeated monthly.
4. Control: No protectant was applied to the controls of the four structures.

3.4 Data Analysis

The data was analyzed using Excel and GenStat Ninth Edition. The results obtained were expressed in percentages and presented using simple descriptive statistics such as frequency tables, bar charts and pie chart. Percentages were transformed using Square-root transformation of percentage values +0.5. Analysis of variance and least significant difference (LSD) at P=0.05 were used to establish differences between treatments.

CHAPTER FOUR

4.0 RESULTS

4.1 Baseline Survey

Among the fifty respondents that were interviewed in the Nadowli district from five selected communities, twenty-four percent (24%) were female and seventy-six percent (76%) male (Figure 4.1).

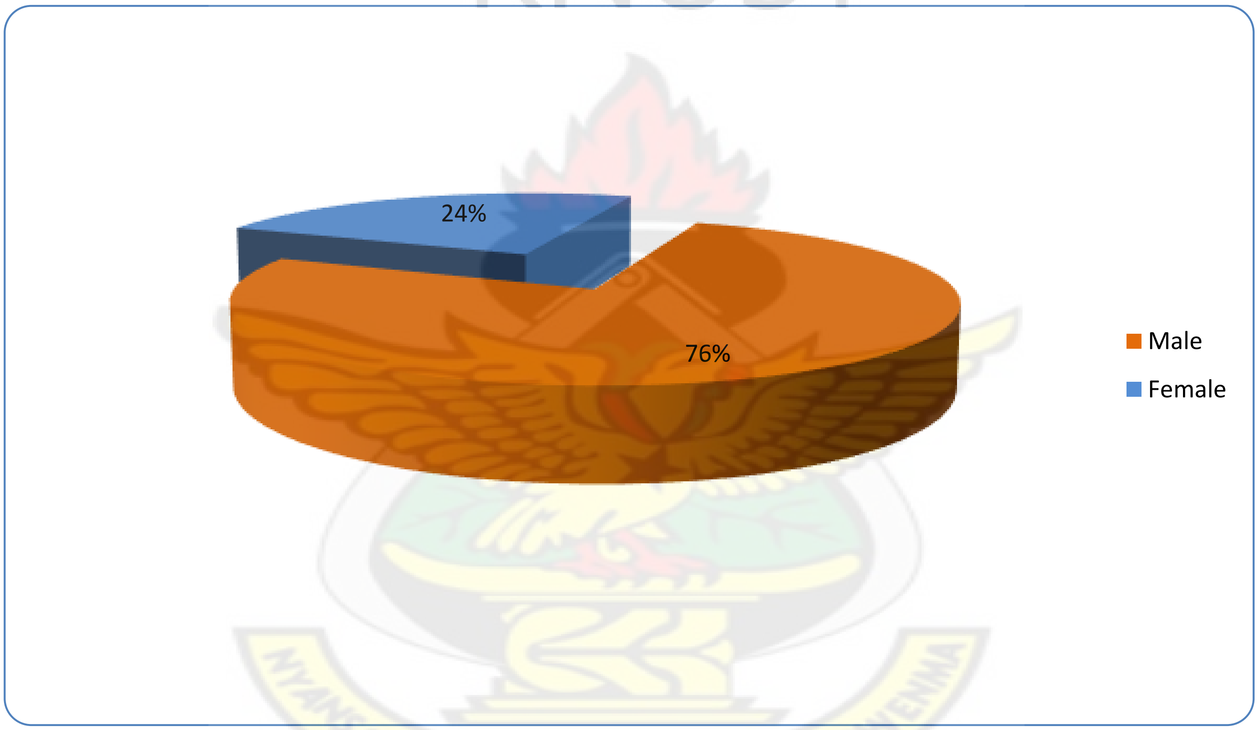

Figure 4.1: Gender characteristics of respondents

Table 4.1 shows the various storage structures used by farmers for cowpea storage in the district. Majority (56%; Table 4.1) of the farmers used barns (*bogre)* in storing their cowpea while Polypropylene, earthen pot and plastic gallon were used by 34%, 8% and 2% by the farmers respectively. The barns however had higher capacities (100 kg or more) than the other structures.

Table 4.1: Storage structures used by farmers in cowpea storage

Storage Structure	No. of Farmers	Percentage
Barn	28	56
Pot	4	8
Polypropylene	17	34
Plastic Gallon	1	2
Total	50	100

Table 4.2 shows the capacity of the various storage structures. Most of the respondents (78%) had structures with holding capacity of more than 50kg of cowpea.

Table 4.2: Capacity of storage structures

Storage Structure	No. Of Respondents	Respondents (%)
Less than 10kg	0	0
10 – 25kg	6	12
26 – 50kg	5	10
Above 50kg	39	78
Total	50	100

When they had to prevent storage pests' infestation, 50% (Figure 4.2) preferred treatment with wood ash, 40% applied chemicals, 8% applied other organic extracts while 2% did not apply any treatment (Figure 4.2).

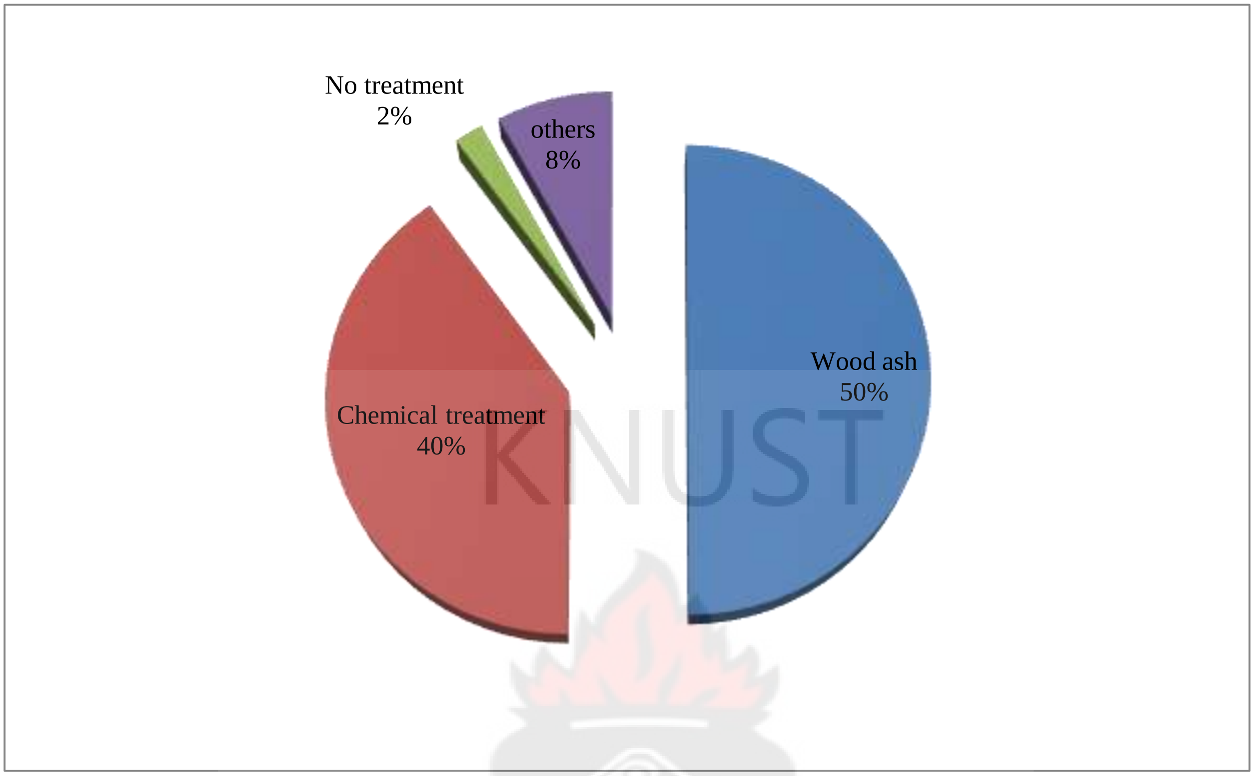

Figure 4.2: Protectants usage before cowpea storage.

The reasons why farmers preferred treatment choices during cowpea storage are presented in Table 4.3. Majority of the farmers reported that, their preferences were attributable to effectiveness of the treatment representing (52%), ready availability of inputs (36%) while 12% was due to affordability.

Table 4.3: Reasons for choice of treatment

treatment	No. of Respondents	Respondents (%)
Cheap	6	12
Readily available	18	36
Effective	26	52
others	0	0
total	50	100

More than eighty percent (82%; Figure 4.3) of the respondents reported that they had serious challenge with storage pest infestation. Insect pests were reported to be the major storage pests in the district. On the other hand, 12% of the respondents indicated that they had their stored cowpea going mouldy. Only 6% of the respondents did not have storage problems.

Other storage problems after the storage period have been reported in Table 4.6.

