KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

COLLEGE OF ENGINEERING

COMPARATIVE STUDY OF COWPEA STORAGE IN DIFFERENT STORAGE STRUCTURES

PROJECT REPORT

SUBMITTED IN FULFILMENT OF THE REQUIREMENT FOR THE MSc DEGREE IN FOOD AND POST- HARVEST ENGINEERRING

BY

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DECLARATION

I do hereby certify that, the work presented herein, as my thesis to the College of Engineering, Kwame Nkrumah University of Science and Technology, Kumasi in fulfillment of the requirements for the award of Master of Science Degree (MSc) in Food and Post-harvest Engineering, is the result of my own investigation under supervision and has not been presented to this or any other University for a degree.

Works by other authors, which served as sources of information have been duly acknowledged by references to the authors.

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ABSTRACT

A survey conducted between August 2006 and April 2007 in cowpea growing communities in the Lawra District indicated that cowpea growers face many challenges in cowpea production. The most important of the challenges was the high incidence of insect pests during cowpea storage. The pest was considered as the single most important factor that limits the increase of cowpea production in the Lawra District, as this can cause total loss of the grain between 3 to 4 months of storage. The survey further revealed that the traditional storage methods were very ineffective in controlling the pest.

The main objective of the research was therefore to use modern methods of pest control in cowpea.

This research was carried out in the Lawra District of the Upper West Region, from August 2007 to May, 2008, within the environment of the farmers, who are to practice and adopt the technologies,

The research design was Complete Block Design (CBD) with three treatments (Hermetic, fumigation and traditional mud-silos, with the traditional mud-silo being the control). Each treatment had three replications. Data gathered included germination test, moisture content, live and dead insect count, hole count and loss assessment.

Finally, relevant conclusions and recommendations were made. Some of the relevant conclusions made were:

i. Both the hermetic and fumigated techniques of storing cowpea were more effective in controlling the cowpea weevil (*Callosobruchus maculatus*), than the traditional mud silos.

ii. The fumigated technique was more effective in maintaining cowpea quality than the hermetic technique.

iii.The traditional mud-silo method of storing cowpea was highly ineffective in maintaining the cowpea grain quality for up to four months, and could even cause total loss to the grain if stored for more than the four months.

It was recommended that the traditional mud-silo could be modified to make it more hermetic in storing cowpea.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 BACKGROUND

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.

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 zone of northern guinea savanna zone of Northern, Upper East and Upper West Regions. The major season for cowpea cultivation in the Lawra 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. The most common variety cultivated by farmers in the Lawra District is the local cowpea, which is of two types – the creeping and erect or *beng pulla* and *beng sagla* respectively. However, other varieties such as *ayiyi*, black eye *asontem* and *ormondoh* are cultivated in small quantities.

The cowpea grain harvested at the end of the season is stored over a period of about eight months. However, in anticipation of grain losses during storage, only the seed for planting in the next season is stored by farmers in the district, and the rest of the crop is sold out at harvest time. The post-harvest storage method practised in the district by these farmers is the traditional method of mud silos (the most widely used), clay pots, calabashes and jute sacks

1.2 TRADITIONAL STORAGE STRUCTURES

The storage structures for cowpea include:

a. Clay pots in which the grain is mixed with wood ash or neem leaf extracts, and

b. Barns (*bogr*), which are of two types:

i. The big *bogr* is built in a room with its opening at the top of the roof, and is used mostly for cereal grain storage, and,

ii. The small *bogr* is mainly used for legume, especially cowpea, storage. It is cylindrical in shape and is built inside a room.

The *bogr* is used mostly to store cowpea grains weighing from 50 to 100kg, mixed with neem leaf extracts. Both the big and small *bogrs* are built of clay mixed with chopped elephant grass.

Other storage methods include barns on raised platforms using sticks and thatch for both the floor and roof (only cowpea in pod is stored with this method) and small containers using mud bricks for construction and using cement for plastering of the floor and walls, and of jute sacks.

1.3 PROBLEM STATEMENT AND JUSTIFICATION:

A large number of pests and diseases attack cowpea at all growth stages. The pests and diseases constitute, without doubt, the most limiting factor affecting intensive cowpea production in Lawra District as they may cause total loss of the grain.

Raemaeker (2001) stated that cowpea bruchids, *Callosobruchus maculatus* and *Callosobruchus chinensis* cause extensive damage to stored grain, infesting as much as 60% of it.

Losses of the grain during the traditional post-harvest storage period are very high, leading to serious financial and nutritional losses of the grain to storage pests in the district. Casewell (1984), as reported by Singh *et al.* (1997), documented the loss of cowpea grain during traditional post-harvest storage in Nigeria. Pods stored for eight months had 50% grain damage by bruchids, 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 farmers' post-harvest storage methods are unable to prevent or even reduce the damage caused by pests 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.

1.4 OBJECTIVE OF THE STUDY

1.4.1 MAIN OBJECTIVE

The main objective of the research was to use modern methods of pest control in cowpea.

1.4.2 SPECIFIC OBJECTIVES

a. To determine the effect of hermetic and fumigation storage on cowpea quality.

b. To determine the effect of hermetic and fumigation storage, as compared with traditional mud-silos, on cowpea quality.

c. To determine the relationship between oxygen reduction and live insect population.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Introduction

Cultivated cowpea is an herbaceous annual belonging to the subtribe phaseolinae, the tribe phaseoleae, the family papilionaceae (or fabaceae) and the order leguminosales (or fabales). The fruits are elongated pods, 12-20 cm long.

The seeds are smaller than those of the common bean. The seed coat of the many cultivars comes in a wide range of colours-white, grey, red, ochre and black. The seed colour may be uniform or mottled, with or without a brown or black ring around the hilum (Raemaekers, 2001).

Cowpea is cultivated extensively in 16 African countries yielding about two-thirds of the world output estimated at 2.5 million tonnes of dry beans. The main cowpea-producing countries are Nigeria, Niger, Burkina Faso, Ghana, Kenya, Uganda, Malawi and Senegal (Raemaekers, 2001).

2.2 Uses of cowpea

It is an important item in the diet of most Africans and Ghana in particular. It is a rich source of plant protein (Ozumba *et al.*, 1991), containing about 25% protein (Dov *et al.*, 1976) as reported by Olapode *et al.*, (2004).

2.3 Nutritional value of cowpea

The diet of most people in developing countries is based on processed cereal grains such as maize, sorghum and rice, on roots such as cassava, and on fruit such as plantain. Other than the starchy roots and tubers, these foods, because they are eaten in large quantities provide considerable protein. But the quality of the protein leaves much to be desired, particularly for children and pregnant and lactating women. Food legumes, because of their high protein content, in general, constitute the natural protein supplement to staple diets, and cowpea in Africa at least, represents the legume of choice for such populations (Singh *et al.*, 1985).

It is obvious that when daily bean intake is high, it provides significant amounts of protein, calories, and other nutrients (Aykroyd, *et al.*, 1964 and Stanton *et al.*, 1966), as reported by Protein Advisory Group of the United Nations system, 1973.

The protein content ranges from 23-30% depending on the genotype and environmental conditions. The lysine content is relatively high and thus the grain improves the protein quantity of cereals.

The raw type seeds contain an average per 100g of edible matter, 10.0g water, 22.08g protein, 59.18g carbohydrates, 3.78g fibre, 3.7g ash, 104mg Ca, and other elements in negligible magnitude. The energy value is 1,420 KJ (340kcal) per 100g (Raemaekers, 2001).

It contains about 24% protein, 62% soluble carbohydrates and small amounts of other nutrients. The most of its nutritional value is provided by protein and carbohydrates. One of the most important nutritional characteristics of food legumes, including cowpea, is that they complement cereal grains (Singh, 1985).

2.4 Storage of cowpea

A number of critical factors affect household food insecurity including poor post-harvest practices (Callers *et al.*, 1998).

Some farmers brought the ashes of goat and cattle dung, which is commonly used to control storage pest (FAO, 2006).

The use of botanical ashes to protect the grain from post-harvest losses caused by insect weevils is highly significant and contributes significantly to the uniqueness and success of this system (Saayman, 1997, as reported by GIAHS Programme, 2006).

Good grain storage prevents grain losses and maintains grain quality. One of the most effective means of achieving this is the use of fumigation or controlled atmosphere storage. The techniques work by holding grain in a gas-tight enclosure in a gaseous atmosphere that will kill or limit agents of biodeterioration.

The difference between the techniques is that fumigation is a relatively short activity; lasting somewhere between one and fifteen days, depending on the type of gas used, whilst controlled atmosphere storage lasts for most or all of storage period (Rippi *et al.*, 1984).

Safer and more effective grain treatments will benefit them both in terms of reduced health risks and higher less seasonal incomes due to an increased viable trading period. Improved grain quality and a longer storage period will also benefit consumers by improving the supply of grain legumes and hence food security during the dry season.

Moreover, there may be a knock-on effect of increased demand for cowpeas amongst traders, enabling small-scale resource poor farmers to sell more of their crop in good season (Altshul, 1998).

Seeds must not be stored too long, since in the course of time it loses the capacity to germinate, (e.g. in grain legumes, because of the increasing amount of hard seed).

In addition, a distinction can be made between traditional and modern storage. Modern storage is a combination of experience gained from traditional method and modern materials (FAO, 1981).

