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EFFECTS OF DIFFERENT DRYING METHODS AND LENGTH OF STORAGE ON QUALITY OF SEED MAIZE VARIETY OBAATANPA

BY

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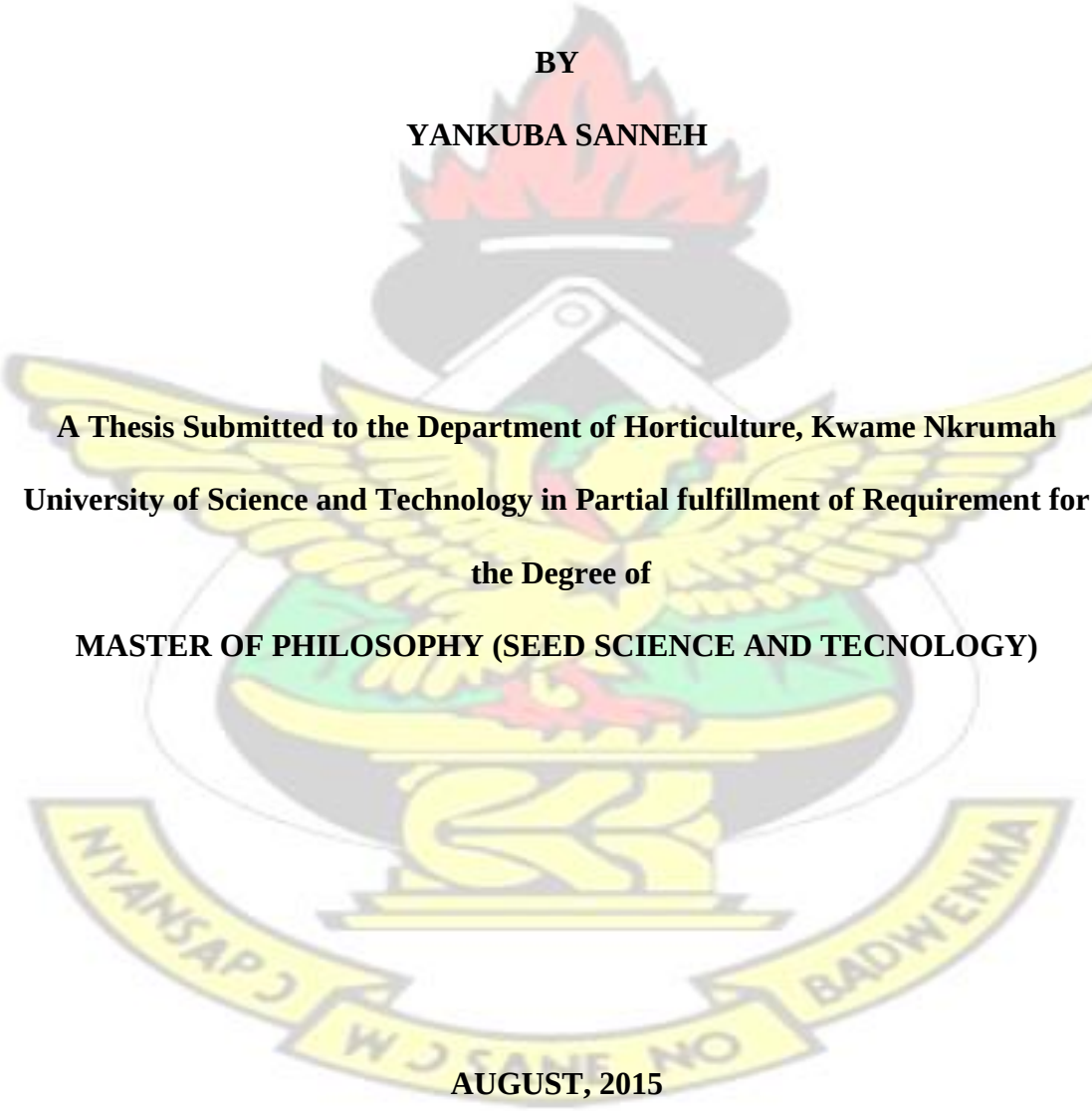

AUGUST, 2015

DECLARATION

I, Yankuba Sanneh, declare that I personally undertook this project and it has not been produced anywhere for award of a degree except other people`s works cited which have been dully acknowledged

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ABSTRACT

The main objective of the research was to identify appropriate drying and storage technologies for improving seed quality by enhancing healthy seedlings. The design of the experiment was 2 × 4 factorial arrangement in complete randomized design (CRD). The factors were drying methods at two levels: sun and oven drying; Storage durations at four levels: 0, 30, 60 and 90 days. The results depicted that, sun drying resulted in the highest percent (1.69%) of weevil infestation of Obaatanpa maize than oven drying with the least (1.00%). For iron content, sun drying had the higher length of drying period (21.82%), than the oven drying which had the least days of drying (15.32%). Among the storage durations, the highest iron content was obtained at 60 days (20.0%), similarly higher in 30 and 90 days. The least iron content was obtained at 0 day (15.5%). The highest potassium content was obtained from sun drying (0.13%) and the least was observed from oven drying (0.1%). In addition, both sun and oven drying at 30 and 90 days storage duration had the highest ash content (1.5%) and the oven drying at 90 days (0.8%) had the least, while at 30 days storage durations had the highest ash content (1.46%) and the lowest from the 0 day of storage (1.08%). Between the drying methods there were no significant differences. The highest percent of seed carbohydrate content was obtained at 90 days (73.94%) and was similarly higher from 0 and 30 days. The lowest was obtained at 60 days (70.62%). For seed germination test, sun drying revealed the highest percentage of seed germination and the lowest was observed for oven drying while storing for 30 days resulted in the highest seed viability. The least seed viability was recorded for 60 days of storage. A total of five pathogen species were identified (*Collectotrichum* spp., *Aspergillus flavus, Aspergillus niger, Penicillium* spp. and *Rhizopus* spp.). The highest occurrence

of fungal infestation was observed from 30 to 60 days after storage while, sun dried seed showed highest occurrence of the pathogens compared to the oven dried seeds.

DEDICATION

I dedicate this thesis to My Mother Fintong Baba, My Late Father Kaddeh Sanneh (R.I.P.), My Late Uncle Kasum Bayo (R.I.P.), My Wife Isatou Baba and My Daughter Fatoumata Sanneh.

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TABLE OF CONTENTS

CONTENT **PAGE**

5.1 Effect of drying methods and storage durations on seed germination and vigor

LIST OF TABLES

TABLE **PAGE**

CHAPTER ONE

1.0 INTRODUCTION

Maize (*Zea mays* L.) with origins in America is now one of the most widely cultivated food crops in the world. It is both tropical and a temperate crop and a major source of energy (PROTA 1, 2006). Growing maize on farms of one to two hectares can provide sustenance to a household and the aggregate effects possibly doubling food production in Africa (Ogunsumi *et al*., 2005). Maize is also used as a principal energy source for intensive animal industries throughout the world. It is usually harvested at a relatively high moisture content to minimize damage in the field when left to dry naturally (Brown, 1996).