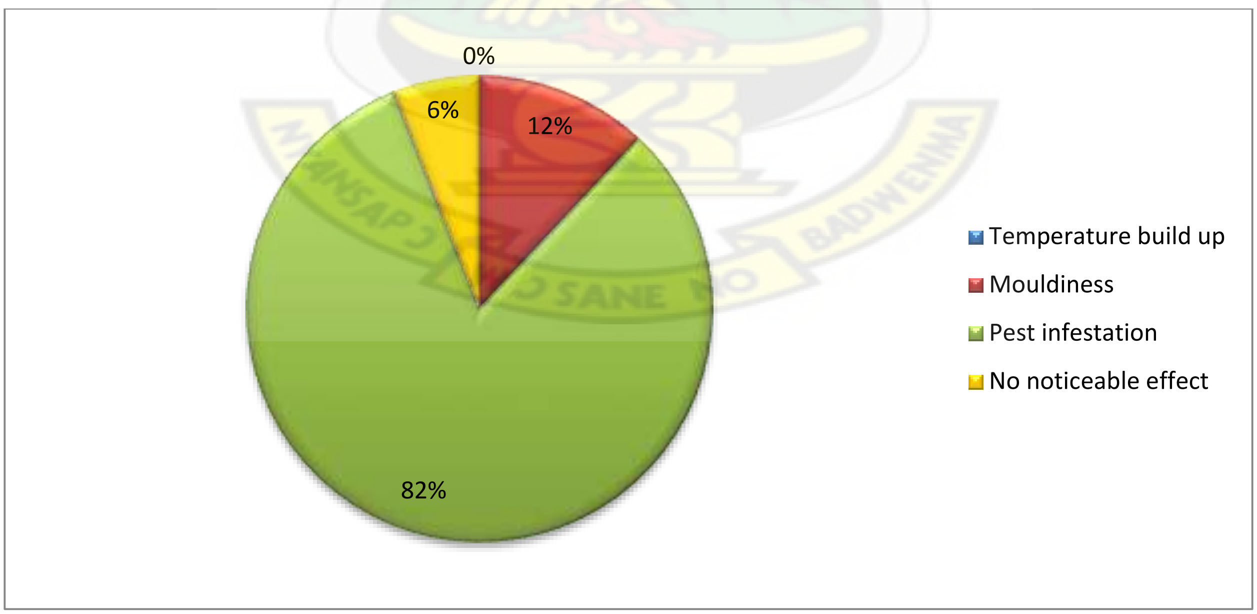

Figure 4.3: Storage problems faced by farmers during cowpea storage

With respect to how the farmers managed the storage challenges. (48%; Table 4.4) of the farmers reported that they periodically sun-dried their cowpea. Some (28%) preferred to treat their cowpea beans with pesticides. In contrast, 22% of the farmers preferred selling off their pest-infested beans immediately they noticed pest infestation. Interestingly, none of the farmers preferred to consume their infested cowpea although some preferred to sell them out.

Table 4.4: Management of storage problems of cowpea

Problem management	No. of Respondents	Respondents (%)
Sell produce immediately	11	22.0
Consume produce	0	0
Treat with chemicals	14	28.0
Sun drying	24	48.0
Do nothing	1	2.0
Total	50	100.0

The survey also indicated that majority (74%) of the respondents stored their produce for more than 3 months whilst 18% of the farmers stored their produce within 3 months (Table 4.5). The rest of the respondents stored their produce less than 3 months.

Table 4.5: Duration of cowpea storage in storage structures

Duration (months)	No. of Respondents	Respondents (%)
1	2	4
2	2	4
3	9	18
Above 3	37	74
Total	50	100

After the storage period (Table 4.6), 32% of the respondents reported of facing no other challenge upon the treatment given before and during storage. Twenty four percent (24%) of the respondents reported that weevil holes in beans as well as colour change after the storage period of three months and above. Some of the farmers (14%) responded that they experienced mouldy beans while few others (6%) reported loss of viability problems when their stored cowpea is used as seed.

Table 4.6: Challenges farmers faced after storage period

challenges	No. of respondents	Respondents (%)
No challenge	16	32
Germination problem	3	6
Colour change	12	24
Mouldiness	7	14
Holed beans	12	24
Total	50	100

4.2 Initial Seed Quality Parameters of Cowpea ("Ormondoh") Used For Storage Studies.

Initial seed quality parameters were assessed in three replicates and average values are presented in Table 4.7. The average seed weight was 9.97 g per 100 seeds. The average percentage damage seeds (perforated) as a result of infestation by insects in the field were 0.67% or a transformed value of 1.08. Initial average germination percentage conducted prior to storage was 88.67% or transformed value of 9.44.

Table 4.7: Initial seed quality parameters of cowpea variety "ormondoh" used for storage

Quality parameters	Average value	Transformed value (Percentages only)
Hundred seed weight (g)	9.97	
Hundred seed damaged (%)	0.67	1.08
Hundred seed germination (%)	88.67	9.44

4.3 Weight Loss of Cowpea

The results of the study showed that there was a general increase in weight loss over the storage period. The use of triple bags consistently resulted in the least loss in weight in each month (Figure 4.4) whereas polypropylene bags recorded the highest for month one and two. By the third month pot had lost most weight (2.48). As regards the protectants (Figure 4.5), solarisation on monthly basis resulted in the least loss in weight over the three months storage period. As expected, the control (no protectant) had the highest loss for all the months.

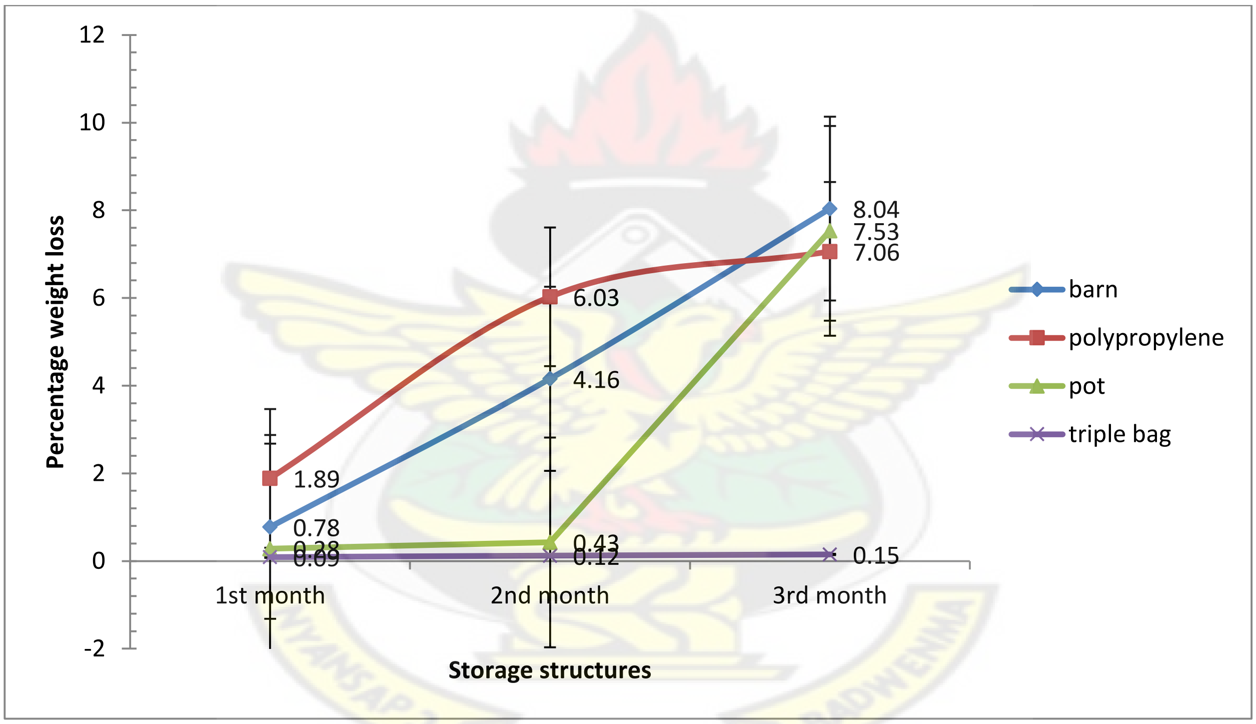

Figure 4.4: Weight loss of cowpea in storage structures

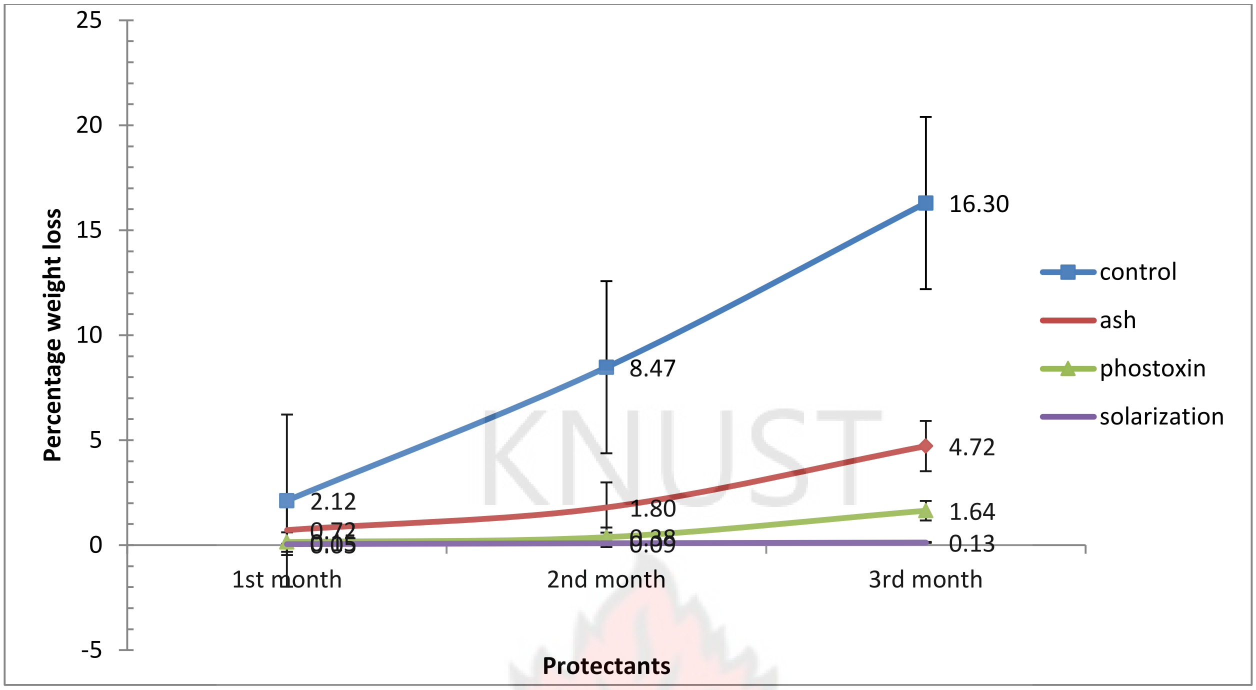

Figure 4.5: Weight loss of cowpea in protectants

Although for month one, triple bag×solarisation had the least loss in weight (0.72), it was similar to triple bag×phostoxin (0.75), triple bag×ash (0.75), pot×solarisation (0.74), pot×phostoxin (0.75), polypropylene sack×solarisation (0.75), barn×solarisation (0.74) and barn phostoxin (0.75); On the other hand, polypropylene sack control had the highest loss (2.42). This trend continued in month two except for polypropylene sack×solarisation (0.83), barn×phostoxin (0.82), pot×phostoxin (0.82) and triple bag×ash (0.83). By the third month, only triple bag×solarisation, triple bag×phostoxin and barn×solarisation had the least weight loss being 0.74, 0.76 and 0.76, respectively. The use of barn without protectant recorded the highest weight loss (5.06).