2.5 Controlled atmosphere storage (Hermetic)

In looking at the replacement of air with CO_2 (or N_2) much emphasis has been placed on the effects of low oxygen concentrations. Recently it has been shown that the toxic effects of low oxygen concentration are much increased by the presence of relatively low level (10-35%) of CO_2 (Ripp *et al.*, 1984).

Controlled atmosphere with elevated carbon dioxide (CO_2) or nitrogen (N_2) and depleted oxygen can be used to control insects and mites in stored grain. (Jayas et al, 1993).

Atmospheres with low oxygen content offer a safe, residue free alternative to chemical fumigants and protectants for controlling insects infesting stored grains and grain products. (McGuaghey,1989, as reported by Donahaye, 1993).

Studies have shown that indoor storage of bag-stacks of rice, maize and soyabeans within sealed plastic enclosures under high CO_2 atmosphere can control pest infestation effectively and prevent quality deterioration of grains when done correctly (Navarro et al, 1993).

Preservation of food grains under natural airtight under ground storage has long been practised in India and other countries. Absence of insect attack has been reported to be a good feature of underground storage structures. In fact, this easy way of solving the insect problems has caught the imagination of many workers in different parts of the world, and many investigations have been carried out to understand the causes of insect death in airtight condition. For example, the following investigations have been carried out according to Shejdall (1980), determination of moisture, oxygen level and germination potential.

Tropical countries are expanding agricultural production to meeting the increasing food requirement of their people. More available food requires storage for longer periods. With the uncertainty of climate, and the need for self-reliance, consideration must be given to storage systems that enable safe storage for long periods at low cost and with minimum use of pesticides. Low cost storage can be achieved on a large scale with the use of hermetic structures (Boxall, *et al.*, 1974 as reported by Shejball, 1980).

Many workers have shown that removal of oxygen by respiration causes insects to die in a sealed container. In practice also there is some risk of oxygen diffusing into containers and permitting some survival (Wickenden *et al*, 1963, as reported by Shejbal, 1980).

Controlled Atmosphere storage involves changing the composition of the gas in the store so that it is different to that of atmospheric air for most, if not all, of the storage period. In the simplest situation, the grain is sealed into a gastight enclosure and the natural product of respiration, carbon-dioxide (CO_2) is allowed to increase. Eventually, the CO_2 concentration rises to the point that insects' populations are prevented from developing further and are eventually killed. The technique is also called hermetic storage (Natural Resources Institute (NRI), 2000).

2.6 Use of phosphine

Phosphine has been widely used as a grain fumigant in Queensland for many years. In a variety of situations, it is the fumigant of preference, being cheap and easy to apply, readily removed when required by ventilation and leaving little residue on the grain. Until recently, grain stored in large bins were routinely treated by adding aluminium phosphide tablets to the grain stream as it was conveyed to or entered the storage bin (Ripp *et al* 1984).

Fumigation is a very specific operation in which a gas is held in an air-tight enclosure for a set period of time. Fumigation is a very convenient pest control technique as grain can be treated without undue disturbance. Grain can be fumigated wherever it is stored (provided that it can be sealed to give sufficient gas-tightness), for example in warehouses, silos, rail-cars, containers, ships or barges. Even whole buildings or mills can be fumigated (Natural Resources Institute (NRI), 2000).

Bruchid control in stored legumes using chemical fumigants and protectants is effective, but there may be problems of objectionable residue on treated commodities, handling hazards, insect development of resistance to the chemicals. (Ofuya *et al*, 1992).

Recommended dosage of phosphine for effective fumigation

Types of fumigation	**gPhosphine/ton**	**gPhosphine/m^3**
Bulk fumigation in gas-tight silos	2 to 4	1.5 to 3
Bagged commodities under gas-Proof sheets	3 – 5	2- to 3.5
In-bag fumigations	0.2 (bag of 50kg)	
Space fumigation, eg empty store		1 per m^3

(NRI, 2000)

2.7 Traditional storage structures

Wide ranges of building materials are available for the construction of rural buildings. Mud/earth/soil is one of the oldest materials used for building constructions in rural areas. Chopped grass or straw is usually incorporated into the mixture prior to building to improve the strength and reduce the degree of cracking (NRI, 1999).

2.8 Pests of cowpea

An area neglected in cowpea research but which is becoming important is consumer appreciation of improved cowpea grain. Results from the hedonic pricing analysis showed, for example, that consumers prefer larger grain size and seeds with low level of bruchid damage (Lowenberg *et al*., 2002).

There is significant grain loss, in both quantity and quality, occurring at on-farm and in cooperative stores. This has caused frustration and anger, particularly for medium and large-scale farmers, as they lose considerable amounts of grain (and cash) each year (Lawrence Wongo *et al*., 2002).

Species of *Callosobruchus* are important primary pests of a number of legumes including cowpeas, pigeon peas, chickpeas, *adzuki* beans, peas, grains and (occasionally) soya beans. (NRI, 2000).

Bruchid weevil is a cosmopolitan pest of stored legume seeds. It is widespread throughout the temperate and tropical world. Several species are agricultural pest that have the potential to destroy stores of legumes. One species in particular, the cowpea weevil, *Callosbruchus maculatus* is a cosmopolitan pest that causes considerable economic damage. Bruchids are major pests in cowpea in Africa. They attack dried cowpeas and other related stored seeds. They are mainly found on cowpea grains in storage and may be the main constraint to increased cowpea production (Gomez, 2003).

2.9 Storage losses

Selling only in the storage season leads to a loss in income because prices rise as grain legumes become increasingly scarce. However, deterioration in grain quality is not just a problem faced by farmers. Traders at all levels within the system also suffer storage losses as a result of insect pest damage and it is also a major problem for food aid agencies (Altshul, 1998).

There are published data providing evidence that insects cause devastating losses in cowpea yields. Weevils at post-harvest can destroy a granary full of cowpeas within two or three months but people need to have the grain to eat for 12 months a year (A BIOTECH, 2002 as reported by Gomez, 2003).

On the other hand, storage losses in West Africa are substantial in spite of the use of storage insecticides by merchants. Except in Senegal, most West African farmers sell cowpea shortly after harvest in part because they do not want to deal with the storage problems. A related problem is the lack of capital to invest in storing cowpea. In Senegal, farmers have slightly more resources than elsewhere in West Africa and there is widespread use of hermetic storage methods developed by the Senegalese Institute for Agricultural Research (ISRA, 2006).

Cowpea that is not stored with either chemical or the non-chemical methods is often completely consumed by bruchid in the 10-12 month of storage. Even if the cowpea is not completely consumed, West African farmers demand a substantial price discount before they will buy bruchid damaged cowpea (Lowenberg-DeBoer, 2003, as reported by Carlos Gomez, 2004).

Insects continue to damage cowpeas after harvest. The major pest is the cowpea weevil. A single cowpea weevil female can reproduce herself 20-fold every 3-4 weeks. Harvested cowpea grain that is brought in from the field before it is stored will have a heavy infestation within 2 -3 months. Foods prepared with this grain have an unpleasant flavour. If taken to the market the price of this grain is discounted (Gomez, 2004).

2.10 Determination of percentage grain losses.

Due to the many factors influencing the rate of grain deterioration, it is exceedingly difficult to quantify the losses in stored grain (Hall *et al.*, 1992).

One hundred (100) grains from thoroughly mixed samples were taken on to an enameled plate and the damaged grains (damaged by moulds, heating and insects) were picked out, counted and expressed as damage percentage (Shejball, 1980).

The grain samples are first cleaned over a sieve to remove insects and other fine material. Some dead insect parts may also be removed during the cleaning. A small portion is then randomly removed from each cleaned sample. Adams and Schulter (1978), as reported by Food and Feed Grains Institute, Food Security Resource Centre, 1986, recommended that this portion contains between 100 and 1000 kernels. Each kernel is observed and damaged kernels are separated from sound kernels.

As reported by Food and Feed Grains Institute, Food Security Resource Centre, 1986, the French Commission (Anon, 1969) proposed the following formula to simplify the calculation of percent weight lost:

$$\text{Percent Weight lost} = \frac{(UNd) - (DNu) \times 100}{U\,(Nd + Nu)}$$

where U = weight of undamaged kernels

D = weight of damaged kernels

Nu = number of undamaged kernels

Nd = number of damaged kernels

2.11 Germination test

The percentage of germination is calculated only from the number of normal seedlings which can be assumed to develop into a strong plant if for example, 380 normal seedlings developed from 8x50 seeds (400 seeds) the seed shows a germination of 95%.

Certain macro-spermous legumes such as peas or horse beans can be allowed to germinate in flat pans on moist sand (FAO, 1981).

To ensure good plant stand, it is always important to conduct germination test before planting as follows:

a. Pick 100 seeds at random from the lot

b. Make a shallow trench 1-2 metres long

c. Place the seeds evenly in the shallow trench

d. Cover with 3-5cm of soil and water well (do not saturate the area)

e. Observe regularly and water when necessary

f. Count the number of seedlings that emerge one week after planting (FCDP, 2005)

Seeds must not be stored too long, since in the course of time, it loses the capacity to germinate (eg in grain legumes because of the increasing amount of hard seed (Ripp, *et al*, 1984).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 STUDY AREA

The research was carried out in Lawra in the office premises of the Ministry of Food and Agriculture (MOFA) in the Lawra District of the Upper West Region. The research period was from 10th August, 2007 to 10th May, 2008.

