ASSESSMENT OF NUTRITIONAL AND PHYSICAL CHARACTERISTICS OF MAIZE (*Zea Mays)* STORED IN METALLIC SILOS

The magnitude of deterioration of maize *(Zea Mays*) in storage and storage losses recorded globally is worrisome especially in the developing countries. However, with the evolution of metallic silos, there has been tremendous reduction in the storage losses. In the storage of maize (*Zea Mays L.*) in metallic silos especially for long period, certain degenerating changes do occur, due to the interaction between the stored maize and the immediate environment. These degenerating changes over time are expected to affect the Nutritional (NP) and Physical (PY) characteristics of the grain. The main objective of study is to evaluates the quality attribute of maize stored in metallic silos for a period of eight months, with a view to assess the extent of deterioration of some NP and PY characteristics, with duration of storage, based on the location of the grain in the bulk and size of the metallic silos. The values obtained were compared to the control, which is the values of the parameters of the stored maize determined using standard methods, before the inception of the storage. The temperature and relative humidity of the immediate environment were also recorded within the period. A randomized block design of 13 quality attributes, 9 sample location and 3 replicates making a total of 351 samples were used. The evaluation of data obtained was done using statistical package for social sciences (SPSS 20) for windows evaluation version to determine levels of significance and trend of deterioration for all values obtained, using Multiple Analysis of Variance (MANOVA) and Duncan's multivariate test. The NP properties evaluated include percentage Ash content AC, Crude Fiber CF, Protein CP, Carbohydrate content CHO, Fats FC, and Energy EV. The PY characteristics evaluated also include, percentage Moisture content MC (wb), Insect Damaged grains ID, Foreign Matters FM, Hectolitre weight HC, Mould infested grains M, and Germinability/viability V. The result of this

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the study

Maize (*Zea mays*) is the most popular cereal crop planted and stored in Nigeria, International Institute for Tropical Agriculture, (IITA, 2009). It constitutes a staple food in South America, South Africa and Sub Saharan Africa (SSA) and accounts for more than 50% of Agribusiness in these regions, Food and Agricultural Organization (FAO, 1995). As important dietary component, it provides a substantial amount of nutrients which includes vitamins, minerals, protein and carbohydrates for human and animal consumption especially in developing countries of the world, due to its ability to be consumed directly and be processed into a wide range of products (IITA, 2009).

It can be stored in a wide range of grain storage structures all over the world, depending on available resources, intended use of the grains, climate, storage duration, capacity, available technology and culture, but are stored in commercial quantity in metallic silos (FAO, 2009).

As a hygroscopic and biological active material, the interaction of Maize (*Zea mays*) with the immediate environment during storage is ongoing. In bulk storage of maize in metallic silos, especially for long period, certain degenerating changes are expected to occur due to this interaction, that will affect the physical and nutritional characteristics but the extent of deterioration of this is yet to be ascertained. The extent of this deterioration or how successful storage of Maize in a metallic Silos in any geo- ecological zone will be, is dependent on the Grain storage factors such as physical, biological, and climatic. This is because climate among others plays major role in the storability of agricultural produce (Alabi, 2001). Climatic variables known to influence storability of maize in metallic silos include temperature, humidity, rainfall or precipitation, solar radiation and wind. However, with proper monitoring and control of these variables, enormous storage losses associated with maize storage can be minimized.

The characteristic/ behaviour of the structural material used for the construction of any silos, in respect to solar radiation and thermal conductivity are also important factors towards successful storage. However, it is known that daily variation of ambient temperature determines the temperature gradient across the wall of the silos, the head space and inside the grain mass. Higher temperature will invariably result to more moisture condensation on the silo walls (Alabadan, 2005). Humidity as a variable also affects the physiological response of stored grain and organism/pest in the storage bin. Wind speed and direction, size of ventilation openings also plays an important role in the thermal state / regime and stability of metallic silos temperatures (Ileleji, 2010).

The rainfall pattern in any geo-ecological zone no doubt plays an important role in the thermal stability of a metallic silos, especially during the rainey seasons since rainfall affects relative humidity of the ambient air directly, and considering high thermal conductivity characteristics of metallic silos. If a metallic silo is porous, it will be even worse because moisture will the transmitted into the silo directly and as well as the grain mass.