In Gambia, maize is the second most important cereal crop after rice and is grown in all the regions of the country. In term of grain quantities, maize is the most important grain crop in a number of West African countries. In Ghana, it constitutes one of the major carbohydrates staples in the cities and urban areas and it is the basic staple food in the Volta, Greater Accra and Central regions. Seed insecurity in Africa have been attributed, among others, to inadequate facilities and inappropriate methods for seed storage among rural farmers. Poor seed storage conditions have been reported to cause up to 10% loss in seed quality in the tropics mainly through loss of viability (Wambungu, *et al*., 2009). In addition, inappropriate seed drying results in seeds being stored with high moisture with consequences of increases in bacterial and fungal infection as well as insect infestation. These circumstances impair the maintenance of sufficient and safe seed resources which are key to farmers' seed security.

The purpose of seed drying is to reduce the respiration of the seed by the removal of excess moisture and to prevent the qualitative deterioration of seeds in storage, which arise from growth of microorganisms and the activities of insects and mites.

A good seed drying and storage system are therefore vital for the maintenance of the physiological quality, particularly viability and seed vigor (FAO, 2004).

The main objective of the research was to identify appropriate drying and storage technologies for improving seed quality. Specifically the objectives were to:

1. assess the effects of the drying methods and storage durations on seed maize proximate and mineral quality.
2. determine the effects of the drying and storage methods on seed borne diseases of maize.
3. determine the effects of the drying methods and storage durations on seed viability and seed vigor.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Maize production

Maize (*Zea mays* L.) is ranked second to wheat among the world cereal crops and the most important cereal crop in Sub-Saharan Africa (SSA). In 2010, the estimated production in sub-Saharan Africa was 57 million tons on about 30 million ha of land (FAOSTAT, 2010). It is a major source of energy for humans and farm animals; contributing 15–50% of the energy in human diets in sub-Saharan Africa (Banziger and Diallo, 2002). It is also used for producing several non-food products (IITA, 2006). Most of it is grown for human consumption and provides food and income for more

than 300 million smallholder farmers in SSA (Pingali, 2001). Cultivation of maize on farms of one to two hectares can provide sustenance to a household and the aggregate effects possibly doubling food production in Africa (Ogunsumi *et al*., 2005).

2.2 Maize seed maturation

High quality seed is the goal of all maize seed producers. The production of maize seed is dependent on timely harvest operations that ensure maximum seed quality and yield. Although many studies have related seed moisture to maturity, moisture levels at physiological maturity have been found to vary widely among maize cultivars (Tekrony and Hunter, 1995). The black layer formation has been proposed as an alternative to seed moisture for determining harvesting time (Tekrony and Hunter, 1995). Harvesting high-moisture (>17% moisture content maize is appealing because it reduces field pest attacks, avoids weather related harvesting delays, and minimizes field losses compared to harvesting at conventional moisture levels (Aljinovic *et al*., 1995). High-moisture maize can be harvested several weeks earlier than maize harvested for dry storage. Earlier harvest places maize closer to physiological maturity and maximum dry matter and avoids losses that can occur when maize is left to dry in the field. The earlier harvesting also opens the possibility of having higher quality residue left in the field, which can potentially be collected for conversion to silage (Wyman, 2003).

2.3 Maize seed drying and storage

Most cereal grains can be stored for long duration without microbial infections, although biochemical changes could occur during storage. During seed storage, seed deterioration processes could be rapidly started and followed by respiration and loss of seed matter, conditions that lead to decrease in the functional and nutritional

properties of the seed (Siadat *et al*., 2011). Maize kernels attain maximum dry matter when they reach physiological maturity, usually at a moisture level of between 35 and 25% wet basis. After maize has reached physiological maturity, kernel moisture content decreases until harvest, which usually takes place at moisture levels between 25 and 17%. Once harvested, temperature and moisture conditions favor rapid growth of fungi in stored maize, making it necessary to either dry the maize or use some other preservation method. The most common seed preservation method is drying, which uses forced-air systems that move either natural air or heated air through the seed. While drying maize is effective in extending the storage life and slowing deterioration, it is energy intensive and costly. Rapid maize drying with heated air can also cause the formation of stress cracks within the kernel due to the differential drying rates of the pericarp and the endosperm (White *et al*., 2010). Maize with moisture contents between 25 and 28% is ideal for ensiling in a sealed structure such as a silo, bunker, or plastic bag. During the initial stage of ensiling, excess oxygen is consumed by aerobic organisms, resulting in an anaerobic environment. During the second stage, soluble sugars are converted to lactic acid, acetic acid, ethanol, mannitol, acetaldehyde, and carbon dioxide by lactic acid bacteria, which results in pH declining to a level that inhibits further microbial growth (Roberts, 1995). Successful seed storage is key to farmers' seed security and may also enable communities to generate income through collecting, storing and selling seeds. Maize needs to be stored from one harvest to the next to maintain a constant supply year round and to preserve seed quality until used (Adetunji, 2009).

2.4 Maize seed storage techniques

Spoilage and total wastage of maize seeds can be minimized through the use of storage techniques. Storage is a way or a process by which agricultural produce or products

are kept for future use, it is an interim phase during transit of agricultural produce from producers to processors and finally from processors to consumers (Adetunji, 2007). The various forms of storage techniques available for maize seed range from on-field, open storage, polythene, jute bags, platform and tree storage, pit storage to build structures (FAO, 2004). Seed storage practices vary according to climatic zones and socio-economic level of inhabitants. For instance, the use of synthetic bags, fumigated and packed into local store or modern warehouses, is quite common in all agro-ecological zones in Nigeria, whereas hanging husked maize over a fireplace, dehusked maize on an elevated platform, and in pots is practiced in the humid forest zones ((Udoh *et al*., 2000). Functions of storage are seed preservation, quality improvement, quantity equalization and market-price stabilization (Adetunji, 2009). Seed storage in Ghana and other developing countries of the world is a major constraint. Maize price is one of the most important factors that influence the storage of maize seed in Ghana. Storage in metal drums is known to provide good control of all storage insect pests. However, the high initial cost of drums in some areas and the tendency for people to use them for other purposes such as water storage limits their use in seed storage. Plastic bags provide a cheaper alternative but insects tend to perforate the bags, even if the seed is fumigated initially (Jacob and Martin, 2013). In response to challenges posed by the maize weevil, improved seed storage technologies have been developed, including super grain bags, and the metal silo (De Groote *et al*., 2013). Metal silos provide a strong barrier against insect pests and rodents and are hermetically sealed, killing any remaining insects through oxygen depletion (Tefera *et al*., 2011). They are durable, allow for long storage periods, and are therefore an important storage technology in the fight against hunger and food insecurity in developing countries. A metal silo with a capacity of 990 kg can conserve enough grain to feed a household of

five members for one year (FAO, 2008). In the traditional agricultural systems of the tropics, commercial seeds have been preserved under ambient conditions employing the principle of low-cost drying

(Engelmann and Engels, 2002). Examples include the popular maize cribs of West Africa, coated seed baskets of Eastern and Southern Africa and the dry-sealed storage in polyethylene bags for elite commercial seeds (Daniel and Adetumbi, 2006).

