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EFFECTS OF COMMONLY USED STORAGE METHODS, CHEMICAL TREATMENT AND STORAGE PERIOD ON MAIZE GRAINS QUALITY IN EJURA-SEKYEDUMASI MUNICIPALITY IN THE ASHANTI REGION

BY

EMMANUEL FRIMPONG

APRIL, 2016

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A THESIS SUBMITTED TO THE SCHOOL OF RESEARCH AND GRADUATE STUDIES, KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER OF PHILOSOPHY (MPHIL.) POSTHARVEST TECHNOLOGY DEGREE

BY

EMMANUEL FRIMPONG

APRIL, 2016

DECLARATION

I do hereby declare that this work submitted to the Department of Horticulture towards the MPhil. Postharvest Technology, is the result of my own research and that, to the best of my knowledge, it contains no material previously published by another person nor material which has been accepted for the award of any degree of the University, except where due acknowledgement has been made in the text.

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DEDICATION

First and foremost, this dissertation is dedicated to Lord God Almighty for in Him I live.

Finally, to my mother, Kate Okyere and grandmother, Cecilia Fordjour for their steadfast love, support and encouragement.

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The author takes this opportunity to express his profound gratitude to all those who have contributed in diverse ways in his education and in the writing of this research dissertation. First and foremost, my deepest and very big thanks go to God, for all that He has done for me, especially for His divine favour, strength, protection, knowledge, sustenance of life and faith to make this dream and work a reality. To God be all the glory and may His name be worshipped forever. Amen!

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ABSTRACT

Postharvest losses in maize production especially during storage, is a major and big challenge in maize growing areas in Ghana. Consequently, the study was undertaken to investigate and come out with suitable storage methods which would minimize both qualitative and quantitative losses of maize during storage. A field survey and laboratory experiments were conducted to evaluate the effects of some storage methods namely: jute sack, polypropylene sack, plastic drum, hermetic triple-layer bag, clay pot and heaping on floor used by farmers in Ejura-Sekyedumasi Municipality, in the Ashanti Region of Ghana, on postharvest quality characteristics of stored Obatanpa maize grains. The experiment was set up in a 6 x 2 x 4 factorial laid out in a Completely Randomized Design (CRD) replicated three times. For each treatment, five kilogram of Obatanpa, treated with Actellic Super and Phostoxin at the recommended rates was stored for a period of four months at ambient conditions. At every one month of storage interval, destructive sampling of 1kg of grains was taken randomly from each treatment for the determination of grain quality parameters including moisture content, weight loss, grain damage, grain colour and odour changes and level of insect pest infestation. Hermetic triple- layer bag proved superior in recording the least weight loss (5.76%) within four months of storage followed by plastic drum (7.38%), clay pot (7.98%), jute sack (10.31%), polypropylene sack (10.98%) and heaping on floor (14.62%). The use of hermetic triple-layer bag and plastic drum significantly minimized grain damage, moisture content number of insect pests that caused grain damage and had no effect on grain colour and odour. Reduction in proximate and minerals composition of maize grains were significantly lowest in grains stored in hermetic triple-layer sack and plastic drum compared to grains stored in jute sack, polypropylene sack, clay pot and heaping on floor methods.

The quality parameters studied were significantly affected by storage duration. Grain moisture content, insect infestation, grain damage and weight loss showed an increasing trend with an extended period of storage. With the two grain protectants (Actellic Super and Phostoxin) used, Phostoxin gave a desirable result than Actellic Super as far as moisture content was concerned. In this regard, Phostoxin fumigation was effective method to maintain the quality of stored maize grains.

In this regard, it is concluded that for better short term and long term storage of maize grains, it is preferable to use hermetic triple-layer bags and plastic drums in combination with Phostoxin treatment to maintain postharvest quality characteristics of stored maize grains.

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CHAPTER ONE

1.0 INTRODUCTION

Maize (*Zea mays* L.) is also known as corn in some countries. It belongs to the family *Poaceae* (Kranja, 2003; Raouf, 2011). Maize is a native of Central America from where it spread to Asia, Europe and Africa through the activities of traders and explorers. It got to West Africa through the Portuguese in the 16th century (AddoQuaye *et al.,* 1993). It is the third most important cereal grain worldwide after rice and wheat (FAO, 1991; Golob *et al.,* 2004; Escobedo, 2010), and the second most important staple food in Ghana, next to cassava (IFPRI, 2013). Maize is now ranked as the third most important food crop in the world (Organization for Economic Cooperation and Development (OECD) of the United Nations (FAO, 2000; Escobedo, 2010). It is referred to as the cereal of the future due to its nutritional value and utilization of its by-products (Lee, 1999), and has become a major staple and cash crop for smallholder farmers in Africa (IITA, 2000). It is a source of food for about 90% of the population in Ghana (FARA, 2013), 900 million poor consumers and one third of all malnourished children (IITA & CIMMYT, 2010).

Maize is among the most important staple food grains for large parts of the world particularly in Africa, Latin America and Asia (Yaouba *et al.,* 2012). Maize is a multipurpose crop, providing food and fuel for human beings and feed for animals. Maize has great nutritional value and can be used as raw materials for manufacturing many industrial products (Afzal *et al.,* 2009). It accounts for about 15 to 56% of the total daily calories in diets of people in about 25 countries, particularly in Africa and Latin America, where animal protein is scarce and expensive (Orlyan, 1999). It is a source of food for humans, feed and fodder for livestocks and a raw material for industrial production of biofuel and ethanol (McCann, 2002; FAO, 2006). The fresh maize can be eaten either boiled or roasted.

In Ghana, maize is the most important cereal produced and widely consumed staple food with increasing production since 1965 (Morris *et al.*, 1999; FAO, 2008). Maize comprises a significant part of the diets of many of the inhabitants in Ghana, and is the most staple food for about 90% of the population with per capita consumption estimated at 44 kg/person/year, and an estimated national consumption of 943, 000 Mt in 2006 (SRID, 2007). Maize flour is used in making a variety of Ghanaian dishes such as banku, kenkey, corn bread, porridge, akple and tuozaafi. Its by-products such as the corn cobs and husk are used as components of household fuel and at times combines with fire wood as a source of energy for cooking purposes in farm households (Omane, 2013). It also plays a vital role in the economic development of most African countries, especially, Ghana. In Ghana, maize accounts for about 5060% of cereals produced, representing the second largest commodity apart from cocoa (GGDP, 2010). Maize is widely produced in all the ten regions in Ghana by vast majority of rural households, but the largest production occurs in Brong Ahafo, Ashanti and Eastern regions (MOFA, 2011). In the years 2009 through 2011, maize production in Ghana is averaged 1.7 million tons from about 990,000 hectares (MOFA, 2011).

In most African countries including Ghana, maize is one of the most important staple foods, but the crop is produced on a seasonal basis, and in many places there is only one harvest per year (FAO STAT, 2009). However, the demand and the consumption of the crop is normally spread over the whole year round. This necessitates the use of suitable and cost effective storage methods to store the excess in order to make the crop available round the year. In maize production, postharvest losses in storage constitute a major threat and challenge to producers as well as other stakeholders. It is estimated that between 20-40% maize grains is lost after harvest in storage in Ghana (Hill & Waller, 1990).

Maize grains storage is very important component in the economics of developing and developed countries alike, but developing countries suffer severe qualitative and quantitative postharvest losses due to the choice and use of storage methods (Sarangi *et al., 2009*). According to Abraham and Firdissa (1991), estimate of annual grains losses of over 50%, valued at 4 billion dollars, including maize have been reported. It is obvious from this background that the cost of preventing food losses is generally less than the cost of producing an additional quantity of food crop of the same quantity and value. Research has demonstrated that there are several reasons that lead to high deterioration and postharvest losses of maize grains in storage which include pests and rodents attack, amount of drying and storage methods and structures used.

The prevalence of inauspicious macro-environment and hardship in most African countries make it difficult to access improved technologies for preserving maize grains and compel maize producers and other stakeholders to use any available material to store maize grains, neglecting the effects that it will have on the grains. Lack of suitable storage methods also forces some farmers to sell all their harvested produce at very low prices in order to be relieved of problem of postharvest losses. This implies that there is the need to adopt suitable and effective storage methods that will help minimize qualitative and quantitative postharvest losses incurred in storage.

Several storage methods are used by maize producers in the Ejura-Sekyedumasi for the storage of maize grains in the municipality, but jute sacks, polypropylene sacks, heaping on floor, earthenware clay pots, plastic empty drums and baskets are the most commonly used methods. A preliminary field survey conducted prior to this study in Ejura-Sekyedumasi Municipality revealed that methods used by maize producers for the storage of maize had resulted in a lot of grain losses season after season. Some maize producers in the Municipality who do not store their maize grains due to anticipated losses in storage and, therefore, dispose of their harvested maize immediately after harvesting by selling them cheaply to consumers, retailers and wholesalers.

However, the effectiveness of storage methods used by maize producers in EjuraSekyedumasi Municipality for the storage of maize grains has not been sufficiently evaluated and reported. This has made it difficult for maize producers, retailers, wholesalers and other stakeholders of maize in the Municipality to make the appropriate choice of storage methods. And hence, this gap in knowledge needed to be addressed.

1.1 PROBLEM STATEMENT

Due to its increasing importance, maize has become a major staple and cash crop for small holder farmers and, has the potentials to be used as strategic grains for food security and poverty reduction (IITA, 2000; AUC, 2006). It is estimated that by 2015, the demand for maize in developing countries will double, and by 2025 maize will have become the crop with the greatest production globally (CIMMYT and IITA, 2010). For this vision to be realized, there is the need to resort to the use of suitable storage methods to store more of the produce. Nevertheless, the potential of maize to ensuring availability of food and as a strategic grain for food security and poverty reduction have not been fully materialized, since a substantial quantity of maize produced is lost due to inadequate postharvest management of which poor storage methods and structures used play major roles (Niarz and Dewar, 2009).

In most developing countries like Ghana, maize production and bulk storage of harvested maize is done by small-scale farmers themselves at the farm gates and in the farmers' residences, and the inauspicious of both macro-economic and financial forces compel farmers to use a variety of traditional methods such as the use of raised platforms on the farm, storage in synthetic fertilizer and jute bags, hanging over the kitchen hearth or fire, spreading and piling up on floor in both completed or uncompleted houses, in gourds and baskets. Farmers often make decisions on the types of storage methods to use based on affordability (Adetunji, 2007). Such methods are cheap to construct and use, but they are not effective in protecting stored maize grains from storage pests, predisposing them to various infestations leading to quantitative and qualitative losses (Obetta and Daniel, 2007). The use of inappropriate storage methods for maize storage does not only jeopardize the quantity of maize grains that the consumer can access, but also the quality of stored maize (Golob, 2004). A number of problems are encountered during storage from such methods. Such storage methods predispose sound and quality grains to various infestations from insects and rodents including mould infestations, leading to losses and reduction in the quality, food and economic value of the produce.

According to Omane (2013), the kind of storage methods used by farmers determine the susceptibility of the stored grains to insects, pests, rodents and other agents such as bad weather conditions that might cause the grains to deteriorate. A good storage method must be able to protect grains from insect pests, rodents and birds and also to maintain for the longer time as possible the initial quality conditions in which grains have been received (Hall, 1980). Traditional maize storage methods in Ghana contribute to food insecurity. However, there is a paucity of scientific information on the extent to which the various methods commonly used for maize grains affect the quality of stored maize. Hence this research was carried out in order to identify the commonly used storage methods for storing maize grains and also assess their effectiveness in maintaining the postharvest quality characteristics of stored maize grains.

1.2 JUSTIFICATION OF THE STUDY

The choice and usage of a particular storage method is influenced by the quantity of maize grains produced. According to Nicol *et al.* (1997) the use of various methods for storing maize grains tends to be specific to a climatic zone and also depends on the financial status of an individual and are constructed to meet the requirements of that particular area and the decision made to use a particular storage is methods based on affordability (Adetunji, 2007).

The use of various storage methods such as the raised platforms on the farm, storage in synthetic fertilizer and jute bags, hanging over the kitchen hearth or over the fire, spreading and piling up on floor in both completed or uncompleted houses, in gourds, in polyethylene sack and earthenware pots and in baskets for storing maize grains by most farmers in maize growing areas in Ghana who are constrained financially to access conventional storage facilities such as hermatic storage bags, leaves much to be desired. Although these methods are the only available storage options for smallholder farmers, little is known about their effectiveness in maintaining the nutritional and marketable quality of stored maize grains.

The seasonal nature of maize production in many African countries where one rainy season is experienced per year necessitates the requirement for good maize storage systems (Owusu *et al.*, 2007). Storage is considered as one of the most critical steps in postharvest that causes significant losses and insect and fungal infestation are amongst the factors that contribute remarkably to grain deterioration during storage.

According to International Journal of Sciences: Basic and Applied Research (IJSBAR) (2014), the main objective of grain storage is to maintain quality of the produce for a long period of time and the basic requirements of every grain storage structure or systems are to protect the grains from insects, rodents and prevent deterioration of the grains by the activities of micro-organisms. Safe storage is one that minimizes quantitative loss and maintains grain quality characteristics that may be expressed in terms of colour, malting quality and many others. Farmers in developing countries rely on traditional storage methods which expose grains to rodents and insect attack, and provide favourable climatic conditions for their proliferation, as well as for that of micro-organisms, thus leading to substantial postharvest losses (Ngamo *et al.,* 2007).

A survey conducted in twenty maize growing communities in Ejura-Sekyedumasi Municipality to identify methods commonly used by farmers for storing maize grains indicated that, majority (30%) of farmers stored maize grains in traditional storage methods, with or without grain protectants for a long period of time which leads to both qualitative and quantitative losses whilst only 3.5% of the farmers had access to the use of improved storage methods. Usually grain quality is evaluated on the basis of its weight, fungal contamination, insect infestation, nutritional content and many others. The deterioration in quality and quantity of maize grains in conventional storage methods used by farmers in Ejura-Sekyedumasi Municipality over long periods of time was not clearly known. Hence, the objective of the present study was to investigate the effects of commonly used storage methods, chemical treatments and storage period on the quality of stored maize grains and share the findings with rural and smallholder farmers who are constrained financially and technically to access newly introduced improved storage methods for maize grains storage, since maize grain quality is important for consumers' preference and producers' profitability.

1.3 MAIN OBJECTIVE OF THE STUDY

The main aim of this study was to identify and evaluate the effect of commonly used storage methods on the postharvest quality characteristics of maize grains in the

Ejura-Sekyedumasi Municipality.

1.4 SPECIFIC OBJECTIVES

1. To identify the commonly used storage methods available for maize storage in the study areas.
2. To evaluate the effect of each commonly used storage method on postharvest quality characteristics of stored maize grains.
3. To assess the duration of storage for the methods used
4. To ascertain the effects of each storage method on proximate and minerals composition of stored maize grains.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 ORIGIN, DISTRIBUTION AND PRODUCTION OF MAIZE

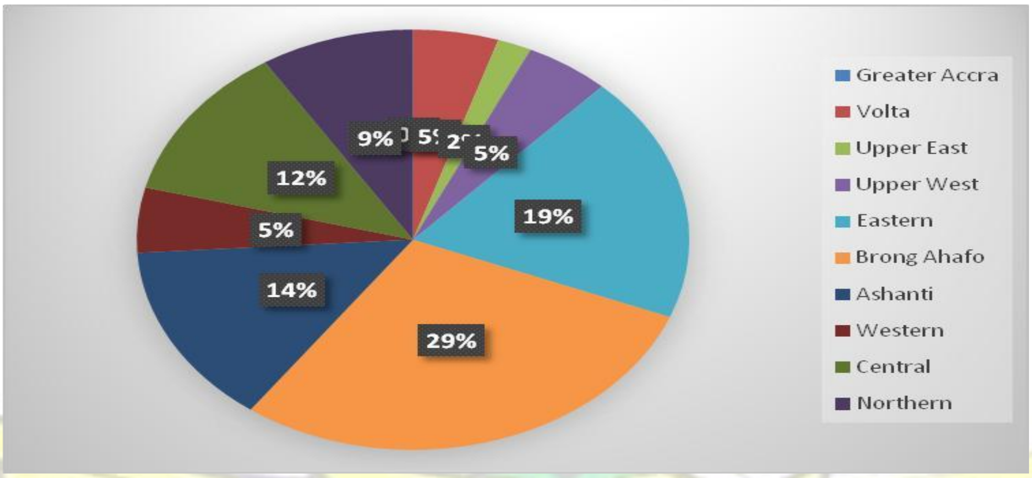
Maize, (*Zea mays* L.) is also known as corn in the United States, is the third most important cereal grain worldwide, after rice and wheat (Golob *et al.,* 2014). It is considered as one of the oldest human cultivated crops. It is generally believed that teosinte (*Zea Mexicana*) is an ancestor of maize (Galinat, 1988). Its centre of origin is believed to be the Mesoamerica region, at least 7000 years ago where it was produced as a wild grass called teosinte in the Mexican high lands (FAO, 2006). Raemaekers

(2001), remarked that maize belongs to eight genera. Three (3) of these are found in America and the remaining five (5) are Asiatic in distribution.

Maize is one of the most important grains after rice and wheat globally (Morris *et al.*, 1999; FAO, 2007). It is produced in more diverse areas of the world than any other grain crop. According to International Food Biotechnology Council (1990), maize is cultivated worldwide and represents a staple food for significant proportion of the world's population. The United States of America is the world's largest producer, exporter and consumer of maize (Kranja, 2003). It is reported that over 40 % of the world's total production of maize is produced by United States of America on about 21 % of the world's total area cropped (Kranja, 2003). Raemaekers (2001), reported that in Africa, the total annual maize production is about 25 million tons, which represents 7% of the world's production. Nigeria produces about 39 % of the total West Africa production with Cameroon, Cote d'lvoire, Ghana and Benin contributing a significant role in maize production.

In Ghana, maize is the number one crop in terms of area planted and accounts for 5060 % of total cereal production, and its annual production increased from 141, 000 metric tonnes in 1983 to 533,000metric tonnes in 1993 (PPMED, 1993) and currently stands at 1, 871, 700 metric tonnes (ISSER, 2011). Maize is the most cultivated crop in Ghana, occupying up to 1, 023, 000ha on arable land compared to rice (197, 000ha), millet (179, 000ha), sorghum (243, 000ha), cassava (889, 000ha), yam (204, 000ha) and plantain (336, 000ha) (SRID, 2007). Maize is produced in the ten regions in the country over a wide range of soils and ecological conditions. Maize is principally produced by smallholder farmers under rain-fed and tillage conditions (Amanor- Boadu, 2012). However, intensive and commercial production of maize in Ghana is concentrated in the middle Southern part (Brong Ahafo, Eastern and Ashanti provinces), where 80 % of maize of the maize is produced, with the remaining 16 % being produced in the Northern regions on the country (Northern, Upper East and Upper West provinces (GGDP, 1991, SRID, 2011).

Figure 2.1: Distribution of production of maize in Ghana by region over the period 2006-2010



Source: Ministry of Food and Agriculture, Statistics, Research and Information Directorate (SRID, 2013)

Table 2.1: Estimated average production and consumption in 12 selected countries in Sub-Saharan Africa (1998-2007)

Name of country	Maize production per annum (1000 tonnes)	Per capital consumption (kg) per annum	Total consumption per annum (1000 tonnes)
Angola	533	37.4	578.9
Cameroon	929	39.2	659.3
Ghana	1,142	40.7	842.7
Kenya	2,654	83.8	2810.2
Malawi	1,832	128.9	1506.3
Mozambique	1,164	57.3	1114.7
Nigeria	5,474	21.4	2924.8
South Africa	9,010	108.7	5056
Tanzania	3,161	112.5	2385.6
Uganda	1,153	27.5	726.3
Zambia	993	119.8	1326.9
Zimbabwe	1,321	114.5	1425.3

Source: FAOSTAT (2010 a, b).

2.2 MAIZE PRODUCTION AND POSTHARVEST LOSSES OF MAIZE IN EJURA-SEKYEDUMASI IN THE ASHANTI REGION OF GHANA

Ejura-Sekyedumasi Municipal is the leading producer of maize in the Ashanti region. According to DADU-SRID (2007), the municipal produces 28,861 tons of maize with an average yield of 2.14 Mt/ha from an estimated crop are of 13,486.44 ha.

Storage of crop is a major challenge in the municipal. Shelled maize grains are stored for some months after they are properly dried to acceptable moisture content and fumigated. Postharvest losses of maize produced in the municipality are estimated at 15-20% as a result of poor storage methods and structures used (DADU-SRID, 2007).

2.3 BOTANY OF MAIZE

Maize, (*Zea mays* L.) botanically belongs to the grass family Poaceae (formerly Gramineae). It is an annual monocotyledaneous plant with an extensive fibrous root system. Maize is a diploid species, with a chromosome number of 2n = 2x = 20 (Cai, 2006).

2.4 CHEMICAL COMPOSITION AND NUTRITIONAL VALUE OF MAIZE

In developing countries, importance of cereal grains especially maize is widely and highly recognized in human nutrition, as it provides substantial amounts of energy and protein to millions of people (FAO, 2011). Nuss and Tanumihardjo (2010) reported that maize grains provide an estimated 10% and 15% of the world's calories and protein respectively. Maize is a multipurpose grain. According to Ullah *et al.* (2010), maize is used directly as a human food, but provides even greater nutritional values when used as an ingredient in the food processing industry and the animal feeding industry.

Kulp and Joseph (2000) remarked that chemically, dried maize kernel contains about 10.4% moisture, 6.8% to 12% protein, 4% ash, 2.0% fiber and 72% to 74% carbohydrate.