Minna, Niger state is located in the Guinea Savannah climate zone of Nigeria, the average daily temperature range throughout the year from available records is between 18 – 39^{0}C, the highest temperature record between February and April, while the lowest were record between November to January. Variation in diurnal temperatures can be as high as 16.5^{0}C during hot dry seasons. Yearly variation in temperatures between the harmattan season and the hot season is about 20^{0}C. The average annual rainfall is about 1250mm and most of it falls between April and October. The dry season varies between 120 to 140 days in a year. The average solar radiation received on a typical day ranges between 21y / hr at sunrise (05.00hrs – 06.00hrs) and 601y / hr in the afternoon (between 12.00 and 14.00hrs). The average sunshine in a day is 9hours. Mean daily relative humidity ranges between 29 % in January to about 85% in August (Alabi, 2001).

The above climatic variables will encourage moisture migration and condensation as far as storage of grains in metallic silos is concerned, but prolonged dry season observed will also ensure that grains are kept dry and at safe moisture content level.

1.2 Statement of Problem

Maize storage in Nigeria dates back to the pre-historic time, but is often associated with high storage losses which is estimated between 25% to 43%, yearly according to (Oyebanji, 1996; Adejumo and Raji,2007; Ahmed,2009). This is due to inefficient and ineffective traditional storage structures, and practices used by farmers. These situation and conditions further makes it difficult for individuals, farmers groups and food industries to achieve the ever growing quest from for high quality stored agricultural produce all year round, especially grains.

Amidst increasing global demand for high quality stored agricultural produce, people who engage in maize storage activities in Nigeria and other developing countries, still pay less attention to the Nutritional and Physical degenerating changes that takes place in the stored grains, provided they are not physically spoilt. Many of these changes can be counterproductive as it may actually harm the consumers and lowers the actual quality of these grains at long run, especially with longer periods of storage. Thus, the absence of grain grading standards in Nigeria has not helped matters.

Since metallic silos store grains in large quantity, and have proved to be efficient in reducing the enormous storage losses recorded with the traditional system of grain storage, the ability to harness or enhance its huge economic potential, through research information on storage duration in relation to quality makes this study a worthy research.

1.4 Aims and Objectives of the study

The main aim of this study is how to reduce enormous storage losses associated with maize storage in metallic silos.

The objectives are to

i. To evaluate the Nutritional and Physical attributes of maize stored in metallic silos based on location of the grain in the bulk and duration of storage.

ii. To assess the above properties in respect to size of the metallic silos used.

iii. To evaluate the effect of size of metallic silos, location of grain in the bulk, and size of metallic silos on the grain germinability/viability.

1.3 Justification of the Study

Maize grain accounts for about 15 to 56% of total daily calories in diets of about 25 developing countries particularly in Africa and South America (Vasal, 2000). With its additional demand by industries, there is no doubt that it is an essential commodity. Research has shown and demonstrated that the best qualities of maize are the ones from the present harvest irrespective of the intended use (FAO, 1995), but maize storage is inevitable due to the susceptibility of manmade or natural emergencies which can disrupt or lower penultimate harvest. Since maize is the most planted and stored cereal crop in Nigeria, and it is stored in commercial quantity in Nigeria and all over the world in metallic silos. Information on the degenerating changes that takes place in the stored maize within the Allowable Storage Time (A S T), in metallic silos, is very important, as it will provide proper / optimum usage, and enhance the economics of maize storage and food security in general.

1.5 The Scope and Limitation of the Study

The scope of this work is to evaluate the Nutritional and Physical characteristics of maize stored in metallic silos located in Minna Niger State, Nigeria for a storage period of eight months. The Nutritional characteristics evaluated are namely, Ash content, Carbohydrate content, crude Fiber, Fats content, and crude Protein. The physical characteristics evaluated in course of this research work includes, percentage Moisture content (wet basis, wb), MC, Hectoliter weight, HC, percentage Foreign matter, FM, percentage Broken grains, BK, percentage Insect damaged ,ID, percentage Mould infested grains ,M, and Germinability/Viability ,V. However, the temperature and relative humidity and temperature of the head space of the silo bin was also monitored and recorded within the period of the research work.

At the end of the studies, the data generated will be analyzed using statistical methods. The result will be evaluated to a logical conclusion and recommendations will be made based on the result.