The Lawra District is located within the Northern Guinea Savanna zone. It is situated at the top corner of the North-Western part of Upper West Region. The district has one rainy season (unimodal) between May and September and a long period of dry harmattan conditions from October to April. The area has a mean annual rainfall of about 1200mm, and an average annual temperature of about 30°C.

3.2 EXPERIMENTAL DESIGN

The experimental design was complete block design with 3 treatments and 3 replications each. However, with the hermetic treatment 27 small plastic containers were used and three containers were taken monthly for the data determination since, with hermetic, the containers could not be opened and sealed back with out oxygen being taken in to the containers.

3.3 RESEARCH MATERIAL/CROP

The research material was cowpea seed, a local cowpea creeping variety known as *beng pula* which is more preferred than other cowpea varieties in the Upper West Region.

3.4 EQUIPMENT

The equipment included an oven dryer, an electronic scale, drying cans, sieves, a weighing scale, Plastic containers (27 small ones, weighing about 0.15kg each with a capacity of about 1kg of the cowpea seed for the hermetic, and 3 medium size paint containers, weighing about 0.6kg each with a capacity of about 7kg of cowpea seed), an Oxygen analyzer, Plastic tubes, Silicone high temperature gasket makers, ABRO Epoxy steel Resin and hardness, Sampling bags and Phosphine tablets.

3.5 METHODS

3.5.1 Determination of moisture content of cowpea

25g of cowpea was placed in drying cans and placed in an oven dryer at a temperature of 103°C for 72 hours, after which the contents were removed from the oven and reweighed (Natural Resource Institute, Chatham, 1992).The moisture content was calculated using the formula;

$$M.C._{\text{(wet basis)}} = \frac{\text{Weight of water in sample (removed by drying)} \times 100}{\text{(Sample weight before drying)}}$$

Source: NRI, 1999

3.5.2 Storage method

In the traditional silos, twenty (20) kilograms of the cowpea was stored in each of the three silos and the openings of the silos sealed with mud, without adding any chemical or giving any treatment, as that was the practice of farmers. The 27 small plastic containers, that weighed about 0.15 kilograms each, were each filled with 1 kg cowpea seed and sealed with RTV silicone High Temperature markers, after their tops were fitted to plastic tubes and sealed with ABRO Epoxy steel Resins and hardeners for storage.

The three plastic paint containers, weighing about 0.6 kg each were each filled with about 9.6 kg of cowpea and were sealed with RTV silicone markers, after applying it at the point of contact between the container and its lid (cover), after placing half a tablet of phosphine in each container. The phosphine tablet was further reduced by half (that is ¼ of the tablet) after the second monthly data was taken.

All the storage containers filled with cowpea were placed in a well ventilated room.

3.6 MONTHLY DATA READING

One kilogram of seed was taken out monthly from each of the three plastic paint containers and from each of the three traditional silos for the determination of relevant parameters. Also three, out of the 27 small plastic containers, were taken every month for the same reasons.

3.7 DETERMINATION OF QUALITY CHARACTERSTICS

The quality characteristics data that were determined included:

i. Determination of oxygen levels in the hermetic storage by using the oxygen analyzer.

The Oxygen analyzer was pushed into the rubber tubes fitted to the plastic containers, after the tubes were bended, tied and cut opened.

Plate 1: Recording of the monthly oxygen level

ii. Monthly determination of moisture content from samples of each treatment: This was done by taking 25 grams of each sample in drying cans and placing them in an oven dryer at a temperature of 103°C for 72 hours (World Food Programme/ Natural Resource institute, 1992).

iii. Determination of dead and live insects. This was done by taking samples of one kilogram from each treatment, and by using a sieve the numbers of dead and live insects were counted manually and recorded.

Plate 2: Sieving out dead and live insects for counting

Plate 3: Weighing of samples for sieving

iv. Determination of number of holed grains in each treatment: This was done by randomly counting 100 grains from samples of each treatment, and manually counting the number of holes in each grain, after sorting them out according to the number of holes.

v. Determination of percentage germination in each treatment: This was done by randomly counting 100 grains from each treatment. The samples were then planted, and germination percentage is taken after 7 days when all grains would have germinated.

vi. Assessment of loss: This was done by randomly counting 100 grains that had holes in them, and 100 grains that had no holes in them and using the count and weigh method the loss in each treatment was then assessed. The grain samples were first cleaned over a sieve to remove insects and other fine material. Some dead insect parts may also be removed during the cleaning. The 100 damaged beans were then opened, cleaned of internal insects and dust, and reweighed to give the corrected weight loss.

The formula for calculating the percentage weight losses was as follows:

$$\text{Percent Weight loss} = \frac{(Und) - (DNu) \times 100}{U(Nd + Nu)}$$

where U = weight of undamaged kernels

D = weight of damaged kernels

Nu = number of undamaged kernels

Nd = number of damaged kernels

3.8 TREATMENTS

The treatments were:

i. Traditional silo, which was the control, had no treatment,

ii. Hermetic, where containers were tightly sealed to prevent the exchange of air between the environment inside the container and the environment outside the container, and

iii. Fumigation, a pallet (0.2gm) of phosphine was put in each container, and was tightly sealed to prevent the infusion of atmospheric air.

3.9 ANALYSIS AND INTERPRETATION

The data was analyzed and interpreted using the appropriate computer software, the Excel spreadsheet

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 RESULTS

4.1.1 Baseline Data

It was observed that in cowpea (*Vigna unguiculata*) the storage pest, (*Callosobruchus maculatus*) starts infestation in the field, as there were weevil damage in some grains with distinctive round holes in them. A number of live cowpea weevils were also found in the freshly harvested cowpea grain bought from a nearby market. However, the initial germination test indicated that there was no much difference in percentage germination drop, as 94.6% of the seed planted germinated.

Results of the base line data taken before storage were:-

Table 1: Baseline data

Type of Type of data	Results
Moisture content ………………………………	14.23
Germinaion test …………………………	94.6%
Oxygen Level ….. ……………….	21%
Live insects …………………………………..	2
Dead insects……………………………….	4
Zero hole ……………………………………	90
One hole…………………………………….	6
Two holes…………………………………..	3
Three holes………………………………..	0

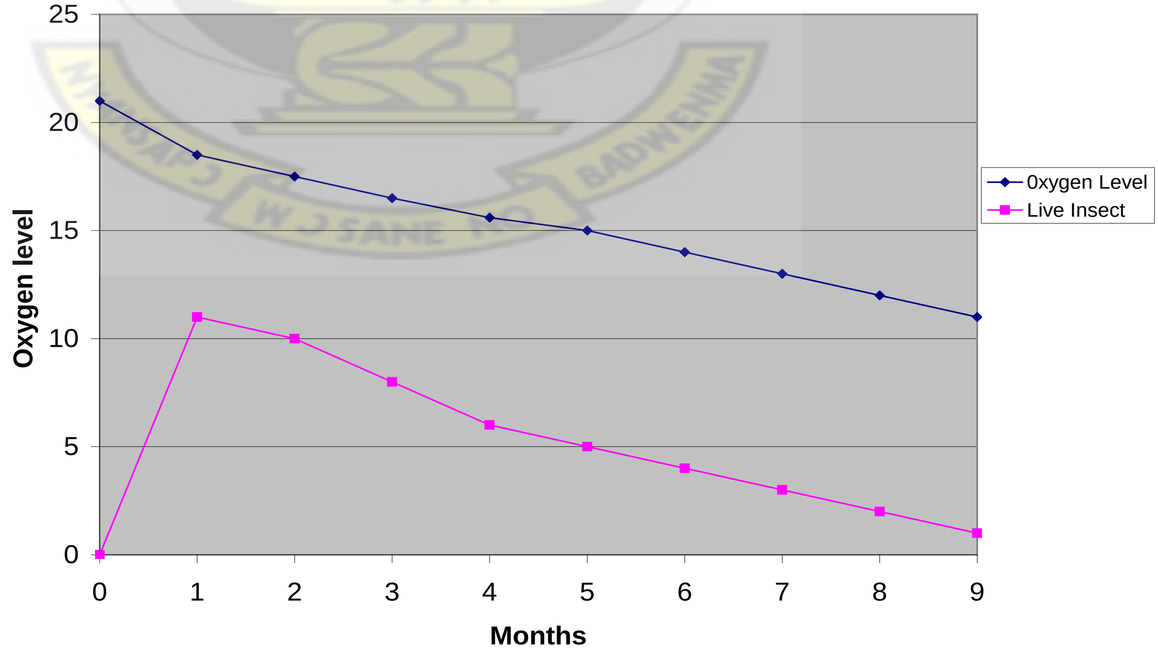

Figure 1: Oxygen level and live insect population

4.1.2 Oxygen level against live insect count:

There was a constant reduction in oxygen level, at least by 1%, every month, as shown in Figure 1.

As the oxygen level decreases the live insect number rises for the first month, but started decreasing until the average of 2 or 3 insects were observed after the 6th to the 9th month.