Maize grains also contain macro and micronutrients such as calcium, phosphorus, iron, sodium, potassium, zinc, copper, magnesium and manganese, with 7 mg/100 g, 210 mg/100 g, 2.7 mg/100 g, 35 mg/100 g, 287 mg/100 g, 2.2 mg/100 g, 0.3 mg/100 g, 127 mg/100 g and 0.45 mg/100 g each , respectively in dry matter basis (db) (Nuss and Tanumihardjo, 2010). Maize also contains important vitamins such as thiamine 0.38 mg/100 g, riboflavin 0.20 mg/100 g and niacin 3.63 mg/100 g, pantothenic acid 0.42 mg/100 g and folate 19 µg/100 g, these vary due to variety, hybrid, growing seasons and soil conditions (Nuss and Tanumihardjo, 2010).

2.5 SOCIO-ECONOMIC IMPORTANCE OF MAIZE

Maize is an important commodity in the diet of most countries and Ghana in particular. It is a principal food crop in Africa, Asia, Latin America, and in some parts of the world (Li *et al.*, 2001).The importance of maize is judged by its area of production, wide variety of its uses, utilization, the role it plays as a staple food in the lives of poor people and share in trade (IITA, 2013). The crop is a primary feed grain in United States and contributes to more than 90% of total feed production and use (USDA, 2012), and in developing countries, it is directly consumed but serves as staple diet for some 200 million people in Africa (IITA, 2009).

Maize is a multipurpose crop used as food for human consumption, feed for animals and as a raw material for industrial production of starch, oil, ethanol as a substitute for petroleum based fuels (Vasal, 2000; Amin *et al.*, 2007). It is boiled or roasted fresh and eaten or milled in wet or dry form into dough or flour for various traditional meals such as kenkey, banku, akple and tuozaafi.

It is a good source of carbohydrate, rich in vitamin A, C and E, contains proteins such as tryptophan and lysine, minerals and fats (IITA, 2009; Onimisi *et al.*, 2009; Buah *et al.,* 2009).

Locally and internationally, the production, processing and sales of maize and its products serve as major means of occupation and income generation for thousands of people worldwide (Bourndillion *et al.* , 2003; USDA, 2009).

2.6 SOME IMPORTANT MAIZE POSTHARVEST PRACTICES

2.6.1 Drying

Moisture is known to the greatest enemy of maize grains after harvesting. Maize grains with high moisture or wet grains are susceptible to insects and mould infestations, and hence maize grains must be adequately dried as soon as possible after harvesting. Drying is described as the systematic reduction of moisture content in produce to safe levels for storage, usually 12-14.5% moisture content. Drying of grains permits the escape of moisture from grain moisture to an acceptable level, which can sustain very low metabolism. Grains can be dried in a crib before shelling and spread on tarpaulins after it has been shelled.

2.6.2 Shelling

Maize shelling involves the removal of grains from the maize cobs. Maize is normally shelled in Sub-Saharan Africa by smallholder farmers by beating maize cobs put in a sack or with the use of bare hands. The use of a maize shelter is preferred, but it cannot be afforded by most farmers (MOFA, 2009). Maize shelling is difficult at a moisture level content above 25%. More efficient shelling is achieved when the grains have been suitably dried to 13-14% moisture content. Maize is shelled in order to reduce required storage space capacity and also to facilitate effective application of insecticides. The act of beating maize cobs with sticks with the view to shelling causes physical damages to maize grains which renders the grains easier for insect penetration and moisture absorption.

2.6.3 Storage

The main objective in any maize grain storage system is to preserve the stored grains in a good condition in order to prevent deterioration both in quantity and quality. Maize grains can be stored up to two (2) years without any significant reduction and deterioration in quantity and quality provided the storage is done using effective and good storage methods. According to Komen *et al.* (2006) substantial quantity of maize is lost in storage in Sub-Saharan Africa due to the use of poor and primitive storage methods and techniques. A good storage method should protect stored maize grains from common storage loss agents such as rodents, insect pests, moulds and birds and also should not allow re-wetting of grains by moisture migration (MOFA, 2009).

2.7 COMMONLY USED METHODS OF STORING MAIZE

Producers, both wholesalers and retailers, traders and other stakeholders usually store maize grains using different methods in order to prevent insect pests damage. The quantity of maize produced in a season, duration of storage and the expected future price influence the type of storage method used (Owusu, 1981). Different types of storage methods are used to store maize in Ghana and differ from region to region based locally available materials. The inauspicious nature of the micro economy and the poor status of smallholder farm households lead them to use maize storage methods which are cheap regardless of their nature, consequently most o the grain losses occur during storage (Obetta & Daniel, 2007). Some producers who cannot store their grains due to anticipated losses during storage dispose them through selling at cheap prices soon after harvesting (MOFA, 2009). Farmers in Sub-Saharan Africa including Ghana, producers, wholesalers and retailers and other stakeholders, still their grains in baskets, gourds, earthenware clay pots, empty drums, bans, cribs, calabashes, bags, sacks and on floor in their houses (Nicol *et al.*, 1997; Komen *et al.*, 2006). These storage methods results in a lot of grain losses due to the poor conditions that these methods present.

Commonly used methods for storing maize in the study includes: heap or pile on floor, jute sacks, polypropylene sack (synthetic fertilizer sack), hermetic triple-layer bags, earthenware clay pots, gourds, over kitchen fire or hearth, roof storage and empty drums.

2.7.1 Jute sacks

These are sacks made of woven jute, cotton, sisal or local grass. Storage of maize in jute sacks is widely used in villages' level, farms and in commercial storage centres, and they can store up to 100 kg of grains and provides the farmer with ease of access to stored grains (Lindblad and Druben, 1976). However, jute sacks can easily be damaged by insects which would expose stored maize grains to rodents infestation.

2.7.2 Polypropylene sacks

Polypropylene sacks (fertilizer sacks) are made by knitting of synthetic fibres. Such sacks have least ability to absorb or transfer heat or moisture, but the pores in such sacks allow stored grains to exchange moisture and heat with the immediate surroundings.

2.7.3 Storage baskets

These are traditional storage methods made of reeds, elephant grass, bamboo, palm branches or sorghum stalks through weaving. Storage baskets can be plastered in order to make them somewhat air-tight (FAO, 1994), and can last provided they are not exposed to moisture (Shepherd, 2010). Storage baskets are cheap to make, since they are made using locally available materials, and they can hold up to 100 kg of maize grains (Lindblad and Druben, 1976). Furthermore, storage baskets have good ventilation and aeration, and as such may not be conducive for moulds growth. However, storage baskets have limited capacity and not economically conducive for the storage of large quantities of maize.

2.7.4 Earthenware clay pots

Earthenware clay pots are of hardened clay which are heated for several hours. Large pots are multipurpose storage facilities. Such pots are used to store small quantities of grains (Lemma, 2006). Earthenware clay pots are small in size and these make them inefficient for storage of large quantities of grains. Also, earthenware clay pots have high fragility and limited capacity.

2.7.5 Metal silos

Metal silos are made of metal sheets. Depending on their sizes, metal silos can store up to 4000 tonnes of grains (Ikisan, 2000). Maize stored in metal silos is not easily attacked by pests and is less infested by moulds since they cannot be damaged by pests and rodents. However, metal silos being good conductors of heat, heat can easily flows through them which can result in build of heat when exposed to heat (Villiers *et al.*, 2006). Also, in metal silos, condensation can occur when temperatures drop, which can result in moisture content problems and cause favourable conditions for infestations (Villiers *et al.*, 2006). Again, metal silos are expensive and poor and smallholder farmers in Africa may not be able to afford it.

2.7.6 Floor storage

Rooms in living houses of both completed and uncompleted houses are set aside for maize storage both in dehusked and shelled or in undehusked forms. Taupauline or polyethene bags are spread on cemented floor before maize are heaped or piled on the floor. Constantly, the piled or heaped maize turned to allow air circulation (Udoh *et al.*, 2000). Floor storage of encourages growth of moulds which can easily leads to aflatoxin infection resulting from high moisture. Furthermore, insect pests and rodents can easily damage the stored grains.

2.7.7 Suspensions above the fire place or kitchen hearth or fire

Farmers usually hang undehusked maize on beams or sticks erected above the kitchen fire (Lemma, 2006; UNIFEM, 1995). This method allows permits drying of maize as a result of smoke and heat from the fire place. The heat and smoke from the fire beneath it can also protect stored maize from insect pests (UNIFEM, 1995). However, this storage method has been criticized for impacting negatively on the physical appearance, taste and colour of stored maize grains.

2.7.8 Hermetic triple layer storage sacks

The triple layer hermetic storage bag was developed by Purdue University and partners to control the cowpea bruchid *Callosobruchus maculates*, but also used for other pulses and cereals (Villers *et al.*, 2006; IITA, 2010). It consists of two sealed plastic bags placed inside a third bag which is made of woven polypropylene or nylon to give additional strength and protection (Amankware *et al.*, 2012). According to IITA (2010), the bag does not use any of the chemicals that are normally misused and overused which cause health hazards. This technology is being widely used since it is simple, effective and profitable to farmers and other users.

2.8 POSTHARVEST CONSTRAINTS AND LOSSES OF MAIZE

A major constraint and setback to the increased and sustained maize in Ghana is high incidence of postharvest grain losses in storage. According to Centre for Agricultural and Rural Cooperation (2014), postharvest loss of maize in Ghana is estimated at 35% which is of great concern to producers and other stakeholders. Research has shown that these postharvest losses occur in the form of weight, nutritional, quality, colour and economic losses. These losses occur at all stages of the postharvest handling, including pre-processing, transportation, storage, processing, marketing and utilization. Poor storage management, unfavourable environmental conditions, inherent grain quality characteristics and ineffective storage methods are responsible for high postharvest losses of maize grains during storage.

2.8.1 Factors and causes of maize grain losses in storage

The main factors or agents which are responsible for postharvest losses in maize are classified as physical, biological, socio-economic, engineering and mechanical factors (Odeyemi & Daramola, 2000).

Temperature and moisture content are considered as the most important physical factors which greatly contribute to maize postharvest losses in storage. Temperature considerably influences the respiration rate of stored products, relative humidity, insect pests proliferation and moisture content. The temperature conditions in tropical and sub-tropical zones create optimum conditions for insect pests infestations in stored maize grains.

2.8.1.1 Moisture

Even with the adoption of good storage management and use of effective storage method, high grain moisture content, stored maize grains cannot be kept from deterioration. Harvested produce contain water in different proportions, and this moisture content fluctuate with time during storage. It is imperative that all harvested produce are stored below their safe moisture content prior to storage in order to prevent creation of conditions which are conducive for micro-organisms to survive and multiply. Higher moisture content is favourable for pest infestation, fungal and mould growth (Tilahun, 2007).

2.8.1.2 Temperature

2.8.2.1 Biological factors that cause postharvest losses of maize grains in storage

Micro-organisms such as fungi and mould, insect pests, rodents and birds are biological factors responsible for causing postharvest losses of maize grains in storage. Their eating activities coupled with urine, body frass and droppings contaminate and result in loss and spoilage of maize grains. Infestations of maize grains by insects pests and other micro-organisms results in release of toxic substances, which alters the food values and the palatability of the maize grains

(Fekadu, 2007).

2.8.2.2 Mechanical and engineering factors that cause postharvest losses of maize grains in storage

Improper drying and the use of ineffective methods of storage are the two most important factors of mechanical and engineering factors that influence postharvest losses of maize grains during storage. Maize grains drying to a safe moisture content is an essential component of a storage system, which helps long term storage (Fekadu, 2007).

Improper drying of maize grains prior to storage leads to build up of heat in the grains. Heat build in stored grains provides excellent growth conditions for insect pests infestations and growth of mould leading to deterioration in quality. Also, improper drying of maize grains before results in discoloration during storage. Discolored grains drastically reduce sensory characteristics and market value of maize grains. However, discoloration is a complex biochemical process, it be avoided by adequate and timely drying of maize grains before storage.

The main objective in any maize grains storage system is to preserve and maintain the stored grains in a good condition with the view to avoiding quality and quantity deterioration. However, farmers in Sub-Saharan African still adopt primitive storage methods and techniques which are not effective to protect stored maize grains from storage losses (Koment *et al*,. 2006). These storage methods are not effective to provide protection from common storage loss agents such as insect pests, rodents and moulds. Poor storage methods used in maize grain storage predispose the stored grains to conditions lead to contamination and pest damage, resulting in huge losses both in quality and quantity.

2.9 STORAGE PESTS OF MAIZE GRAINS

In Sub-Saharan Africa, the greatest setback during maize storage is that it is susceptible pests to attack, of which insect pests (Makate, 2010), moulds (Weinberg *et al.*, 2009) and rodents (IRRI & CIMMYT, 2009). The attack of stored maize by these pests is associated with loss of millions of tonnes of maize quality as a result of reduction in the nutrient content (Jood *et al.*, 1992).

2.9.1 Insect pests of stored maize grains

The most important insect pests in Sub-Saharan African associated with maize storage include the maize weevils (*Sitophilus zeamais, Sitophilus oryzae and Sitophilus granaries*) and the larger grain borer (*Prostephanus truncatus*), and are known to cause losses of 10-20% within 3 months and 40% within 6 months of storage respectively (Lamboni & Hell, 2009; Boxall, 2002; Tefera *et al.*, 2011). The infestation of maize by these insect pests commences in the field, but most damage is done during storage (Yuya *et al.*, 2009). These storage pests impact negatively in significant maize grain losses, in both quantity and quality in storage. The maize weevils and the larger grain borer cause severe damages to maize by damaging the grains kernel through their feeding and boring activities, making the kernels more susceptible to mould infestations (Sallam, 1999).These storage insect pests reduce the nutritional value of stored maize grains by feeding on the nutrient rich germ and the outer layer of the maize grain kernels. Also, maize weevils and the larger grain borer (*Sitophilus zeamais, Sitophilus oryzae and Sitophilus granaries*) and the larger grain borer (*Prostephanus truncatus)* affect the quality of maize grains by contaminating the stored maize with their wastes, which may further results in interference with odour, colour and taste of the maize grains, hence affect the quality (Wright, 2011).

2.9.2 Rodents

Rodents are another pest to stored maize. Three types of rodents are known to cause significant losses in maize grains, both in quality and quantity. These are black rats (*Rattus rattus*), brown rats (*Rattus norvegicus*) and house mice (*Mussmus callus*) (De groote, 1996). Depending on their species, rodents are known to consume considerable produce per day. It is estimated that about 15% of maize produced in Africa is lost to rodents alone each year (Stenseth *et al.*, 2003). According to Cao *et al.* (2002), rodents make holes in storage containers, and through this create moisture problems in the stored products and contaminate food grains with their excretions and hair. Rodents consume the most nutritious parts of maize grains, thus, causing reduction in the protein and vitamin contents of the grains.

2.9.3 Grain Protectants Used for Maize Grain Storage

2.9.3 1 Actellic super

Actellic super is a broad spectrum in insecticide of low mammalian toxicity with stomach and contact fumigant activity against pests of stored grains. Actellic super contains 0.3 % permethrin and 1.6 % pirimiphos methyl as the main active ingredients (Dale & Golob, 1997). The pyrethroid compound in it effectively kills *P. trucatus* and the pirimiphos methyl, being an organophosphate controls *S. zeamis* and other pest populations when applied at the rate of 100 per 90 kg of maize. For shelled maize grains, it is applied at 50 g for every 90 kg bag of grains.

2.9.3.2 Phostoxin tablets

Phostoxin tablet is another effective fumigant for storing insect pests of stored maize grains. Fumigation with phostoxin gas is done at the rate of 1-2 tablets per 100 kg of grains. The tablet during its application is wrapped in piece of cloth or tissue paper before it is placed inside container for storage, and treatment should be repeated after 4-6 months (Adejumo & Raji, 2007).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 INTRODUCTION

The research was conducted in two phases. The first phase was a survey research which involved field observation and questionnaire administration and the second phase was at the laboratory where storage experiment, determination of grain quality characteristics, proximate and mineral composition analysis were done.

3.2 SURVEY

A preliminary field survey was conducted to sample views from maize producers on maize storage methods used for storing maize grains. Areas in the Ejura-Sekyedumasi Municipality where commercial production and storage of maize occur well were identified. The survey targeted maize farmers in the Municipality who produce and store maize.

3.3 STUDY AREA

The survey was conducted in the Ejura-Sekyedumasi Municipality in the Ashanti region of Ghana.

3.4 PROFILE OF THE STUDY AREA

The Ejura-Sekyedumasi Municipality is located in the northern part of the Ashanti region, and it shares boundries with Atebubu-Amantin District to the Northwest, Mampong Municipality to the East, Sekyere South District to the South and Offinso Municipality to the West. Ejura-Sekyedumasi Municipality is located within Longitudes 1^0 5W and $1^0$39'W and Latitudes 7^0 9'N and $7^0$36'N. The municipal has its capital at Ejura, which is located approximately 98 km Northwest of Kumasi, the capital of Ashanti region (ESDA, 2008). It has a population of 101, 826 (GSS, 2010). The municipality has a total land area of 1340.1 km^2 and constitutes about 7.3% of the region's total land area. The municipality has two rainfall patterns; bi-modal pattern in the South and uni-modal pattern in the North. The main rainy season is between April and November, and dry season span from October to March. It has an annual rainfall which varies between 1,200 mm and 1,500 mm. Agriculture is the leading sector in terms of employment and income generation in the municipality. Several types of crops are produced in the municipality. Prominent among them are maize, yam, beans, rice, plantain, cassava and groundnuts. Crops are grown mostly for subsistence purposes. However, crops such as maize, beans and watermelon are produced mainly for commercial purposes (Ghana Statistical Service, 2010).

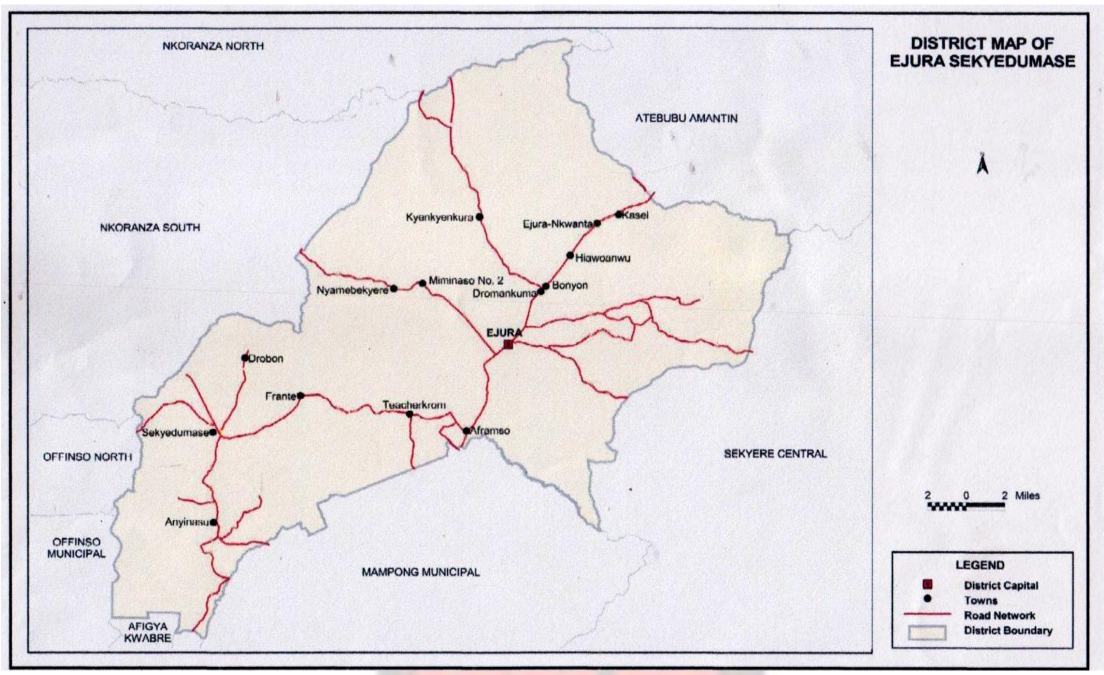


Figure: 3.1 Map of the study area

3.5 FIELD WORK AND DATA COLLECTION

A preliminary field survey was conducted in farming communities in EjuraSekyedumasi Municipality in order to obtain first-hand information in areas where farmers intensively produce and store maize. The field survey was done with the assistance of trained extension personnels who resided in the municipality. The field survey was then followed by identification and selection of communities for the study.

3.6 COMMUNITIES SELECTED FOR THE STUDY

Stratified sampling method was used to group the communities in the Municipality into maize producing and non-producing areas. Purposive sampling technique was then used to select twenty (20) communities in the Municipality where commercial production and storage of maize normally occur for the study. The communities were:

Ejura, Sekyedumasi, Anyinasu, Hianwoanwu, Dromankoma, Frante, Kasei, Ejura Nkwanta, Bonyon, Aframso, Osei krom, Drobon, Bemi beposo, Makyere akura, Teacher krom, Kyenkyenkura, Nyamebekyere, Miminaso no.2, Dukukrom Basare akura and Sarkyikura. These communities were selected for the study because they are major maize growing areas in Ejura-Sekyedumasi Municipality.

3.7 TARGET GROUP AND SAMPLE SIZE

The research study targeted only maize producers in the Municipality. A total of two hundred (200) maize farmers were selected from the twenty (20) communities chosen and used as the sample size for the study. Ten (10) maize farmers each from the 20 communities selected were randomly chosen to avoid bias.