2.5 Effect of seed storage on seed quality

Seed quality is one of the most important factors affecting early performance and productivity of most agricultural crops. It has been reported that cereal and legume grains undergo pronounced biochemical and nutritional changes during storage. The moisture contents in the grains or humidity and the storage temperature have been shown to cause dramatic changes in the acidity, pH, free amino nitrogen, protein and starch quality (Rehman *et al*., 2002). In storing maize seeds, prevailing factors such as moisture content and water activity are key determinants of the impact of fungi on the seed quality (Pacin *et al*., 2009). Ageing in seeds stored in the dry state, involves the gradual loss of integrity of membranes, which are barriers that play an essential role in biochemical or physiological events. Temperature and moisture content are particularly important factors influencing the longevity of seeds, and therefore the ageing of seeds is closely tied to storage conditions. The ageing process is characterized by many physiological and biochemical changes: membranes tend to leak, enzymes lose catalytic activity, and chromosomes accumulate mutations (Spano *et al*., 2006). Research efforts in storability measurement have historically followed one of two approaches. The first have been to evaluate the current condition of the seed and use that information to predict future storability. The second is to subject a representative sample to storage test. The condition of the sample is evaluated after the

seed has been stored for a specific period. The amount of mould growth is used as an indicator of the storability of the seed. The second method requires more time than the first; however, the results are usually more applicable (Marks and Stroshine 1995). Many factors are responsible for seed ageing; genetics, mechanical damage, relative humidity and temperature of the storage environment, seed water content, presence of microflora and seed maturity are most effective factors. The reduction in seed viability is mainly a function of interaction between temperature and seed moisture content (McDonald, 2004).

2.6 Insect problems of stored maize seeds

In sub-Saharan Africa, maize has become one of the most important staple foods produced mainly by small-scale farmers and is stored generally in traditional granaries both for food, feed and for sale (Richter *et al*, 1998). Losses of maize in the field and during storage are considered the major cause of food insecurity (Makundi *et al*., 2007). The major cause of post-harvest losses during maize storage is infestation by insects. Estimates show that insects contribute about 30–40% to postharvest losses (Makundi *et al*., 2006). A wide range of pest species has been reported to cause weight loss in stored products due to direct feeding on the produce. Among the most important insect pests of stored maize seeds is the maize weevil (*Sitophilus zeamais)* (Makundi *et al*., 2010). Losses caused by postharvest pests like the maize weevil constitute a major constraint to increasing maize production through the introduction of improved varieties (Adda *et al*., 2002). In recent years, postharvest losses to storage insect pests is an increasingly important constraint in Africa. Farmers in West Africa often stored their unshelled with the husk intact. An understanding of the biology of the maize weevil in relation to storage form will assist in the development of improved management practices for the control of this pest. The median development period of

the maize weevil has been found to be significantly longer on maize stored as cobs compared to shelled maize (Vowotor *et al*., 1995). (Kossou *et al*., 1992) suggested that this longer weevil development time on maize stored as cobs was due to the less nutritious endosperm diet of first instar larvae which hatch from eggs laid on the kernels crown, as well as to the difficulty experienced by the newly developed adult in emerging from a kernel because of obstruction from adjacent kernels. The climatic condition in Ghana favors the cultivation of maize as well as the development and proliferation of storage pests and fungal diseases which cause considerable damage in storage and constitute an obstacle to processing. Stored-product pests are particularly important because they attack the final agricultural products. The maize weevil is a serious pest of stored maize, causing considerable losses. It has been estimated that out of a total annual harvest of 250–300,000 tons of maize in Ghana, about 20% was lost to insect pests.

In some cases total loss can occur (Obeng-Ofori and Amiteye, 2005). Monitoring of insect pest populations in stored seed can be based on both direct and indirect sampling methods. Direct samplings, in which counts of insects are obtained on the basis of a volumetric or weight sample of seed, are indeed the most accurate way to measure insect density, because the insect count is obtained from a known sample size, and because these techniques are less selective in relation to life stages, mating status and sex. Indirect sampling techniques are typically based on trapping, which may involve use of attractants (Nansen *et al.*, 2004). Genetic resistance of maize seed to storage insects is an important component of integrated control for rice storage, but progress toward finding and using such resistance has been limited. Assessment of the intrinsic level of weevil resistance in maize feed has shown large variation among maize genotypes (Kagodaa *et al*., 2010).

2.7 Microbial infestation in stored maize seed

From the time maize is harvested, its quality begins to deteriorate due to the growth of storage fungi (moulds). Fungi consume maize dry matter and cause a kernel appearance change (known in the seed trade as mould damage) that reduces maize commercial grade and value. Estimates of the rate of deterioration of shelled maize are needed so that drying and storage systems can be designed and managed to minimize quality loss (Wilcke *et al*., 1993). Seed-borne pathogenic fungi have been reported to cause field and market losses of maize. Sowing of fungi-free seeds might be the best management option but most farmers in developing countries find it difficult to obtain certified pathogenic fungi-free or resistant seeds. Those seeds that look healthy externally might be internally infected with pathogenic fungi (Anjorin *et al*., 2008).

2.8 Maize seed viability, germination and vigor

Orthodox seeds, i.e. seeds that can be stored with low moisture content, retain viability for varying periods and with time they succumb and die. There is generally a gradual decline in germinability and subsequent vigor of the resultant seedling associated with a higher sensitivity to stress upon germination, and eventually a loss of the ability to germinate (Rice and Deyer, 2001). Several factors affecting seed viability should be considered to determine the optimal storage conditions. In particular, seed survival is not only genetically but also environmentally controlled. Temperature and seed moisture content, are determinant factors for seed longevity (Walters, 1998). Seed dry weight was found to be a better indicator of seed vigor than black layer or seed moisture since it correlates with shoot dry weight (Tekrony and Hunter, 1995). Seed ageing results in seedling growth reduction and this might happen due to decline in weight of mobilized seed reserve (seed reserve depletion percentage), which is not related to seed reserve utilization efficiency. The weight of mobilized seed is the most

sensitive component of seedling growth (Mohammadi *et al*., 2011). Various methods have been used by researchers in order to investigate seed ageing. Moderate or high temperature conditions at ambient (12%) moisture levels were used to assess seed vigor in wheat and barley. It has been shown that the loss of seed germination ability following natural ageing or controlled deterioration is because of series of metabolic blemish that affect embryonic and non-embryonic parts of the seeds (Dell'Aquila *et al*., 1998). Some studies revealed that in monocots like maize, the radicle and scutellum are possibly the primary sites of seed deterioration. Many physiological processes have been linked to seed ageing; for example in aged seeds of some species, phospholipid portion of cellular membrane decreased and fatty acids levels increased, although no extensive lipid peroxidation occurs (Siadat *et al*., 2011). Among the stages of the maize plant life cycle, seed germination, seedling emergence and establishment are key processes in the survival and growth of plants (Hadas, 2004). Germination is regulated by duration of wetting and the amount of moisture in the soil (Gill *et al*., 2002). The most important physical factor affecting seed viability are high moisture and high temperature; however the most noxious effect has been always attributed to moisture content. Moisture content is an important factor in seed viability preservation due to the role of water in the activity of the processes which determine its vigor and longevity, and which allow the development of insects and storage fungi. High temperatures accelerate physiological damage in seed. Consequently, seed longevity can be increase by not only reducing seed moisture content but the storage temperature as well. Seed deterioration can be best defined as an increase probability of death of an individual seed as deterioration proceeds. Seed death is indicated by the failure to germinate and seed longevity in the period until seed death occurs (Tang *et al*., 2004)