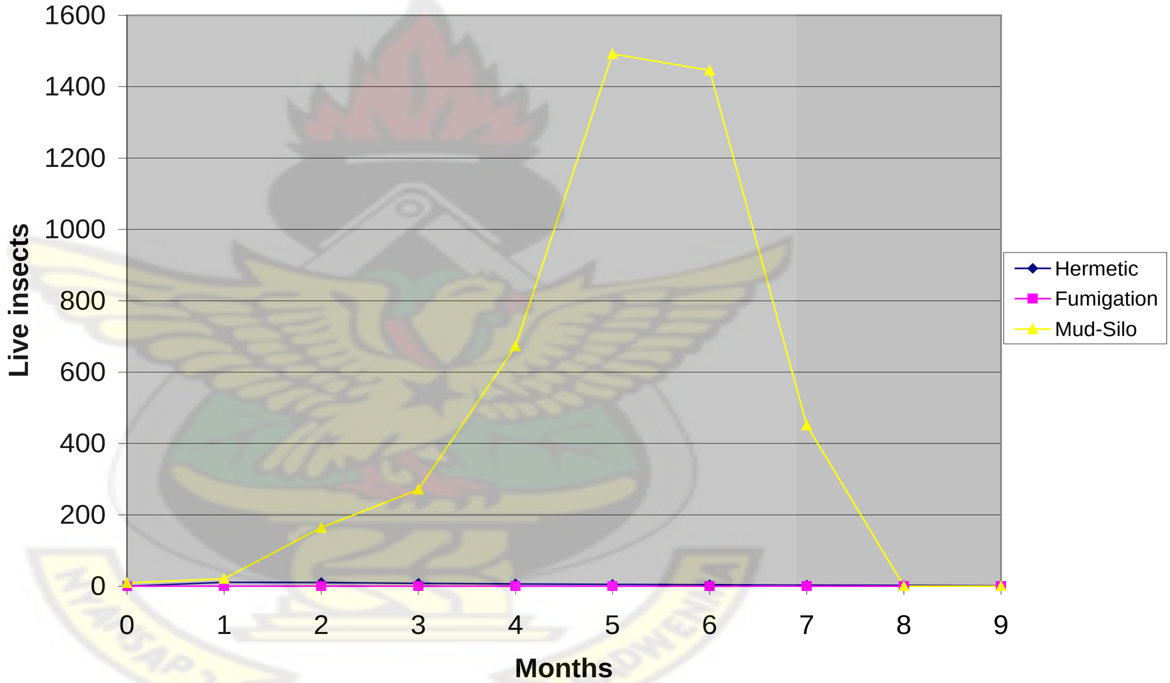

Figure 2: Average live insect count

4.1.3 Live insect count

In the fumigation storage there were no live insect observed from the first month of storage, and throughout the whole nine months storage period.

In the hermetic storage there were a few insects observed throughout the nine months storage period, however, the numbers were not very much different from that of the fumigation storage, as seen in Figure 2.

However, in the traditional storage it was observed that the number of live insects multiplied from one month to the other and reached a peak in the fifth month, and then started to reduce until no live insects were observed during the eighth and ninth months.

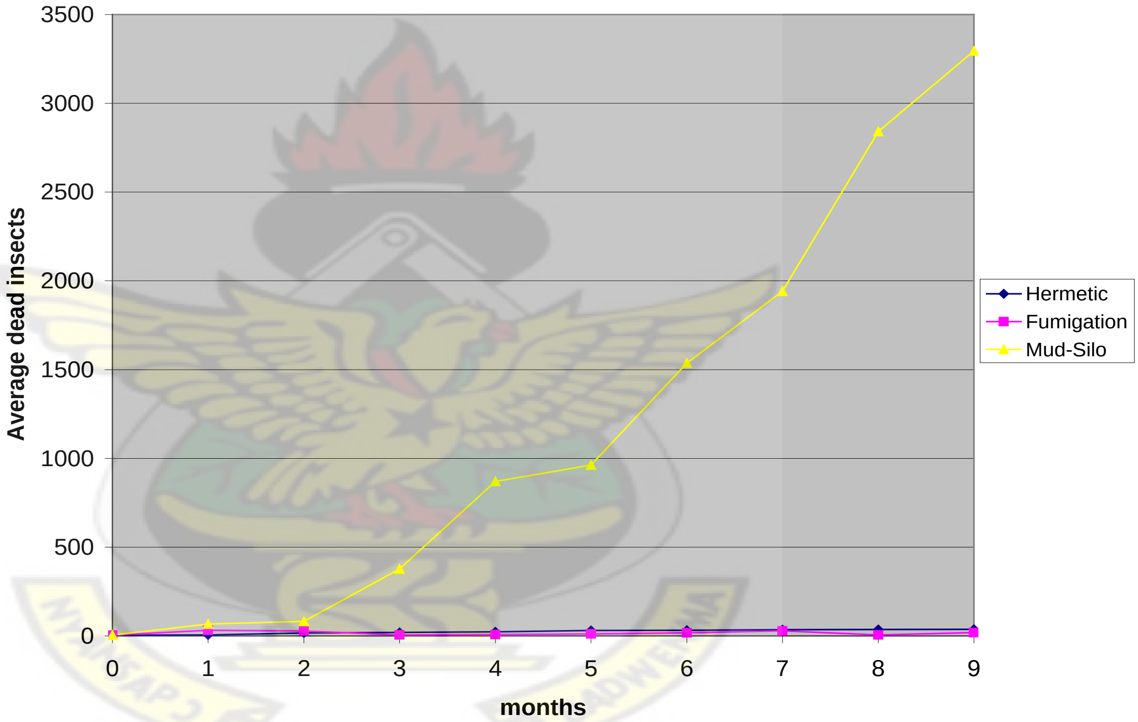

Figure 3: Average Dead Insect Count

4.1.4 Dead Insect count

From Figure 3 , the number of dead insects observed in the fumigation was very low, between 1 and 4, throughout the nine months period. There was also no significant difference, in insect population, between the fumigation and hermetic storage.

4.1.5 Number of holed count

4.1.5.1 Zero hole count

Figure 4 illustrates the results of the zero hole count for all the three treatments. The average zero hole count per month per sample of cowpea grain in the hermetic experienced a slight reduction in number of one hole from an initial 90% to about 87.7% in the first month, and to about 74% in the last month of storage period.

With the fumigation containers the average zero hole count was not significantly different from one month to the other through out the nine months period.

In the traditional storage containers, there was a significant reduction in zero hole count from an initial 90% before storage to about zero percent from the 6th to the last (ninth) month.