3.8 METHODS

3.8.1 Questionnaire Design and Administration

Having conducted a preliminary survey in Ejura-Sekyedumasi Municipality between the months of August and September, 2014, questionnaires were designed for administration. Both closed and open-ended questions were structured and administered to two hundred (200) maize producers selected from the municipality. The questionnaires were administered by interviewing the selected respondents and writing down the responses accordingly. Some of the major aspects captured in the questionnaires included respondents background, years of experience in farming, postharvest operations and practices in maize farming, storage structures and methods used for storing maize grains, duration of storage, challenges encountered during storage and farmers knowledge about postharvest losses.

3.8.2 Preliminary laboratory work

Samples of the most commonly grown improved maize variety Obatanpa, was then purchased from the farmers. Samples of the maize grains were taken to Grains

Development Board Unit of certified seed growers department under the Ministry of Food and Agriculture, at Asuoyeboah, Kumasi for identification and also had the moisture content determined.

3.9 LABORATORY EXPERIMENT AND EXPERIMENTAL SITE

The laboratory experiment mainly involved the storage of maize grains for a period of 4 months. The experiment commenced from December, 2014 to April, 2015. This was carried out in the Laboratory of the Department of Horticulture, at the Kwame Nkrumah University of Science and Technology, Kumasi.

3.9.1 Source of grain samples

Maize grain used for the laboratory experiment in the study was Obatanpa. Samples of grains were sourced from a single farmer in one of those 20 maize growing communities selected for the study during the field survey carried out.

3.9.2 Samples preparation and conditioning

In the laboratory, the grain samples were manually cleaned and sieved to any fluffy material, for example debris, straw and stones. The grains were thoroughly fumigated in order to any hidden infestation.

3.9.3 Baseline information

Prior to the commencement of the laboratory experiment, samples of the maize grains were analyzed for parameters such as grain moisture, weight of 1000 grains, grain damage per 200 grains, grain colour, grain odour and insect infestation. Also, the following proximate compositions: carbohydrate content, crude protein, crude fibre content, moisture content, crude fat content and mineral ash content were assessed. This was done in the laboratory of Department of Horticulture, KNUST and Centre for

Scientific and Industrial Research – Crop Research Institute (CSIR-CRI), Fomesua. These data were used as the baseline reference for comparison with the studied parameters which were evaluated on monthly bases during the study.

3.10 EXPERIMENTAL DESIGN AND TREATMENTS

The experimental design was 6 x 2 x 4 factorial laid in a Completely Randomized Design (CRD) with three replications. The experiment had factors at different levels.

These were:

Factor: A, was storage method at six (6) levels which consisted of:

i. polypropylene sack ii.
jute sack iii. heap on
floor method iv. empty
plastic drum
v. triple-layer hermetic bag vi.
clay pot

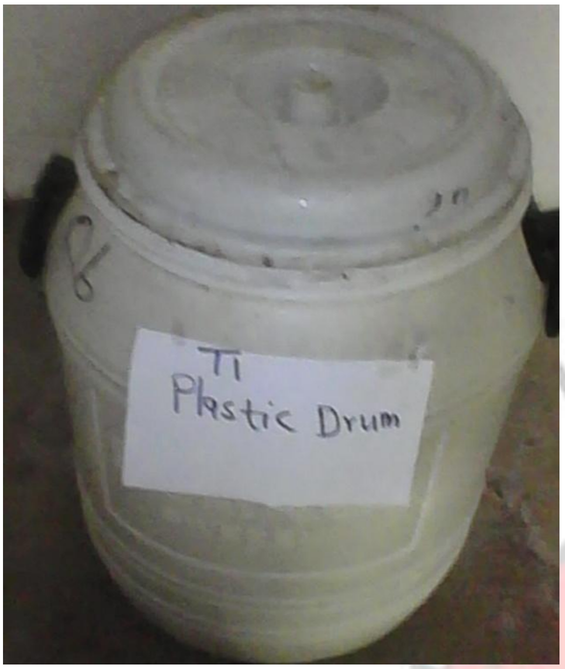
Factor**:** B, two grain protectants which were: Actellic super and phostoxin

Factor: C, was storage durations in months at four levels which were:

i. 1 month ii.
2 months iii.
3 months iv.
4 months.

3.11 DESCRIPTION OF THE LABORATORY EXPERIMENT

The maize variety used for the study was Obatanpa. Obatanpa is an improved maize variety released to farmers by the Ministry of Food and Agriculture, which was identified as the most widely and commonly grown by farmers in Ejura-Sekyedumasi Municipality. One eighty kilograms (180 kg) of Obatanpa was purchased from farmers who were randomly selected for interview during the preliminary field survey carried out. All the maize grains used was purchased from only one farmer. This was done in order to eliminate variability which could be attributed to differences in production, harvesting and postharvest handling method used. The initial moisture content of the maize variety used for the experiment was 12.8%. The triple-layer hermetic bags, Actellic super and the Phostoxin were procured from Wompene Chemicals, a private based agrochemical shop in Tamale in the Northern region of Ghana. The clay pots, polypropylene sacks and the plastic drums were also purchased from shops in Central Market, Kumasi in the Ashanti region of Ghana. Five (5) kilograms Obatanpa was put in each of the six storage methods for storage. Actellic
Super, 5 mg/5 kg of grains was applied in each treatment. Similarly, 0.25 g of Phostoxin was wrapped in a piece of cloth and placed inside 5 kg of maize grains stored in each method. All the storage methods were tightly sealed with ropes, except the heaping on the floor and stored under ambient conditions for a period of four (4) months from December, 2014 to April, 2015.



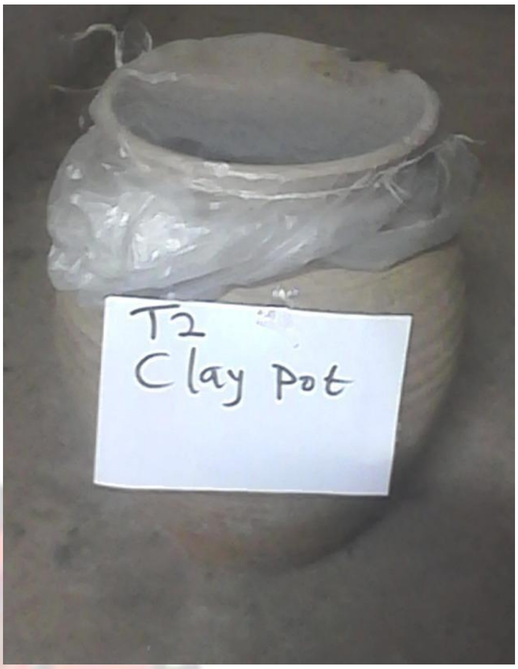


Plate 3.1: Plastic Drum **Plate 3.2: Clay Pot**

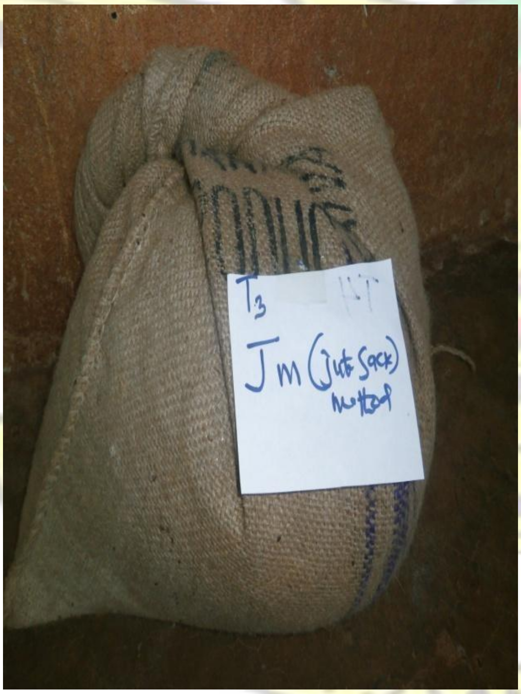


Plate 3.3: Jute Sack **Plate 3.4: Polypropylene Sack**

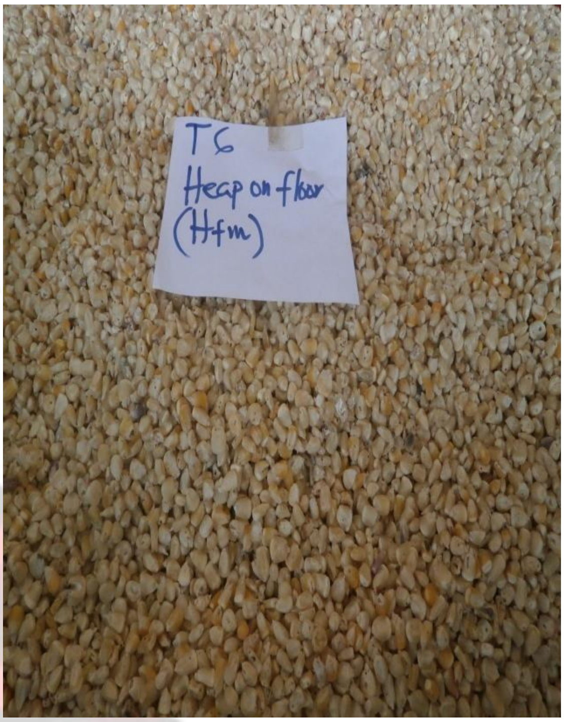


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Plate 3.5: Triple Hermetic Bag **Plate 3.6: Heap on floor**

3.12 PARAMETERS STUDIED AND DATA COLLECTION

Data was collected on the following parameter assessed during and after the study: Percentage weight loss per 1000 grains, percentage grains damage per 200 grains, grain colour change, grain odour change, number of live insects per kilogram of grains responsible for grain damage, moisture content, storage temperature and relative humidity, moisture content and proximate composition analyses which included total carbohydrate content, crude protein content, crude fibre content, mineral content, ash content and moisture content using AOAC (2000) methods.

3.12.1 Weekly Determination of Storage Environment Temperature and Relative Humidity

The ambient storage temperature and relative humidity in the storage environment was measured on weekly basis in the course of the study with the aid of portable digital thermo-hydrometer (EXTECH 44550 Pocket Humidity, made in China) at 3:00 pm.

3.12.2 Monthly Determination of Grain Moisture Content (%)

The grain moisture content was determined in each grain sample by drying a 2 g sample in a thermostatically controlled oven (Gallenkamp, model OV 88O, made in England) at 105^0C for 5 hours till to constant weight. The procedure of AACCC (2000) method No. 44-15A was followed for the determination of moisture in each sample. The moisture content of the grain samples was determined on a weight basis using the formula below: Moisture content (%) =

$$\frac{\text{Weight of grain sample} - \text{weight of dried grain sample}}{\text{Weight of the grain sample}} \times 100.$$

3.12.3 Determination of Change in Weight per 1000 Grains

Destructive sub-samples of grains were taken randomly from each treatment and assessed for weight loss every one for a period of 4 months. Two hundred grams of grains were accurately weighed using a weighing scale (Camry model, made in China). The weight and number of insect damaged and undamaged grains were assessed and used to determine the percentage grain weight loss using the method described by Gwinner *et al.* (1996).

Weight loss (%) = UNd – DNu x 100/U (Nd + Nu).

Where U = weight of undamaged grains; D = weight of insect damaged grains; Nu = number of undamaged grains and Nd = number of damaged grains.

3.12.4 Determination of Grain Colour Change

Colour changes of maize grains in each storage method was carefully monitored observed on monthly basis using a modified scale developed by *Ogendo et al.*,(2004). The scale used had scoring scale of 1- 5 as follows:

i. No detectable change, grain is naturally white with a few yellow/ red grains.

ii. Slight changes, which is ≤ 5% from natural white/yellow/red to light brown. iii. Moderate change, > 5 to 30 % from natural white/yellow/red to light brown iv. Great change, thus, 30 to 50 % from natural white/yellow/red to dark brown.

v. Highly significant change, thus, > 50% making grain unacceptable for human consumption.

3.12.5 Determination of Grain Damage per 200 Grains

Insect damage grain was determined by the counting method as described by Wambugu *et al.* (2000). Monthly destructive samplings of 200 grains were randomly taken from each storage method, and the number of grains damaged by insect pests was manually counted. Grains with emergence holes were counted as damage, and the percentage grain damage was calculated with the help of the formula,

% GD = D1/D2 X 100, where D1 is the number of grains with holes and D2 is the total number of grains counted.

3.12.6 Determination of Number of Insects per Kilogram Of Grains

A procedure devised by Chikuku *et al.* (2011) with modification was used to estimate insect infestations in the experiment. A kilogram (1 kg) of maize grains was randomly weighed from each storage method using a weighing scale (Camry, made in China) and thoroughly sieved out insects within the grains. Insects obtained from the sieved grains were manually counted and recorded after one month for a period of 4 months.

3.12.7 Grain Odour Change Determination

The change in grain odour due to the effects of chemicals and storage methods used was assessed for every month for four months. This was done using a scoring scale devised Ogendo *et al.*, (2004). The following were the scales used to determine the change in grain odour:

1) No difference in grain odour
2) Grain has little offensive odour
3) Grain has moderately offensive odour
4) Grain has offensive odour
5) Grain has very offensive odour

3.12.8 Proximate Composition Analysis of Grain Samples from each Storage Method

The proximate composition analysis which included total carbohydrate content, crude protein content, crude fibre content, mineral content, ash content and moisture content of samples of grains from each storage method was carried out the standard methods recommended by AOAC (2002).

3.12.8.1 Determination of grain moisture content

The moisture content was determined by weighing hundred grams (2 g) of grain samples from each storage method into a previously cleaned, dried and weighed glass crucible. The glass crucible together with its content was put into a thermostatically controlled oven (Gallenkamp, model OV 88O, made in England) at 105^{0}C for 5 hours.

The sample was then reweighed after it was cooled in a desiccator. The moisture content was then expressed as percentage of the dry weight using the formula,

$$\% \text{ moisture content} = \frac{\text{Weight of grain sample} - \text{weight of dried grain sample}}{\text{Weight of the grain sample}} \times 100.$$

3.12.8.2 Ash content determination

A dried sample of 10 g was weighed into a dry and previously weighed porcelain dish and then placed in a muffle furnace for heating at 600^0C for 6 hours for ashing. It was later cooled in a desiccator and then weighed. The percentage ash content was determined as:

$$\% \text{ Ash} == \frac{\text{Weight of ash}}{\text{Weight of sample}} \times 100.$$

3.12.8.3 Determination of crude fat content

Ten (10 g) of grain sample dried for the determination of moisture content was weighed and transferred into a paper thimble, which was plugged at the opening with cotton wool and then placed into a thimble holder. The thimble was transferred into a Soxhlet extractor and petroleum ether was weighed into a dried and weighed flask. The extraction flask was placed on low heat on a heating mantle for 3 hours. The flask was then removed and the solvent evaporated on a steam bath. The flask with the fat was again heated at100^0C for 20 minutes in an oven, and cooled in desiccators and weighed. The fat produced was determined and expressed as percentage of original sample.

Thus, $\% \text{ Fat} = \frac{\text{Weight loss of sample (extracted fat)}}{\text{Sample weight}}$

3.12.8.4 Determination of crude protein content

Ten grams (10 g) of maize samples from each storage method was weighed into a digestion flask with small amount of potassium sulphate and mercuric oxide. Twenty five (25ml) concentrated sulphuric acid was added to the samples in the digestion flask and the contents were well shaken until the whole samples were thoroughly wet. The flask was placed on digestion burner in a fume chamber and heated till the solution became clear. The resulting solution was then cooled at room temperature and the digested sample solutions transferred into a 100ml volumetric flask and topped up to the mark.

The distillation apparatus was flushed with distilled water for 10 minutes, and 25ml of boric acid was poured into a 250 ml conical flask and 3 drops of mixed indicator added, changing the solution pink. The conical flask together with its content was placed under the condenser with the tip of the condenser totally immersed in boric acid solution. 10ml of the digested sample solutions and about 40% solution of NaOH was transferred into the decomposition flask and the funnel stopcock well closed. The ammonia (NH_3) liberated during the distillation process which was absorbed on boric acid was titrated against 0.1M hydrochloric acid (HCl) until the solution changed from bluish green to pink. The end point was noted and the titre values obtained were used to calculate the total nitrogen and the percentage crude protein as:

$$\% N = \frac{\text{Volume of acid x Molarity of standard acid x 0.014 x 100}}{\text{Weight of sample (g)}}$$

% Crude protein content = nitrogen content x 6.25

3.12.8.5 Total Carbohydrate

The total carbohydrate was determined by differential method. This was done by subtracting the total protein, lipid, moisture and ash content from 100. Thus, % carbohydrate – (% moisture + % ash + % fat + % protein + % fibre

3.13 DATA ANALYSIS

The analysis of data was done in two ways. The data collected on the field survey conducted was analysed with Statistical Package for the Social Sciences (SPSS) Version 16.0.

Laboratory data was analysed using Statistix 9.0 software (Student Edition) and the means for significant factors were compared using Tukey Highest Significant Difference (HSD) test and significance was accepted at 1%.

CHAPTER FOUR

4.0 RESULTS

4.1 INTRODUCTION

This chapter presents the findings, analysis and the interpretations of the research conducted. The first section of this chapter constitutes the socio-demographic characteristics of respondents. The socio-demographic characteristics presented here are gender, age, educational levels of respondents, level of production, storage methods adopted and general knowledge on postharvest losses and control measures in maize production. The analysis of the socio-demographic characteristics has been summarized in tables, charts and in graphs. A total of 200 farmers and producers who were randomly selected from twenty maize producing communities in Ejura Sekyeredumasi Municipal were involved in completing questionnaires to ascertain background information.

The second part of this chapter gives the results of postharvest quality characteristics of maize grains conducted in the laboratory. It also contains results of proximate analysis conducted.

4.2. BASELINE SURVEY

4.2.1 Gender distribution of Respondents

Data on the sex of two hundred (200) respondents that were interviewed showed that males dominated in the production of maize with 78.5% against 21.5% of the females (Table 4.1). This implies that males the majority of farmlands are owned by males, hence dominated in the production of maize in the municipality.

Table 4.1: Gender Distribution of Respondent

Gender	Frequency	Percentage	Valid Percent	Cumulative
MALE	157	78.5	78.5	78.5
FEMALE	43	21.5	21.5	100.0
Total	200	100.0	100.0	

4.2.2 Ages of Respondents

The ages of respondents ranged from 18 years to 50 years and above. The results showed that majority of respondents (46.5%) in the study area were between 31- 40 years while the least (6%) were above 50 years old. Also, 33.5% of the respondents were between 41-50 and 14% between 30 years, (Table 4. 2). This implies that majority of the respondents were in their youthful and productive ages, hence greater participation in maize production.

Table 4.2: Ages of Respondents

Ages (years)	Number of respondents	Percentage (%)
18 – 30	28	14.0
31 – 40	93	46.5
41 – 50	67	33.5
Above 50	12	6.0
Total	200	100

4.2.3 Educational background of Respondents

Regarding educational level, majority of the respondents (51%) had no formal education, 39% basic education, 8.5% secondary education and the remaining 1.5% tertiary education.

Table 4.3: level of education of respondents

Level of education	Frequency	Percent	Valid Percent	Cumulative
No formal education	102	51.0	51.0	51.0
Basic education	78	39.0	39.0	90.0
Secondary	17	8.5	8.5	98.5
Tertiary	3	1.5	1.5	100.0

Total	200	100.0	100.0

4.2.4 Farming experience of Respondents

The study revealed that majority of the farmers (58.8%) had practiced farming between 6- 10 years and the least percentage of farmers (11%) had between 1-5 years' experience in farming (Table 4.4).

Table 4.4: Farming experience of respondents

Experience in farming	Frequency	Percent	Valid Percent	Cumulative
1 – 5 years	22	11.0	11.0	11.0
6 – 10 years	117	58.5	58.5	69.5
Above 10 years	61	30.5	30.5	100.0
Total	200	100.0	100.0	

4.2.5 Farm sizes of Respondents

Table 4.5 shows that majority of the respondents (75%) used 6-10 acres of land for production of maize while about 16% had access to 1-5 acres of land. Also, 9% of the farmers used more than 10 acres of land for cultivation of maize.

Table 4.5: Farm sizes of respondents

Farm size (acres)	Frequency	Percent	Valid Percent	Cumulative
1-5 acres	32	16.0	16.0	16.0
6 – 10 acres	150	75.0	75.0	19.0

Above 10 acres	18	9.0	9.0	100.0
Total	200	100.0	100.0	

4.2.6 Varieties of maize grown by respondents

Though a number of maize varieties are grown in the study area, the survey revealed that Obatanpa was commonly grown by majority (59%) of the sampled farmers followed by Mamaba variety (32%) as shown in Table 4.6.

Table 4.6: Most popularly maize varieties produced by respondents

Maize variety	Frequency	Percent	Valid Percent	Cumulative Percent
Mamaba	65	32.5	32.5	32.5
Obatanpa	118	59.0	59.0	91.5
Others	17	8.5	8.5	100.0
Total	200	100.0	100.0	

4.2.7 Forms of maize storage

The survey results indicated that 67% of respondents stored their maize grains in shelled form, 21.5% stored maize in dehusked cob, while 11.5 % stored maize in undehusked cob as shown in table 4.7.

Table 4.7: Forms of maize storage practised by respondents

Forms of maize storage	Frequency	Percent	Valid Percent	Cumulative
Dehusked cob	43	21.5	21.5	21.5

Shelled grains	143	67.0	67.0	88.5
Undehusked cob	23	11.5	11.5	100.0
Total	200	100.0	100.0	

4.2.8 Reasons for forms of storing maize

Various reasons were given by respondents for storing maize in different forms. 63.5%) of the respondents indicated that such forms of maize storage saved space, 31% said they prevent pest infestation during storage while 5.5% gave other reasons (Table 4.8).