2.9 Proximate analysis of maize seed

Cereals are predominantly composed of carbohydrates, mostly in the form of starch, with considerable amounts of protein as well as some lipids, vitamins and minerals. Both genetic and environmental effects create significant variation in the amount and quality of each of these constituents (Baye *et al*., 2006).

Proteins are an important group of biomacro-molecules that are involved in physiological functions. On the other hand, protein content and amino acid composition depends on genotype and growing conditions. Alcohol-soluble prolamins represent the major storage proteins in cereals such as maize. In some plants however prolamins are not the major storage proteins (Gorinstein *et al*., 2002).

Starch is the predominant carbohydrate reserve in many plants. It is found in both photosynthetic and non-photosynthetic tissues. Starch found in the chloroplasts of leaves and other photosynthetically competent cells is termed 'transitory starch'. Long term storage of starch is achieved in the amyloplasts, the specialized starchcontaining plastid, which is conspicuously evident in nonphotosynthetic harvestable storage organs such as seeds. Transitory starch is composed almost entirely of the branched amylopectin, whereas reserve starch contains significant amounts of linear amylose chains in addition to amylopectin. Because of its greater availability, almost all end-uses of plant starch are of the reserve type (Slattery *et al*., 2000). The major chemical component of the maize kernel is starch, which provide up to 72 to 73 percent of the kernel weight. The composition of maize starch is genetically controlled. There is significant negative relationship between starch content and crude protein. The crude protein decreases with increasing starch content of maize seed (Idikut *et al.*, 2009). Ash value is defined as the quantity of mineral matter which, after application of the described working methods, remains as incombustible residue of the tested substance.

Percent ash content of different maize varieties were found in the range of 0.7% to 1.3%, the highest (Ullah *et al*., 2010).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Description of the study area

The experiment was conducted at the Department of Horticulture, Kwame Nkrumah University of Science and Technology, Kumasi. The site is in the semi-deciduous forest zone with elevation of 168m above sea level and has a bimodal rainfall distribution. The major rainy season starts in late March and ends in mid-July. There is a short dry spell from mid-July to mid-September followed by minor rainy season from mid-September to mid-November. The mean annual rainfall is 1500mm. The mean minimum and maximum temperatures are 21^0C and 31^0C, respectively. The mean annual relative humidity is about 60% at noon and 95% in the morning. The soil at the experimental site is ferric Acrisol (Nachtergaele, 2003).

3.2 Seed production

3.2.1 Background of maize var. Obaatanpa

Obaatanpa is an open pollinated maize variety released by the CSIR-Crops Research Institute in 1992. Obaatanpa is an intermediate maturing, white and dent endosperm maize variety that was developed from GH8363SR. GH8363SR had its source from EV8363, an IITA streak conversion from CIMMYT population 63 and released in Ghana under its current name. It has also been released formally in other African countries under various names including 'Faaba' in Benin, Debunyuman in Togo and Mali, and ' Susuma' in Mozambique. On the national maize program it serves as a

source of the opaque-2 gene which confers high lysine and tryptophan on normal maize varieties. It has a yield potential of 5.4 ton/ha and is widely grown by Ghanaian farmers.

3.2.2 Field preparation

A 72m^2 land area was prepared by the no tillage method using Roundup herbicide (Glyphosate) a week before planting.

3.2.3 Sowing of seeds

The spacing used was 80cm between rows and 40cm between plants. Two seeds were planted per hill and then thinning was done two weeks after sewing to one plant per stand. The sowing depth was 3-4cm.

3.2.4 Cultural practices

Basal fertilizer, NPK 15: 15: 15, was applied two weeks after planting. Topdressing with Urea application was done four weeks after planting. Weeding was done three times at an interval of two weeks.

3.2.5 Harvesting and processing of maize seeds

Harvesting was done at 105 days after sowing. The cobs were plugged from the plant using hand and bags were used to collect the cobs from the field. Sampled cobs were dehusked and shelling was carried out manually after which seven kilograms of seed maize was collected for oven and sun drying.

3.3 Experimental design

The experimental design was a 2 x 4 four factorial arrangement in a Completely Randomized Design (CRD). The first factor was drying method at two levels; sun and

oven and the second factor was storage duration at four levels; 0, 30, 60, 90 days after drying. The experiment was replicated six times.

3.4 Experimental procedure

3.4.1 Sun drying

The samples were subjected to sun drying which started on 21st October, 2014 at an initial seed moisture content of 21.2%. On 24th October, a seed moisture content of 11% was attained. That is, it took 4 days of sun drying to attain the desired seed moisture content. The moisture meter was used for determining the moisture content.

3.4.2 Oven drying

Seeds with initial moisture of 21.2% were subjected to oven drying at 40°C on 28th October, 2014. On the 30th October, a seed moisture content of 11% was attained.

3.4.3 Seed storage

Both oven and sun dried seeds were stored in plastic bottles and tightly closed with a lid. The samples were stored at relative humidity of 60% and temperature of 27^0C. The storage durations employed were 0 (no storage), 30, 60 ad 90 days of storage.

3.5 Data collected

3.5.1 Weevil infestation determination

Weevil infestation was determined for all the samples under the storage durations including the zero storage. Each sample was poured on a white plastic plate and visually checked for the presence of weevils. The number of weevils present were counted and recorded.

3.5.2 Determination of microbial infection

The determination of microbial infection was a two-stage process; surface sterilization and identification.

3.5.2.1 Surface sterilization

Twenty four maize seeds of each treatment were immersed in 4% of clorox for 30 seconds. With the aid of sterile forceps, the samples were transferred into sterile distilled water to wash off excess clorox. Samples were later transferred on to a sterile blotter paper to allow drying after which samples were transferred on to the PDA in a petri dish. Plates were incubated at room temperature until growth occurred. Organisms matured within 7 to 10 days after incubation.

3.5.2.2 Microbial identification

Identification was done by using colony and spore characteristics following the procedure described by Barnett and Bary (1972).

3.6 Seed viability assessment

Seed viability was determined by conducting germination tests. This was done according to the International Seed Testing Association rules (ISTA). The soil was sterilized and 100 seeds were sowed in each tray which were replicated four times for each treatment. Water was sprinkled on the trays every morning. Assessment of the seed started at the fourth day after sowing. Emergence counts were made each day until no more visual observation were made of seedling emergence.