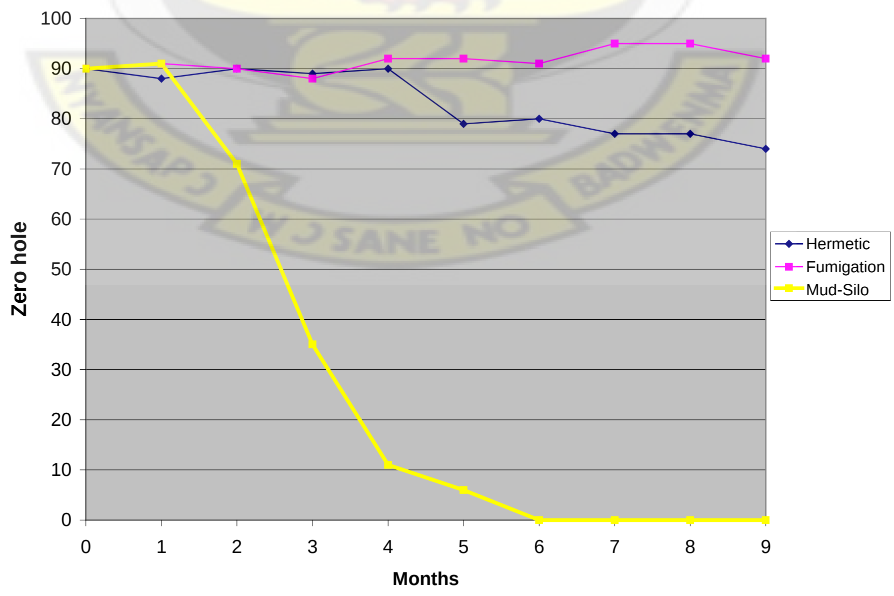

Figure 4: Average Zero hole count

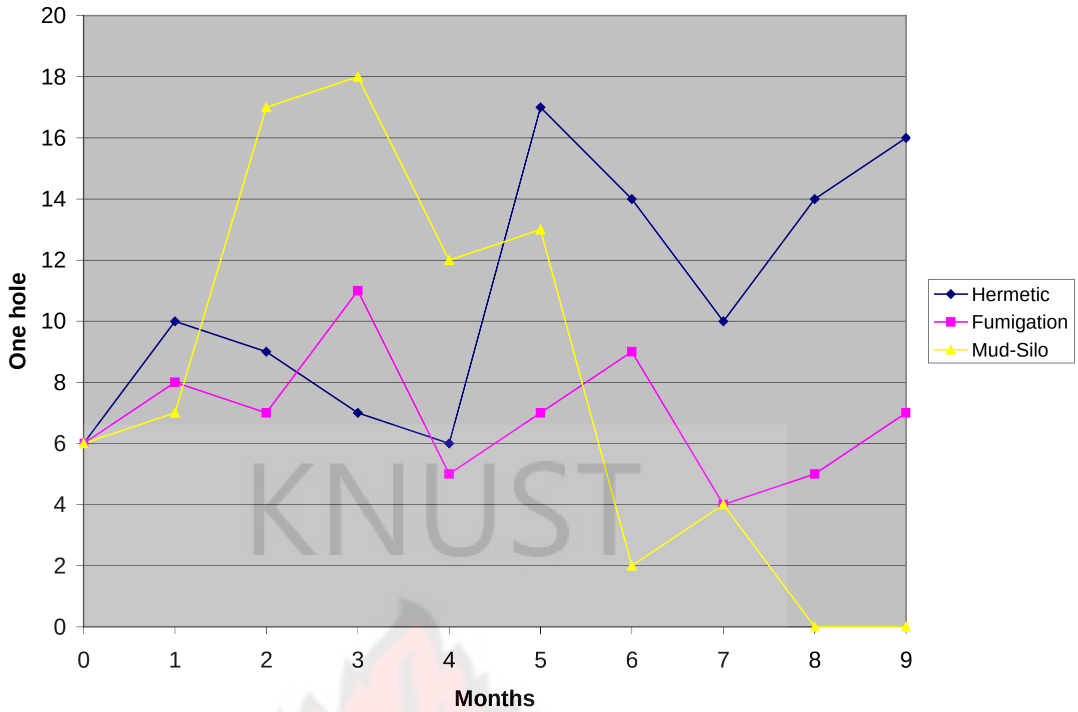

Figure 5: Average 1 hole count

4.1.5.2 One hole count

Figure 5 above represented the one hole count results for all three treatments

In the hermetic storage it was observed that the number of one hole cowpea grains increased from an initial 6% before storage to about 16% in the ninth month. However, the trend of increment was irregular, as in some months the number of holed grains would be higher and sometimes lower in the following month than in the previous month.

The one hole count in the fumigation was about 6% before storage for most of the months throughout the storage period, except in the 1st, 3rd and 6th months when the average one hole count was about 8, 10.7 and 9% respectively.

From the initial hole count of 6% before storage in the traditional storage, the number of one hole grains increased to 6.7 in the 1st month, 17 in the 2nd month, 17.7 in the 3rd, 12 in the 4th month and 13.30 the 5th month. However, the number of one hole grains dropped to about 2% in the 6th month and 4% in the 7th month, with no one hole observed in the 8th and 9th months, as seen in Figure 5.

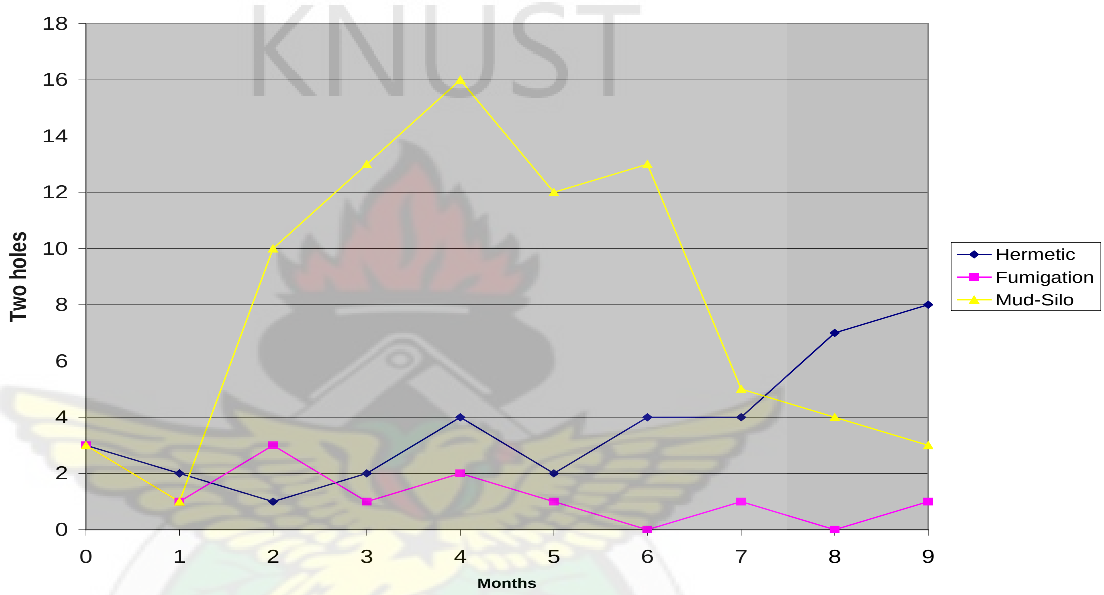

Figure 6: Average 2 hole count

4.1.5.3 <u>Two hole count</u>

In Figure 6, the number of two hole cowpea grains in the hermetic storage was not very much different from the 1st month of storage to the 7th month of storage, whose average was between 1 and 4. However, the average count of two holes per the sample of 100 grains in the 8th and 9th months was about 7 for the 8th month and 8 in the 9th month.

With the fumigation storage it was observed that the average number of two hole grains per month was not different from that of hermetic. The average number of two hole grain ranged from 1% to 3% through out the storage period.

The average number of two hole cowpea grain per month in the traditional silos, which was the control, in the 1st month was about 1%, rising to 10% in the 2nd month, 13% in the 3rd month, 16.3% in the 4th month, 12.3% in the 5th month, 12.7% in the 6th month and dropping to about 4.7 in the 7th month, 3.7% in the 8th month and about 2.7% in the 9th month.

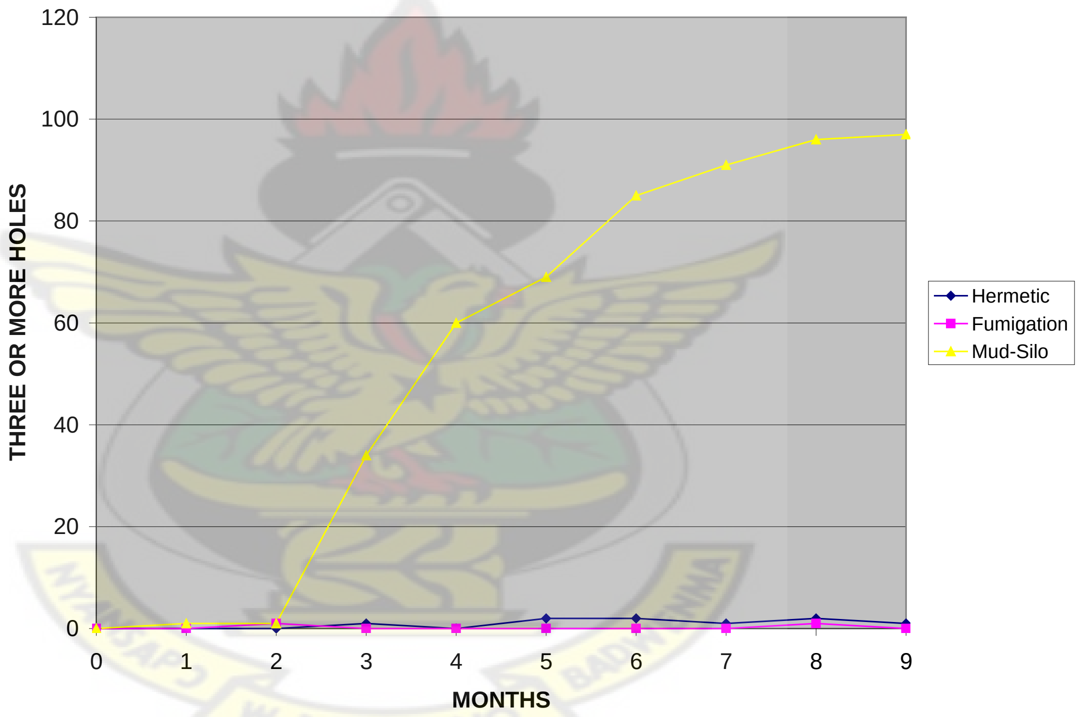

Figure 7: Average 3 or more hole count

4.1.5.4 Three or more holed count

There were generally few cowpea grains observed with three or more holes per the 100 grains sampled in the hermetic containers. The average three hole count was between 0.3 – 2%.

Also in the fumigation storage, the number of three hole cowpea grains observed per month throughout the nine months storage period was very few. The average percentage count per the 100 sampled grains was 0.0 to 0.7%.

However, the number of three hole cowpea grains per the sample of 100 grains, in the traditional silos, increased from the zero percent before storage to about one percent in the 1st and 2nd months. The percentage then increased sharply from the 1% in the 2nd month to about 97%, after the last month of storage (as seen in figure 7 above).