Table 4.8: Reasons for forms of maize storage practised by respondents

Reasons for choice of Form of maize storage	Frequency	Percent	Valid Percent	Cumulative
Save space	127	63.5	63.5	63.5
Prevent pest infestation	62	31.0	31.0	94.5
Other reasons	11	5.5	5.5	100.0
Total	200	100.0	100.0	

4.2.9 Commonly used methods of maize storage adopted by Respondents Table 4.9 shows the various commonly used storage methods for storing maize grains in the study area. Eight storage methods; jute sack, clay pot, crib, plastic drum, triple bag, heaps on floor, polypropylene sack and over kitchen fire were identified and adopted by the respondents for storing their maize grains. A greater percentage (30%) of the respondents stored maize grains in polypropylene sacks, 20% stored in jute sacks, 13.5% stored in plastic drum, 2.5% stored in crib, 6% stored in clay pot, 8.5% stored over fire, 7% stored in triple-hermetic triple bag while 16% stored by heaping the maize grains on the floor. The most commonly used ones are the polypropylene jute sacks and least preferred ones are the crib and the triple bag.

Table 4.9: Storage methods used by respondents for storing maize

Storage method	Number of Respondents	Percentage (%)
Polypropylene sack	60	30
Jute sack	40	20
Plastic drum	27	13.5
Clay pot	12	6.0
Over kitchen fire	17	8.5
Heap on floor	32	16.0
Crib storage	5	2.5
Triple sack	7	3.5
Total	200	100

4.2 .10 Duration of maize grain in storage methods

The survey findings indicated that majority (48%) of the respondents estimated the storage duration of their maize grains to be 4 months whilst 32.5% of the respondents estimated theirs to be 3 months. The rest of the respondents stored their maize in less than 3 months.

Table 4.10: Duration of maize in storage

Duration of maize in storage (In months)	Frequency	Percent	Valid Percent	Cumulative
1 month	2	1.0	1.0	1.0
2 months	7	3.5	3.5	4.5
3 months	65	32.5	32.5	37.0
4 months	96	48.0	48.0	85.0
Above 4 months	30	15.0	15.0	100.0
Total	200	100.0	100.0	

4.2.11 Pre- storage treatments used by respondents for maize storage

A relatively greater percentage (63.5%) of the farmers did not apply any agrochemical to their maize prior to storage as postharvest treatment whilst 36.5% applied agro-chemical treatment before storing their produce (Table 4.11).

Table [1].11: Pre-storage treatment used by Respondents

Means of treatment	Frequency	Percent	Valid Percent	Cumulative

[1] .2. 13: Stages in postharvest losses of maize grains in the study area

The majority of the respondents (46.5%) attributed postharvest losses of maize in the study area to storage, 38% of the complained of maize due to several factors other

Chemical treatment	73	36.5	36.5	36.5
No chemicals	127	63.5	63.5	100.0
Total	200	100.0	100.0	

4.2.12 Chemicals used by Respondents as pre-storage treatment

From the survey conducted, Actellic super and phostoxin were identified as the main chemicals farmers apply on their maize grains as postharvest treatment before storage. Among all the farmers interviewed, 19% apply Phostoxin whilst 10.5% Actellic Super as chemical treatments during storage as shown in Table 4.12.

Table 4.12: Chemicals used by respondents as pre-storage treatments during maize storage

Chemical used for storage	Frequency	Percent	Valid Percent	Cumulative Percent
Acetellic super	21	10.5	28.8	28.8
Phostoxin	38	19.0	52.1	80.8
Others	14	7.0	19.2	100.0
Total	73	36.5	100.0	
Total	200	100.0		

than storage, 12% of them to inadequate drying before storage while only 3.5% of the respondents attributed losses to shelling (Table 4.13).

Table 4.13: Stages in postharvest losses of maize grains in the study area

Losses in maize	Frequency	Percent	Valid Percent	Cumulative Percent
Drying	24	12.0	12.0	12.0
Shelling	7	3.5	3.5	15.5
Storage	93	46.5	46.5	62.0
More than one	76	38.0	38.0	100.0
Total	200	100.0	100.0	

4.2.14 Challenges farmers faced during storage

Table 4.14 shows that 61.5% of the respondents indicated that pest infestations was the major challenge encountered during storage of maize grains, 11% of the respondents complained of a high build of temperature in stored maize grains as a result of storage method used. Also, about 9% of respondents reported of change in colour of maize grains, 6% of the respondents experienced mouldy grains, 8.5% of respondents complained that maize grains normally experienced bad odour, while only 4% of them reported of no noticeable effect during storage.

Table 4.14: Challenges faced during storage periods

Storage challenge	Frequency	Percent	Valid Percent	Cumulative

Pest infestation	123	61.5	61.5	61.5
Temperature build up	22	11.0	11.0	72.5
Colour change	18	9.0	9.0	81.5
Moulding	12	6.0	6.0	87.5
Change in odour	17	8.5	8.5	96.0
No noticeable effect	8	4.0	4.0	100.0
Total	200	100.0	100.0	

4.2.15 Ways of managing and reducing postharvest losses and challenges during storage

Majority (35.5%) of the respondents indicated that the use of good storage methods was important in minimizing storage losses. Twenty percent (20%) of the respondents mentioned that the use of effective storage methods, adequate drying and chemical treatment of grains prior to storage were major ways of reducing postharvest losses. Fifteen percent (15%) of the respondents claimed that proper drying of maize before storage would help reduce postharvest losses of maize in storage, whereas 15%, 6%, 2.5% and 6% of the respondents were of the view that the training of farmers on postharvest losses of produce, proper use of chemicals, the use of resistant varieties and selling of produce immediately after harvest respectively would greatly reduce postharvest losses in maize.

Table 4.15: Ways of managing and reducing postharvest losses and challenges during storage

Ways of managing postharvest storage challenges	Frequency	Percent	Valid Percent	Cumulative Percent
Proper drying	30	15.0	15.0	15.0
Good storage	71	35.5	35.5	50.5
Training on postharvest losses	30	15.0	15.0	65.5
Proper use of chemical	12	6.0	6.0	71.5
Use of resistant variety	5	2.5	2.5	74.0
More than one	40	20.0	20.0	94.0
Sell produce immediately	12	6.0	6.0	100.0
Total	200	100.0	100.0	

4.3 BASELINE INFORMATION ON GRAIN QUALITY AND RESULTS OF LABORATORY WORK

4.3.1 The Initial Grain Quality of Obatanpa Maize Variety Used for the Experiment

The maize grains used for the study was obtained from farmers in Ejura-Sekyedumasi municipality. The grains used were very wholesome. Prior to the commencement of the laboratory set-up, the following grain quality parameters assessed: grain colour, grain odour, moisture content, weight in gram of 1000-grain, percentage damage of per 200 grains and number of insect pests per kilogram of grains in the laboratory of the Department of Horticulture, Kwame Nkrumah University of Science and Technology, Kumasi. This was done to serve as a baseline reference for comparison during subsequent assessment of those parameters in the course of study.

The initial moisture content of the grains used was 12.8%, with 1000-grain weight of 296.8 g and showed no evidence of pest damage. No live insect pests were also observed. The grain colour and odour record scale of 1 based on the scale used, which indicated no detectable change in grain colour with grain naturally white with a few yellow/red grains for colour, and no difference in grain odour for odour. Also, proximate composition analysis was carried out and the result is shown in the Table: 4.16.

Table 4.16: Proximate composition of pre-stored grains

Nutrient element	Carbohydrate (%)	Protein (%)	Ash (%)	Fat (%)	Moisture (%)	Fibre (%)
Value	78.68	11.13	1.73	4.00	1.94	2.52

Source: Field work

4.3.2 Ambient Temperature and Relative Humidity of the Storage Environment

The ambient temperature of the storage environment recorded during the storage period range from 25.5^{0}C to 31.2^{0}C, with a mean value of 29.01 while that of the relative humidity range from 59 to 71%, with a mean value of 66.11% (Table:4.17). An increasing upsurge trend was observed in ambient temperature from December, 2014 to February, 2015 to reach a maximum level of 31.2^{0}C, and then decreased gradually to a minimum value of 28.5^{0}C in March, 2015. Also, the relative humidity experienced an increasing trend in December, 2014 from 59 % to 70 % in January,

2015 (Table 4.17). It then decreased to reach a minimum level of 62 % in February, 2015, for which it again increased to 71 % and continued to fluctuate to reach a maximum level of 71 %.The ambient temperature and relative humidity of the storage environment were in a range of 25 ^{0}C – 31.2^{0}C and 59 % - 71 % respectively.

Table 4.17: Ambient temperature and relative humidity of the storage environment

Storage periods (in days)	Temperature (^{0}C)	Relative humidity (%)
1	25.5	59
8	27.2	68
15	28.8	70
22	29.5	70
29	28.8	64
36	29.1	62
43	30.4	67
50	31.1	62
57	31.2	71
64	28.3	65
71	29.1	69
78	28.1	65
85	28.5	68
92	28.6	61
99	29.4	63
106	30.3	65
113	28.7	70
120	29.5	71
Mean	**29.01**	**66.11**

4.3.3 Effect of Storage Method on Postharvest Quality Characteristics of Stored Grains

The results of effects of storage methods on postharvest quality characteristics of stored maize grains are presented in Table 4.18. It was observed that percentage weight loss (g) of 1000-grain, grain moisture content, percentage grain damage per 200-grain, grain colour and odour changes and number of insects pest per kilogram of grains were significantly (p=0.01) affected by the type of storage method in which grains were stored. The comparison of storage methods indicated that significantly highest mean percentage weight loss, grain damage, grain moisture content and number of insects pest per kilogram of grains were observed in grain stored in heaping of floor, polypropylene sack, clay pot and jute sack and lowest values were observed in plastic drum and hermetic triple-layer sack storage methods. Changes in grain colour (4.00 score) and odour (3.00 score) were significantly higher in grains stored in heap on the floor than triple-hermetic bag, plastic drum, jute sack and polypropylene sack. Grains stored in heaping on floor had higher moisture content (15.53%).

Table 4.18: Effects of storage methods on postharvest quality characteristics on stored grain quality

Storage Methods	% Weight loss	% grain damage	% Colour change	% Odour change	% Moisture content	Number of live insects
Triple bag	5.76 e	14.75 f	1.75 c	1.50 b	13.60 c	8.75 f
Plastic drum	7.38 d	23.00 e	2.25 bc	2.50 ab	13.90 c	14.50 e
Jute sack	10.31 c	29.50 d	2.25 bc	2.75 a	14.70 b	28.75 d
Polypropylene sack	10.98 b	32.75 c	3.25 ab	3.00 a	14.73 b	30.50 c
Clay pot	7.98 d	41.38 b	3.75 a	3.25 a	14.10 bc	39.50 b
Heap of floor	14.62 a	46.13 a	4.00 a	3.00 a	15.53 a	40.50 a

*Means in column followed by the same letter (s) are not significantly different (P=0.01) using Tukey HSD. % = percentage

4.3.4 Effect of Storage Period on Postharvest Grain Quality Characteristics Grain storage period had a significant (p=0.01) influence on grain moisture content, weight loss of 1000-grain, grain damage per 200 grains, grain colour change, grain odour change and insect pest infestation/kg of grains (Table: 4.19). Changes in grain colour and odour, percentage weight loss of 1000-grain and percentage grain damage per 200-grain increased with an extension of storage period. An increasing pattern in number of insect pests/kg of grain infestation was recorded during the whole storage period and the maximum (11.92%) value of infestation was recorded at four (4) months of storage. Similarly, grain moisture content increased during the first one (1) month of storage and continued to increase till 4 months of storage (14.05%).

Table 4.19: Effects of storage period (in months) on postharvest quality characteristics of stored maize grains

Storage Duration	% Weight loss	% Grain damage	% Moisture content	% colour change	% Odour change	Number of live insects
1	1.40 d	19.83 d	12.48 c	1.58 c	1.42 c	6.75 d
2	3.06 c	29.00 c	13.68 b	1.75 bc	1.83 b	8.58 c
3	7.14 b	34.42 b	14.00 ab	2.00 b	2.50 a	10.41 b
4	10.44 a	41.75 a	14.05 a	2.58 a	2.67 a	11.92 a

*Means in column followed by the same letter (s) are not significantly different at (P=0.01) using Tukey HSD

4.3.5 Effect of Chemical Treatment on Postharvest Quality Characteristics of Stored Maize Grains

From Table 4.20, grain protectants applied varied significantly moisture percent of maize grains stored. During the four months storage period, maize grains treated with

Phostoxin had the lower moisture percent while that treated with Actellic Super dust had the higher moisture percent.

Table 4.20: Effect of chemicals used on postharvest harvest quality characteristics of stored maize grains

Chemicals Used	% Weight loss	%Grain damage	% Colour change	% Odour change	% Moisture content	Number of live insects
Actellic super	4.61 a	6.69 a	2.00 a	2.13 a	9.58 a	13.60 a
Phostoxin	4.59 a	6.66 a	1.96 a	2.08 a	9.25 b	13.50 a

*Means in column followed by the same letter (s) are not significantly different (P=0.01) using Tukey HSD

4.3.6 Interactive Effect of Storage Method and Storage Period on Stored Grain Quality

The interactive effect of storage method and storage period on percentage weight loss, moisture content, grain damage, colour change, odour change and number of insect pests/kg showed significant difference (Table 4.21). Percentage weight loss of 1000grain (21.29%), grain damage (89.50%) and the number of insects pest infestation/kilogram of maize grains were significantly higher in grain samples taken from heaping on floor (Hfm * m4) at 4 months of storage of storage while the lowest values of 4.81%, 15% and 7%, respectively were observed in hermetic triple-layer sack (Tbm *m4) at 4 months of storage. The minimum grain moisture content was (13.20%) was detected from grains stored in hermetic triple-layer sack (Tbm*m1) at 1 month of storage. Grains stored in heaping on floor at 4 months of storage (Hfm* m4) had a modal score of 5, indicating that grain had highly significant change making grain unacceptable of human consumption whereas grains stored in hermetic triplelayer sack at 1 month (Tbm*m1) had the least modal score of 1, indicating grain had no detectable change in colour (Table 4.21).

Table 4.21: Interaction effects of storage methods and storage period on grain quality

Sources of Variation	% Weight loss	% Moisture content	% Grain grain damage	% Colour change	% Odour change	No. of live insects
Hfm* m1	7.65 hijk	14.10 cdefg	78.50 e	3.00 abc	2.00 ab	19.00 j
Hfm* m2	10.78 ef	15.20 abcd	81.00 d	4.00 ab	2.00 ab	37.00 f
Hfm* m3	18.76 b	16.50 abc	83.50 c	4.00 ab	4.00 a	49.00 c
Hfm* m4	21.29 a	16.80 a	89.50 a	5.00 a	4.00 a	57.00 a
Pym*m1	7.74 hijk	13.70 defg	78.50 e	3.00 abc	2.00 ab	16.00 kl
Pym*m2	9.13 gh	14.40 bcdefg	57 .00 k	3.00 abc	2.00 ab	22.00 i
Pym*m3	11.89 de	14.90 bcdef	66.00 i	3.00 abc	4.00 a	37.00 f
Pym*m4	15.16 c	15.90 abc	75.00 f	4.00 ab	4.00 a	47.00 d
Jm * m1	8.02 hijk	13.90 defg	57.00 k	1.00 c	2.00 ab	19.00 j
Jm * m2	9.09 gh	14.90 bcdef	62. 00 j	2.00 bc	3.00 ab	24.00 h
Jm * m3	10.89 ef	14.90 bcdef	62 .00 j	3.00 abc	3.00 ab	31.00 g
Jm * m4	13.30 d	15.10 bcde	69.00 h	4.00 ab	3.00 ab	41.00 e
Clm* m1	5.55 lm	13.30 fg	72.50 g	3.00 abc	3.00 ab	25.00 h
Clm *m2	7.44 ijk	15.00 bcdefg	75.00 f	4.00 ab	3.00 ab	32. 00 g
Clm *m3	9.02 ghi	14.20 cdefg	81.00 d	4.00 ab	3.00 ab	46.00 d
Clm* m4	9.91 fg	13.90 defg	86.00 b	4.00 ab	4.00 a	55.00 b
Pdm* m1	5.52 jm	13.70 defg	26 .00 m	1.00 c	1.00 b	10.00 n
Pdm *m2	8.56 ghijk	13.90 defg	26.00 m	2.00 bc	3.00 ab	16.00 kl
Pdm*m3	8.56 ghijk	14.30 cdefg	26.00 m	3.00 abc	3.00 ab	17.00 k
Pdm*m4	6.83 lk	13.90 defg	29.50 l	3.00 abc	3.00 ab	15.00 l
Tbm*m1	4.14 m	13.20 g	19.00 0	1.00 c	1.00 b	6.00 o
Tbm*m2	7.37 jk	13.90 defg	23.00 n	2.00 bc	1.00 b	10.00 n
Tbm*m3	6.73 kl	13.90 defg	19.50 o	2.00 bc	1.00 b	10.00 n
Tbm*m4	4.81 m	13.40 efg	15.00 p	2.00 bc	1.00 b	7.00 o

*Mean In columns followed by the same letters are not significantly different at P=0.01 using Tukey HSD. Hfm=Heap on floor, Pym=polypropylene sack, Jm=Jute sack method, Pdm=Plastic drum, Tbm=Triple bag, m1=first month, m2=second month, m3=third month, m4=forth month

4.3.7 Interaction Effect between Storage Method and Chemical Treatment on Grain Quality

Storage method and chemical treatments showed a significant (P=0.01) influence on grain quality characteristics at the end of 4-months storage period. The results indicated that maximum percentage mean weight loss (11.41%) was recorded in grains stored in heaping of floor with Phostoxin treatment (Hfm * Px) and was not significantly different from that recorded (11.36 %) in grains stored in heaping of floor with Actellic Super treatment (Hfm *Ac), followed by grains stored in polypropylene sack with Actellic Super treatment (Pym *Ac) (8.20%) as shown in Table 4.22, whereas percentage weight loss was minimum (1.25%) in grains stored in hermetic triple-layer sack with Phostoxin treatment (Tbm * px) which was similar to that recorded (1.56 %) in grains stored in hermetic triple-layer sack with Actellic treatment (Tbm * Ac). Also, a significantly higher percentage grain damage (14.13%) was observed in grains stored in heaping on floor with Phostoxin treatment (Hfm * Px) as compared to grains stored in hermetic triple-layer sack with Phostoxin treatment (Tbm * px) which showed lowest (2.50%) (Table: 4.22). Grains from the hermetic triple-layer sack treated with Phostoxin (Tbm * px) recorded the lowest mean percentage moisture of 12.73% while the grains treated with Phostoxin and stored in heaping on floor (Hfm * Px) recorded the highest mean percentage moisture of 14.18% which was not significantly different from that of the heaping on floor combined with Actellic treatment (Hfm *Ac) mean value of 14.15%. There was also highly significant difference (p=0.01) in the number of insects pest infestation/kg of grains from the interaction between storage method and chemical treatment. Heaping on floor combined with Phostoxin treatment (Hfm * Px) had the highest (18.75%) number of insects pest infestation/kg of grains whereas hermetic triple-layer sack combined with Phostoxin (Tbm * px) recorded the least (2.50%) number of insects pest infestation/kg of grains (Table 4.22).

Interaction between storage methods and chemical treatments significantly (p=0.01) showed differences in grain colour and odour. The results in Table 4.22 shows that grains treated with Phostoxin and stored in heaping on floor (Hfm * Px) recorded a modal score of 2.75%, which indicated a slight change in grain colour while that of grains treated with Phostoxin and stored in hermetic triple-layer sack (Tbm * px) recorded a modal score of 1, which indicated no detectable change in colour.

Table: 4.22: Interaction Effect between storage method and chemical on grain quality.

Sources of Variation	% Weight loss	Grain damage %	Moisture content %	Colour change %	Odour change %	No. of live insects
Hfm * Px	11.41 a	14.13 a	14.18 a	2.75 a	3. 00 a	18.75 a
Hfm *Ac	11.36 a	13.63 a	14.15 a	2.50 a	3.00 a	16.75 b
Pym *Px	7.23 c	8.25 b	13.75 ab	2.25 ab	2.25 b	11.50 cd
Pym *Ac	8.20 b	7.25 c	13.83 ab	2.25 ab	2.25 b	12.00 c
Jm * Px	6.30 d	6.00 de	13.65 ab	2.00 ab	2.00 b	9.75 e
Jm * Ac	6.99 cd	6.25 cd	13.73 ab	2.00 bc	2.00 b	11.00 d
Clm*Px	3.52 e	5.13 f	13.33 bc	2.25 ab	2.00 b	6.75 fg
Clm *Ac	2.79 ef	5.38 ef	13.40 bc	2.25 ab	2.00 b	7.25 f
Pdm * Px	2.33 f	4.00 g	13.38 bc	1.50 bc	1.25 c	6.25 g
Pdm * Ac	2.79 ef	4.25 g	13.38 bc	2.00 ab	1.25 c	7.25 f
Tbm * px	1.25 g	2.50 h	12.73 c	1.00 c	2.00 b	2.50 i
Tbm * Ac	1.56 g	3.00 h	13.15 bc	1.00 c	1.75 bc	3.25 h

*Means in column followed by the same letter (s) are not significantly different (P=0.01) using Tukey HSD. Hfm = Heap on floor, Pym=polypropylene sack, Jm= Jute sack, Clm=Clay pot method, Pdm=Plastic drum, Tbm=Triple bag, Ac=Actellic super, %= percentage

4.3.8: Interaction Effect between Chemical and Storage Period on Stored Grain Quality

The interaction effect between storage period and chemical significantly (p=0.01) varied percentage weight loss, moisture content, damaged grains, colour and odour changes and number of live insects that caused grain damage (Table 4.23). In all period of storage, grains treated with both phostoxin and actellic observed increased in reduction in parameters assessed as the storage duration progressed. In both chemical treatments, phostoxin recorded the minimal values than actellic.