3.7 Seed conductivity test

Four replications of 50 damaged seeds of each treatment were weighed to 2 decimal places and moisture content recorded. The seeds of each replication were placed in

200ml beaker and 50ml of deionized water was added. Seeds were stirred gently by a stirring rod to ensure that all seeds were completely immersed and evenly distributed. The beakers were covered by aluminum foil to reduce contamination. The beakers were placed at constant temperature of 20^0C for 24 hours. The electrical conductivity of the leachates of each replication was measured by using a conductivity meter (EUTECH PC 700) and conductivity per gram of seed weight was calculated (µScm1g-1) and recorded as per (ISTA, 2007).

$$\text{Conductivity (µS/cm/g)} = \frac{\text{onductivity reading- lank reading}}{\text{(g) of replicate}} \text{ eight}$$

3.8 Seed proximate quality

3.8.1 Crude fiber determination

The carbohydrate of food is contained in 2 fractions: (1) the crude fiber and (2) the nitrogen-free extractives. Crude fiber refers to the organic residue of a feed that is insoluble after successive boiling with 0.255 N H_2SO_4 and 0.312 N NaOH solutions according to specified procedures. The determination of crude fiber is an attempt to separate the more readily digestible carbohydrates from those less readily digestible. The crude fiber fraction contains cellulose, lignin and hemicelluloses. Boiling a sample with dilute acid and alkali is an attempt to imitate the process that occurs in the digestive tract. This procedure is based on the supposition that carbohydrates, which are readily dissolved by this procedure, will also be readily digested by animals, and those that are not soluble under these conditions are not readily digested. At best, this is only a rough approximation of the indigestible material in feedstuffs, but quite a large part of it may in fact be digested by ruminant animals. Nevertheless, crude fiber is used as a rough indicator in estimating the energy value of feeds. It is also valuable

because of the correlation existing between it and the digestibility of the feedstuff. Crude fiber content was determined using the following procedure: Residue from ether was transferred to a digestion flask. 200ml of the boiling H_2SO_4, anti-foaming agent were added. Digestion flask was immediately connected with condenser and heat. At the end of 30 minutes, flask were removed and filtered immediately through linen and were washed with boiling water until washings are no longer acidic. A quantity of NaOH solution was heated to boiling point and kept at this temperature under reflux condenser until use. Residue was washed back into a flask with 200 ml of the boiling NaOH solution. The flask was connected with reflux condenser and boiled for exactly 30 minutes. At the end of 30 minutes, the flask was removed and immediately filtered into the Gooch crucible. After thorough washing with boiling H_2O, samples were washed with about 15ml of 95% ethanol. Crucible and contents were dried at 110^0C to constant weight, cooled in a desiccator and weighed. Contents of the crucible were incinerated in muffle furnace at 550^0C for 30 minutes until the carbonaceous matter were consumed. Contents were cooled in a desiccator and weighed. Losses in weight were recorded as crude fiber. Crude fiber content was obtained using the formula below:

$$\text{Crude fiber content (\%)} = \frac{A - B}{C} \times 100$$

Where A = weight of dry crucible and sample, B = weight of incinerated crucible and ash, C = sample weight.

3.8.2 Crude protein determination

Nitrogen (N) is the major element next to C, H and O_2 found in living things. In most proteins, N constitutes 16% of the total make-up. The crude protein content is

calculated from N content of the food, determined by a modification of a technique originally devised by Kjeldahl (Jaber *et al.*, 2009). The micro-Kjeldahl technique is adopted to estimate the total N content in a variety of samples ranging from microbial cells to meat.

With this method, the N in protein or any other organic material is converted to ammonium sulphate by H_2SO_4 digestion. This salt, on steam-distillation, liberates NH_3 which is collected in boric acid solution and titrated against standard acid. Since 1ml of 0.1N acid is equivalent to 1.401mg N, calculation is made to arrive at the N content of the sample. It is assumed that the N is derived from protein containing 16% N, and multiplying the N figure by 100/16 or 6.25, an approximate protein value is obtained. There are three main steps involved in the determination of crude protein as follows:

1. Digestion of sample

1-2g of the sample was weighed and transferred to a 500ml digestion flask. A spoonful of the catalyst ($CuSO_4$-$NaSO_4$) and 25ml concentrated H_2SO_4 were added to the digestion flask. Boiling chips were also added and digested until the solution becomes colorless.

2. Distillation of digest

After cooling, the digest was diluted with a small quantity of distilled ammonia-free water and transferred to the distillation apparatus. The Kjeldahl flasks were rinsed with successive small quantities of water. 100ml conical flasks containing 25ml of boric acid solution were placed and few drops of mixed indicator were added. 50ml of 40% sodium hydroxide solution was added to the test solution in the apparatus.

Ammonia was distilled and collected on the boric acid.

3. Titration of distillate

The solution was titrated against the standard acid until the first appearance of pink colour. A reagent blank was run with equal volume of distilled water and the titration volume was subtracted from that of sample titration volume. Crude protein content was obtained using the formula below:

The N content of the sample can be calculated by the formula:

$$\text{Total Nitrogen } (N_T) \text{ (g kg}^{-1}) = \frac{(\text{ml HCl} - \text{ml blank}) \times \text{Normality} \times 14.01}{\text{Weight of sample (g)} \times 10}$$

Therefore, % Crude Protein (CP) = Total Nitrogen (N_T) x 6.25 (Protein factor)

3.9 Seed minerals

Seeds were tested to determine the levels of the following minerals: Phosphorus (P), Potassium (K), Calcium (Ca), Magnesium (Mg) and Iron (Fe)

3.9.1 Determination of phosphorus and potassium contents

Phosphorus and potassium were determined in plant ash using the VanadoMolybdenum method. Approximately 0.5 g of the plant material was weighed into a porcelain crucible and ashed in a muffle oven at a temperature of 450-500^{0}C. The ashed sample was removed from the oven after cooling then made wet with 1-2 drops of distilled water and 10ml of 1:2 dilute HNO_3 added. The crucible was then heated on a water bath until the first sign of boiling was observed. The crucible was removed and allowed to cool. The content was filtered into a 100 ml volumetric flask using a no. 540 filter paper. The crucible was washed two times with about 5ml distilled water followed by the filter which was also washed two times with about 20

ml distilled water. After 10ml each of ammonium vanadate and ammonium molybdate solutions were added and shaken thoroughly. The solution was allowed to stand for 10 minutes for full colour development and then filled to the 100 ml mark. A standard curve was also developed concurrently with P concentrations ranging from 0, 1, 2, 5, 10, and 15 to 20 µg P per millilitre of solution. The absorbance of the sample and standard solutions were read on the spectrophotometer (spectronic 21D) at a wavelength of 470nm. A standard curve was obtained by plotting the absorbance values of the standard solutions against their concentrations. Phosphorus concentration of the samples was determined from the standard curve. Potassium in the ash solution was determined using a Gallenkamp flame analyzer. Potassium standard solutions were prepared with the following concentration: 0, 10, 20, 40, 60 and 100µg K per millilitre of solution. The emission values were read on the flame analyzer. A standard curve was obtained by plotting emission values against their respective concentrations.