Table 4.8: Weight loss of cowpea caused by Bruchids

Storage Technology	Month		
	1	2	3
barn×control	1.73b	3.58b	5.06a
barn×ash	1.01d	2.14c	2.69e
barn×phostoxin	0.75ef	0.82hi	0.85h
barn×solarisation	0.74f	0.75ij	0.76ij
polypropylene×control	2.42a	4.61a	4.71b
polypropylene×ash	1.49c	1.60d	1.61g
polypropylene×phostoxin	0.95d	1.27e	2.19f
polypropylene×solarisation	0.75ef	0.83h	0.83hi
pot×control	0.98d	1.06g	4.32c
pot×ash	1.03d	1.17f	3.21d
pot×phostoxin	0.75ef	0.82hi	1.56g
pot×solarisation	0.74f	0.74j	0.83hi
triple bag×control	0.83e	0.83h	0.86h
triple bag×ash	0.75ef	0.83h	0.85h
triple bag× phostoxin	0.75ef	0.75ij	0.76ij
triple bag×solarisation	0.72f	0.74j	0.74j
Lsd	0.085	0.075	0.078
cv (%)	5.0	3.2	2.3

4.4 Percentage Damage of Cowpea during Storage.

The storage structures showed a general increase in cowpea damage (perforated) by Bruchids over the storage period (Figure 4.6). Triple bag constantly recorded the least cowpea damage by Bruchids for the three months storage period. However, polypropylene sack recorded the highest beans damage for the first and second month. By the third month, pot had the most weight loss.

Monthly solarisation also resulted in the least damage of the beans over the three months storage period (Figure 4.7). The control (without any protectant) expectedly had the highest beans damage over the entire storage period.

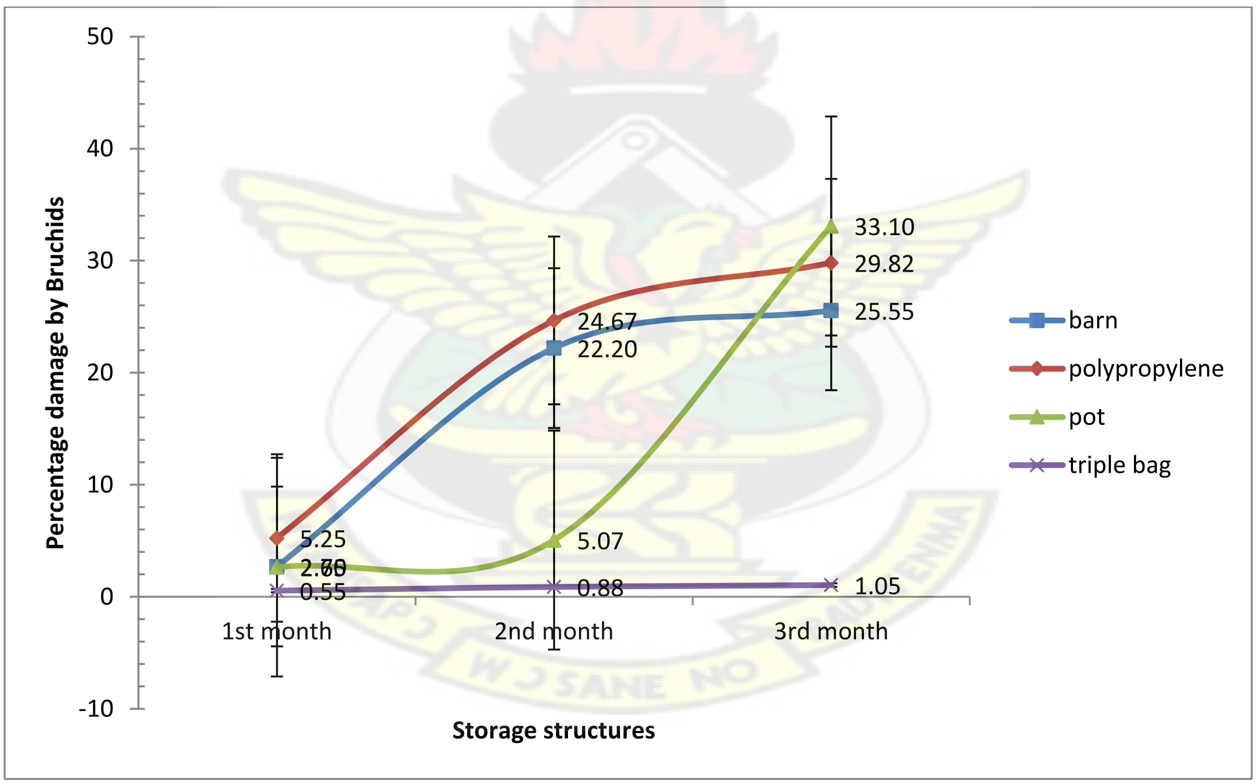

Figure 4.6: Percentage damage of cowpea in storage structures

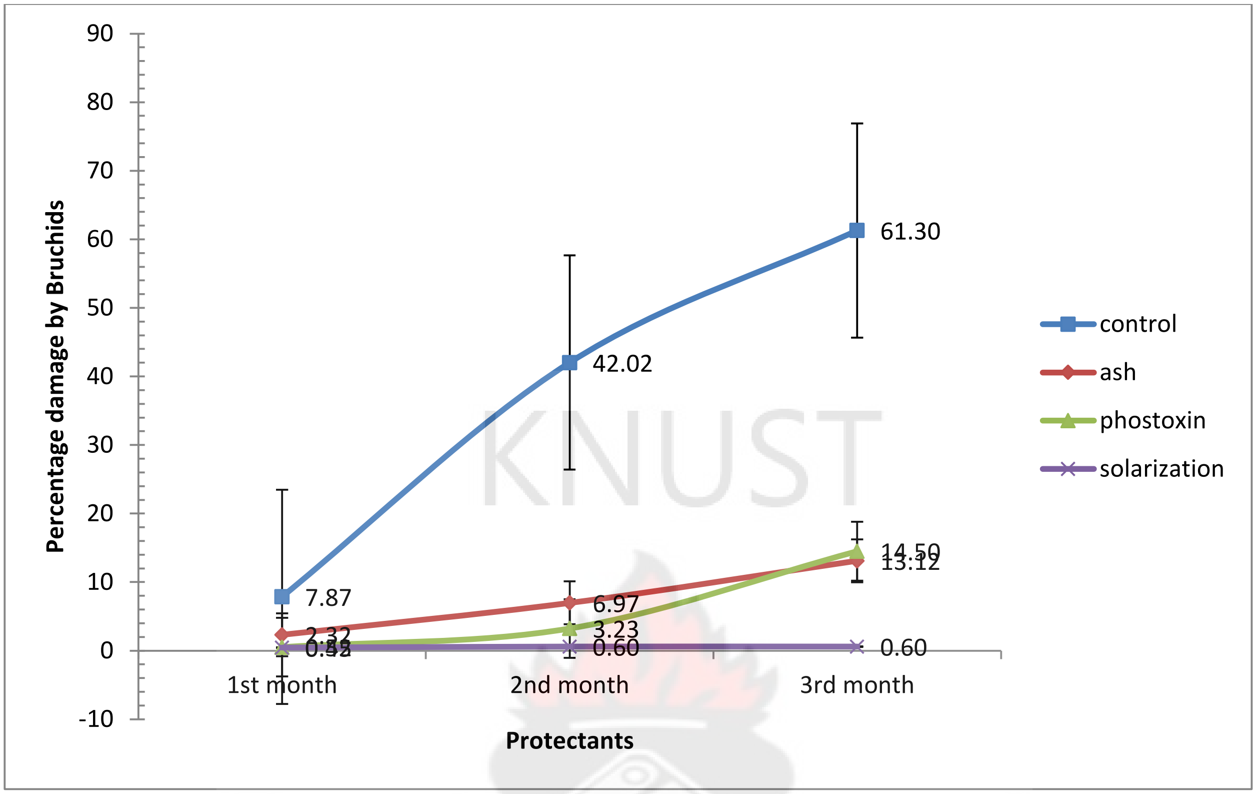

Figure 4.7: Effect of protectants on Bruchid damage

Regarding the interaction (Table 4.9), triple bag×phostoxin (0.87) and barn×solarisation (0.87) had the least seeds damage for the first month of storage. Triple bag×phostoxin resulted in the least damage over the second month of storage. By the third month of storage triple bag×phostoxin (1.01), pot×solarisation (1.02) and barn×solarisation (0.98) recorded the least damage. In contrast, polypropylene sack×control (9.36) recorded the highest cowpea beans damage over the storage period.