Table 4.23: Interaction effect of chemical and storage period on grain quality

Sources of Variation	% weight loss	% moisture content	% grain damage	Grain colour (%)	Grain odour (%)	Number of life insects
Px * ml	1.42 d	12.45 b	4.67 e	1.67 bc	1.50 b	7.00 e
Px * m2	2.84 c	13.68 a	5.75 d	1.67 bc	1.67 bc	8.67 d
Px * m3	6.89 b	13.95 a	7.92 bc	1.83 bc	2.50 a	9.83 c
Px * m4	10.23 a	13.92 a	8.33 ab	2.76 a	2.76 a	11.50 b
Ac * m1	1.38 d	12.50 b	4.83 e	1.50 c	1.33 b	6.50 e
Ac * m2	3.29 c	13.68 a	5.75 d	1.83 bc	1.83 b	8.50 d
Ac * m3	7.40 b	14.05 a	7.50 c	2.17 ab	2.50 a	11.00 b
Ac * m4	10.66 a	14.18 a	8.67 a	2.50 a	2.67 a	12.33 a

*Means in column followed by the same letter (s) are not significantly different (P=0.01) using Tukey HSD. Px = phostoxin, Ac= Actellic super, m= month, *= combined with, %= percentage, m1= month 1, m2 = month 2, m3 = month 3, month4 = month 4, No. = number.

4.3.9 Interaction Effect of Storage Methods, Chemicals and Storage Period on Grain Postharvest Quality Characteristics

The interaction effect of storage method, chemical treatment and storage period on grain postharvest quality characteristics is presented in Table 4.24. Storage method, chemical treatment and storage period interaction significantly (P=0.01) varied grain moisture content, percentage damage, number of insect pests that caused damage to stored grains, changes in grain colour and odour. The treatment effects were highly significant at month m3 (90 days) and m4 (120 days) periods of storage. Grains treated with Px and stored in Hfm for m4 had consistently higher (15.00%) percentage increase in moisture content. Also, the results indicated that the percentage grain damage significantly differed. Lowest in mean (2.00%) percentage grain damage was observed in Pbm * m4 * Px and the highest (19.00) was recorded in Hfm * m4 * Px.

The results on percentage number of insect pests that caused grain damage during four months period of storage was influenced by interaction effect of storage method, storage period and chemical (Table 4.24). Maize grains treated with chemical Px stored in Hfm for four months recorded significant percentage number of insect pest population compared to grains treated with the same chemical Px and the chemical Ac and stored in other methods.

A decreased trend in weight loss of 1000-grain was noted throughout the storage period and significantly varied by the interaction effect of storage method, storage period and chemical. Maize grains treated with Px and stored in Tbm for four months consistently recorded lower (p=0.01) values than other treatments including the control (Hfm). However, a similar lower response was observed in grains treated with

Ac and stored in Tbm for four months.

The results from Table: 4.24 shows that a change in grain colour significantly varied by the interaction effect among storage method, storage period and chemical. Grain colour change was noted in the Hfm * m4* Px and Hfm * m4 * Ac but the change was within the acceptable range.

Table 4.24 shows that change in grain odour differed (p=0.01) during storage as a result of interaction among storage methods, storage period and chemical. Grains treated with chemicals Px and Ac stored in Hfm for four months had the greatest impact on grain odour.

Table 4.24: Interaction effects of storage methods, storage period and chemicals used on postharvest quality

Sources of	% Weight	% Moisture	% Grain	% Colour	% Odour	No. of

Variation	loss	content	damage	change	change	live
insects						
Hfm*m1*px	4.31 jklmn	12.60 efghi	5.00 ijk	2.00 bc	3.00a	13.00 hi
Hfm*m1*Ac	3.30 lmnop	12.70 efghi	10.50 d	1.00 c	3.00 a	11.00 jk
Hfm*m2* Px	5.93 hij	14.50 abcd	14.00 c	2.00 bc	3.00 a	18.00 cd
Hfm*m2*Ac	6.57 fgh	14.20 abcde	13.50 c	2.00 bc	3.00 a	16.00 ef
Hfm*m3*Px	14.58 c	14.70 ab	16.00 b	3.00 ab	3.00 a	19.00 c
Hfm*m3*Ac	15.09 c	14.70 ab	13.50 c	3.00 ab	3.00 a	19.00 c
Hfm*m4*Px	20.82 a	15.00 a	19.00 a	19.00 a	3.00 a	25.00 a
Hfm*m4*Ac	20.48 a	14.90 a	17.00 b	4.00 a	3.00 a	21.00 b
Pym*m1*Px	1.45 qrs	12.60 egfhi	7.00 fgh	2.00 c	1.00 b	9.00 lm
Pym*m1*Ac	1.95 pqr	12.60 efghi	5.50 hij	1.00 c	1.00 b	7.00 no
Pym*m2*Px	3.87 klmno	13.90 abcdefgh	7.00 fgh	2.00 bc	2.00 ab	11.00 jk
Pym*m2*Ac	4.31 jklm	13.90 abcdefgh	6.00 ghi	2.00 bc	2.00 ab	11.00 jk
Pym*m3*Px	8.89 e	14.00 abcdefg	9.00 de	2.00 bc	3.00 a	11.00 jk
Pym*m3*Ac	9.03 e	14.00 abcde	10.00 d	3.00 ab	3.00 a	13.00 hi
Pym*m4*Px	14.72 c	14.50 abcd	10.00 d	3.00 ab	3.00 a	15.00 fg
Pym*m4*Ac	17.49 a	14.60 abc	10.00 d	3.00 ab	3.00 a	17.00 de
Jm*m1*Px	2.29 nopq	12.60 efghi	5.00 ijk	2.00 bc	1.00 b	8.00 mn
Jm*m1*Ac	2.22 opq	12. 50 fghi	5.00 ijk	2.00 bc	1.00 b	9.00 lm
Jm*m2*Px	3.97 klmn	13.70 abcdefghi	5.00 ijk	2.00 bc	2.00 ab	9.00 lm
Jm*m2*Ac	5.32 hijk	13.90 abcdefgh	5.00 ijk	2.00 bc	2.00 ab	9.00 lm
Jm*m3*Px	7.82 efg	14.10 abcdef	7.00 fgh	2.00 bc	3.00 a	10.00 kl
Jm*m3*Ac	8.08 ef	14.00 abcdefg	7.50 efg	2.00 bc	3.00 a	12.00 ij
Jm*m4*Px	11.11 d	14.20 abcde	10.00 d	2.00 bc	3.00 a	12.00 ij
Jm*m4*Ac	12.33 d	14.50 abcd	9.00 de	2.00 bc	3.00 a	14.00 gh
Clm*m1*Px	0.27 rs	12.40 ghi	3.50 klmn	2.00 bc	1.00 b	5.00 pq
Clm*m1*Ac	0.30 rs	12.50 fghi	3.50 klmn	2.00 bc	1.00 b	5.00 pq
Clm*m2*Px	1.35 qrs	13.70 abcdefghi	3.50 klmn	2.00 bc	1.00 b	6.00 op
Clm*m2*Ac	1.42 qrs	13.60 abcdefghi	4.00 jklmn	2.00 bc	1.00 b	9.00 lm
Clm*m3*Px	3.77 klmno	13.80 abcdefgh	6.00 ghi	2.00 bc	3.00 a	7.00 no
Clm*m3*Ac	4.71 ijkl	13.90 abcdefgh	6.00 ghi	2.00 bc	3.00 a	8.00 mn
Clm* m4*Px	8.69 e	13.40 abcdefghi	7.50 efg	3.00 ab	3.00 a	8.00 mn
Clm* m4*Ac	6.33 ghi	13.60 abcdefghi	8.00 ef	3.00 ab	3.00 a	8.00 mn
Pdm*m1*Px	0.17 s	12.40 ghi	3.50 klmn	1.00 c	2.00 ab	5.00 pq
Pdm*m1*Ac	0.27 rs	12.40 ghi	3.00 lkmno	2.00 bc	1.00 b	5.00 pq
Pdm*m2*Px	1.62 pqrs	13.60 abcdefghi	3.00 lmno	1.00 c	1.00 b	6.00 op
Pdm*m2*Ac	1.62 pqrs	13.50 abcdefghi	3.50 klmn	2.00 bc	1.00 b	7.00 no
Pdm*m3*Px	3.77 klmno	13.90 abcdefg	5.00 ijk	1.00 c	1.00 b	7.00 no
Pdm*m3*Ac	4.61 ijkl	13.90 abcdefg	6.00 ghi	2.00 bc	1.00 b	9.00 lm
Pdm*m4*Px	3.77 klmno	13.60 abcdefghi	5.00 ijk	1.00 c	1.00 b	7.00 no
Pdm*m4*Ac	4.64 ijkl	13.70 abcdefghi	4.50 ijkl	2.00bc	1.00 b	8.00 mn
Tbm*m1*Px	0.00 s	12.10 i	1.50 o	1.00 c	2.00 ab	1.00 r
Tbm*m1*Ac	0.24 rs	12.30 hi	1.50 o	1.00 c	1.00 b	2.00 r
Tbm*m2*Px	0.27 rs	12.70 efghi	2.00 no	1.00 c	2.00 ab	2.00 r
Tbm*m2*Ac	0.47 rs	13.00 cdefghi	2.50 mno	1. 00c	2.00 ab	2.00 r
Tbm*m3*Px	2.43 nopq	13.20 bcdefghi	4.50 ijkl	1.00 c	2.00 ab	4.00 q
Tbm*m3*Ac	2.86 mnopq	13.60 abcdefghi	4.50 ijkl	1.00 c	2.00 ab	5.00 pq
Tbm*m4*Px	2.29 nopq	12.90 defghi	2.00 no	1.00 c	2.00 ab	2.00 r
Tbm*m4*Ac	2.66 mnopq	13.70 abcdefghi	3.50 klmn	1.00 c	2.00 ab	4.00 q

*Means in column followed by the same letter (s) are not significantly different (p=0.01) using Tukey HSD. Px = Phostoxin, Ac=Actellic, Hfm= Heap on floor, Jm=Jute sack method, pym=Polypropylene method, m1= first month, m2=second month, m3=third month, m4=fourth month

4:3:10 Effect of storage methods on proximate composition of stored maize grains

Table 4.25 gives an account on the effect of storage methods on proximate composition of Obatanpa variety used for the study. The analysis was done just before and after the storage experiment. The results in Table 4.25 showed that the level of ash, crude fibre and moisture content varied significantly among the storage methods after four months of storage. The level of crude fibre increased slightly in grains stored in clay pot (Clm) and reduced in plastic drum (Pdm). Likewise, the level of ash significantly increased when grains were stored with plastic drum (Pdm) and decreased when stored with polypropylene (Pym). The analysis as shown in Table 4.25 proved that hermetic triple-layer bag (Tbm) and plastic drum (Pdm) performed best as they recorded significantly lowest moisture content compared to that of jute sack (Jm), polypropylene sack (Pym), clay pot (Clm) and heaping on floor (Hfm).

Table 4.25: Effects of storage methods on proximate composition on maize grains

Storage method	Fat		Fibre		Protein		Ash		Carbohydrate		Moisture	
	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After
Tbm	4.00a	4.00a	2.52a	2.52ab	11.13a	11.13a	1.73a	1.70ab	78.68a	78.68a	1.94a	2.65c
Pdm	4.00a	3.50a	2.52 a	1.23b	11.13a	11.00a	1.73a	2.50a	78.68a	75.90a	1.94a	5.85b
Jm	4.00a	2.50a	2.52 a	2.49ab	11.13a	10.26a	1.73a	1.52ab	78.68a	73.65a	1.94a	9.85a
Pym	4.00a	3.00a	2.52 a	2.50ab	11.13a	11.00a	1.73a	0.79b	78.68a	72.71a	1.94a	10.00a
Clm	4.00a	3.45a	2.52 a	2.71a	11.13a	10.75a	1.73a	1.50ab	78.68a	71.0 a	1.94a	10.58a
Hfm	4.00a	4.00a	2.52 a	2.52a	11.13a	11.05a	1.73a	1.73ab	78.68a	69.45a	1.94a	11.05a

Lsd (0.01)

*Means in column followed by the same letter (s) are not significantly different (P=0.01). Tbm=Triple bag method, Pdm=Plastic drum, Jm=Jute sack method, Pym=Polypropylene sack method, Clm=Clay pot method, Hfm= Heap on floor method

4.3.11 Effects of storage methods on minerals content of stored maize grains. The results in Table 4.26 showed significant reductions in calcium, potassium, sodium, phosphorus and magnesium contents of maize stored after four months of storage using the six storage methods. The level of calcium significantly (p=0.01) increased in maize grains stored in clay pot (0.19%) while in both heaping on floor and plastic drum methods, the level of calcium significantly declined with recorded values of 0.11% and 0.11%, respectively.

Likewise, the potassium content of maize grains stored in polypropylene sack increased slightly but reduced significantly in heaping on floor.

There was significant effect of storage methods on sodium level of the stored maize grains. Maize grains stored in plastic drum significantly increased to 0.50% compared to the initial content of 0.35% whiles in clay pot method, the level of sodium significantly reduced to 0.15%.

The level of phosphorus in maize grains stored in the six storage methods significantly (p=0.01) varied. Interestingly, phosphorus content reduced when stored with clay pot (Clm), polypropylene sack (Pym), heaping on floor (Hfm) and plastic drum (Pdm) but increased when stored with jute sack (Jm) and triple hermetic bag (Tbm).

The results in Table 4.26 showed significant increases in percentage of magnesium in clay pot, jute sack, polypropylene sack, plastic drum and hermetic triple-layer bag except in heaping on floor method where magnesium decreased. The highest percentage of magnesium was observed in grains stored in jute and polypropylene sacks.

Table 4.26: Effects of storage methods on minerals content of maize grains after storage

Storage method	Calcium		Potassium		Sodium		Phosphorus		Magnesium	
	Before	After	Before	After	Before	After	Before	After	Before	After
Clay pot	0.13a	0.19 a	0.16a	0.14b	0.35a	0.15 d	0.19 a	0.13 ab	0.11a	0.12 b
Jute sack	0.13 a	0.13 b	0.16a	0.12bc	0.35a	0.40 bc	0.19a	0.21 a	0.11a	0.15 a
Polypropylene sack	0.13a	0.13 b	0.16a	0.17a	0.35a	0.48 a	0.19a	0.14 ab	0.11a	0.15 a
Triple sack	0.13a	0.13 b	0.16a	0.16a	0.35a	0.35c	0.19a	0.21 a	0.11a	0.11 b
Heap on floor	0.13a	0.11 c	0.16a	0.11c	0.35a	0.45ab	0.19a	0.09 b	0.11a	0.08 c
Plastic drum	0.13a	0.11 c	0.16a	0.12bc	0.35a	0.50 a	0.19a	0.13 ab	0.11a	0.14 ab
(Lsd										

All values are in percentages. Means in columns followed by a common letter are not significantly different (p=0.01). All values are in percentages.

CHAPTER FIVE

5.0 DISCUSSION

5.1 SURVEY

5.1.1 Background Information of Respondents

The results of the field survey revealed that 78.5% of the respondents interviewed were males whiles 21.5% were females. This indicates males domination and participation in maize production than females in the study area probably because maize production is energy demanding. This may have implication in terms of knowledge and technology aimed at improving maize production in the Municipality. Also, majority (46.5%) of the farmers interviewed were within the most economic working and youthful age, and this implies that maize production in the Municipality has a brighter future. Regarding educational background and information, the survey report indicates that about 51% of the respondents had no formal education, indicating high rate of illiteracy in the study area which may be an obstacle to appreciating and accepting technological improvement and advancement aimed at maize production.

5.1.2 Identified Maize Varieties Grown by Respondents

The results of the field survey revealed that a number of maize varieties are grown by farmers in Ejura-Sekyedumasi Municipality of which two hybrid and newly improved varieties, Mamaba and Obatanpa dominate. Majority (59.0%) of the sampled farmers grow Obatanpa variety and this suggested that it is the variety of economic importance to the farmers in the Municipality.

5.1.3. Storage Methods Used by Respondents

The various commonly used methods of storage for storing maize grains by respondents in the various maize growing communities in the study area are shown in Table 4.2.9**.** The results indicated that jute sacks, polypropylene sacks, clay pots, plastic drums, over kitchen fire, heap on floor and triple-hermetic bags were the commonly used storage methods for storing maize grains in the Municipality. Polypropylene sacks and jute were the most commonly used storage methods for storing maize grains. A greater percentage (30%) of the respondents stored maize grains in polypropylene followed by jute sacks (20%) and smaller percentage stored maize grains in crib storage (2.5%). Bediako *et al.* (2000) stated that a wide variety of methods are used for grain storage including pots, tins and baskets, but the most common is the polypropylene sack and jute sack.

5.1.4 Ambient Temperature and Relative Humidity of the Storage Environment

The ambient temperature and relative humidity of the storage environment were in a range of 25 ^{0}C – 31.2^{0} C and 59 % - 71 % respectively. The quality of stored grains in any storage method depends upon the prevailing environmental conditions of the storage environment. During the storage, the fluctuation in trend observed in both ambient temperature and relative humidity had a great impact on the quality characteristics of the grains stored. Higher ambient temperature and relative humidity created conducive and favourable grounds for insect pests' growth, development and infestations, which resulted in quality deterioration in some of the grain quality parameters assessed. This study collaborates with an earlier study research on grains storage conducted by Alabadan and Oyowo (2005) revealed that ambient temperature and relative humidity have a maximum influence on the quality of stored grains.

Higher relative humidity and ambient temperature provide the favourable conditions for the production of insect, mould and other micro-organisms which deteriorate the grain quality during storage.

5.2 STORAGE EXPERIMENT

5.2.1 Effects of Storage Methods on Postharvest Quality Characteristics of Maize Grains

5.2.1.2 Percentage damage of maize grains during storage

At the onset of the experiment, there was no insect damage seen on the maize grains used for the study. From the results obtained, method of storage, period of storage and their interactions showed a significant difference on percentage grain damage. The highest percentage grain damage was observed in grains stored in heaping on floor followed by clay pot, polypropylene sack, jute sack and then plastic drum while the lowest grain damage was noted in hermetic triple-layer bag. The least in percentage grain damage recorded in hermetic triple-layer bag could be attributed to low insect pests infestation in grains as a result of reduced oxygen concentration and increased carbon dioxide levels in this air-tight method resulting in asphyxiation and mortalities of insect pests reducing grain damage. Similar findings and observations were reported by Calderon and Navarro (1980) and Donahaye *et al.* (2001). Period of storage significantly (P=0.01) increased percentage grain damage in first month (m1) from 19.83% to 29.00% in second month, and then continued to increase in subsequent months to get the highest value of 41.75% in 4-month of storage (Table 4.19). This continual increase in grain damage could be attributed to physiological phenomenon of ageing which occurred in the stored grains as living organisms.

Table 4.21 represents the interactive effects between storage methods and storage period (sm *m) on grain damage. The results indicated that the highest percentage grain damage was recorded in grains stored in heaping on floor method and lowest in grains stored in triple hermetic bag method.

The interaction between chemical and period of storage on grain damage is shown in Table 4.23. Grain damage was minimum in grains treated with phostoxin and maximum in grains treated with Actellic Super in all period of storage. The minimum value of percentage grain damage recorded in grains treated with phostoxin can be attributed to its high efficacy of controlling pest infestation of stored grains to a lower population density or caused higher mortality of insect pests. At a lower insect pests' population density, pests are ineffective of causing economic damage to grains in storage.

Also, the interaction effect of storage method and duration of storage imparted significantly on percentage grain damage. The trend in percentage grain damage increased consistently with extended period of storage with the highest mean percentage damage noted in grains sampled from heaping on floor method. The highest percentage (89.50%) of grain damage in heap on floor method might be due to the exposure of the stored to insect pest infestation and other factors which cause grain damage (Desjardins *et al.*, 2000; Mohammed *et al.*, 2001; Hayma, 2010; Askun, 2006; Hell *et al.*, 2010; Mathew, 2010).

Results from Table: 4.22 shows that the interaction effect between storage methods and chemicals influenced percentage grain damage. The highest percentage grain damage was detected in grains sampled from heaping on floor method in combination with Actellic Super, which was not significantly different from that of phostoxin fumigation with heaping on floor method, while lowest percentage grain damage was observed in triple combined with phostoxin fumigation. This was a result of a result of gas-tight nature of triple hermetic bag which prevented the escape of phostoxin and provided long term protection against pest infestation.

The interaction among storage methods, grain protectants and storage duration affected percentage grain damage. Lowest percentage damage was found in grains treated with phostoxin and stored in triple-hermetic bag at 4 months of storage while the highest percentage damage was observed in grains treated with phostoxin and stored in heaping on floor method.