1.6 Contribution of study to literature

This research work is expected to provide basic information on how the quality attributes of maize stored in metallic silos are affected over storage period. It will also provide specific information on the Nutritional and Physical characteristics, and the integrity of the stored maize if used as seed,

This information would be invaluable to people who engage in maize storage in metallic silos, as a business or responsibility, in Guinea Savannah climate of Nigeria. It will also enable them to plan and program their storage activities depending on the dynamics of deterioration and intended use, in order to maintain quality and to make economic gains.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Maize/preamble

Maize or corn (Z*ea mays*) is a cereal crop that is widely grown and stored all over the world in South America, Asia and African continents. Maize is a member of grass family called (Poaceae), as shown in Table 2.1 It is the most produced and stored annually, in the grain family (IITA, 2009; Nukenine, 2010). About 50 species are known to exist consisting of different species, agro-adapted environment, size, shape and use. Several millions of people particularly in developing countries, especially Sub-Saharan Africa (SSA) derive their protein and calorie requirement from maize. (Mbuya; Nkongolo; Kalonji-mbuyi, 2010) Maize ranks third to rice and wheat as the most important cereal crop, mainly used as staple food and animal feeds in most of the developing countries (Akande and Lamidi, 2006; Olakojo; Omueti; Ajomale; Ogunbodede, 2006; and Mbuya *et al.*2010). It is rich in vitamin A, C and E, Carbohydrates, essential minerals, protein, dietary fibres, and calories which are good source of energy.

In Nigeria the bulk of maize produced that serves as a major source of protein for weaning children, sick adult and children, or eaten during lean period of crop production cycle, has a biological nutritional value of 40% of that of milk (Bressani,1992; Durojaiye,2012). Nigeria is the largest producer of maize in Africa with about 8 million Metric Tonnes per year and 85% of maize produced is consumed as food (IITA, 2009). The majority of Nigeria maize production is from the Guinea and Sudan Savannah climatic region, and from mainly peasant farmers who use predominantly the traditional system of cultivation (Ogunbodede and Olakojo, 1999). Return to research investment on maize in Nigeria is 1:38 suggesting that every Naira invested a return of N38 is expected resulting I poverty reduction of 3% per year translating to1.2million persons being lifted out of poverty every year (Alene; Menkir;Ajala; Badu-Apraku;Olarewaju;Mayong and Ndiaye, 2009). The choice of the species of maize planted or stored depends largely on the intended use as shown in Table 2.2.

However, different types and species differ in morphology, physiology and internal structure. However, the most common types include the white and yellow maize.

Table 2.1: Scientific classification of maize

Kingdom	Plant
Sub kingdom	Anglosperm, monocot/commelinds
Order	Poales
Family	Poaceae
Sub family	Panicoideae
Tribe	Andropogoneae
Genus	Zea
Species	Zea mays

Source: FAO, 1995.

2.1.1. Origin of maize

Maize originated from American continent where it was cultivated by Red Indian long before arrival of Christopher Columbus. It is the most important crop grown in the United State of America (U.S.A) and valued over four billion dollars annually. The European discovery of corn was in 1492 after Christopher Columbus arrived in the Caribbean. Columbus son Ferdinand wrote to his father "I saw a grain they call maize and it is most tasty when boiled, roasted or ground into flour" Columbus took a seed home and by 1500, the maize was growing not just in Spain and Portugal as well as Turkey, slave traders brought corn to Africa (Agoda; Atanda; Usanga; Ikotun; and Isong, 2011).

Maize was introduced into Africa in 1500 and has since become one of Africa's dominated food crops; like in many other regions it is consumed as a vegetable though a grain crop.

Table: 2.2. Different types of maize and nomenclatures

Type	**Species**
Flour corn	*Zea mays amylacea*
Pop corn	*Zea mays everta*
Dent corn	*Zea mays indentata*
Flint corn	*Zea mays indurate*
Sweet corn	*Zea mays saccharata*
Waxy corn	*Zea mays certain*
Amylomaize	*Zea may*
Pod corn	*Zea mays tunicate*
Striped maize	*zea mays Japonica*

Source: 11TA, 2009

2.1.2. Morphology of maize

Maize plant is completely green in appearance, often about 2.5m tall, though some natural strains vary. It stands straight with leafy stalk which produces the ear that contains the grain. Elongated stigmas, called silk emerges from whorl of husk leaves at the end of the ear. The pericap of a matured ear is fused with seed coat referred to as caryopsis, typical of grasses. The entire kernel is often referred to as "seed". The cob is close to a multiple fruit in structure, except that the individual fruits (the kernels) did not fuse into a single mass. The maize grain is about the size of peas and adheres in a regular row around a white pithy substance, which forms the ear. Maximum size of kernel is estimated at 2.5cm/ 1m. An ear commonly holds 600 kernels. They are of various colours, blackish, bluish-gray, purple, green, red, white and yellow depending on species, and other vital factors that came into play in breeding / cultivation (FAO, 1995). Different types of maize, nomenclature and the nutritional value per 100kg of white maize are stated in Tables 2.2 and 2.3 respectively.