Table 4.9: Percentage damage of cowpea caused by Bruchids

Storage Technology	Month		
	1	2	3
barn×control	2.90b	8.49b	9.17b
barn×ash	1.62d	4.08c	4.25g
barn×phostoxin	0.98f	1.08jkl	1.08jk
barn×solarisation	0.87g	0.98m	0.98m
polypropylene×control	3.98a	8.96a	9.36a
polypropylene×ash	2.20c	2.73f	2.83h
polypropylene×phostoxin	1.17e	3.43e	4.96f
polypropylene×solarisation	0.98f	1.05kl	1.05kl
pot×control	2.87b	4.00d	8.58c
pot×ash	1.54d	1.99g	5.15e
pot×phostoxin	0.98f	1.11jk	5.76d
pot×solarisation	1.02f	1.02lm	1.02klm
triple bag×control	0.98f	1.28i	1.40i
triple bag×ash	1.20e	1.35h	1.38i
triple bag× phostoxin	0.87g	0.87n	1.01lm
triple bag×solarisation	1.02f	1.14j	1.14j
$Lsd_{(P=0.05)}$	0.081	0.062	0.065
cv (%)	3.1	1.4	1.1

4.5 Germination Percentage of Cowpea

The results of the germination test of the cowpea are shown in Figure 4.8 (storage structures) and Figure 4.9 (protectants). Seeds in the triple bag had consistently had the highest germination percentage over the three months storage period, whereas those in the polypropylene sack had the lowest germination percentage in each of the three months. Regarding the protectants, monthly solarisation resulted in the highest germination percentage over the three months storage period. Undoubtedly, the untreated control had the lowest germination percentage in each of the three months.

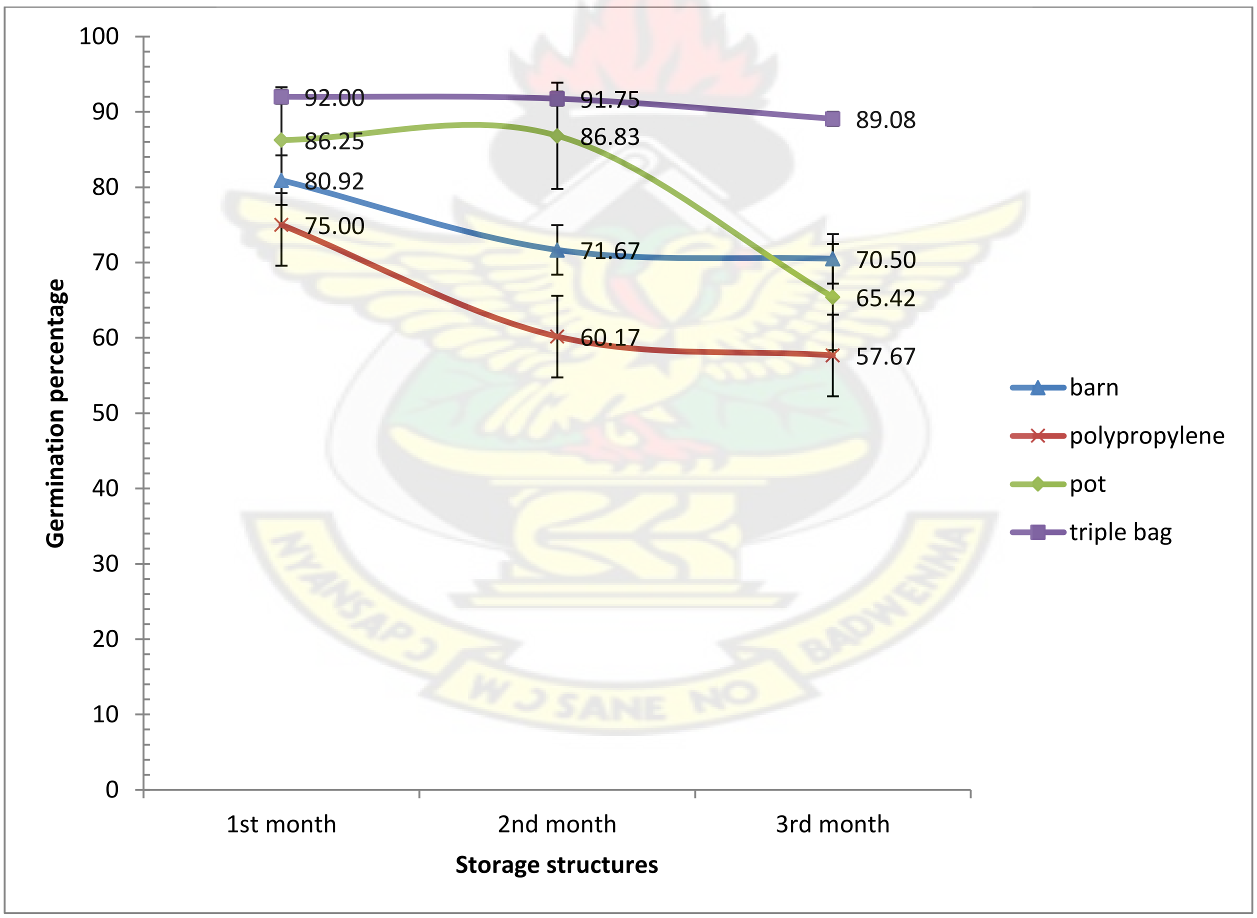

Figure 4.8: Germination percentage of cowpea in storage structures

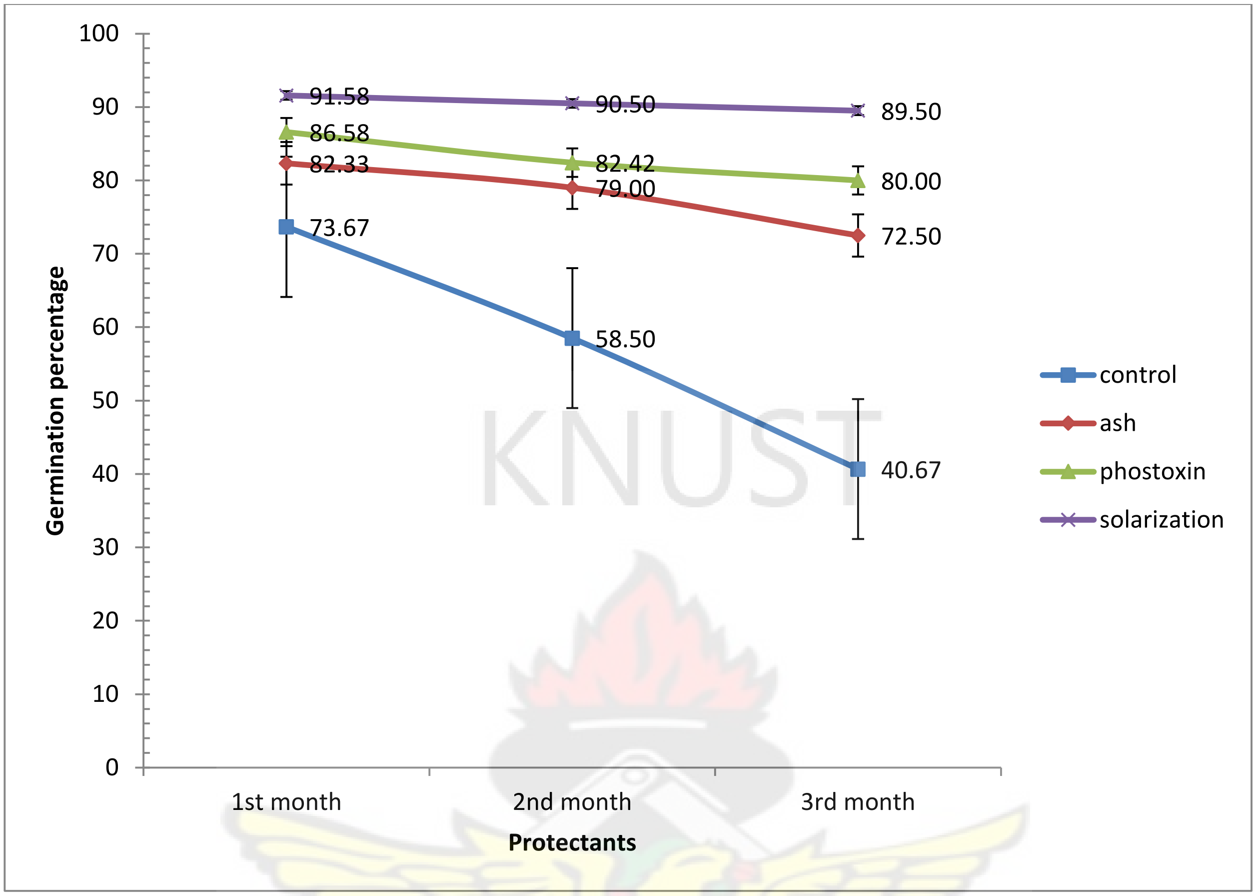

Figure 4.9: Effect of protectants on Bruchid damage

Table 4.10 shows the interaction results of the germination percentage over the three months storage period. After the first month of storage barn×phostoxin (9.70), triple bag×control (9.81) and triple bag×solarisation had the highest germination percentage. Barn×phostoxin (9.43), barn×solarisation (9.55), polypropylene×solarisation (9.44), pot×ash (9.50), pot×phostoxin (9.44), triple bag×phostoxin (9.37) and triple bag×solarisation (9.64) resulted in the highest germination percentage after the second month of storage. By the third month only barn×phostoxin (9.69) and barn×solarisation (9.62) had the highest germination percentage. On the other hand, polypropylene×control (4.45) recorded the lowest germination percentage over the three months storage period.

Table 4.10: Germination percentage of cowpea

Storage Technology	Month		
	1	2	3
barn×control	7.93i	6.20e	5.08j
barn×ash	8.88f	8.30cd	8.48f
barn×phostoxin	9.70ab	9.43ab	9.69a
barn×solarisation	9.48de	9.55a	9.62ab
polypropylene×control	7.80j	4.71f	4.45k
polypropylene×ash	8.55h	8.09d	7.74h
polypropylene×phostoxin	8.69g	8.11d	7.88g
polypropylene×solarisation	9.62bc	9.44ab	9.53bc
pot×control	8.77fg	8.90bc	5.28i
pot×ash	9.44e	9.50ab	8.44f
pot×phostoxin	9.43e	9.44ab	8.77e
pot×solarisation	9.60bcd	9.53a	9.37d
triple bag×control	9.81a	9.74a	9.55b
triple bag×ash	9.50cde	9.67a	9.44cd
triple bag× phostoxin	9.48de	9.37ab	9.44cd
triple bag×solarisation	9.69ab	9.64a	9.43d
lsd$_{(P=0.05)}$	0.125	0.601	0.100
cv (%)	0.8	4.1	0.7

4.6 Change in taste of Cowpea during Storage

After the first month of storage, there was no change in the taste of the cowpea stored in both the storage structures and the protectants. As a result the interaction between the storage structures and the protectants did not also indicate any changes in taste.