5.2.1.3 Effects of storage methods on moisture content

Moisture percent of maize grains was significantly influenced by storage methods, period of storage, chemicals and their interactions. Moisture content of maize grains increased with the progress of storage period and the maximum increase was detected at 4 months of storage. This could be attributed to monthly variation in relative humidity and optimum temperature throughout the period of storage (Hruskova and Machova, 2002). This causes the oxidation of carbohydrate and yield carbon dioxide, water and energy.

Method of storage influenced moisture content. In this experiment, grains stored in heaping on floor method consistently had the highest grain moisture content (15.53%), followed by polypropylene sack (14.73%), jute sack (14.70%) and clay (14.10%) whilst triple-hermetic bag had the lowest increase in moisture content (13.60%), but was not significantly different from that allowed by plastic drum (13.90%). The main reason behind the increase in moisture content observed in heaping on floor was as a result of its open nature, which easily permitted unlimited swap over of moisture. With that of moisture increase in jute sack, polypropylene sack and clay was as a result of their high tendency to absorb moisture in ambient condition. Similar result was reported by *Gurinto et al.* (1991) that moisture content of shelled maize grains increased from 14% to 15.8% in jute sack and polythene lining bags at 90 days of observation. Another reason behind the increase in moisture content could be attributed to higher respiration rate of insect infestation of the stored grains. Sanches *et al.* (1997) stated that water is one of the finished results of respiration which increases the moisture content inside grains storage bins and also, the metabolic products of fungi and insect inside infested grains increased the moisture content (Olajujigbe, 2006).

The application of grain protectants varied grain moisture content. Grains treated with phostoxin allowed lower increase in moisture (9.58%) than actellic (9.25%). For this reason, phostoxin fumigation to stored grains achieved desirable results as far as moisture content is concerned. The lower the moisture contents of stored grains, the better the grains keep and the longer the usable period or shelf life. Also, grain with low moisture content is less susceptible to insect infestation and growth of fungi. The interaction among methods of storage, chemicals and period of storage also significantly affected grain moisture content. Significantly, the highest (15.00%) increase in moisture content was noted in grains treated with phostoxin and stored in heap on floor method, but not statistically different from actellic treated grains stored in heaping on floor method (14.90%) and the lowest was observed in phostoxin treated grains combined with triple-hermetic bag stored for four months.

5.2.1.4 Weight loss of maize grains

A decrease in weight of 1000-grain was recorded throughout the storage period. Weight loss of maize grains showed an increasing trend with the passage of storage period and highest weight loss was noted at the end of the 4 months of the storage period (Table 4.19). Grain weight was found to be dependent on storage duration and whatever the storage condition, increase in storage time leads to a significant loss in weight of grains

(Gonzalez, 2013). Similarly, with respect to the methods of storage effect, the highest rate of decrease in weight per 1000 grains was found in grain samples taken from heaping on floor followed by polypropylene sack, jute sack, clay pot, plastic drum and the lowest found in hermetic triple-layer bag (Table 4.18). The lowest in percentage weight loss in grains stored in hermetic triple-layer bag is in agreement with the previous discoveries of Anankware *et al.* (2012) who perceived that maize stored in hermetic triple-layer bag record low weight loss compared to jute and polypropylene sacks which recorded higher weight losses. The reduction in weight of stored grains could be due to high insect pests infestation and grain damage. Insect pests grow and feed the carbohydrate content inside the endosperm of grains which lead to loss in weight and increase grain damage (Pomeranz *et al.*, 2000). The effectiveness of triple-hermetic bag resulting in least weight loss was as result of its air-tight nature which prevented or minimized exchange of gases and insect pests invasion and their feeding activities. Murdock *et al.*, (2012) observed that insect invasion and feeding ceases in grains stored in triple-hermetic bag and prevents or minimizes gas exchange, depletes O_2 and increases CO_2 resulting in insects dying. It can, therefore, be inferred from the results that the least in weight loss noted in triple hermetic bag was as a result of low grain damage and minimal insect activities. This is because grain damage and weight loss are related, and hence the higher the grain damage, the higher the grain weight loss and vice versa.

With respects to higher order interactions thus, interaction among storage method, storage duration and chemical, grains treated with grain protectants phostoxin (Px) and actellic (Ac) and stored in triple-hermetic bag recorded the least weight loss over the four months storage duration, followed by plastic drum (Table 4.24**).** The possible reasons could be due to air-tight property of these methods which prevented loss of chemical constituents of fumigation or the grain protectants making fumigation effective in minimizing insect infestation.

5.2.1.5 Effects of storage methods on number of live insect pests/kilogram of maize grains.

There was no insect infestation observed on the maize grains used for this present study before storage. Storage period increased the number of insect pests infestation per kilogram that caused grain damage throughout the experiment and the highest rate of number of insect pests/kg of grains was noted in grains at 4 months of storage (Table 4.19). This could as a result of non-existence of proper hygienic storage conditions (Danho *et al.*, 2003). With regard to storage methods, the highest percentage of number of insect pests infestation/kg of grains was observed in grains stored in heaping on floor, followed by clay pot, polypropylene sack, jute sack, plastic drum and lowest in hermetic triple-layer bag. However, chemical treatments had no effect on insect infestation of stored grain. The highest number of live insect pests recorded in heaping on floor method could be attributed to high moisture content and build of heat in this storage method, which provided favourable environment for growth, survival and proliferation of insect pests. The efficiency of triple-hermetic bag for recording the lowest counted number of live insect pests that caused damage to grains could be as a result of its ability to keep the content air-tight and led to accumulation and increased concentration of carbon dioxide and reduced oxygen concentration, which resulted in low rate in breeding and high mortality. In the absence of triple-hermetic bag, plastic drum could be the next alternative choice in creating unfavourable conditions for development and proliferation of insect pests.

5.2.1.6 Change in grain colour during storage

Change in grain colour was observed during the first month of storage. There was no change in grain colour during the four months duration of storage in phostoxin and actellic interaction with triple-hermetic bag (Table 4.24). Heap on floor method interaction with phostoxin and actellic treated grains stored for four months noted a significant change in colour with scale 4, which signifies great colour change from natural white/yellow to dark brown**.** The change in grain colour could be attributed to the mixture of insect frass and urine with the grains stored in this method.

In the case of storage methods, there was increase in change of grain colour during storage period in some of the storage methods (Table 4.18). Grains stored in polypropylene sack, clay pot and heap on floor had their colour changed from natural white/yellow to brown, indicating moderate change, but the change in colour was within the recommended range.

A highly significant (p=0.01) change in colour of grain was observed in storage method interaction with storage period (Table 4.21). Grains stored in heap on floor method and stored for months severely had a change in colour with score 5 rendering the grains unsafe for consumption and unacceptable. This could be as a result of higher infestation and damage by insect pests and fungal growth, heating and mustiness.

5.2.1.7 Change in grain odour

There was a slight change in grain odour was noted in grains among storage method, duration of storage and chemical interactions. The interaction between grain protectants phostoxin and actellic super interaction with heap on floor, polypropylene, jute and clay pot resulted in change in odour in the second, third and fourth months of storage (Table 4.24). The change in this odour could be attributed to infestation with insect pests, faecal materials and fungal growth resulting mouldiness and mustiness.

5.2.1.8 Effects of storage methods on proximate composition of stored grains. The proximate composition of stored grains was analysed on the basis of carbohydrate, protein, ash, moisture content, fibre and ash content retained after four months storage. From Table 4.3.10, there was increase in moisture content in all the storage methods after storage compared to pre-stored, and significantly the highest increase in moisture content was observed in grains stored in heap on floor method which was not significantly different from that of jute sack, polypropylene sack and clay pot whiles the lowest increase was observed in triple-hermetic bag. Grain moisture content which normally increases after storage might be as a result of increased insect metabolism (Rubasinghege *et al.,* 2007).

From Table 4.25, there was a decrease in ash content in hermetically stored grains, as well as decrease in grains stored in jute sack, polypropylene and clay pot whereas in heap on floor method, ash content was retained. A decrease in ash content after months of storage could be as a result of insect feeding activity and reproduction (Bamaiyi *et al.,* 2006). However, ash content in plastic drum had an increase. This could be due to generation of more residues as a result of contamination from insect excreta.

Crude fibre content decreased in plastic drum, jute sack, polypropylene sack and in heaping on floor methods whilst in clay pot, there was increase in crude fibre content compared to pre-stored grains. Increase in crud fibre content of stored grains may be attributed to insect pests hollowing out the grain contents leaving only the bran, which is mostly fibre (Bamaiyi *et al.,* 2006). Also, the husk of grains is rich in crude fibre content and any decrease in values after storage may be due to emergence holes created by weevils (Rubasinghege *et al.,* 2007).

5.2.1.9 Effect of storage methods on the minerals composition of stored maize grains before and after the storage experiment

The minerals content of the stored maize grains analysed consisted of calcium, potassium, sodium, phosphorus and magnesium. This was done prior to storage and after the storage experiment. Methods of storage significantly influenced the minerals content after storage. There was a reduction in the minerals content of calcium, potassium, phosphorus, magnesium and sodium after the storage period. Significant reduction ($p=0.01$) in minerals content was obtained in maize grains stored in heaps on floor method where insect pests infestation was higher whereas maize grains stored in triple hermetic bag retained the highest minerals content. This result agrees with the findings of Jood and Kapoor (1993) who reported that minerals content of stored maize grains decrease as a result of feeding activities of *Sitophilus zeamais*.

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATION

6.1 CONCLUSION

The present study reiterated the need to use appropriate and effective storage methods and chemical treatments for maize grains storage and their impact on grain quality parameters. Apart from the use of appropriate storage methods for storing maize grains, the initial condition of grains for storage needs to be taken into account before storage as insect damage grains for storage could aggravate incidence of both qualitative and quantitative losses during storage.

The findings of the survey of this present study have shown that:

- Both males and females were involved in intensive and commercial production of maize in Ejura-Sekyedumasi Municipality, with greater percentage being males.
- There was a general reduction in the quality parameters assessed in all the storage methods used after storage. Based on the results obtained, hermetic triple-layer bag and plastic drum gave desirable and better results than jute sack, polypropylene sack, clay pot and heaping on floor for the parameters assessed. Hermetic triple-layer bag and plastic drum methods significantly reduced grain deterioration.
- Laboratory analysis carried out on proximate and mineral compositions per the storage methods evaluated indicated a general reduction. However, there were some exceptions as most of the nutritional and minerals compositions of maize stored in triple bag and plastic drum were maintained.
- As the storage period extended, there was a decrease in grain quality parameters gradually. This indicated natural ageing is inevitable in grains.
- The application of Phostoxin to grains was most effective in protecting grains from insect damage and maintaining the least moisture content than Actellic Super up to four months of storage.
- Grain quality parameters assessed when stored in jute sack, polypropylene sack, clay pot and heaping on floor were very low and, this shows that these storage methods were ineffective of protecting stored grains from pests. Therefore, farmers should not store their maize grains using these storage methods.
- In conclusion, the overall results shows that hermetic triple-layer bags and plastic drums are better and suitable storage methods for both short and long terms storage of maize grains than jute sack, polypropylene sack, clay pot and

heaping on floor under ambient conditions. The use of such storage methods by resource poor farmers will enable them to store enough grains of high quality for future use.

6.2 RECOMMENDATIONS

Based on the results of the study, the following recommendations are made:

- Triple-hermetic bags and plastic drums should be considered by producers and other stakeholders of maize for storing their harvested maize grains due to the fact that these storage methods resulted in minimizing weight loss, nutrient loss, allowing increased in moisture content of stored grains to a considerable and prevented insect pests attack and low grain damages.
- Further study should be conducted on the same topic, but this time in a different maize growing area with an extended period of time, for about six months to one year for meaningful conclusion to be drawn.
- Research should be done on how loss of proximate and minerals composition of stored maize grains affect its nutritional quality.

REFERENCES

Abraham, T. and Firdissa, E. (1991). Insect pests of farm-stored maize and their management practices in Ethiopia. International Organization for Biological and Integrated Control of Noxious Animals and plants. West Palaeaarctic Regional section Bulletin 23, 45-57.

AACC. (2000). Approved Methods of American Association of Cereal Chemists. The American Association of Cereal Chemists. Inc., St. Paul, Minnesota, USA.

Addo, S., L.A. Birkinshaw, and R.J.Hodges (2002). Ten years after the arrival in Ghana of Larger Grain Borer: Farmers' responses and adoption of IPM strategies. International Journal of Pest management. 48(4): 315-325.

Addo-Quaye, A.A., Saah, M., Techie-Menson, C.K.B., Adam, I, Tetteh, J.B., Arko, V.K. and Kitson, J.E. (1993). *General Agriculture for Senior Secondary School*. Gangaram and sons Ltd. Bonbay-India. $P_{p.}$172-177.

Adejumo, B.A. and A.O. Raji (2007). Technical appraisal of grain storage systems in the Nigerian Sudan savannah. Agricultural Engineering International. CIGR.J., 9: 1-12.

Adetunji, M.O. (2007). Economics of storage techniques by farmers in kwara state, Nigeria. *Pakistan of social sciences 4(3),* pp.442-480.

AUC (African Union Commission) (2006). Resolution of the Abuja Food Security Summit. Addis Ababa, Ethiopia.

Afzal M, Nasir Z, Bashir MH, Khan BS (2009). Analysis of List Plan resistance in some genotypes of maize against Chilo Partellus (Swinhoe) (Pyralidae:Lepidoptera). *Pakistan J. Botany.* 41 : 421-428.

A.I.Yuya, A.Tadessse, and T.Tefera (2009). Efficacy of combining Niger seed oil with malathion 5% dust formulation on maize against the maize weevil, Sitophilus zeamais (Coleoptera: Curculionidae). *Journal of Stored Products Research*. 45:67-70.

Alabadan, B.A., (2005). Temperature changes in Bulk stored Maize. AU J.T. 9, 3, 187 – 192.

Amin A, A., Sh. M. Rashad, M.S. Hassanein and Nabila, M.Zakari, (2007). Response of Some White Maize Hybrids to Foliar spray with Benzyl Adenine. Res.J.Agric. Biol. Sci., 3(6): 648-656.

Anankware J.P., Obeng-Ofori D, Afreh-Nuamah K, Oluwole F.A., Bonu-Ire M (2012). Triple-layer hermetic storage: a novel approach against *Prostephanus truncatus (*Horn) (Coleoptera: Bostrichidae) and *Sitophilus zeamais* (Mot) (Coleoptera: Curculionidae). Entomol. Orinthol. Herpetol.

AOAC (2000; 2002). Official Methods of Analysis (17^{th} edi.). Association of Official Analytical Chemists, Washing, D.C. United State of America.

AOAC (2005). Official methods of Analyses, Association of Official Analytical Chemists, Virginia, USA.

Askun, T., (2006). Investigation of fungal species diversity of maize kernels. J. Biol. Sci., 6: 275-281.

Bamaiyi, L.J., Onu, I., Amatobi, C.I.and Dike, M.C. (2006). Effect of *Callosobruchus maculates* Infestation on Nutritional Loss on Stored Cowpea Grains. *Arch. Phytopath. Plant Prot*. 39(2): 119-127

Bediako J. A, Chianu J. N, Dadson J.A., (2009). Crop storage efficiency and market competitiveness: Case of groundnut and cowpea in Ghana. pp 13-26.

Bourndillion, M., Hebinick P., Hoddinott, J. Kinsey B., Marondo, J., Mudege N., and Owens T. (2009). Assessing the impact of high-yielding varieties of maize in resettlement areas of Zembabwe. International Food Policy Research Institute, Washington, D.C.

Boxall, RA.A. (2002). Critical review of the methodology for assessing farm level grain losses after harvest. Report of Tropical Development and Research Institute 1986; G191, Vill + 139 pp.

Buah S.S.J., Abatania L.N. and Aflakpui, G.K. (2009). Quality Protein Maize Response to Nitrogen Rate and Plant Density in the Savanna Zone of Ghana.

Cai, H. (2006). Chapter 3: Maize Genome mapping and molecular breeding in plants Volume 1. Cereals and Millets. 135-153. C.Kole, ed. Heidelberg, Germany Springer.

Calderon, M., Navarro, S., (1980). Integrated approach to the use of controlled atmospheres for insect control in grain storage. Pages 73-78.

Cao, Dongfeng, Pimentel, D., Hart.K., (2002). *Encyclopedia of Pest Management*. Marcel Dekker, Newyork.

Centre for Agricultural and Rural Co-operation (2014). Analysis of the postharvest knowledge system in Ghana.

Chikukura L, Mvumi BM, Chikonzo R, Chenzara C. (2011). Evaluation of selected indigenous pesticidal plant powders against stored maize and cowpea insect pests.

CIMMYT and IITA (2010). Maize – Global alliance for improving food security and the livelihoods of the resource-poor in the developing world. Draft proposal submitted by CIMMYT and IITA to the Consortium Board. El Batan, Mexico. 91 pp.

DADU-SRID (2007). Crop production profile

Dale, D.P., Golob, P., (1997). Protection of farm stored maize against infestation by *Prostephanus truncatus* (Horn), and *Sitophilus* species in Tanzania.

Danho M, Haubruge E, Gaspar C, Lognay G. (2003). Selection of grain-hosts by Larger Grain Borer (Coleoptera: Curculionidae). *Belgian Journal of Zoology* 130, 3-9.

De Groote (2004). Protection of stored grains and pulses. Agrodok Series (No.31). Digigrafi, Wageningen.

Desjardins, A.E., G. Manandhar, R.D. Plattner, C.M. Maragos, K. Shrestha and S.P. Donahaye, E.J., Navarro, S., Sabio, G., Rindner, M., Azrieli, A. and Dias, R. (2001). Reflective covers to prevent condensation in sealed storages in the tropics. Executive Printing Services, Clovis, CA, U.S.A. pp. 227-230.

Ejura-Sekyedumasi Municipal Assembly (2008) (ESMA). Municipal Analytical Report.

Escobedo, G.E., (2010). *Comparative analysis of the grain quality protein maize and normal maize cultivars*.

FAO (1991). Grain Yield and Components of Maize.

FAO (2000). *Grain storage techniques: Evolution and trends in developing countries*

FAO (2004a). Grain Storage Techniques: Evolution and trends in developing countries.

FAO (2006). Maize; International market profile. Grain team food and agriculture organization of the United Nation economic and Social department trade and markets division.

FAO (2007). Effects of Deterioration Parameters on storage of maize.

FAO (2008). Missing Food: The Case of Postharvest Grain Losses in Sub-Saharan Africa.

FAO STAT (2009). *Plant Production and Protection Series*. Volume 28, FAO, Rome, Italy

FAO (2013). Food and Agriculture Organization Statistics, February, 2013.

FAO Databases (2008). FAOSTAT: Agriculture Data. Available online: http://faostat.org.

Fekadu L. (2007). Fundamentals Science and Technology of food grain drying, cleaning and storage practices.

Forum for Agricultural research in Africa (FARA) (2013). Patterns of change in maize policy in Africa: Implications for maize policy development. Networking support functions 3. Regional Policy and Markets.

G.C., Y.D. (2006). Efficacy of indigenous plant materials and modified storage structures to insect pests of maize during on farm storage. J. Inst.Agric.Anim.Sci.. 27: 69-76.

Galinat, W.C. (1988). The origin of corn. *In* Sprague, G.F and Dudley, J.W. (eds). Corn and corn improvement. *Agronomy Monographs No. 18; pp. 1-31. American Society of Agronomy: Madison, Wisconsin.*

GGDP (Ghana Grains Development Project) (1991). Maize Improvement, 1992 Annual Report.

GGDP, (2010). Comparison of improved and local maize varieties in Ghana with emphasis on Sitophilus zeamais. *Journal of Stored Product Research.*

Ghana Grain Development board GGDP (2010). Comparison of Improved and Local maize varieties in Ghana with emphasis on *Sitophilus zeamais*. *journal of Stored Product Research*

Ghana Grain Development Project (GGDP) & Millennium Development Authority (MiDA) (2007/2010). Investment Opportunity in Ghana, Maize and Soya price.

Ghana Statistical service (2010). District Population and Housing census, EjuraSekyeredumasi District.

Ghana Statistical Service (GSS) (2010). Population and Housing Census (2010 PHC)

Golob (2004). Maize: Tanzania (East and Central Africa). In Golob, P., Hodges, R, Farrell, G. Crop Postharvest: *Science and Technology vol.2.* Backwell Publishing Company, Oxford. Pp. 26-41.

Golob, P. N., Kutuwa A. Devereau, R.E. Bartosik, and J.C. Rodriguez, (2014). *Effects of deterioration parameters of maize a review.*

Gonzalez-Torralba J, Arazuri S, Jaren C. (2013). Influence of temperatures and relative humidity during storage on wheat bread making quality.

Gwinner J, Hamisch R, Muck O. (1996). Manual of the prevention of postharvest grain losses.

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

Hayma, J., (2003; 2010). *The Storage of Tropical Agriculture Products. 4th Edn.,* Agromisa Foundation, The Netherlands, ISBN: 9789077073605, PP: 6-25.

Hell, K., K.F. Cardwell, M. Setamou, and H.M. Peohling (2000). The influence of storage practices on aflatoxin contamination in maize in four agro-ecological zones of Benin, West Africa. Journal of Stored Products Research. 36: 365-382.

Hell, K., C. Mutegi, and P. Fandohan (2010). Aflatoxin Control and Prevention strategies in maize for Sub-Saharan Africa. *Julius-Kuhn-Archiv, 425 S- 534.*

Hill, D.S. and Waller, J. M. (1990). Pests and diseases of Tropical crops (United Kingdom). Field Handbook Longman Scientist and Technical: 1990. 432 P.
Hruskova V, Machova D. (2002). Changes of wheat flour properties short time storage.