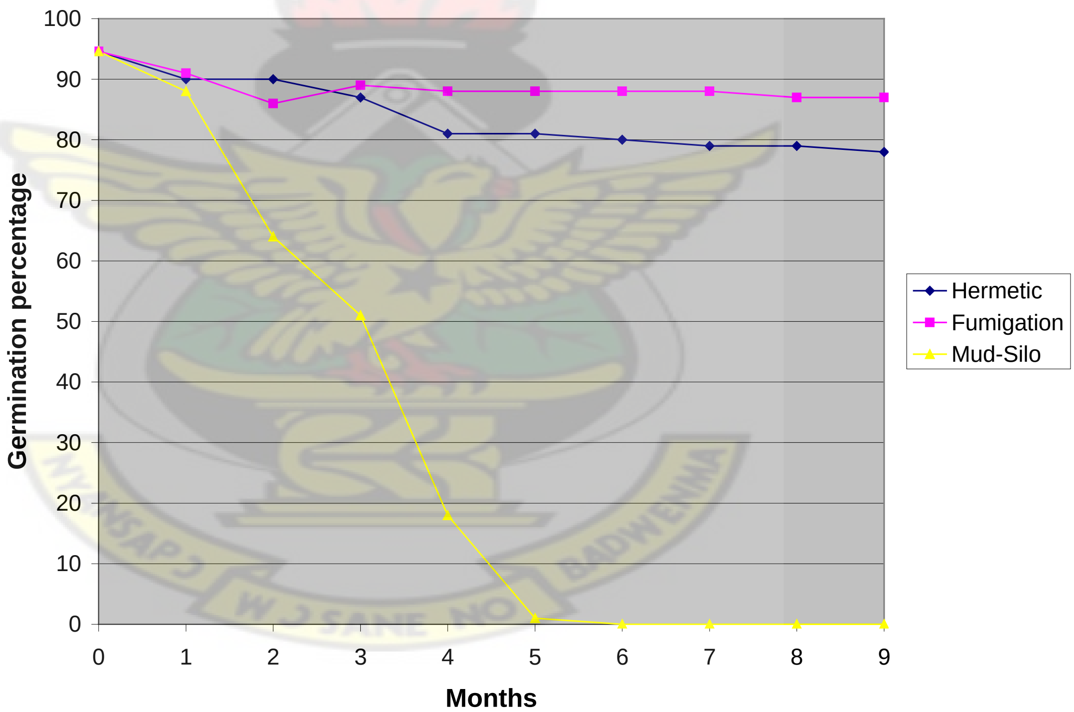

Figure 8: Average percentage germination

4.1.6 Average percentage germination

It was observed that in the hermetic storage there was a monthly gradual reduction germination percentage, as seen from Figure 8. The difference in percentage germination from the germination test before storage and the germination test after the ninth month was 16.6%.

The initial germination test before storage was 94.6% whilst the last germination test after the ninth month was 78%. The maximum monthly difference was about 6% that was between the 3rd and 4th months, followed by 3% between the 2nd and 3rd months. The rest of the months hard a monthly decrease of 1%.

For fumigation storage, it was observed that there was also a gradual reduction in percentage germination from the test before storage to the ninth month, which was the last month of storage period. The difference between the test before storage and the test during the last month (ninth month) was 7.6%.

It was observed that there was a significant reduction in percentage germination in the traditional silos. The reduction was so drastic that the germination percentages dropped to 1% in the 5th month, and finally to zero percentage from 6th – 9th months, as shown in Figure 8.

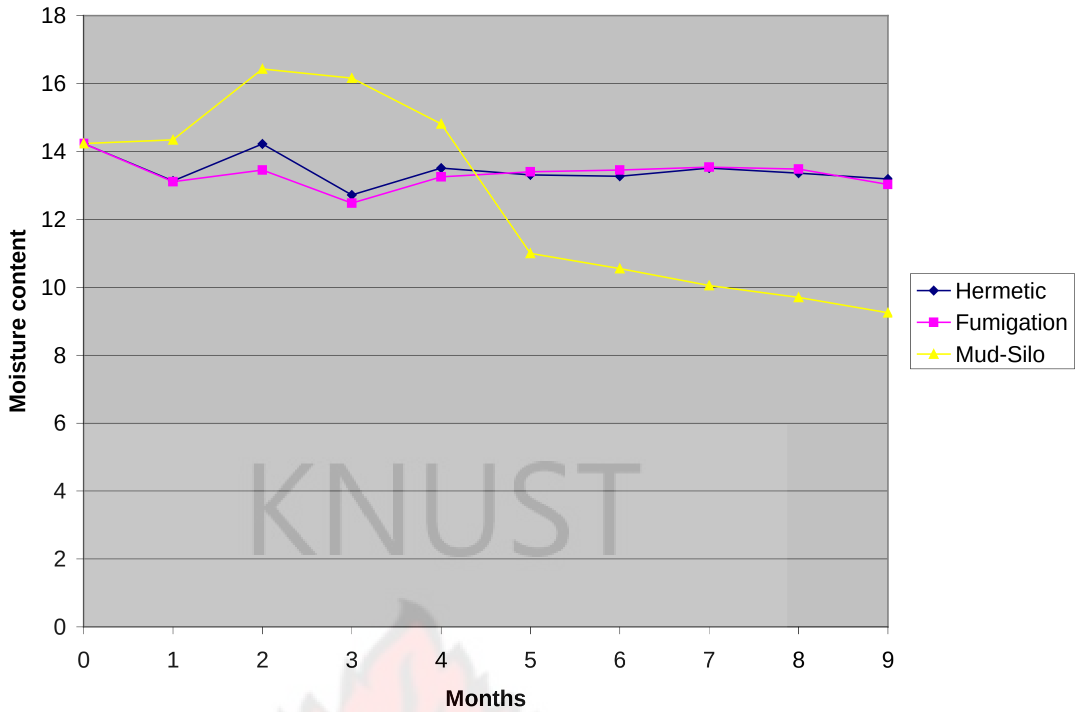

Figure 9: Average Moisture Content

4.1.7 Average Moisture content

In the hermetic storage there were not very much differences in the moisture content from the initial moisture content before storage and the last (ninth) month of storage. Just like the hermetic storage there was not very much difference in the moisture content of the fumigation storage through out the nine months storage period. The highest moisture content was the initial moisture content of 14.23% before storage and the lowest moisture content of 12.48% was recorded in the 3rd month. The slight difference in the moisture content did not follow a regular trend; it was increasing and decreasing, as seen in Figure 9.

In the traditional silos, it was observed that the moisture content first increased after the first month to the 3rd month of storage, until it started to drop from the 4th month to the last (ninth) month of storage. The highest moisture content level was in the 2nd month of storage, which was 16.43% and the lowest moisture content level was 9.25%, after the ninth month, as seen in Figure 9 above.

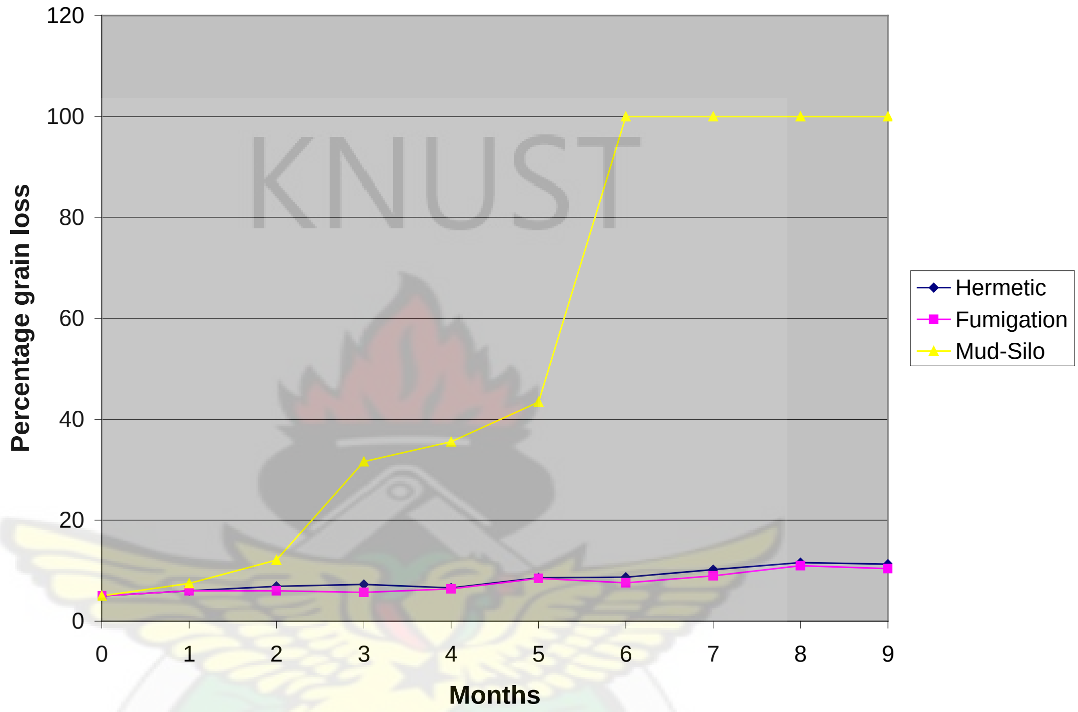

Figure 10: Average percentage grain loss

4.1.8 Determination of percentage grain loss

Figure 10 shows the change in percentage loss in weight over the period of storage.

There was some insignificant difference for the change in percentage loss for both the hermetic and the fumigation containers. The change in percentage lose for both storage techniques was minimal, with about 6% change, from beginning to end of storage, for the hermetic and about 4.6% for the fumigation technique.

However, there were vast percentage losses in the traditional storage technique. From 5% before storage, the losses went up to about 32% during the 3rd month of storage, and from there the losses further increased to about 100% from the 6th to last (ninth) month of storage.

The Food and Feed Grains Institute (1986) formula was used to calculate the percentage losses.

The formula is as follows:

$$\frac{(UNd) - (DNu) \times 100}{U\,(Nd + Nu)}$$

Where: U = Weight of undamaged kernels

D = Weight of damaged kernels

Nu = Number of undamaged kernels

Nd = Number of damaged kernels

4.2. DISCUSSIONS

4.2.1 POST HARVEST CHARACTERISTICS OF COWPEA

Cowpea weevil (*Callosobruchus maculatus)* is a major pest of cowpea in Ghana. It attacks dried cowpea and other related stored seeds. The pest in mainly found on cowpea grain in storage, and may probably be the main constraint to increased cowpea production.