Triple bag and pot had no change in taste over the second month of storage while polypropylene sack and barn recorded the highest taste change after beans were cooked (Figure 4.10). By the third month only triple bag had the least change in taste with beans tasting normal. On the other hand, polypropylene sack and pot resulted in the highest change in taste.

As regards the protectants (Figure 4.11), monthly solarisation, phostoxin and ash treatments resulted in no change in taste over the second month of storage. By the third month, only monthly solaristion had the least change in taste whereas the untreated control resulted in the highest change in taste and with beans tasting chaffy.

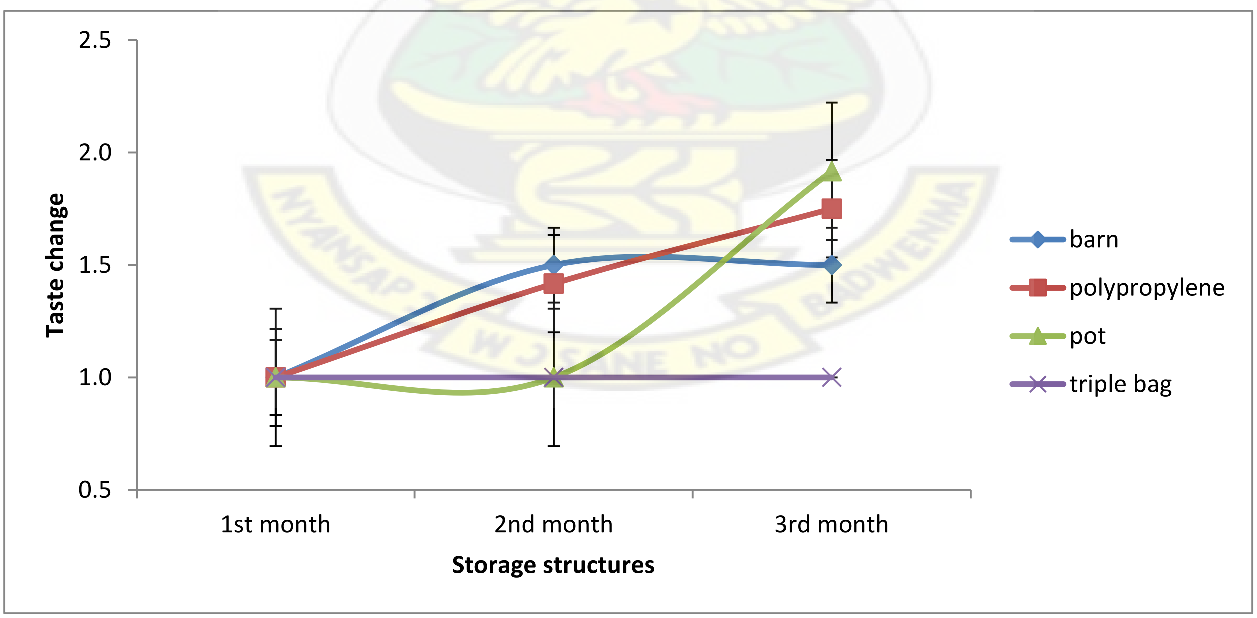

Figure 4.10: Change in taste of cowpea stored in storage structures

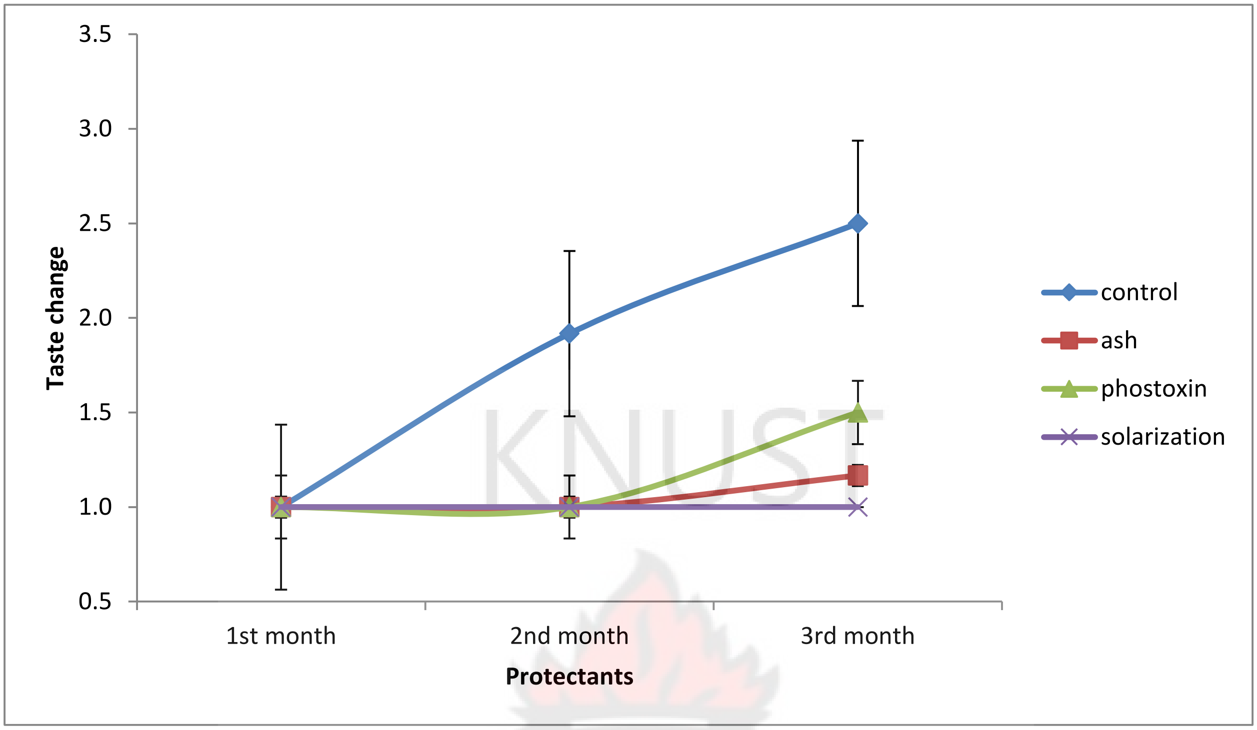

Figure 4.11: Change in taste of cowpea stored in protectants

For the interaction (Table 4.11), triple bag×solarisation, triple bag×phostoxin, triple bag×ash, triple bag×control, pot×solarisation, polypropylene sack×solarisation, polypropylene sack×ash, barn×solarisation, barn×phostoxin and barn×ash had the least taste change (1.0) for the second month of storage. Similar to these also were pot×phostoxin, pot×ash and polypropylene sack×phostoxin. In contrast, barn×control (3.0) had the highest taste change. This trend continued in the third month with the exception of polypropylene sack×phostoxin (2.0), pot×ash (3.0) and pot×phostoxin (2.0). However, barn×control, polypropylene sack×control and pot×control had the highest taste change (3.0) and with cooked beans tasting chaffy and musty.

Table 4.11: Change in taste of cowpea after cooking

Storage Technology	Month	
	2	3
barn×control	3.0a	3.0a
barn×ash	1.0c	1.0d
barn×phostoxin	1.0c	1.0d
barn×solarisation	1.0c	1.0d
polypropylene×control	2.7b	3.0a
polypropylene×ash	1.0c	1.0d
polypropylene×phostoxin	1.0c	2.0b
polypropylene×solarisation	1.0c	1.0d
pot×control	1.0c	3.0a
pot×ash	1.0c	1.7c
pot×phostoxin	1.0c	2.0b
pot×solarisation	1.0c	1.0d
triple bag×control	1.0c	1.0d
triple bag×ash	1.0c	1.0d
triple bag× phostoxin	1.0c	1.0d
triple bag×solarisation	1.0c	1.0d
$lsd_{(P=0.05)}$	0.24	0.24
cv (%)	11.7	9.4

Note: 1=normal taste; (1.1 – 1.9)=better; (2 – 2.9)=poor; 3=complete spoiled

4.7 Colour change of cowpea during storage

There was no change in the colour of the cowpea stored in the structures and the protectants as well. Also no change in colour as a result of interactions between the storage structures and the protectants was observed.

For the second month of storage, the use of triple bag and pot recorded the least change in colour of cowpea beans stored in them whereas barn and polypropylene sack resulted in the highest colour change (Figure 4.12). However, by the third month only triple bag recorded the least colour change and pot had the most colour change of beans.

Among the protectants (Figure 4.13), monthly solarisation, phostoxin and ash had the least colour change. In contrast, the untreated control had the highest colour change for month two and three.