2.1.3. Maize Breeding

There has been considerable success in maize breeding from research institutes, which has resulted in large plants producing large ears. Modern breeding begin with individuals who selected highly productive varieties of interest, in the field and then sold the seeds to other farmers. The early efforts were based on mass selection until later efforts were on ear to row selection and percentage compositions of interested and non interested constituents. Hybrids were made from selected inbred lines and were crossbreed to get desired advantage or effect depending on the end users area of interest. The outcome of this crossbreeding to get a desired effect gave rise to genetically modified (GM) maize which is grown commercially all over the world especially in developed countries(IITA,2009).

In Nigeria, IITA scientists have developed high yielding and diseases resistant varieties that are adaptable to various agro ecological zones.

Table: 2.3. Nutritional value per 100g of maize seed

Maize	Nutritive value
Energy	360 Kg
Carbohydrates	19.02g
Sugar	3.22g
Dietary fibre	2.7g
Fat	1.18g
Protein	3.22g
Tryptophan	0.023g
Threonine	0.129g
Isocunine	0.129g
Leucine	0.348g
Lysine	0.137g

Methionine	0.067g
Cystine	0.026g
Phenylalanine	0.150g
Tyrosine	0.123g
Valine	0.185g
Arginine	0.131g
Histidine	0.089g
Alanine	0.295g
Aspartic acid	0.244g
Glutamine acid	0.636g
Glycine	0.636g
Proline	0.292g
Serine	0.153g
Water	75.96g

Source: IITA, 2009.

The discovery of the Quality Protein Maize(QPM) which varies with Opaque-2 mutant gene by International Maize and Wheat improvement centre in 1964 containing about twice the level of lysine and tryptophan and 10% higher grain yield than most modern varieties of tropical maize, brought hope in the effort of its improvement as human and animal nutrition(Akande and Lamidi,2006;Olakojo *et al,* 2006).high level of these two amino acids not only enhance the manufacture of complete protein in the body but also offers 90% of nutritional value of skim milk, alleviating nutrition.

Remarkable achievement has been recorded in development of weed and other pest resistant species that were released in Nigeria and Cameroun. This development led to early, intermediate and late maturing varieties, yields up to twice the traditional varieties (Mbuya *et al*, 2010). Early maturing types that have enabled maize to expand to new areas, where short rainy season has adversely affected production in the past like in Sudan(FAO,1996). Effective simple machines and tools that reduce processing, harvesting time/ labour and production losses have been developed by post-harvest researcher.

The research to enhance the nutritive content of maize is also on going to combat malnutrition and disease caused by micro- nutrient deficiencies, as well as on the development of myco-toxin resistance variety to minimize health hazards of the toxins if ingested. Many forms and type of maize are used for food and other immediate and secondary production activities depending on the amount of starch each variety contains.

2.1.4. Maize storage in Nigeria

Over half of Africans earn their livelihood from agriculture, which is the most important enterprise, and key to economic development of the continent, but tropical Africans countries are among the world leaders in food insecurity (FAO, 2010). Food security can be achieved only if there is increase agricultural productivity, efficient storage system/structures and reduced pre and post – harvest losses. However, majority of the post harvest losses recorded in Nigeria is through handling, insufficient and inefficient storage system/ facilities. (Adejumo and Raji, 2007)

Maize storage can be defined as a way or process by which maize as an agricultural produce can be kept for future use. It is an interim or repeated phase during transit of agricultural produce from producers to processors and its products from processors to consumers (Nukenine, Monglo, Awason, Ngamo, Tchvenguem and Ngassoum, 2002). Maize as the most produced and stored crop in Nigeria hold the capacity of food storage and security. The length and period with which you can store maize in Nigeria within the allowable storage time (A.S.T) depends on agro-climate, ecological zone, grain variety, storage conditions, quality and quantity of commodity to be stored(FAO, 1995).