There are published data providing evidence that insects cause devastating losses in cowpea yields. The weevil, a post harvest pest, destroy a granary full of cowpea within two or three months (Gomez , 2003).

Mature dried pods should be harvested promptly Delayed harvesting will encourage weevil infestation in the field.

The variety of cowpea grain used in this research was the local creeping white cowpea which was the most preferred cowpea variety by consumers and cowpea farmers in the Lawra District. However, this variety is highly susceptible to the cowpea weevil.

4.2.2 CONDITION OF COWPEA BEFORE THE RESEARCH

The cowpea grain; which were bought at farm gate immediately after harvest, were observed to contain cowpea weevils. Also, some of the grains were damaged with distinct round holes seen in them.

This supported the claim by the GTZ (2006) that delayed harvesting will encourage cowpea weevil infestation in the field.

A single cowpea weevil female can reproduce herself 20 fold every 3 -4 weeks. Harvested cowpea grain that has a very high infestation which starts in the field before it is stored will have a heavy infestation within 2 or 3 months (Gomez, 2004).

4.2.3 DETERMINATION OF MOISTURE CONTENT

Determination of the moisture content was highly imperative as this would determine the keeping quality of the grain. It is very important to know the moisture content of grain during drying and storage as it is the indicator for grain quality and safe storage. FCDP, (2005) recommended the ideal moisture content level to be 8 -10%, while the German Agency for International Cooperation (GTZ, 2006), recommended a moisture content level of between 12 -14% during storage.

After the storage period, however, there was no significant difference in the moisture content between the samples in the hermetic and fumigation storage. This was probably due to low respiration of product, coupled with the absence or low insect activity, as a result of the containers in both treatments being properly sealed to prevent the entrance of air and moisture (Figure 9).

However, the moisture content of the traditional silos was significantly different from those of the hermetic and the fumigated stores. This was probably due to the presence of high levels of insects and insect activity, as well as the ability of the silos to absorb moisture from the atmosphere. This meant that the amount of water held in the air inside the silos was higher than that of the product inside when the insect population was higher, and later the water held in the air inside became lower than that of product inside due to a drop in insect population.

4.2.4 GERMINATION PERCENTAGE TEST

The samples in the hermetic store exhibited some significant differences (even though not very wide) between the initial germination test, carried out before storage and the final germination test after the storage period. This was probably due to the presence of the insect pest as the oxygen level, from the beginning of the trial was still high enough for the bioactivity of the insects to continue, and which might have caused some deterioration in some of the seeds, thereby reducing the germination percentage.

Germination percentage in the fumigated storage was insignificantly different from the initial germination percentage taken and the final germination percentage. This was probably due to the absence of the cowpea weevil and low biodeteriorating factors in the fumigated storage, as well as the effectiveness of controlling the amount of water held in the air inside the containers.

However, there were significant differences in the traditional silos (Control) from the initial germination percentage and the final one. This was probably due to persistent increase in insect population in the traditional silos. It might also be due to changes in the moisture content level of the product and its environment inside the containers as the containers were very permeable to atmospheric moisture (figure 8).

4.2.5 DETERMINATION OF OXYGEN LEVEL AS AGAINST LIVE INSECT POPULATION IN THE HERMETIC CONTAINERS

Many workers have shown that removal of oxygen by respiration causes insects to die in a sealed container (Shejbal, 1980)

In practice also there is some risk of oxygen diffusing into containers and permitting some survival (Wickedness et al, 1963 as reported by Shejbal, 1980). Controlled atmosphere storage involves changing the composition of the gas in the store so that it is different to that of atmospheric air for most, if not all, of the storage period.

In the simplest situation, the grain is sealed into a gas-tight enclosure and the natural products of respiration; carbon dioxide is allowed to increase. Eventually, the carbon dioxide concentration rises to the point that insect populations are prevented from developing further and are eventually killed. This technique is also called hermetic storage (NRI, 2000). Low cost storage can be achieved on a larger scale with the use of hermetic structures (Shejbal, 1980). Controlled atmosphere (CA) is one of the few non-chemical methods for grain disinfestation and protection. Those atmospheres are based on changing the ratios of the respiratory gases, oxygen (O_2) and/or carbon dioxide (CO_2) in the storage atmosphere (Dowsett *et al.*, 1993).

Controlled atmospheres (CA), with elevated carbon dioxide (CO_2) or Nitrogen (N_2) and depleted oxygen can be used effectively to control insects and mites in stored grains (Jayas *et al.*, 1993).

100% mortality of *Callosobruchus maculatus* 9 days were needed in the 1% oxygen (O_2) atmosphere at the same temperature was recorded in only approximately 15 days in 3% O_2 atmosphere.

Furthermore, for commodities stored at high temperature (>30^{o}C) that prevail often during harvest in many legumes seed producing countries, low-oxygen controlled atmospheres (1% or less) can provide a rapid means of disinfestation with exposure of one day or even less (Ofuya *et al*., 1993).

From Figure I, when the oxygen level was 21% the adult insect number was zero, (since the grain was cleaned of insects just before storage). However, the adult insect number increased sharply to 11 when the O_2 level was 19%. Further depletion of the O_2 to about 11% in the 9th month resulted in a corresponding decrease in insect population to 1. This was due to the oxygen depletion and carbon dioxide (CO_2) accumulation due to the metabolic activities of the insects, which could not sustain insect life, and therefore the main cause of the low number of insects in the hermetic containers.

One of the major life processes is respiration, the breakdown of substrates in the presence of oxygen to release carbon dioxide (CO_2). From Figure 1 it can be observed that the respiration of the seeds themselves and the insects used up the oxygen in the containers and produced carbon dioxide (CO_2). Since insects cannot survive in the oxygen -depleted environment in the containers, their development was retarded and they eventually died off.

A similar work conducted by Ofuya *et al*., (1993) indicated that; for 100% mortality of *Callosobruchus maculatus* 9 days were needed in 1% oxygen atmosphere at 25^{o}C, whereas the same mortality at the same temperature was recorded in only approximately 15 days in 3% oxygen atmosphere.

The above statement attests to the fact that the 11% oxygen level at the end of the ninth month could still support some insect life, hence the presence of some few live insects during the ninth month at 11% oxygen level

(Figure 1). However, the development of the insect was completely inhibited that even though there were a few live adult insects present, no live insect larvae were observed from the sixth to the ninth month of storage (Figure 2), probably suggesting a high mortality rate of insect larvae at an oxygen level of about 13% at room temperature (since all the treatments were under room temperature). The only drawback of this storage system is the slowness to achieve significant depletion of the oxygen levels in order to obtain a complete disinfestation of the grain Even though there was a gradual increase in dead insect population as seen in Figure 3, the quality of the grain was not affected much, as dead insect numbers were few.

4.2.6 DETERMINATION OF LIVE INSECT COUNT IN THE FUMIGATED AND TRADITIONAL MUD-SILO STORAGE

4.2.6.1 Fumigated storage against live insects

Determination of live insect population is very vital as this determines the eating and market quality of the grain.

Harvested cowpea grain that has a very high infestation which starts in the field before it is stored – will have a heavy infestation within 2 or 3 months. Foods prepared with this grain have an unpleasant flavour. If taken to the market the price of this grain is discounted (Gomez, 2004).

Phosphine has been widely used as a grain fumigant in Queensland for many years. In a variety of situations, it is the fumigant of preference, being cheap and easy to apply, readily removed when required by ventilation and leaving little residue on the grain (RIPP et al, 1984).

Studies show that low-dosage phosphine (PH_3) fumigation for insect control, and consideration of grain quality is economical, practical, simple and safe (Peng Qing, 1993)

Phosphine released from metal phosphide preparations is currently the major fumigant in use for the protection of stored product worldwide. Phosphine is the preferred fumigant for routine treatment, especially in developing countries where other control techniques, including controlled atmosphere storage will be expensive and therefore cannot be readily adopted (Rajendran, 1993). It is an established fact that insects respond better to lower concentrations with lower exposure period than to higher concentrations with shorter exposure periods with phosphine (Rajendran, 1993).

Leakage of phosphine outward and air inward is a function of the degree of sealing of the structure. Leakages will not only vary between structure types but will also vary within a particular structure type due to differences in sealing, history of use and local micro and macro- meteorological conditions (Bank *et al*., 1993).

As seen in Figure 3, it was observed that there was a 100% mortality (unlike the hermetic) of live and larvae insects after one month of storage at 0.2g of phosphine to 10kg of seed.

This suggests that the phosphine treatment can achieve a faster disinfestation rate, achieving a 100% mortality of adult and larvae insects in one month or less. As a result of the well sealed fumigation containers, there was no reinfestation of the insects throughout the 9 months storage period. Also, the population of dead insects in the fumigated containers was very few thereby maintaining a better quality and viability than the hermetic and the traditional silo.

4.2.6.2 Traditional mud-silo storage

With the traditional silos the increase in the live insect population was probably due to non treatment of the cowpea in storage and the use of not too appropriate storage structures, whilst the drop in the insect population during the last two months to zero was probably due to hot spot and no or little food for the insects once they had consumed all the grain in the container.