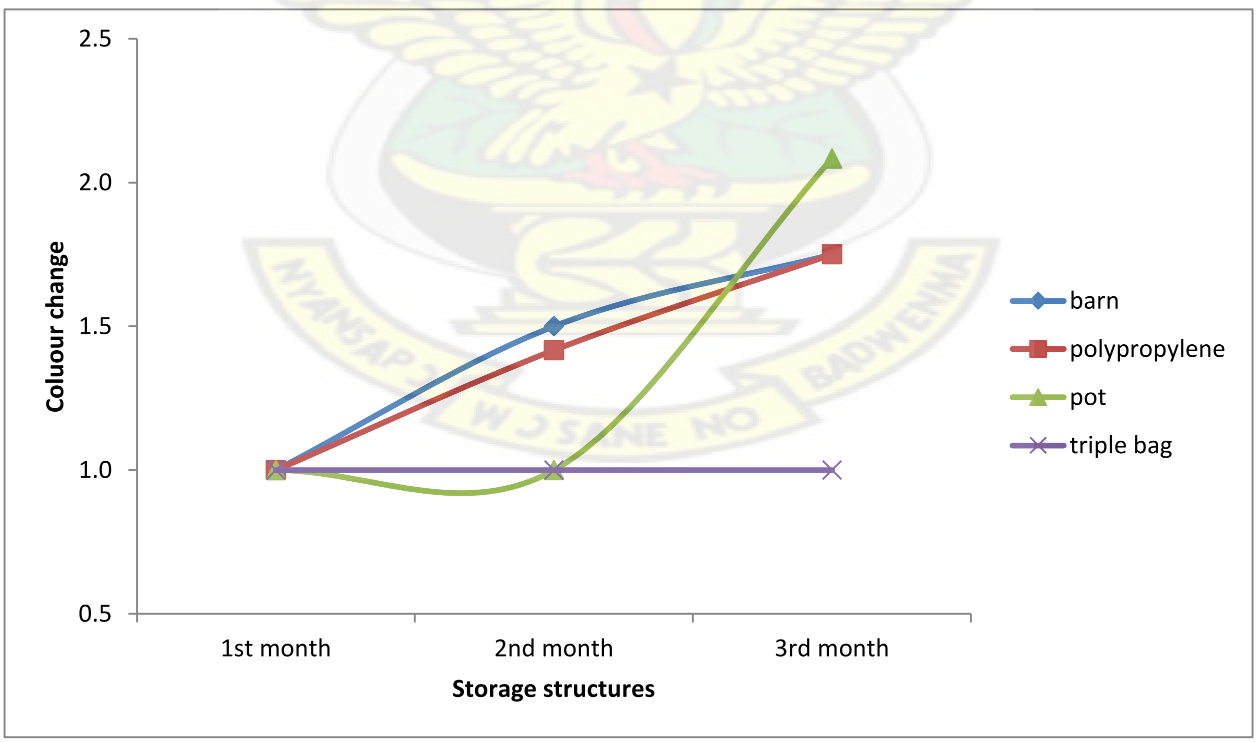

Figure 4.12: Colour change of cowpea in storage structures

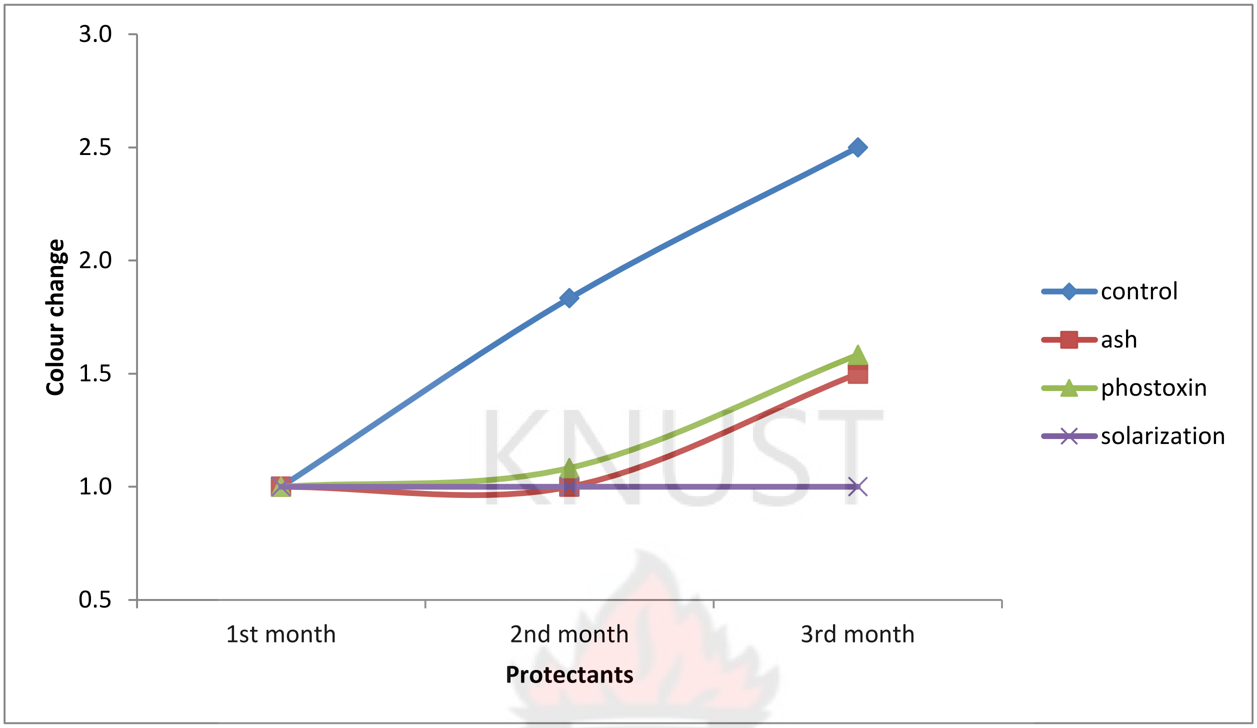

Figure 4.13: Colour change of cowpea treated with protectants

Table 4.12 presents the interaction results of the storage technologies. For the second month of storage, triple bag×solarisation, triple bag×phostoxin, triple bag×ash, triple bag×control, pot×solarisation, pot×phostoxin, polypropylene sack×solarisation, polypropylene sack×ash, barn×solarisation, barn×phostoxin had the least colour change (1.0) which were similar to barn×ash, polypropylene sack×phostoxin, pot×control and pot×ash. This trend continued in month three except for barn×ash (2.0), polypropylene sack×phostoxin (2.0), pot×control (3.0), pot×ash (2.0) and pot ×phostoxin (2.3). In contrast, barn×control consistently recorded the most colour change (3.0) for month two and three. By the third month, polypropylene sack×control and pot×control also resulted in the most colour change.

Table 4.12: Colour change in cowpea

Storage Technology	Month	
	2	3
barn×control	3.0a	3.0a
barn×ash	1.0c	2.0c
barn×phostoxin	1.0c	1.0d
barn×solarisation	1.0c	1.0d
polypropylene×control	2.3b	3.0a
polypropylene×ash	1.0c	1.0d
polypropylene×phostoxin	1.3c	2.0c
polypropylene×solarisation	1.0c	1.0d
pot×control	1.0c	3.0a
pot×ash	1.0c	2.0c
pot×phostoxin	1.0c	2.3b
pot×solarisation	1.0c	1.0d
triple bag×control	1.0c	1.0d
triple bag×ash	1.0c	1.0d
triple bag× phostoxin	1.0c	1.0d
triple bag×solarisation	1.0c	1.0d
$lsd_{(P=0.05)}$	0.34	0.24
cv (%)	16.6	8.8

Note: 1=no colour change; between 1 and 2=tainted with white eggs; between 2 and 3=darkened; 3=darkened with powdery beans

CHAPTER FIVE

5.0 DISCUSSION

5.1 Introduction

The cowpea seed bruchid, *Callosobruchus maculatus* (F.) (Coleoptera: Bruchidae) is a cosmopolitan field-to-store pest ranked as the principal postharvest pest of cowpea in the tropics (Jackai and Daoust, 1986; Singh *et al.*, 1990). It causes substantial quantitative and qualitative losses manifested by seed perforation and reduction in weight, harvest value and germinability of seeds (IITA, 1989; Adeduntan and Ofuya, 1998).

The use of synthetic insecticides has been the major means through which cowpea seeds are protected during storage. The use of synthetic pesticides over the years has revealed the nuisance they constitute to the ecosystem such as their undesirable side effects on non-target organisms including man and the fact that they are environmental disruptive (Schwab *et al*., 1995).

5.2 Baseline Survey

The baseline survey which involved administering of questionnaire to 50 cowpea farmers in five communities, twenty four percent (24%) of the respondents were female. Majority of the farmers (56%) use barns (*Bogre*) which were mostly own by the male farmers, followed by polypropylene sacks and pots respectively. From the results of the study, the respondents indicated that the use of barns was better in maintaining the quality characteristics of cowpea (Table 4.1). However, in this study, the use of barns was found to be inferior to hermetic storage or triple bagging. Unfortunately, farmers have not been using these modern technologies due to ignorance and the limited availability of triple bags.

Most of these structures had capacities above 50 kg (Table 4.2). Structures with higher capacities give the farmer the opportunity to store more produce after harvest to be used or sold later when produce is in limited supply and price go high. Pest infestation among others has been a major problem of the cowpea farmer with eighty two percent (82%) of the respondents attesting to this as shown in Figure 4.3. This could have been attributed to the fact that, the farmers' technologies may not be effective. Some of the factors that might resulted to this are: use of inappropriate chemicals, abuse of chemicals or use of expired chemicals. Another problem respondents reported of during cowpea storage is mould infection which could be attributed to inappropriate drying leading to high storage moisture content of cowpea. Farmers tend to arrest the storage problems by other methods such as sun drying their infested cowpea grains where the temperature is not high enough to kill all the stages of storage pest (Table 4.4). As supported by Golob (2009), sun drying is not as effective as solarisation. Others prefer to treat the beans with chemicals which might not be effective when the wrong chemical is used or wrong application of the chemicals. Still, some farmers sell their produce immediately which could be at a time when prices are low.

With the knowledge of the pest infestation, most farmers add wood ash to their cowpea as a protectant before storage in which the success of it is believed to come from 'good hands' and 'non-menstruation women' (Figure 4.2). From the results of the study, wood ash is not very effective as compared to phosphine treatment. However, the advantages of wood ash over chemical treatment are that: wood ash is cheap and readily available, it is not very harmful as compared to the synthetic chemicals and it does not have noticeable residual effect as synthetic chemical does. Other farmers resort to the use of synthetic chemicals which are mostly mishandled and misapplied. Few farmers use other organic extracts from mahogany, pepper and other herbal leaves which are usually mixed with the beans which had the disadvantage of the quantity that can be used to treat a given quantity of bean.