Calculation:

% P or K = (C x 100) / (1000 x s)

Where C = concentration of P or K from the standard graph, 100 = percentage factor, 1000 = convection factor from gm to g, and s = weight of sample taken.

3.9.2 Determination of calcium and magnesium contents

For the determination of calcium plus magnesium, a 25ml aliquot of the extract as described in the determination of plant phosphorus and potassium, was taken and transferred into an Erlenmeyer flask. The following reagents were added, potassium ferrocynide (1ml), buffer solution (5ml) and a drop Eriochrome Black T indicator and the solution titrated against Ethylene Diamine Tetra Acetic (EDTA) to a blue end point. The titre value was recorded.

For the determination of calcium, another 25ml aliquot of the extract was transferred to an Erlenmeyer flask. Cabamate (1ml of 2% solution), potassium hydroxide (5ml) and a pinch of murexide indicator were added. The solution was titrated with EDTA to a purple end point.

% Ca or Mg = (T x N x 100) / (1000 x s)

Where T = Titre value, N = Normality of EDTA, 100 = percentage factor, S = sample weight, 1000 = conversion factor from gm to g.

3.9.3 Determination of iron content

Sample was oven-dried at 70^0C for 48 hours. About 1.0g of the sample was then weighed into a crucible and placed in a muffle furnace at a temperature of 550^0C for 3 hours.

The crucible with its content was left to cool after which the sample was removed from the desiccators and 10ml of 1:2 dilute Nitric acid solution was added. It was placed on a hot plate until the first sign of boiling was observed. After this the sample was filtered into 20ml flask and made to the mark with distilled water.

Concentration of Fe was determined using the Atomic Absorption Spectrophotometer (AAS) after calibrating the AAS with standards of the Fe element to be determined.

3.10 Data Analysis

The data collected was analyzed by performing an Analysis of Variance (ANOVA) using STATISTX version 9 Software. Mean comparisons based on Tukey's HSD were carried out to determine significant differences P set at 0.01 (P = 0.01).

CHAPTER FOUR

4.0 RESULTS

4.1 Weevil infestation of maize

There were significant differences between the drying methods for weevil infestation. Sun dried maize had significantly higher weevil numbers than the ovendried maize (Table 4.1).

Table 4.1: Effect of drying methods on iron content of maize seed

Drying methods	Number of weevils in maize
Sun	1.69
Oven	1.00
HSD 1%	0.44

4.2 Microbial infection of maize

A total of five fungal species were identified on the maize in storage. These were *Collectotrichum* spp., *Aspergillus flavus, Aspergillus niger*, *Penicillium* spp. and *Rhizopus* spp. *Aspergillus flavus* was identified on stored maize, irrespective of the duration. *Collectotrichum* spp. was also identified on maize stored at all the storage durations except for the 30 and 60 days oven-dried maize. *Penicillium* spp. and Rhizopus spp. were identified only in the sun-dried maize stored for 90 days.

4.3 Minerals content of seed maize

4.3.1 Iron (Fe)

There were significant differences among the storage durations for the iron (Fe) content of seed maize (Table 4.2). Maize stored for 60 days contained the highest iron content (20.0%), significantly greater than that of maize without storage which had the

lowest iron content. Generally, Fe content in seed maize increased with storage up to 60 days duration (Table 4.2).

There were also significant differences between the drying methods for Fe content of seed maize (Table 4.3). Sun dried seed maize contained the highest Fe content (21.82%), significantly greater than the oven-dried seed maize which contained the lowest content (15.32%) of Fe (Table 4.3).

Table 4. 2: Effect of storage duration on Iron (Fe) content of stored maize seed

Storage durations (days)	Mean percent Fe content
0	15.5
30	19.0
60	20.0
90	19.8
HSD 1%	4.18

Table 4.3: Effect of drying methods on Iron (Fe) content of seed maize

Drying methods	Mean percent of Fe content
Sun	21.82
Oven	15.32
HSD 1%	2.23

4.3.2 Potassium

There were significant differences between the drying methods for potassium (K) content of the seed maize (Table 4.4). Sun-dried seed maize contained the highest K content (0.13%), significantly greater than that of oven dried seed maize (0.1%).

There were no significant drying methods x storage durations interactions.

Table 4.4: Effect of drying methods on potassium content of seed maize

Drying methods	Mean percent of K content
Sun	0.13
Oven	0.10
HSD 1%	0.01

4.3.3 Calcium (Ca)

There were no significant drying method x storage duration interactions for calcium content of seed maize. There were also no significant differences between the treatment main effects for the calcium content of seed maize. Calcium content ranged from 0.9% to 0.10%.

4.3.4 Magnesium

There were also no significant drying method x storage duration interactions for magnesium content of seed maize. There were also no significant differences between the treatment main effects for the magnesium content of seed maize.

Magnesium content ranged from 0.9% to 0.10%.

4.3.5 Phosphorus

There were also no significant drying method x storage duration interactions for phosphorus content of seed maize. There were also no significant differences between the treatment main effects for the phosphorus content of seed maize.

Phosphorus content ranged from 0.18% to 0.22%.

4.4 Proximate composition of seed maize

4.4.1 Percent carbohydrate content of seed maize

There were significant differences between the storage durations for the carbohydrate content of seed maize (Table 4.5). The highest carbohydrate content was found in seed maize stored for 90 days (73.9 %), significantly greater than the least found in seed maize stored for 60 days (70.6 %) (Table 4.5).

Table 4. 5: Effect of storage durations on percent carbohydrate content of seed

Storage durations (days)	Mean percent carbohydrate content
0	73.0
30	72.1
60	70.6
90	73.9
HSD 1%	2.70

4.4.2 Percent ash content

There were significant drying method x storage duration interaction for maize seed ash content (Table 4.6). Both sun drying at 90 days storage duration and oven drying at 30 days storage duration had the highest ash content (1.5%) significantly different from the oven drying at 90 days (0.8%) which had the least.

There were also significant differences among the storage durations. The highest ash content was obtained at 30 days (1.46%) and the lowest from the without (0 day) storage (1.08%). There was no significant difference in ash content between the drying methods (Table 4.6).

Table 4. 6: Effect of storage durations on percent ash content of seed maize

	Storage durations				
Drying methods	0	30	60	90	Mean
Sun	1.0	1.4	1.1	1.5	1.25
Oven	1.2	1.5	1.2	0.8	1.17
Mean	1.08	1.46	1.13	1.17	

HSD 1% Storage durations=0.34; Drying methods=0.18; Storage durations x Drying methods =0.58

4.4.3 Percent fat content

There were no significant drying method x storage duration interactions for fat content of seed maize. Furthermore, there were also no significant differences between the treatment main effects for the fat content of seed maize. Fat content ranged from 0.2% to 0.3%.