However, the ability of any country to perform well in storage is a function of its existing storage structures, management of the storage structures, area of domicile of the storage structures and its efficiency in the protection of the grains stored against pilferage, deterioration and spoilage. Until the recent years, the bulk of maize produced in Nigeria was from south west zone. (Ogunbodede and Olakojo, 1999) confirmed that over the years, the Western Nigeria generally produced about 50% of total quantity of green maize produced in Nigeria, and the remaining being shared between the North and the Eastern part. Though large proportion of green maize is still produced in western Nigeria, there has been a dramatical shift of dry grain production to Savannah especially the northern Guinea Savannah. This climatic zone is now regarded as the maize belt of Nigeria as shown in Figure 2.1. (Ogunsote and Ogunsola, 2002). However, notwithstanding that Nigeria is the largest producer of maize in Africa, the total average yield of maize per hectare is still low. While, it is about 8.6 Tonnes/ Hectare (t/Ha) in developed countries, Nigeria manages to produce about 2.5 t /Ha, (FAO, 2010)

The three major tiers of maize storage in Nigeria include the in-house/on farm storage, the store/warehouse storage and the high capacity storage in silos. In Nigeria presently, the majority of maize activities happen within the on farm storage / in house where farmers uses the traditional methods of storage, such as grain barns, mud granaries, thatched rhombus and mud rhombus. These storage systems are mainly used by small scale farmers who produce over 90% of the total output (Igbeka, 1990).

Result of various researches by (Adejumo and Raji, 2007) and (Igbeka, 1990) also shows that the grains stored using this traditional storage structures suffered severe damages. Storage losses are enormous and are mainly due to seepage, insect infestation, inadequate strength, lack of air tightness for fumigation. Hence poor and or inadequate storage facilities and methods is the major impediment in the use of the traditional system. It is generally known that out of about 10 millions tonnes of cereal grain and legumes produced annually in Nigeria, about 1.5 to 2 million tonnes are lost as a result of poor storage. This problem often forces farmers to sell their produce at a giveaway price, after harvest because of fear of deterioration and spoilage. The little they can risk to keep will be for the next season planting or for immediate sale any time there is pressing family problem (subsistence and survival) and the rest goes into the middlemen storage in market shops or warehouses.