The farmers interviewed believed that their choice of using the preferred protectant is that, they are effective and others are of the view that their choice is because the protectant is readily available as shown in Table 4.3. Few of the farmers representing 12% think that, their choice of the protectant is because its choice is cheap.

Majority of the farmers (74%) interviewed stored their produce above 3 months, eighteen percent (18%) storing for up to 3 months with the remaining 8% storing their produce from two months and below (Table 4.5). Cowpea stored for a long period had the advantage of attracting high price during off season but with associated storage cost which could be paid when produce are stored well.

Despite the treatment of beans with protectants and trying to arrest the problem when it occurs during storage, some farmers still realised holed beans in their stock as a result of bruchids infestation, others realised change in colour and germination problem (Table 4.6). These problems faced by these cowpea producers after the storage period is an indication of the ineffective of their storage technologies they use.

5.3 Weight Loss of Cowpea

The results of the study suggest that the use of triple bag was more efficient in minimizing weight loss caused by insects during storage (Figure 4.4). This could be due to the insulation (air and water barrier) property of the plastic material holding the beans. This prevents the activities of the Bruchids (feeding and reproduction) as air and for that matter oxygen is limited. The triple bag owes its effectiveness to the hermetic operation enabled by the PICS sacks which established in a few hours a low oxygen environment and enriched CO_2 and stopping the bruchid from causing the damage (PICS, 2010). In the absence of triple bag the use of barn could be the next preferred choice with respect to minimizing weight loss caused by insects.

With regards to the interaction, triple bag×phostoxin, triple bag×solarisation and barn×solarisation which most minimized the loss in weight over the three month storage period is preferred as shown in Table 4.8. The air tight property of the triple bag makes triple bag fumigation effective in minimizing the activities of the Bruchid as regards to weight loss caused by their feeding. Also, triple bag solarisation and barn solarisation in reducing weight loss was due to the fact that, solarisation treatment kills all stages of insects which after storage in the structures minimizes the effect of the insects on the cowpea beans. FCDP (2005) stated that heat disinfestations technique is strongly recommended as it eliminates all the stages of insects before storage and re-infestation is avoided by storing the cowpea in a clear plastic bag, tightly sealed. In the absence of the triple bag and barn, monthly solarisation of cowpea beans stored in pot and polypropylene sack could be the next preferred choice in minimizing weight loss caused by insects. According to Morris and Tran (2002), solarisation repeated monthly is a very effective treatment which kills all stages of the bruchids.

Phostoxin interaction with earthen pot recorded a sharp rise in beans weight loss as a result of bruchids feeding in the second and third months which also mean that, the earthen pots are not fully airtight (Table 4.8). This was confirmed by Golob *et al.* (1999), who proved that pots are not hermetic which they tested, by CO_2 measurements. It is also an established fact that, cowpea seeds stored in earthen pots suffered proportionate weight loss with insect population (Olakojo *et al.* 2007).

Ash interactions with barn, pot and polypropylene sack was not very effective in protecting beans from insect damage which lead to weight loss (Table 4.8). Although it is stated that ash is effective in controlling storage pests (Coleopterae) (Gwinner *et al.* 1996), the results of this study which are in contrast with those findings are supported by Swella and Mushobozy (2007) who also recorded grain damage in cowpea admixture with ash.

5.4 Percentage Damage of Cowpea During Storage

At the onset of the study it was observed that only 0.67% of the cowpea beans from the field were perforated (Table 4.7). This is similar to the report of Gomez (2004) who indicated that seed infestation begins in the field at low level.

The results showed that triple bag was more efficient in protecting cowpea beans against Bruchid damage than the use of pot, barn and polypropylene sacks (Figure 4.6). This might be due to the air-tight condition of the triple bag which allows carbon dioxide level to accumulate inside the bag making it not conducive for the survival and proliferation of Bruchids. This finding corroborates the report of PICS (2010) who stated that the triple bag technology allows less air exchange with the outside world and the Bruchids consume the little oxygen available, while emitting the CO_2 and returning to quiescence to die later. In the absence of the triple, barn storage could be the next preferred choice in minimizing Bruchids damage.

Regarding the protectants, solarisation or heat disinfestation is the preferred treatment to apply to cowpea beans before storage to minimize Bruchids infestation (Figure 4.7). Cowpea Bruchid larvae and eggs are killed when exposed to temperatures around 60^{o}C for one hour (FCDP, 2005) and this temperature was attained through solarisation.

Phostoxin fumigation with the triple bag recorded the least damage over the three months storage period and thus preferred (Table 4.9). The observed efficacy of triple×phostoxin is not surprising as fumigation in hermetic material is a very good technology in grain protection against insect infestation. The next preferred storage technology was barn×solarisation and pot solarisation which also recorded minimal beans damage. Activities of the bruchids were suppressed by the monthly solarisation which gave repeated disinfestations and prevention of re-infestation of the stored beans. (See Appendix II-a for good protected cowpea plate).

However, phostoxin interaction with polypropylene sack recorded significance level of damage from the first month till the end of the storage period in the third month (Table 4.9). This was as a result of the polypropylene sack not giving gas-tight condition when fumigated. Fumigating polypropylene sacks are ineffective and dangerous as the gas is released straight through the fabric of the polypropylene or jute sacks into the surrounding atmosphere (Morris and Tran, 2002). The required concentration of gas is not attained and pests are not killed (Morris and Tran, 2002). Phostoxin fumigated pot also recorded high level damage during the third month signifying a reduction in the fumigant concentration in the pot allowing re-infestation. It therefore meant that the pots were not entirely hermetic. Also, a good fumigation, which lasts from seven to ten days, will kill all insects present but it will not provide long-lasting protection against infestation (Golob, 2009). Fumigation is not effective unless the storage structure to be treated is well sealed and the grain temperature is well above 10^{o}C (50^{o}F) (Upadhyay and Ahmad, 2011).

Ash interactions with barn and pot recorded high level of grain damage (Table 4.9). In the polypropylene sack, barn and pot interactions with ash, the beans damage in them were realised at the periphery. The reason was that oxygen supply was high at the walls of the structures. In addition, the ash source can also be a contributing factor since the ashes used in this experiment were collected from various fire places not knowing the tree type they were produced from. It is stated that, wood ashes from *Kaya senegalensis*, *Eucalyptus Spp.*, *Alfzelia Africana*, *Ceiba pentranda* and *Parkia Africana* are particularly recommended for the control of development stages of Coleopterae living on beans (Gwinner *et al.*, 1996). Also, ash does not prevent larvae already in the seed from completing their development and for this reason, grain not visibly infested by cowpea weevils can be put into ash storage and yet show emergence holes when the store is opened weeks or months later (Murdock *et al*., 2003).

The untreated control of the polypropylene sack, barn and pot recorded the substantial level of cowpea damage as shown in Table 4.9. As high as 87% of cowpea beans were infested by bruchids with distinct round holes. With the exception of the triple bag, the untreated control of the polypropylene sack, barn and pot offer little or no protection.

5.5 Germination Percentage of Cowpea

The average baseline germination percentage was about 89% (Table 4.7). It was realised that some seeds with distinct round holes as a results of insect infestation germinated during the germination test.

Even though there were significant differences among the triple bags interactions with the protectants, these interactions germination percentages were within the range of the initial germination tests conducted before storage. The triple bags interactions with the protectants recorded a high germination percentage throughout the storage period (Table 4.10). According to FCDP (2005), storing cowpea as seeds must be stored hermetically in moisture proof containers.

Monthly solarisation interactions with the storage structures beans also recorded a high germination percentage within the initial test conducted. This means that solarisation does not alter the germinability of seeds. This supported the report of Murdock *et al*. (2003), who stated that solar disinfestations, despite the high temperatures to which the grain is exposed, germinates and cooks normally.

Also, phostoxin fumigated barn had good germination percentage except the polypropylene sack and pot which had heavy infestation and hence decline in the germinability of seed as infestation increase in the second and third months (Table 4.10). Therefore, fumigated storage structures do not alter the viability of the seeds as long as protection against infestation is insured. Krishnasamy and Seshu (1990) reported that, at normal recommended dose of 3g per m^3 of phosphine fumigation will not affect germination or vigour.

Wood ash interactions with pot, barn and polypropylene sack indicated a decline in the germination percentages (Table 4.10). This might have been as a result of the intense feeding which reduces the viability of the seed.

The untreated control interactions with polypropylene sack, pot and barn recorded the lowest germination percentage and continued to decrease as the duration of storage increases which was as a result of heavy bruchids infestation (Table 4.10).

Consumers have strong aversion to grain that has been damaged by weevils but it still can be effective as seed, although, germination percentage may have been reduced (Kebe and Sembene, 2011).

At the end of the storage period, monthly solarisation among the protectants and triple bag among the storage structures proved to be effective in protecting cowpea for good germination.

Also, protectants interactions with triple bags and monthly solarisation interactions with the storage structures all recorded good germination percentages as classified by FCDP (2005), which indicated that above 85% of emerged seedling, number of seeds per hill should be two; 70 – 84%, 3 seeds per hill; 60 – 70%, 4 seeds per hill and below 60%, the seeds has to be discarded for new seeds.

5.6 Change in Taste of Cowpea During Storage

There was no taste change in stored beans after the first month. Triple bags and pots interactions with ash, phostoxin and monthly solarisation did not result in any change in taste in the second month of storage (Table 4.11). According to PICS (2010) beans stored in triple bags are ready to be consumed.

Beans in barn control and polypropylene sack control which recorded taste change might have been as a result of the heavy infestation by the bruchids (Table 4.11). Barn and polypropylene interactions with phostoxin and monthly solarisation did not also record grain taste change.

After the end of the storage period there were no taste change in the triple bags interaction with control, ash, phostoxin and monthly solarisation (Table 4.11). In addition, monthly solarisation interactions with barn, polypropylene and pot did not record taste change. In the same vein, barn interaction with phostoxin and ash had normal taste. Polypropylene sack interaction with ash also had a normal taste.