4.2.7 DETERMINATION OF HOLE COUNT

Empirical analysis of cowpea price and quality data using hedonic price analysis revealed that consumers in most areas have a preference for larger sized grain and are more sensitive to storage damage than previously thought. Data from Ghana, Cameroon and Senegal indicate that consumers discount prices from the first bruchid hole (Langyintuo *et al*., 2000). From the above statement, it was therefore very important to conduct hole count during the research period to determine the quality of the grain.

In the hermetic containers the slight drop in the zero hole count from 90 to 74%, the increases in one hole (6 – 16%), two hole (3 – 8%), and three hole (1%), altogether making a total decrease of zero hole to 74% (Figures 4, 5, 6 and 7), was probably due to the presence of biodeterioration activities, especially by the cowpea weevil, as the initial oxygen level was still deterrent enough to be able to cause any effective disinfestations of the insect. This suggests that the hermetic storage would have lost the premium price of the grain cowpea.

In the fumigated containers there were no significant difference from the initial zero hole count through to the final zero hole count, from 92% initially to 91% being the final zero hole % (Figure 4). There were marginal increases in the one, two and three holes, bringing the total zero hole quality to 91%. This suggests that, in fumigated storage the premium selling price of the grain was maintained throughout the storage period, indicating the overall quality of the grain and selling price were better than both the hermetic and the traditional silos. This was probably due to the effectiveness of the phosphine tablets used for storage, and the speed with which the phosphine disinfestation activities attack the weevil, thereby causing 100% insect mortality, in 30 days or less. The limitation of this system, even though very effective and very fast in grain disinfestation, is the problem for contamination by its residue, and also insects may develop resistance to the insecticide.

In the traditional silos, the reduction in the zero hole count as the months went by was very enormous. As early as the third month, the percentage of zero hole grain left was 35%. At six months of storage there was no single zero hole grain left in the containers. This means that the price of the cowpea grain in the traditional silos would have been discounted to the third selling price, as early as the third month of storage, and at six months there would have been no price at all, as all the grain would have been lost to insect infestation and no consumer would like to purchase such cowpea grains.

This suggests that there would have been a lot of biodeterioration activity, due to non treatment with chemicals or non- adoption of non-chemical techniques in grain storage in the traditional silos, creating a conducive environment inside the containers for fast insect development, causing heavy infestations and fast deterioration of the grain inside the silos.

4.2.8 DETERMINATION OF DEAD INSECT COUNT

The number of dead insect in the fumigation storage was lower than the hermetic and traditional silos, probably due to the unfavourable conditions inside the containers limiting insect development and insect infestation, causing all insects to die within the first month of storage (Figure 9).

In the hermetic storage the number of dead insect count was higher than in the fumigated storage. This might probably be because the oxygen level reduces gradually and might still support biodeterioration activities, initially, which would in turn prolong the life span and multiplication of insects for grain infestation (Figure 9).

However, with time, the reduction in the oxygen level might create a condition, inside the container environment, not conducive for the survival of the insects, causing all the insects to die eventually, at a later period than the fumigated storage.

In the traditional silos, due to the non treatment with chemicals or non-chemical techniques inside the silos a conducive environment was created for biodeterioration activities to facilitate the fast multiplication of insects.

Initially there was enough food in the mud silos, but as the food quantity was reduced by the heavy insect infestation the insect population also reduced, and finally when all the food was used up by the insects all the insects also died.

4.2.9 LOSS ASSESSMENT

There was no significant difference in percentage loss in the fumigated storage, from the initial 6% to final 10% (Figure 10)

Also there was no significant difference in percentage loss between the fumigated and hermetic storage of 6% initially to 11% in the last month. The percentage loss was low in the two storage system (hermetic and fumigated) probably due to phosphine and the sealed airtight conditions in the fumigated and hermetic containers respectively. This would have probably caused biodeterioration activities being very low in the fumigated and hermetic systems, inhibiting insect development and infestation and causing the death of all insects.

In the traditional silos, however, the percentage loss was very heavy, from an initial loss of 7.5%, it rose to 31.6% in the third month, and finally to 100% from the 6^{th} to the 9^{th} month. This would have probably been to the conducive environment for insect activity and multiplication which would cause the insects to increase rapidly resulting in the extensive damage caused, up to 100% within 6 months in the traditional silos.

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Both the hermetic and fumigated techniques of storing cowpea are more effective in controlling the cowpea weevil (*Callosobruchus maculatus*), compared to the traditional mud silos. Also the fumigated technique is more effective in maintaining cowpea viability and quality than the hermetic technique.

The traditional mud silo method of storing cowpea, without any treatment, is highly ineffective and highly unreliable in controlling the cowpea weevil if cowpea is to be stored for a long period of about 4 to 9 months. It might even lead to about 100% loss in grain quality and viability, as was observed in this trial.

Storing cowpea for longer periods reduces its capacity to germinate. As was seen in Figure 8, all the three treatments decreased, with time, in germination percentage.

This goes to support the claim by Ripp et al (1984), that the seeds must not be stored too long, since in course of time they lose the capacity to germinate. The cowpea weevil, the notorious cowpea post harvest pest, if not handled with prudent post-harvest management techniques, can destroy a granary full of cowpea within four or five months, as in this study there was a 100% loss of grain in the traditional method by the 6th month of storage.

This study has therefore affirmed the claim by Gomez (2004) that weevils can destroy a granary full of cowpea within two to three months, if not stored with either chemical or the CRSP non-chemical methods.

The cowpea weevil can reproduce itself very fast, within a month or two, as in the traditional silos (control) where there was a heavy infestation of live and dead insects by the 3rd month. Gomez (2004) attested to this when he stated that 'a single cowpea weevil female can reproduce herself 20-fold every 3-4 weeks.

5.2 Recommendation

Farmers and cowpea dealers are advised to adopt the fumigation and the hermetic techniques of storing their cowpea for a better keeping quality, safer and a better market price, instead of the unreliable and unsafe traditional methods.

It is recommended that the mud silo could be modified to make it more hermetic in storing seeds.

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APPENDIX

Results (data) from treatments

Dead insect count
Average Dead insect count

Month	Treatment		
	Hermetic	Fumigation	Mud-Silo
0	4	4	4
1	5	31.3	67.3
2	16.7	27.3	81.7
3	19.7	5.7	376.7
4	22.7	7.3	870.3
5	31	10.7	962
6	32	17.3	1537
7	35	28.7	1941.3
8	36.3	5.3	2841
9	37	19	3294.7

Average Oxygen Level against
Live Insect Number

	0xygen Level	Live Insect
0	21	0
1	18.5	11
2	17.5	10
3	16.5	8
4	15.6	6
5	15.00	5
6	14.00	4
7	13	3
8	12	2
9	11	1

Average Live insect count

Month	Treatment		
	Hermetic	Fumigation	Mud-Silo
0	0	0	9
1	11	0	21
2	10	0	164
3	8	0	271
4	6	0	673
5	5	0	1492
6	4	0	1446
7	3	0	451
8	2	0	0
9	1	0	0

Average Zero hold count

	Treatment		
	Hermetic	Fumigation	Mud-Silo
0	90	90	90
1	88	91	91
2	90	90	71
3	89	88	35
4	90	92	11
5	79	92	6
6	80	91	0
7	77	95	0
8	77	95	0
9	74	92	0

Average one hole count

	Treatment		
	Hermetic	Fumigation	Mud-Silo
0	6	6	6
1	10	8	7
2	9	7	17
3	7	11	18
4	6	5	12
5	17	7	13
6	14	9	2
7	10	4	4
8	14	5	0
9	16	7	0

Average two hole count

	Treatment		
	Hermetic	Fumigation	Mud-Silo
0	3	3	3
1	2	1	1
2	1	3	10
3	2	1	13
4	4	2	16
5	2	1	12
6	4	0	13
7	4	1	5
8	7	0	4
9	8	1	3

Average three hole count

	Treatment		
	Hermetic	Fumigation	Mud-Silo
0	0	0	0
1	0	0	1
2	0	1	1
3	1	0	34
4	0	0	60
5	2	0	69
6	2	0	85
7	1	0	91
8	2	1	96
9	1	0	97

Average moisture content

Months		Treatment	
	Hermetic	Fumigation	Mud-Silo
0	14.23	14.23	14.23
1	13.13	13.11	14.34
2	14.22	13.45	16.43
3	12.72	12.48	16.16
4	13.51	13.25	14.81
5	13.31	13.4	11.00
6	13.27	13.45	10.55
7	13.51	13.54	10.05
8	13.36	13.48	9.7
9	13.19	13.03	9.25

Average Germination per centage

Month		Treatment	
	Hermetic	Fumigation	Mud-Silo
0	94.6	94.6	94.6
1	90	91	88
2	90	86	64
3	87	89	51
4	81	88	18
5	81	88	1
6	80	88	0
7	79	88	0
8	79	87	0
9	78	87	0

Average percentage Grainn loss

Month	Treatment		
	Hermetic	Fumigation	Mud-Silo
0	5	5	5
1	6	6	7.5
2	6.9	6	12.1
3	7.3	5.7	31.62
4	6.6	6.4	35.57
5	8.6	8.5	43.42
6	8.7	7.6	100
7	10.2	9	100
8	11.6	11	100
9	11.3	10.4	100