4.4.4 Percent fiber content

There were no significant drying method x storage duration interactions for fiber content of seed maize. There were also no significant differences between the treatment main effects for the fiber content of seed maize. Fiber content ranged from 0.17% to 0.2%.

4.4.5 Percent protein content

There were no significant drying method x storage duration interactions for protein content of seed maize. There were also no significant differences between the treatment main effects for the protein content of seed maize. Protein content ranged from 0.30% to 0.33%.

4.5 Seed germination and seedling vigor

4.5.1 Germination percentage

There were significant drying method x storage duration interactions for percent germination of seed maize (Table 4.7). The highest germination percentage was obtained for sun-dried seed maize without storage (99.7 %) whereas the least was obtained for oven-dried seed maize stored for 90 days (3%). Sun-dried seed maize at all the storage durations resulted in significantly higher germination percentages than the oven-dried seed maize without storage. Among the storage durations, storing seed maize for 30 or 60 days resulted in higher germination percentages than no storage and storage for 90 days. Among the drying methods, sun drying led to a significantly higher seed maize germination percentage than oven drying (Table 4.7).

Table 4. 7: Effect of storage durations x drying methods on germination percentage (%) of maize seed

	Storage durations				
Drying methods	0	30	60	90	Mean
Sun	99.2	97.7	98.3	96.8	98.00
Oven	80	97.7	94	3.00	68.88
Mean	89.58	97.67	96.17	50.33	

HSD 1% Storage Duration= 6.77, Drying methods= 3.89; Storage Duration x Drying methods= 10.96

4.5.2 Seedling height

There were significant drying method x storage duration interactions for seedling height at 14 days after planting (Table 4.8). The tallest seedlings were obtained from sun dried seed maize stored for 90 days (37.8 cm) significantly greater than the shortest obtained from oven dried seed maize stored for 90 days (14.8 cm). Among the storage

durations, significantly taller seedlings were obtained from seed maize stored for 30 and 90 days. The shortest seedlings were obtained from seed maize stored for 60 days. For the drying methods, significantly taller seedlings were produced from sun-dried seed maize than the oven-dried seed maize.

Table 4. 8: Effects of storage duration and drying methods on height (cm) of maize seedling at 14 days after planting

	Storage durations				
Drying methods	0	30	60	90	Mean
Sun	26.5	29.1	21.5	37.8	28.72
Oven	20.6	26.2	17.0	14.8	19.65
Mean	23.55	27.63	19.28	26.29	

HSD 1% Storage durations=0.43, Drying methods =0.25, Storage durations x drying methods =0.70

4.5.3 Seedling number of leaves

There were significant drying method x storage duration interactions for number of leaves at 14 days after planting (Table 10). Seedlings from sun dried seed maize recorded significantly more leaves (4.0) than the other treatments. The least number of leaves were produced by seedlings from oven-dried seed maize stored for 0, 60 or 90 days as well as sun-dried seed maize stored for 60 days (Table 4.9). Among the storage durations, seedlings with significantly more leaves were obtained from seed maize stored for 30 and 90 days. For the drying methods, seedlings with significantly more leaves were obtained from sun-dried seed maize than from the oven-dried seed maize.

Table 4. 9: Effects of storage duration and drying methods on seedling leaf production at 14 days after sowing

	Storage durations				
Drying methods	0	30	60	90	Mean
Sun	3.1	3.7	3.0	4.0	3.44
Oven	3.0	3.4	3.0	3.0	3.10
Mean	3.04	3.56	2.98	3.50	

HSD 1% Storage durations = 0.15, Drying methods = 0.08, Storage durations x drying methods = 0.24

4.5.4 Seedling girth

There were significant drying method x storage duration interactions for seedling girth 14 days after planting. Seedlings of sun dried seed maize stored for 90 days had the biggest seedling girth, significantly greater than the other treatments (Table 4.10). The lowest seedling girth was recorded by plants from the sun-dried seed maize without storage. The methods of drying did not influence the seedling girth. However, storing maize for 30 days or 90 days led to bigger seedling girths significantly greater than those without storage (Table 4.10).

Table 4. 10: Effects of storage duration and drying methods on seedling girth (cm) at 14 days after planting

	Storage Duration				
Drying methods	0	30	60	90	Mean
Sun	0.1	0.2	0.2	0.3	0.20
Oven	0.2	0.2	0.2	0.2	0.21
Mean	0.16	0.23	0.21	0.23	

HSD 1% Storage durations =0.02, Drying methods =8.96, Storage durations x Drying methods = 0.03

4.5.6 Seed electrical conductivity test

There were significant drying method x storage duration interactions for seed electrical conductivity test (Table 4.11). The highest conductivity value (9.7 µS/cm/g) was recorded by oven-dried maize without storage. The lowest conductivity value (2.4 µS/cm/g) was recorded by oven-dried maize stored for 30 days, though not significantly different from oven-dried maize stored for 60 and 90 days. Among the methods, sun-dried maize recorded a significantly higher conductivity value (6.0 µS/cm/g) than the oven-dried maize. Also among the storage durations, no storage (0 days) duration resulted in a significantly higher conductivity value (8.57 µS/cm/g) than any of the storage durations (Table 4.11).

Table 4. 11: Effects of storage durations x drying methods on electrical conductivity (µS/cm/g) of maize seed.

	Storage Duration				
Drying Methods	0	30	60	90	Mean
Sun	7.4	5.5	5.0	6.2	6.03
Oven	9.7	2.4	2.5	2.5	4.30
Mean	8.57	3.95	3.77	4.35	

HSD 1% Storage durations =2.78, Drying methods =1.60, Storage durations x Drying methods =4.50

CHAPTER FIVE

5.0 DISCUSSIONS

5.1 Effect of drying methods and storage durations on seed germination and vigor performance of maize

Sun-dried seed maize at all the storage durations resulted in higher germination percentages than the oven-dried seed maize without storage and storage for 90 days. This may be due to the intermittent absorption of natural heat while for the oven drying, the seeds were subjected to a continuous force of heat generation which might have

reduced the in-vitro rumen starch degradation of the maize kernels (Monika, 2015). Cordava and Burris (2002) also reported that, using sun for drying maize seeds resulted in germination percentage as high as 90-96%. Although there were differences in seed vigor between the treatments, all the values were within the range classified as high vigour and therefore could be utilized for planting. In spite of the high vigour of the seeds, seedling vigour was better in sun-dried maize from the various storage durations than the oven-dried maize stored for similar durations. Among the storage durations, 30 days durations proved the best in terms of seedling vigor even though it was not significantly different from 0 and 60 days durations. The seed must have reached their peak of germination potential after days of storage where all the organs are fully developed and the enzymatic reaction necessary for germination are probably at their optimum.