Pot interactions with control, ash and phostoxin recorded significant changes in taste in the beans stored in them which also suffers heavy infestation as shown in Table 4.11). The taste was musty. Also, polypropylene sack interactions with control and phostoxin recorded taste change. In addition, barn interaction with control indicated a change in taste of the beans. It was realised that, when the infestation is high as in the case of the above that the heavy infested beans had taste change when cooked. The possible reason to the change in taste is that, infestations with insect pests that results in hot spots and increased humidity, fungal infestation results in reduction of grain quality, change in colour, taste, smell and reduction of germination ability (Prasat *et al*., 1988; White and Jayas, 1993).

5.7 Colour Change of Cowpea During Storage

Colour change was realised during the second month of storage. There was no change in colour in the triple bags interactions with control, ash, phostoxin and monthly solarisation (Table 4.12). Pots interactions with control, ash, phostoxin and monthly solarisation, did not result in any colour change. Also, barn-phostoxin interaction, barn-ash interaction and barn-solarisation interaction all recorded normal bean colour of medium brown. Polypropylene sacks interactions with ash and monthly solarisation indicated bean normal colour.

However, barn and polypropylene sack interactions with their controls recorded colour change over the second month storage (Table 4.12). Polypropylene sack interaction with phostoxin also indicated colour change of beans. Cowpea beans were tainted with white bruchids eggs and the usual medium brown colour changed to darkened brown.

There was an increase in the colour change of beans in some of the storage technologies after the entire storage period (Table 4.12). Barn, polypropylene sack and pot interactions with the control recorded a massive colour change with beans tainted with bruchids white eggs, darkened and powdery beans. Most of the cowpea beans could be crushed between the fingers as a result of heavy feeding by the bruchids (see Appendix II-b for heavily infested cowpea plate). Also, pot×ash, polypropylene sack×phostoxin and pot×phostoxin interactions also indicated visible bruchid eggs on beans and the darkening of the medium brown beans. The darkened colour might have resulted from bruchid feeding which causes hot spots and further fungal development. According to Yakubu *et al.* (2012), poor storage condition predisposes cowpea beans to fungal spoilage, this being exacerbated by insect damage. Fungi growing in stored cowpea cause decrease in germinability, discolouration of parts or all the seed, heating and mustiness (Bunyam, 1987). The fungi decrease the quality of the cowpea through discolouration or change in taste and also decrease in nutritive value (Yakubu *et al.*, 2012).

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The storage technologies as practiced by farmers which include barns, pots and polypropylene sack were inferior in maintaining the quality of the cowpea beans compared to the triple bagging technology in the district. This was attributable to the practice of inappropriate technologies. In order to mitigate storage pest infestation farmers did resort to sun drying and chemical treatment which did not give a lasting protection to the cowpea beans compared to solarisation monthly resulting to re-infestation. However, farmers are aware of the premium price rewarded when cowpea were held and sold off the bumper season and as such they attempted to store their cowpea above three months. This long storage period went with its challenges such as holed grains, colour change, mouldiness and low germination percentage (when used as seed) due to inappropriate storage technologies.

The triple bag with its hermetic technology did give the maximum protection of cowpea beans than the other storage structures against Bruchid infestation, loss of germinability, colour and taste of the cowpea beans. The next alternative with regards to cowpea protection was the use of barns. The storage structure which offered the least protection of cowpea against Bruchid infestation among the storage structures is polypropylene sack and as such, the least preferred.

As regards the use of the protectants to treat cowpea before and during storage, monthly solarisation was superior in providing protection against Bruchid infestation, colour, taste loss as well as loss of germinability compared to phostoxin fumigation, wood ash and untreated control. In the absence of the use of monthly solarisation, fumigating with phostoxin is found to give the best protection. The use of wood ash although inferior to phostoxin had better protection than the control.

The findings from this study show that the interactions of triple bag×solarisation, triple bag×phostoxin and barn×solarisation were better in protecting cowpea beans against weight loss due to insects feeding. Pot×solarisation and polypropylene sack×solarisation were the next storage technologies proven to be better in storing cowpea against weight loss by insects.

Triple bag×phostoxin, barn×solarisation and pot×solarisation were better in protecting cowpea against insect damage. In the absence of the above technologies, polypropylene sack×solarisation is a better alternative in protecting cowpea against insect damage.

Results from this study also indicated that, barn×solarisation and barn×phostoxin provided the highest germination percentage. These were followed by triple bag×control and polypropylene sack×solarisation. However, triple bag×phostoxin and triple bag×ash equally resulted in cowpea germination percentage above the sample germination percentage conducted at the onset of the study.

As regards taste change, triple bag interactions with phostoxin, solarisation, wood ash and untreated control were better in providing protection of cowpea beans against taste change when cooked. Similar to these technologies were barn×solarisation, barn×phostoxin, barn×ash, pot×solarisation, polypropylene sack×ash and polypropylene sack×solarisation which also recorded no taste change.

Storing cowpea in triple bag with solarisation, phostoxin, ash and untreated control interactions were better in protecting cowpea beans against colour change. In addition, barn×phostoxin, barn×solarisation, pot×solarisation, polypropylene sack×ash and polypropylene sack×solarisation also resulted in no colour change of cowpea beans.

The study has shown that the common methods of storing methods of cowpea in the Nadowli District were pots, barns and polypropelene sacks. However, the use of modern technologies such as triple bags was not common although this study has shown that they protect cowpea better in storage. Many farmers and consumers of cowpea stored their cowpea without the use of protectants. For better grain quality, safe produce and better price, farmers and traders should be encouraged to adopt and practice monthly solarisation of cowpea before and during storage.

6.2 Recommendations

Further research should be carried out on the comparative assessment of these storage technologies with extended period of six months which might yield the time when prices of cowpea are expected to soar.

Also, further research should be carried out on the amount of wood ash to be used for better protection and appropriate wood species which ash will give a better protection against the cowpea bruchids.

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APPENDICES

Appendix I: Data collection tools and materials

Plate a: Triple bag

Plate b: Barn

Plate c: Pot

Plate d: Solar drying

Plate e: Brecknell Electronic Scale

Plate f: Germination test

Appendix II: Results of Cowpea after Storage

Plate a: Wholesome cowpea after storage

Plate b: Infested cowpea after storage

Appendix III: Results of treatments

a: Weight loss of cowpea in storage structures

	Month		
Storage structures	1	2	3
barn	1.06b	1.82b	2.34b
polypropylene	1.40a	2.08a	2.33b
pot	0.87c	0.95c	2.48a
triple bag	0.77d	0.79d	0.80c
lsd$_{(P=0.05)}$	0.043	0.037	0.039
cv (%)	5.0	3.2	2.3

b: Weight loss of cowpea in protectants

	Month		
Protectants	1	2	3
control	1.49a	2.52a	3.74a
ash	1.07b	1.43b	2.09b
phostoxin	0.78c	0.91c	1.34c
solarisation	0.74d	0.76d	0.79d
lsd$_{(P=0.05)}$	0.043	0.037	0.039
cv (%)	5.0	3.2	2.3

c: Percentage damage of cowpea in storage structures

	Month		
Storage structures	1	2	3
Barn	1.60b	3.66b	3.87c
polypropylene	2.08a	4.04a	4.55b
Pot	1.60b	2.03c	5.13a
triple bag	1.02c	1.16d	1.23d
lsd$_{(P=0.05)}$	0.041	0.031	0.032
cv (%)	3.1	1.4	1.1

d: Percentage damage of cowpea in protectants

	Month		
Protectants	1	2	3
control	2.68a	5.68a	7.13a
ash	1.64b	2.54b	3.40b
phostoxin	1.00c	1.62c	3.20c
solarisation	0.97c	1.05d	1.05d
$lsd_{(P=0.05)}$	0.041	0.031	0.032
cv (%)	3.1	1.4	1.1

e: Germination percentage of cowpea in storage structures

	Month		
Storage structures	1	2	3
barn	9.00c	8.37b	8.22b
polypropylene	8.66d	7.59c	7.40d
pot	9.31b	9.34a	7.96c
triple bag	9.62a	9.60a	9.46a
$lsd_{(P=0.05)}$	0.062	0.300	0.050
cv (%)	0.8	4.1	0.7

f: Germination percentage of cowpea in protectants

	Month		
Protectants	1	2	3
control	8.57d	7.39c	6.09d
ash	9.09c	8.89b	8.52c
phostoxin	9.32b	9.09b	8.94b
solarisation	9.60a	9.54a	9.49a
$lsd_{(P=0.05)}$	0.062	0.300	0.050
cv (%)	0.8	4.1	0.7

g: Change taste of cowpea in storage structures

	Month		
Storage structures	1	2	3
barn	1.0	1.5a	1.5b
polypropylene	1.0	1.4a	1.8a
pot	1.0	1.0b	1.9a
triple bag	1.0	1.0b	1.0c
$lsd_{(P=0.05)}$		0.12	0.12
cv (%)		11.7	9.4

h: Change taste of cowpea in protectants

	Month		
Protectants	1	2	3
control	1.0	1.9a	2.5a
ash	1.0	1.0b	1.2c
phostoxin	1.0	1.0b	1.5b
solarisation	1.0	1.0b	1.0d
$lsd_{(P=0.05)}$		0.12	0.12
cv (%)		11.7	9.4

i: Colour change of cowpea in storage structures

	Month		
Storage structures	1	2	3
barn	1.0	1.5a	1.8b
polypropylene	1.0	1.4a	1.8b
pot	1.0	1.0b	2.1a
triple bag	1.0	1.0b	1.0c
$lsd_{(P=0.05)}$		0.17	0.12
cv (%)		16.6	8.8

j: Colour change of cowpea in protectants

	Month		
Protectants	1	2	3
control	1.0	1.8a	2.5a
ash	1.0	1.0b	1.5b
phostoxin	1.0	1.1b	1.6b
solarisation	1.0	1.0b	1.0c
$lsd_{(P=0.05)}$		0.17	0.12
cv (%)		16.6	8.8