IITA (2000). Adoption of a New Maize and Production Efficiency in Africa.

IITA (2009). Maize Research and Impact. International Institute of Tropical Agriculture.

Ikisan (2000). History of maize. www.ikisan.com. (Assessed March, 2015).

International Food Biotechnology (1990). Biotechnologies and Food: *Assuring the safety of foods produced by genetic modification.*

International Food Policy Research Institute (IFPR) (2013). Patterns of Adoption of Improved Maize Technologies in Ghana.

International Food Policy Research Institute (IFPRI) (2013). Ghana Crop Calender.

International Institute of Tropical Agriculture (2010). Phenomenal increase in maize production in West Africa and Central Africa.

International Institute of Tropical Agriculture (IITA) (2009). Research for Development: Cereals and Legumes System.

International Journal of Science: Basic and Applied Research (IJSBAR) (2014). *Eucalyptus grandis* and *Tagetes minuta* leaf powders effectively protects stored maize against *Sitophilus zeamais* without affecting grain organoleptic properties.

International Maize and Wheat improvement Centre (2000). Signs of insect infestations in the tropics.

IRRI/CIMMYT (2009). Maize Seed Management-Postharvest Treatment and Storage.

ISSER (2011). The state of the Ghanaian Economy in 2010. Institute of Statistical, Social and Economic Research (ISSER). University of Ghana, Legon. 209 pp.

John Doebley (2004). The Genetics of Maize Evolution.

Jood, S., Kapoor, A.C.,Singh, R., (1992). Biological evaluation of Protein Quality of Maize as Affected by Insect Infestation. *Journal of Agricultural and Food Chemistry*. 40, 12, 2439 – 2442.

Katinila, N.Verkuij H. Mwangi W., Anandajayasekeram, P.Moshi, A. (1998). Adoption of maize Technologies in Southern Tanzania. CIMMYT, Mexico.

Komen J., Motoko C., Wanyama J., Rono S. and Mose L. (2006). International Journal of Food Microbiology 119 (1-2): 131-139: *Economics of Postharvest Maize Grain Loss in Trans Nzoia and Uasin Gishu Districts: N.W. Kenya*.

Kranja, D & M. Renkow (2003). The welfare effect of maize Technologies in marginal and favoured Regions of Kenya. Unpublished draft paper under review. Michigan State University, East Langing, M.I.

Kulp, K., and G. Joseph (2000). *Handbook of cereal science andTechnology. 2nd ed.* Newyork, Marcel Dekker Inc.

Lamboni, Y., Hell, K., (2009). Propagation of mycotoxigenic fungi in Maize Stores by Postharvest Insects. International Journal of Tropical Science. 29, 1, 31- 39. Lee, S. (1999). Low temperature damp corn storage with and without chemical preservatives. Doctoral (PhD) dissertation. The University of Guelph.

Lemma, T., (2006). Storage Systems and Pest Management in Small – Scale Agriculture in Ethiopia, in: Bekele, E., Azerefegne, F., Abate, T. (Eds). Facilitating the Implimentation and Adoption of Integrated Pest Management in Ethiopia, Planning Workshop 13 – 15 October, 2003.

Li, A.Y., J.D. Gong, Q.Z. Gao and F.R. Li (2001). African Agricultural systems and productivity in perspective.

Liu , Z., J. Gao and J.Yu. (2010). Aflatoxins in stored maize and rice grains in Liaoning Province, China. Journal of Stored Products Research 42 (4): 468-479.

Lindblad, C., Druben, L., (1976). *Small Farm Grain Storage Vol III. Storage Methods*. South Africa, Volunteers in Technical Assistance.

Madamba, R. (2002). Producing cowpea seed. The *Crop Breeding Institute.*

Makate, N., (2010). The Susceptibility of Different maize varieties to postharvest infestation by *Sitophilus zeamais (*MOTSCH) (Coleoptera: Cuclionidae). *Scientific Research and Essay*. 5, 1, 030 – 034.

Malaker, P.K., I.H.Mian, R.K.Bhuiyan and M.M.Reza (2008). Effects of storage containers and time on seed quality of wheat.Bangladesh J.Agric.Res. 33 (3): 469477.

Mathew, S., S., (2010). A review on the wheat grain quality under post harvest storage. Int. J. Pharm. Applied Sci., 1: 38-42.

McCann J.C. (2002). Maize and Grain: *Africa's Encounter with New World Crop, 1500-2000. Harvard University Press, Cambridge.*

McCormick, (2000). Occurrence of *Fusarium species* and mycotoxins in Nepalese maize and wheat and the effect of traditional processing methods on mycotoxin levels. J. Agric. Food Chain., 48: 1377-1388.

MOFA (2011) (Ministry of Food and Agriculture), Head Office, Accra. 2011. Maize production records.

MOFA (2012) (Ministry of Food and Agriculture). Patterns of Adoption of Improved maize Technologies in Ghana.

Mohammed, S.S., Abdul-Malik, M.A. Abdul-Sattar and A.A. Al-Abssy (2001). Mycobiota and mycotoxin of stored imported wheat grains in Egypt. Botany Department, Faculty of Science, Assiut University, Egypt.

Moreno E, Benavides C, Ramirez J. (1988). The influence of hermetic storage on the behavior of maize seed germination. *Seed Science and Technology* 16, 427-434.

Moriss , M.L., Tripp., R. and Dankyi, A., (1999). Adoption and impacts of improved maize production technology. A case study of the Ghana Grains Development Project, Economics Programme Paper 99-01, Mexico, D.F., CIMMYT.

Motte, F., R. Feakpi, and M. Awuku (1995). Farmer Experimentation in small-scale maize storage: Experiences from Volta Region in Eastern Ghana. Proceedings from Conference on Postharvest Technology and Commodity Marketing in West Africa, 29 Nov to 1 Dec 1995, Accra, Ghana. IITA 1998. 216-219.

Murdock L.L, Margam, V., Baoud, I. Balfe, S. & Shade, R.E. (2012). Death by dessication: Effects of hermetic storage on cowpea bruchids. Journal of Stored products Research, 49, 166-170.

Ngamo TSL, Ngassoum MB, Mapongmestsem PM, Haubruge E, Hance T. (2007). Current postharvest practices to avoid insect attacks on stored grains in Northern Cameroon. Agricultural Journal 2, 242-247.

Niaz, I. and S.Dawar, (2009). Detection of seed borne mycoflora in maize (Zea mays L.). Park. J. Bot., 41: 443-451.

Nicol, J., Darko, J.O. and Ofosu, A (1997). *A Manual of PostHarvest Technology of Major Food Crops in Ghana, 89.* Postharvest Development Unit, Agricultural Extension Services Department, Ministry of Agriculture, Ghana.

Nuss, E.T. & Tanumihardjo, S.A. (2010). Maize: a paramount staple food crop in the context of global nutrition. Comprehensives Reviews in Food Science and Food Safety 5(4): 415-436.

Nuss, E.T., Tanumihardjo, S.A., (2010). Maize: A Paramount Staple in the Content of Global Nutrition. Comprehensive Reviews in Food Science and Food Safety. 9, 4, 417-436.

Obeng-Ofori D. (2007). The use of botanicals by resource poor farmers in Africa and Asia for the protection of stored agricultural products. Stewart Postharvest Review: 6: 1-8.

Obeng-Ofori D. (2011). Protecting grains from insect infestations in Africa: producer perceptions and practices. Stewart Postharvest Review, 3 (10): 1-8.

Obetta, S., Daniel, C., (2007). Preliminary Investigation into some Quality Control Indices for Selected Stored Grain in Makurdi, Nigeria. *Nigerian Food Journal*. 25, 1, 117 – 129.

Odeyemi O.O. & Daramola A.M. (2000). Storage practices in the tropics, Volume 1. Food storage problem. First edition (2002): 253 pp.

Ogenda. J. O. Deng. A.L. Belmain, S.R. Walker, D. J.Masander, A.A.O (2004). Effects of insecticidal plant materials, *Lantana camara* L. and *Tephrosia vogelli*. Hook, on the quality parameters of stored maize grains. *Journal of food Technology in Africa 9 (1): 29-35.*

Omane Kwabena Sarpong (2013). The Significance of Postharvest Maize Handling to food Sufficiency in Subsistence Farm households in Aframso; Ejura-Sekyedumasi District, Ghana.

Omane Kwabena Sarpong (2013). The significance of postharvest maize handling to food sufficiency in subsistence for households in Aframso in Ejura-Sekyedumasi, Ghana. A thesis submitted for the award of masters degree in Agroecology, Norwegian University of Life Sciences.

Onimisi, P.A., Omage, J.J., Defwang, I.L. and Bawa, G.S. (2009). Replacement value of Normal Maize with Quality Protein Maize (Obatanpa) in broilers Diet. *Pakistan Journal of Nutrition 8(2): 112-115.*

Olajuyigbe O., Stephen OF, (2006). Studies on stored cereal degradation by *Alternaria tenuissima. Acta Botanica Maxicana* 77, 31-40.

Orlyan N.A and Goleva G.G. (1999). Correlation analysis in breeding ultra early maturing maize hybrids. Kurukuzai Sorgo. 6: 9-12.

Owusu EO, Osafo WK, Nutsukpu FR (2007). Bioactivities of candlewood solvent extracts against two stored products insects. Af. J. Sci. Technol. 8:17-21

Owusu, P.J. (1981). A Study of the Indices of Insect Pest in Stored Maize in selected Ecological Areas in the Ashanti region. BSc. Dissertation Submitted to the Department of Crop and Soil Sciences, Faculty of Agriculture, Kwame Nkrumah University of Science and Technology, Kumasi. 46. University Press, Ghana.

Panthee, D.R. (1997). Identification of a suitable indigenous storage structures for wheat seed storage. J.Inst. Agric. Anim. Sci. 17-18: 55-62.

Pomeranz Y, Hall GE, Czuchajowska Z, Lai FS (2000). Test weight, hardness and breakage susceptibility of yellow dent corn hybrids. Cereal Chemistry 63, 349-351.

PPMED(1993). Background information on Ghana:

www.fao.org/wairdocs/x5426e/x5426e03.htm (Assessed 2015 March 15).

Quizada, M. Mendoza, A. Mend-Albored, E. Moreno- Martinez (2006). Hermetic storage system preventing the proliferation of *Protephanus truncatus* Horn and fungi in maize with different moisture content. *Postharvest Biology and Technology*. 39: 321-326.

Raemakers, R.H. (2001). *Crop Production in tropical Africa.* Directorate General for International Co-operation, Karmenlientenstraat 15-Rue des petis Curmers 15-B-1000 Brussels, Belgium. Pp . 23-45, 335-345.

Raouf S.S. (2011). Grain yield and physiological growth indices in maize (*Zea mays* L.). Hybrids under seed bio priming with plant growth promoting rhizobacteria (PGRR). *Journal of food, Agriculture and Environmental* 9 (384), July-October, 393 pp.

Rubashinghege G.R.S., Abeywickrama K. and Paranagama, (2007). Effect of selected essential oils on physiochemical changes of stored cowpea, Vigna unguiculata, treated to control cowpea bruchid, Callosobruchus maculates (F). pp: 23-24.

Sallam, M.N., (1999). *Chapter II Insect Damage on Post-harvest.*

Sanches –Marines RI, Cortez-Rocha MO, Ortega-Dorame F, Morales-Valdes M, Silveira MI. (1997). End-use quality of flour from *Rhyzopertha dominica* infested wheat. Cereal Chemistry 74, 481-483.

Sarangi, S.K., Singh, R., and Singh, K.A. (2009). Indigenous methods of rat proof grain storage by Adi tribes of Arunachal Pradesh, 8(2): 230-233.

Shepherd, (2010). A *Guide to Maize Marketing for Extension Officers, revised edition*. FAO, Rome.

SRID (2012). Statistics, Research and Information Department of the Ministry of Food and Agriculture, Ghana.

SRID, (2007). Statistic Research and Information Department of the Ministry of Agriculture, Ghana: Production of some major crops in Ghana.

SRID, MoFA (2007). National Crop production estimates 2002-2006. Statistical Research and Information Department, Ministry of Food and Agriculture.

Stenseth, N., Leirs, H., Skonhoft, A., Davis, S.A., Pech, R.P., Andreassen, H.P., Singleton, G.R., Lima, M., Machangu, R.M., Makundi, R.H., Zhang, Z., Brown, P., Shi, D., Wan, X., (2003). Mice and Rats: The Dynamics and Bio-Economics of Agricultural Rodent pests. *Frontiers in Ecology and Environment*. 1, 7, 000- 000.

Tefera, T. (2012). Postharvest losses in African maize in the face of increases food shortages. J.Food Security, 4: 1876-4517.

Tefera, T., Muo, S., Likhayo, P., (2011). Effects of Insect Population Density and Storage Time on Grain Damage and Weight Loss in Maize due to the Maize weevil *Sitophilus zeamais* and the Larger Grain Borer *Prostephanus truncates*. *African Journal of Agricultural Research*. 6, 10, 2249-2254.

Tilahun, S. (2000). "Grain based Ethiopian traditional common foods processing Science and Technology". *In: Training module for centre of research on grain quality process and technology transfer*, Haramaya University, Ethiopia, 2007.

Udoh, J.M., Cardwell F.K., Ikotun T., (2000). Storage structures and aflatoxin content of maize in five agroecological zones in Nigeria.

Ullah, I., M. Ali, and Farooqi (2010). Chemical and nutritional properties of some maize (Zea mays L.) varieties grown in NWFD, Pakistan. *Pakistan Journal of Nutrition* 9(11): 1113-1117.

UNIFEM (1995). *Storage: Food Cycle Technology Source.* Intermediate Technology and UNIFEM, London.

UNIFEM. (1995). Storage*: Food Cycle Technology Source Books*. Intermediate Technology and UNIFEM, London.

United States Department of Agriculture Economic Research Service (USDA) (2009). *Maize: A dependable Source of protein*

United States Department of Agriculture Economic Research Service (USDA) (2012). Grain Feed Production and Protection.

Vasal, S.K (2000). Control of horse purslane (*Trianthema partulacastrum* L.) in maize by using allelopathic extracts.

Villiers , P., Bruin, T., Navarro, S., (2006). Feed Technology Update. Volume 1, Issue 3. Links Publishing, Honolulu.

Vincent Amanor-Boadu (2012). The Maize Prize Trends in Ghana 2007-2011- METSS-Ghana Research and Issue paper services No. 01-2012-April, 2012.

Wambugu, P.W., P.W. Mathenge, E.O.Auma, and H.A. van Rheenen (2009). Efficacy of traditional maize (Zea mays L.) seed storage methods in Western Kenya. *African journal of Food, Agriculture, Nutrition, and Development.* 9(4): 1110-1128.

Weinberg, Y.Y., Chen, Y., Finkelman, S., Ashbell, G., Navarro, S., (2009). The Effect of Moisture Level on High-moisture maize (Zea mays L.) under hermetic storage conditions-in vitro Studies.

Wright, V., (2011). *Assessment of Insect Infestation in stored Maize and their Relationship to Aspergillus flavus contamination*. <http://www.mycotoxins.net.br/boletin41.pdf> (Assessed 2014 December 29).

Yaouba, A, Tatsadjiou, N., Jazet, D.P.M. & Mbofung, C.M. (2012). Inhibition of fungal development in maize granaries under storage condition by essential oils. *International Journal of Bioscience 2 (6): 41-48.*

APPENDICES

Appendix I: Samples of questionnaires administered to respondents

Questionnaires administered to respondents during the field survey conducted in Ejura-Sekyedumasi Municipality to identify some commonly used storage methods used to store maize grains in the Municipality.

Section A: the bio-data of respondents

1. What is the name of this community……………………………?
2. Sex: A. Male [ ] B. Female [ ]
3. How old are you………………………………………………?
4. What is your main occupation………………………………...?
5. Have you been to school before?
   A. Yes [ ] B. No [ ]
6. What was your educational level?
   A. Primary [ ]
   B. JSS/JHS [ ]
   C. SSS [ ]
   D. Tertiary [ ]
   E. Others [ ]

Section B: Data on production activities

7. For how long have you been farming?
8. What type of production do you engage in?
   A. Subsistence [ ] B. commercial [ ]
9. What is the size of your farm…………………………?
10. What variety of maize do you grow…………………..?
11. Can you mention the name of the variety of maize grown....?
12. Why do you choose to grow that variety…………………...?
13. Do you store your maize after harvesting………………….?
    A. Yes [ ] B. No [ ]

14. In what form do you store your harvested maize………….?

15. What method do you use to store your maize……………,.?

16. Why do you use such method……………………………..?

17. Do you apply any chemical prior to storage………………?

18. Can you mention the name of the chemical use?

19. Do you encounter any change for storing your maize in that method?

A. Yes [ ] B. No [ ]

20. What are some of the challenges you encounter……………..?

Appendix II: ANOVA tables of treatment effects on postharvest grain quality characteristics.

Student Edition of Statistix 9.0

Analysis of Variance Table for moisture content

Source	DF	SS	MS	F	P
rep	2	16.5675	8.28375		
Months	3	14.4950	4.83167	23.03	0.0000
SM	5	26.7100	5.34200	25.46	0.0000
Months*SM	15	13.0900	0.87267	4.16	0.0001
Error	46	9.6525	0.20984		
Total	71	80.5150			

Grand Mean 14.408 CV 3.18

Student Edition of Statistix 9.0

Analysis of Variance Table for percent grain damage

Source	DF	SS	MS	F	P
rep	2	0.1	0.07		
month	3	4602.2	1534.08	2641.09	0.0000
storage	5	8032.9	1606.58	2765.90	0.0000
month*storage	15	1794.9	119.66	206.01	0.0000
Error	46	26.7	0.58		
Total	71	14456.9			

Grand Mean 31.250 CV 2.44

Student Edition of Statistix 9.0

Analysis of Variance Table for live insects that caused grain damage

Source	DF	SS	MS	F	P
rep	2	33.4	16.70		
Months	3	4714.5	1571.50	9951.45	0.0000
SM	5	10117.0	2023.40	12813.1	0.0000
Months*SM	15	2154.0	143.60	909.34	0.0000

Error	46	7.3	0.16
Total	71	17026.2	

Grand Mean 27.083   CV 1.47

Student Edition of Statistix 9.0

Analysis of Variance Table for weightlos

Source	DF	SS	MS	F	P rep
	2	18.75	9.375		
Months	3	320.59	106.865	520.19	0.0000
SM	5	598.70	119.740	582.86	0.0000
Months*SM	15	272.62	18.175	88.47	0.0000
Error	46	9.45	0.205		
Total	71	1220.12			

Grand Mean 9.5037   CV 4.77

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Analysis of Variance Table for colourcha

Source	DF	SS	MS	F	P rep
	2	15.528	7.76375		
Months	3	26.500	8.83333	19.30	0.0000
SM	5	47.500	9.50000	20.76	0.0000
Months*SM	15	9.500	0.63333	1.38	0.1957
Error	46	21.053	0.45766		
Total	71	120.080			

Grand Mean 2.9167   CV 23.19

Student Edition of Statistix 9.0

Analysis of Variance Table for grain odour

Source	DF	SS	MS	F	P rep
	2	10.176	5.08792		
Months	3	29.000	9.66667	14.88	0.0000
SM	5	23.500	4.70000	7.23	0.0000
Months*SM	15	17.500	1.16667	1.80	0.0650
Error	46	29.884	0.64966		
Total	71	110.060			

Grand Mean 2.6667   CV 30.23

Student Edition of Statistix 9.0

Analysis of Variance Table for weight loss

Source	DF	SS	MS	F	P
rep	2	20.46	10.231		
CHEM	1	4.14	4.141	19.23	0.0000
Month	3	1796.66	598.886	2781.51	0.0000
PM	5	1701.12	340.225	1580.16	0.0000
CHEM*Month	3	1.73	0.575	2.67	0.0518
CHEM*PM	5	6.75	1.349	6.27	0.0000
Month*PM	15	615.59	41.039	190.61	0.0000
CHEM*Month*PM	15	19.90	1.327	6.16	0.0000
Error	94	20.24	0.215		
Total	143	4186.59			

Grand Mean 5.5096 CV 8.42

Student Edition of Statistix 9.0

Analysis of Variance Table for moisture

Source	DF	SS	MS	F	P
rep	2	42.135	21.0675		
CHEM	1	0.391	0.3906	2.01	0.1591
Month	3	58.532	19.5106	100.63	0.0000
PM	5	21.393	4.2786	22.07	0.0000
CHEM*Month	3	0.362	0.1206	0.62	0.6024
CHEM*PM	5	0.798	0.1596	0.82	0.5362
Month*PM	15	5.139	0.3426	1.77	0.0512
CHEM*Month*PM	15	0.444	0.0296	0.15	0.9999
Error	94	18.225	0.1939		
Total	143	147.419			

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Grand Mean 13.552 CV 3.25

Analysis of Variance Table for life insects

Source	DF	SS	MS	F	P
rep	2	18.38	9.188		
CHEM	1	4.00	4.000	20.63	0.0000
Month	3	542.00	180.667	931.83	0.0000
PM	5	3157.25	631.450	3256.86	0.0000
CHEM*Month	3	17.00	5.667	29.23	0.0000
CHEM*PM	5	41.75	8.350	43.07	0.0000
Month*PM	15	226.75	15.117	77.97	0.0000
CHEM*Month*PM	15	30.25	2.017	10.40	0.0000
Error	94	18.23	0.194		
Total	143	4055.60			

Grand Mean 9.4167 CV 4.68

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Analysis of Variance Table for grain odour change