5.2 Proximate composition of seed maize as influenced by drying methods and storage durations

The application of sun drying resulted in higher mineral ash content than oven drying. In addition, among the storage durations 30 days storage resulted in higher ash content while and lower at 0 day storage. Flint-Garcia *et al.*(2009) reported that ash content in maize kernel irrespective of their varieties are significantly and negatively correlated with moisture, fiber, carbohydrate contents and seed weight. The higher ash content recorded by the oven methods and after 30 days of storage may be due to lower moisture and lower contents of fiber and carbohydrate. The lower moisture content is important as it enables long storage by minimizing fungal contamination and spoilage of maize (Mlay *et al.*, 2005). Several studies have been conducted on maize proximate analysis. Ullah *et al*. (2010) revealed that, percent ash content of different maize varieties were found in the range of 0.7% to 1.3%. Peplinski *et al*. (1994) reported

values of ash between 1.3 and 1.5%. These values are comparable with those of the present study.

5.3 Weevil and microbial infestation

Sun drying resulted in higher (1.69%) weevil infestation than the oven drying which had the least (1.00%). During oven drying, the exposure to higher temperature in a short period of time may have destroyed weevil eggs preventing them from hatching during the period of storage. Five fungal species identified prevailed during different storage period. *Aspergillus* spp. was present during the whole period of storage including the zero day of storage meaning that it was seed borne and also persistent. Wright *et al*. (2005) reported that, *A. flavus* infection showed strong correlation to high densities of weevils. *Collectotrichum* spp. infected the seed only after 30 to 60 days which was probably its peak period of multiplication but *Penicillium* spp. and *Rhizopus* spp. were able to reach this peak only after 90 days.

5.4 Mineral composition of seed maize as influenced by drying methods and storage durations

Potassium is one of the major elements which affects yield and quality of seed (Ruiz Remero, 2000). The high K content in sun-dried seeds could explain the higher seedling vigour observed as compared to the oven dried seeds. Mengel (2007) also stated that seedlings do not germinate well without potassium and that as soon as the potassium reserves of seeds are exhausted the seedling dies. Miguel and Filho (2002) also reported that the higher amount of K content in the sun dried maize seeds indicated membrane integrity. Iron is also an essential nutrient which is responsible for significant increases in yield and quality of plants as well as seed (Celik *et al.*, 2010). The lower Fe content in the oven-dried maize could be attributed to the level of heat applied. Agoreyo *et al.* (2012) indicated that application of forceful heat destroyed Fe

content of maize seed. Storage of maize resulted in a higher concentration of the mineral element which could be due to the continuous loss of moisture in storage and therefore a concentration of the mineral.

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATION

6.1 Conclusions

The following conclusions can be made from the present study:

1. Potassium content was higher when seed maize were sun-dried compared to oven drying
2. Weevil incidence was higher in sun-dried seed maize than in the oven-dried ones
3. The highest seed maize carbohydrate content was recorded at 90 days storage duration and the lowest was from 60 days
4. For seed germination and vigor, seed maize dried under the sun performed better than seed maize dried using the oven

6.2 Recommendation

This research should be repeated using different maize seed varieties at different storage intervals.

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APPENDIX

Analysis of Variance Table for Slvs

Source	**DF**	**SS**	**MS**	**F**	**P**
Rep	5	0.08687	0.01737		
Storage	3	3.30229	1.10076	96.77	0.0000
Drying	1	1.43521	1.43521	126.17	0.0000
Storage*Drying	3	1.82063	0.60688	53.35	0.0000
Error	35	0.39812	0.01137		
Total	47	7.04313			

Grand Mean 3.2687 CV 3.26

Analysis of Variance Table for germination percentage

Source	DF	SS	MS	F	P
Drymthds	1	10179.2	10179.2	407.78	0.0000
Stordura	3	17977.9	5992.6	240.07	0.0000
Drymthds*Stordura	3	16926.2	5642.1	226.02	0.0000
Error	40	998.5	25.0		
Total	47	46081.8			

Grand Mean 83.438 CV 5.99

Analysis of Variance Table for number of leaves Source DF SS MS F P

Rep	5	2.7607	0.55214		
Storage	3	4.5378	1.51261	2.78	0.0553
Drying	1	6.6730	6.67301	12.28	0.0013
Storage*Drying	3	4.5378	1.51261	2.78	0.0553
Error	35	19.0235	0.54353		
Total	47	37.5329			

Grand Mean 1.3729 CV 53.70

Analysis of Variance Table for Seedling girth

Source	DF	SS	MS	F	P

Rep	5	0.00099	0.00020		
Storage	3	0.03271	0.01090	83.59	0.0000
Drying	1	0.00017	0.00017	1.29	0.2631
Storage*Drying	3	0.04792	0.01597	122.49	0.0000
Error	35	0.00456	0.00013		
Total	47	0.08635			

Grand Mean 0.2060 CV 5.54

Analysis of Variance Table for Seedling height

Source	**DF**	**SS**	**MS**	**F**	**P**
Rep	5	3.70	0.741		
Storage	3	489.57	163.191	40.72	0.0000
Drying	1	987.54	987.542	246.40	0.0000
Storage*Drying	3	788.05	262.682	65.54	0.0000
Error	35	140.28	4.008		
Total	47	2409.14			

Grand Mean 24.188 CV 8.28

Analysis of Variance Table for Conductivity

Source	**DF**	**SS**	**MS**	**F**	**P**
Drymthds	1	35.932	35.9321	8.53	0.0057

Stordura	3	187.908	62.6361	14.87	0.0000
Drymthds*Stordura	3	65.787	21.9289	5.21	0.0039
Error	40	168.440	4.2110		
Total	47	458.067			

Grand Mean 5.1631 CV 39.74

Analysis of Variance Table for Ash

Source	**DF**	**SS**	**MS**	**F**	**P**
Storage	3	1.04167	0.34722	3.55	0.0228
Drying	1	0.08333	0.08333	0.85	0.3618
Storage*Drying	3	1.37500	0.45833	4.68	0.0068
Error	40	3.91667	0.09792		
Total	47	6.41667			

Grand Mean 1.2083 CV 25.90

Analysis of Variance Table for Carbohydrate (CHO)

Source	**DF**	**SS**	**MS**	**F**	**P**
Storage	3	72.155	24.0516	3.95	0.0147
Drying	1	8.442	8.4420	1.39	0.2460
Storage*Drying	3	38.402	12.8007	2.10	0.1152
Error	40	243.572	6.0893		
Total	47	362.571			

Grand Mean 72.407 CV 3.41

Analysis of Variance Table for Iron (Fe)

Source	DF	SS	MS	F	P
Storage	3	156.88	52.293	3.58	0.0219
Drying	1	507.00	507.000	34.75	0.0000
Storage*Drying	3	9.19	3.062	0.21	0.8889
Error	40	583.52	14.588		
Total	47	1256.59			

Grand Mean 18.567 CV 20.57

Analysis of Variance Table for Potassium (K)

Source	DF	SS	MS	F	P
Storage	3	0.00153	0.00051	0.99	0.4062
Drying	1	0.01021	0.01021	19.82	0.0001
Storage*Drying	3	0.00143	0.00048	0.92	0.4388
Error	40	0.02060	0.00052		
Total	47	0.03377			

Grand Mean 0.1142 CV 19.88