Source	DF	SS	MS	F	P
rep	2	18.375	9.1875		
CHEM	1	0.062	0.0625	0.32	0.5715
Month	3	36.688	12.2292	63.07	0.0000
PM	5	39.313	7.8625	40.55	0.0000
CHEM*Month	3	0.188	0.0625	0.32	0.8092

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CHEM*PM	5	0.313	0.0625	0.32	0.8984
Month*PM	15	25.937	1.7292	8.92	0.0000
CHEM*Month*PM	15	0.937	0.0625	0.32	0.9918
Error	94	18.225	0.1939		
Total	143	140.038			

Grand Mean 2.1042 CV 20.93

Analysis of Variance Table for grain damage

Source	DF	SS	MS	F	P
rep	2	56.73	28.367		
CHEM	1	0.02	0.016	0.08	0.7841
Month	3	322.55	107.516	519.71	0.0000
PM	5	1849.58	369.916	1788.11	0.0000
CHEM*Month	3	2.80	0.932	4.51	0.0053
CHEM*PM	5	12.08	2.416	11.68	0.0000
Month*PM	15	147.98	9.866	47.69	0.0000
CHEM*Month*PM	15	35.73	2.382	11.52	0.0000
Error	94	19.45	0.207		
Total	143	2446.91			

Grand Mean 6.6771 CV 6.81

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Analysis of Variance Table for grain colour change

Source	DF	SS	MS	F	P
rep	2	10.344	5.17188		

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CHEM	1	0.063	0.06250	0.24	0.6253
Month	3	20.687	6.89583	26.48	0.0000
PM	5	37.813	7.56250	29.04	0.0000
CHEM*Month	3	1.688	0.56250	2.16	0.0979
CHEM*PM	5	1.812	0.36250	1.39	0.2343
Month*PM	15	17.937	1.19583	4.59	0.0000
CHEM*Month*PM	15	6.937	0.46250	1.78	0.0496
Error	94	24.476	0.26039		
Total	143	121.758			

Grand Mean 1.9792 CV 25.78

ANOVA tables for proximate composition analysis
Proximate before storage

Student Edition of Statistix 9.0

Completely Randomized AOV for ash

Source	DF	SS	MS	F	P trt
5	1.27420	0.25484	1.53	0.2529	
Error	12	2.00060	0.16672		
Total	17	3.27480			

Grand Mean 1.2467 CV 32.75

Homogeneity of Variances	F	P
Levene's Test	4.00	0.0228
O'Brien's Test	1.78	0.1920
Brown and Forsythe Test	3.95	0.0238

Welch's Test for Mean Differences

Source	DF	F	P trt
	5.0	M	0.0000
Error		M	

Component of variance for between groups 0.02937
Effective cell size 3.0

Treatment Mean clay
pot 1.7300 heap on
floor 1.4300 jute sack
1.0200 plastic drum
1.1400 polypropylene
0.9400 triple bag
1.2200
Observations per Mean 3
Standard Error of a Mean 0.2357
Std Error (Diff of 2 Means) 0.3334

Completely Randomized AOV for carbohydrate

Source	DF	SS	MS	F	P trt
5	18.0670	3.61340	10.73	0.0004	
Error	12	4.0402	0.33668		
Total	17	22.1072			

Grand Mean 77.093 CV 0.75

Homogeneity of Variances	F	P
Levene's Test	3.17	0.0472
O'Brien's Test	1.41	0.2895
Brown and Forsythe Test	2.87	0.0627

Welch's Test for Mean Differences

Source DF F P trt
5.0 M 0.0000
Error M

Component of variance for between groups 1.09224
Effective cell size 3.0

Treatment Mean clay
pot 76.390 heap on
floor 75.460 jute sack
77.570 plastic drum
77.700 polypropyl
76.860 triple bag
78.580
Observations per Mean 3
Standard Error of a Mean 0.3350
Std Error (Diff of 2 Means) 0.4738

Completely Randomized AOV for fat

Source DF SS MS F P trt
5 0.75025 0.15005 0.30 0.9047
Error 12 6.04000 0.50333
Total 17 6.79025

Grand Mean 3.8283 CV 18.53

Homogeneity of Variances	**F**	**P**
Levene's Test	2.37	0.1027
O'Brien's Test	1.05	0.4321
Brown and Forsythe Test	2.09	0.1375

Welch's Test for Mean Differences

Source DF F P trt
5.0 M 0.0000
Error M

Component of variance for between groups -0.11776
Effective cell size 3.0

Treatment Mean clay
pot 3.5000 heap on
floor 3.6000 jute sack
4.0000 plastic drum
3.8700 polypropylene
4.0000 triple bag
4.0000 Observations per Mean
3
Standard Error of a Mean 0.4096
Std Error (Diff of 2 Means) 0.5793

Completely Randomized AOV for fibre

Source	DF	SS	MS	F	P trt
5	0.41320	0.08264	0.25	0.9336	
Error	12	4.02040	0.33503		
Total	17	4.43360			

Grand Mean 2.3033 CV 25.13

Homogeneity of Variances	F	P
Levene's Test	3.18	0.0465
O'Brien's Test	1.41	0.2872
Brown and Forsythe Test	3.01	0.0546

Welch's Test for Mean Differences

Source	DF	F	P trt
5.0	M	0.0000	
Error	M		

Component of variance for between groups -0.08413
Effective cell size 3.0

Treatment Mean clay
pot 2.3900 heap on
floor 1.9800 jute sack
2.2800 plastic dr
2.3800 polypropyl
2.3600 triple bag
2.4300
Observations per Mean 3

Standard Error of a Mean 0.3342
Std Error (Diff of 2 Means) 0.4726

Completely Randomized AOV for moisture content

Source DF SS MS F P trt
5 76.5496 15.3099 45.93 0.0000
Error 12 4.0004 0.3334
Total 17 80.5500

Grand Mean 5.6633 CV 10.20

Homogeneity of Variances F P
Levene's Test 3.20 0.0459
O'Brien's Test 1.42 0.2850
Brown and Forsythe Test 3.17 0.0472

Welch's Test for Mean Differences
Source DF F P trt
5.0 M 0.0000
Error M

Component of variance for between groups 4.99218
Effective cell size 3.0

Treatment Mean clay
pot 6.8700 heap on
floor 8.9700 jute sack
4.7700 plastic drum
3.9700 polypropylene
6.6500 triple bag 2.7500
Observations per Mean 3
Standard Error of a Mean 0.3333
Std Error (Diff of 2 Means) 0.4714

Completely Randomized AOV for protein

Source DF SS MS F P trt
5 16.3450 3.26901 6.54 0.0037
Error 12 6.0004 0.50003
Total 17 22.3454

Grand Mean 9.8650 CV 7.17

Homogeneity of Variances	F	P
Levene's Test	2.40	0.0994
O'Brien's Test	1.07	0.4254
Brown and Forsythe Test	2.37	0.1027

Welch's Test for Mean Differences

Source DF F P trt

5.0 M 0.0000

Error M

Component of variance for between groups 0.92299

Effective cell size 3.0

Treatment Mean clay

pot 9.120 heap on floor

8.560 jute sack 10.360

plastic drum 10.940

polypropylene 9.190 triple

bag 11.020 Observations

per Mean 3

Standard Error of a Mean 0.4083

Std Error (Diff of 2 Means) 0.5774

ANOVA tables for proximate composition after storage

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Completely Randomized AOV for ash

Source	DF	SS	MS	F	P storage
5	4.62460	0.92492	5.43	0.0077	
Error	12	2.04520	0.17043		
Total	17	6.66980			

Grand Mean 1.6267 CV 25.38

Homogeneity of Variances	**F**	**P**
Levene's Test	3.96	0.0235
O'Brien's Test	1.76	0.1954
Brown and Forsythe Test	3.56	0.0333

Welch's Test for Mean Differences

Source DF F P storage

5.0 M 0.0000

Error M

Component of variance for between groups 0.25150
Effective cell size 3.0

storage Mean clay pot
1.5000 heap on floor
1.7300 jute sack
1.5200 plastic drum
2.5200 polypropylene
0.7900 triple bag
1.7000 Observations per Mean
3
Standard Error of a Mean 0.2384
Std Error (Diff of 2 Means) 0.3371

Completely Randomized AOV for carbohydrate

Source DF SS MS F P storage
5 147.738 29.5477 1.72 0.2043
Error 12 206.005 17.1671
Total 17 353.744

Grand Mean 73.453 CV 5.64

Homogeneity of Variances F P
Levene's Test 3.95 0.0238
O'Brien's Test 1.76 0.1965
Brown and Forsythe Test 3.48 0.0358

Welch's Test for Mean Differences
Source DF F P storage
5.0 15 18.45 0.0000
Error 4.7

Component of variance for between groups 4.12686
Effective cell size 3.0

storage Mean clay
pot 71.010 heap
on floor 69.450 jute
sack 73.650 plastic

drum 75.900
polypropylene 72.710
triple bag 78.000
Observations per Mean 3
Standard Error of a Mean 2.3921
Std Error (Diff of 2 Means) 3.3830

Completely Randomized AOV for fat

Source DF SS MS F P storage
5 5.9800 1.19600 2.39 0.1006
Error 12 6.0100 0.50083
Total 17 11.9900

Grand Mean 3.3833 CV 20.92

Homogeneity of Variances F P
Levene's Test 2.39 0.1002
O'Brien's Test 1.06 0.4270
Brown and Forsythe Test 2.24 0.1170

Welch's Test for Mean Differences
Source DF F P storage
5.0 M 0.0000
Error M

Component of variance for between groups 0.23172
Effective cell size 3.0

storage Mean clay pot
3.4500 heap on floor
4.0000 jute sack 2.3500
plastic drum 3.5000
polypropylene 3.0000 triple
bag 4.0000 Observations
per Mean 3
Standard Error of a Mean 0.4086
Std Error (Diff of 2 Means) 0.5778
Completely Randomized AOV for fibre

Source DF SS MS F P storage
5 4.44325 0.88865 2.65 0.0774
Error 12 4.02520 0.33543
Total 17 8.46845

Grand Mean 2.3283 CV 24.87

Homogeneity of Variances	F	P
Levene's Test	3.18	0.0467
O'Brien's Test	1.41	0.2878
Brown and Forsythe Test	2.95	0.0581

Welch's Test for Mean Differences

Source DF F P storage

5.0 M 0.0000

Error M

Component of variance for between groups 0.18441

Effective cell size 3.0

storage Mean clay pot

2.7100 heap on fl 2.5200

jute sack 2.4900 plastic

drum 1.2300 polypropylene

2.5000 triple bag 2.5200

Observations per Mean 3

Standard Error of a Mean 0.3344

Std Error (Diff of 2 Means) 0.4729

Completely Randomized AOV for moisture

Source DF SS MS F P storage

5 171.283 34.2566 68.28 0.0000

Error 12 6.020 0.5017

Total 17 177.303

Grand Mean 8.3633 CV 8.47

Homogeneity of Variances	F	P
Levene's Test	2.38	0.1010
O'Brien's Test	1.06	0.4287
Brown and Forsythe Test	2.23	0.1185

Welch's Test for Mean Differences

Source DF F P storage

5.0 M 0.0000

Error M

Component of variance for between groups 11.2516
Effective cell size 3.0

Storage method	Mean
clay pot	10.580
heap on floor	11.250
jute sack	9.850
plastic drum	5.850
polypropylene	10.000
triple bag	2.650

Observations per Mean 3
Standard Error of a Mean 0.4089
Std Error (Diff of 2 Means) 0.5783

Completely Randomized AOV for protein

Source	DF	SS	MS	F	P storage
5	1.56045	0.31209	0.83	0.5533	
Error	12	4.52020	0.37668		
Total	17	6.08065			

Grand Mean 10.865 CV 5.65

Homogeneity of Variances	F	P
Levene's Test	2.82	0.0656
O'Brien's Test	1.25	0.3449
Brown and Forsythe Test	2.39	0.1005

Welch's Test for Mean Differences

Source	**DF**	**F**	**P** storage
5.0	M	0.0000	
Error	M		

Component of variance for between groups -0.02153
Effective cell size 3.0

storage method Mean clay
pot 10.750 heap on floor
11.050 jute sack 10.260
plastic drum 11.000
polypropylene 11.000 triple
bag 11.130 Observations
per Mean 3

Standard Error of a Mean   0.3543
Std Error (Diff of 2 Means) 0.5011

APPENDIX III: ANOVA FOR MINERALS ANALYSIS

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Completely Randomized AOV for Calcium

Source DF SS MS F P trt
5 0.01300 0.00260 52.00 0.0000
Error 12 0.00060 0.00005
Total 17 0.01360

Grand Mean 0.1333 CV 5.30

Homogeneity of Variances F P
Levene's Test 2.40 0.0994
O'Brien's Test 1.07 0.4253
Brown and Forsythe Test 2.40 0.0994

Welch's Test for Mean Differences
Source DF F P trt
5.0 M 0.0000
Error M

Component of variance for between groups 8.500E-04
Effective cell size 3.0

Treatment Mean clay
pot 0.1900 heap on
floor 0.1100 jute sack
0.1300 plastic drum
0.1100 polypropylene
0.1300 triple sack 0.1300
Observations per Mean 3
Standard Error of a Mean 4.082E-03
Std Error (Diff of 2 Means) 5.774E-03

Completely Randomized AOV for Potassium

Source DF SS MS F P trt
5 0.00720 0.00144 21.60 0.0000
Error 12 0.00080 0.00007
Total 17 0.00800
Grand Mean 0.1300 CV 6.28

Homogeneity of Variances F P
Levene's Test 1.60 0.2336
O'Brien's Test 0.71 0.6267
Brown and Forsythe Test 1.60 0.2336

Welch's Test for Mean Differences

Source	DF	F	P trt
5.0	M	0.0000	
Error	M		

Component of variance for between groups 4.578E-04
Effective cell size 3.0

Treatment Mean clay pot
0.1400 heap on floor 0.1100
jute sack 0.1200 plastic
drum 0.1200 polypropylene
0.1700 triple sack 0.1600
Observations per Mean 3
Standard Error of a Mean 4.714E-03
Std Error (Diff of 2 Means) 6.667E-03

Completely Randomized AOV for Magnesium

Source	DF	SS	MS	F	P trt
5	0.01045	0.00209	31.35	0.0000	
Error	12	0.00080	0.00007		
Total	17	0.01125			

Grand Mean 0.1283 CV 6.36

Homogeneity of Variances F P
Levene's Test 1.60 0.2336
O'Brien's Test 0.71 0.6267
Brown and Forsythe Test 1.60 0.2336

Welch's Test for Mean Differences

Source	DF	F	P trt
5.0	M	0.0000	
Error	M		

Component of variance for between groups 6.744E-04
Effective cell size 3.0

Treatment Mean clay pot
0.1200 heap on floor 0.0800
jute sack 0.1500 plastic
drum 0.1400 polypropylene
0.1500 triple sack 0.1100
Observations per Mean 3
Standard Error of a Mean 4.714E-03
Std Error (Diff of 2 Means) 6.667E-03

Completely Randomized AOV for Sodium

Source DF SS MS F P trt
5 0.24460 0.04892 91.72 0.0000
Error 12 0.00640 0.00053
Total 17 0.25100

Grand Mean 0.3933 CV 5.87

Homogeneity of Variances F P
Levene's Test 3.53 0.0341
O'Brien's Test 1.57 0.2420
Brown and Forsythe Test 2.30 0.1101

Welch's Test for Mean Differences
Source DF F P trt
5.0 M 0.0000
Error M

Component of variance for between groups 0.01613
Effective cell size 3.0

Treatment Mean clay pot
0.1500 heap on floor 0.4500
jute sack 0.4000 plastic
drum 0.5000 polypropylene
0.4800 triple sack 0.3500
Observations per Mean 3
Standard Error of a Mean
0.0133
Std Error (Diff of 2 Means) 0.0189

Completely Randomized AOV for Phosphorus

Source DF SS MS F P trt
5 0.03505 0.00701 4.08 0.0213
Error 12 0.02060 0.00172
Total 17 0.05565
Grand Mean 0.1517 CV 27.32

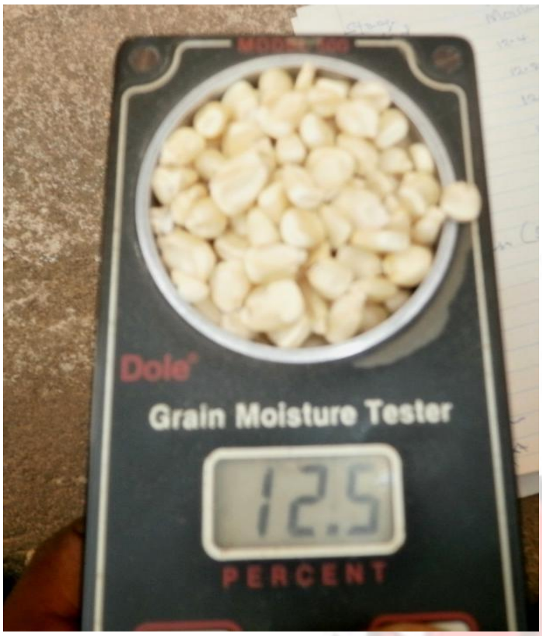
Homogeneity of Variances F P
Levene's Test 3.95 0.0238
O'Brien's Test 1.76 0.1965
Brown and Forsythe Test 3.49 0.0354

Welch's Test for Mean Differences
Source DF F P trt
5.0 M 0.0000
Error M

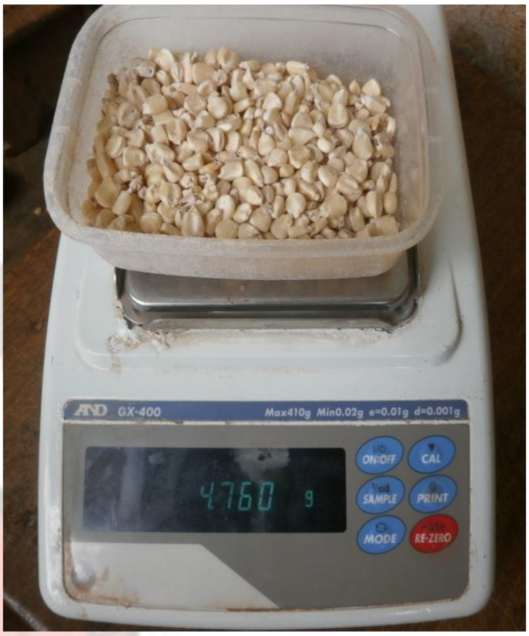
Component of variance for between groups 0.00176
Effective cell size 3.0

Treatment Mean clay pot
0.1300 heap on fl00r 0.0900
jute sack 0.2100 plastic
drum 0.1300 polypropylene
0.1400 triple sack 0.2100
Observations per Mean 3
Standard Error of a Mean 0.0239
Std Error (Diff of 2 Means) 0.0338

Appendix IV: SOME PICTURES TAKEN DURING THE STUDY



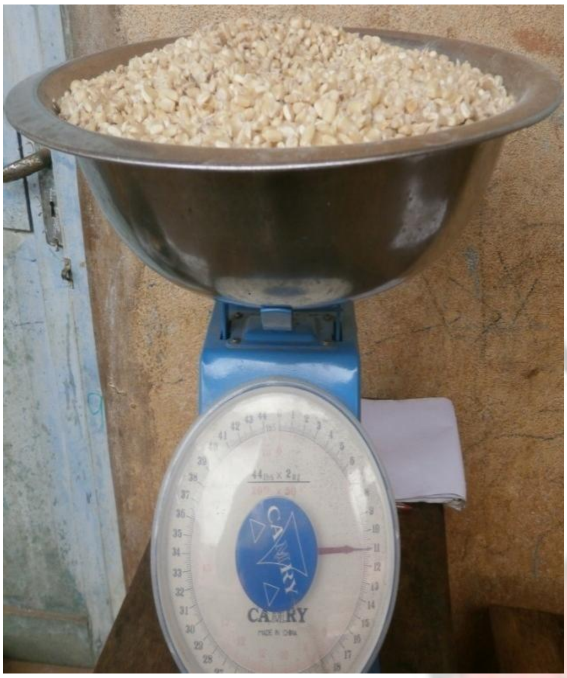
Picture1: Moisture determination



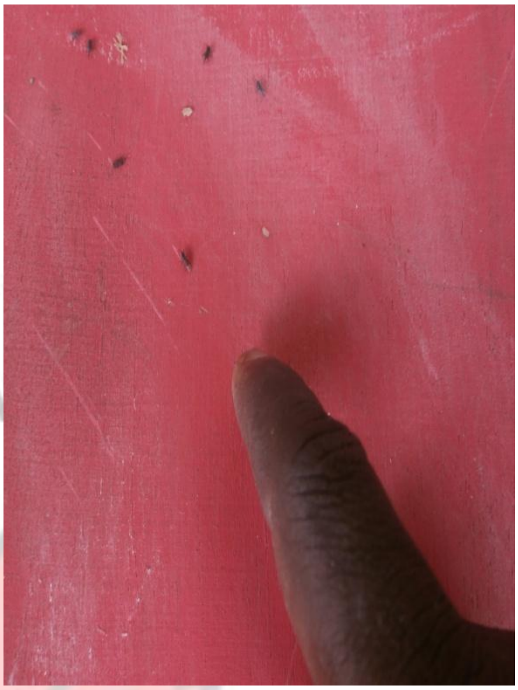
Picture 2: Weight determination

Picture 3: Sieving for insects

Picture 4: Temperature & Relative humidity measurement



Picture 5: Weighing of grains for storage



Picture 6: Counting of live insects