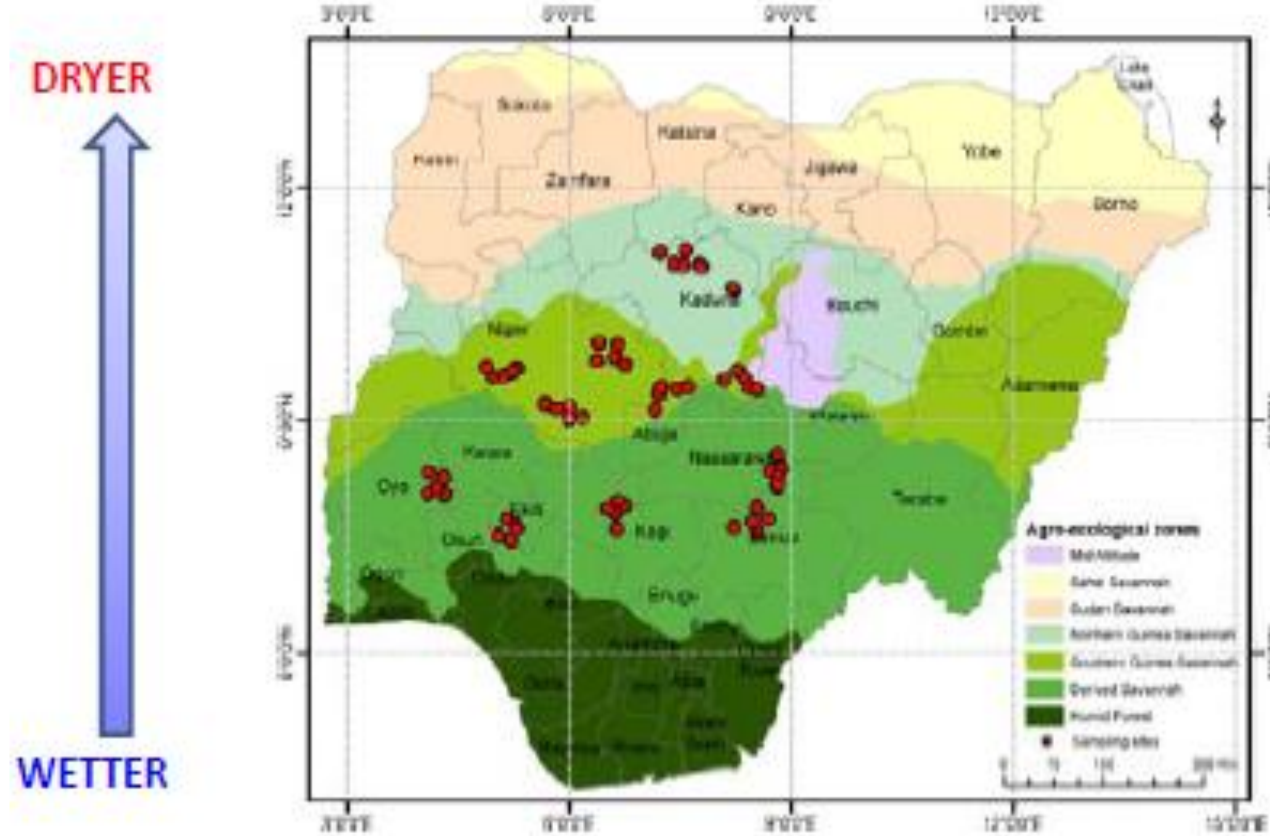


Figure 2.1: Geo-ecological/climatic zones in Nigeria

Source: Ileleji, 2010

The warehouses / market shop storage is another tier of storage that helps in holding more quantities that what the farmers cannot. In this tier of storage, business tends to be good because, apart from the fact that they bought the grain so cheap, they have more expertise in storage than local farmers and will be able to manage the grain until they are sold. The intent of holding grains in this tier is mainly for future use or commercial purposes especially for their big customers who are grain merchants, industries and government agencies that purchases grains for different purposes. However, the number of such warehouses and market shops are grossly inadequate and the cost of building more expensive.

The third tier of storage is the Federal Government stock in the custody of Strategic Food Reserve Department of Federal Ministry of Agriculture. Nigerian government embarked on construction of silos across the nation in 1987 and completed a total of six (8) silo complexes with each having the capacity of 25,000MT, with a total tonnage of 200,000MT in the first phase. Subsequently other silo complexes were constructed to boost the storage capacity as far as the national stock is concerned. Presently the total Federal Government has increased the total storage spaces in its silo complexes to 1.3 million metric tons. The primary responsibility of this Department is to keep the nation's food stock, mainly grains during period of emergencies and the stabilization of price of food items by releasing to the public when the prices are high in the open market. The Department also acts as buyers of last resort, by mopping up of all excess grain at end of the year's harvest at a good price (Okolo, 2013).

Before the era of Government owned silo complexes, successive Nigerian Governments had concentrated all their agricultural policies on increase in food production, believing that increasing overall output would mean regular food supply. It only exerted strain on existing methods of harvesting, handling and storage that lead to higher food losses and lower prices of food items. According to the initial blueprint for storage of agricultural produce in Nigeria, the Federal Government through the Strategic Food Reserve Department is suppose to hold 5% of the nation's total output of grains after harvest and the State Government is expected to hold 10%. However, the balance of 85% is expected to be held by private sector such as small scale farmers, Farmers cooperatives and grain merchants (Alabi, 2001). This never came to be, because of interest and lack of efficient and effective storage structures. Today the reverse is the case, what was advocated to be held by the private sector is what the Federal Government is trying to achieve, the private sector is holding about 15% and the state is completely non-functional in this regards.

However, the stock government owned silo complexes holds yearly depends on the total quantity of excess grains available, government policies and price. Over the years government sets committees, or by the use of government procurement machineries or consultants to determine government buying price, but it has its limitations, and on so many occasions the federal government is not able to stock their enormous capacity silos, due to low price benchmark slated by government's machineries, but private organizations do. It explains why most government owned silos are under stock in Nigeria. The storage spaces in the government silo complexes are under utilized according to records. The ratio of utilization of Minna silo complexes since inception in 1991 is 1: 4 (Okolo, 2013).

The situation at present in terms of storage of maize is Nigeria is worrisome because the truth is that the total output is still far below expected. There are not much excess grains for storage due to low production/output, and neighboring countries in the sub- Saharan region that has made Nigeria a marketing hub for grain crops, as a result comes in at end of every year harvest season to buy grains especially maize. To buttress this claim, the Federal Government has put up its 33 numbers of Strategy Food Reserve Silo Complexes nationwide for lease, in the Public Private Partnership (PPP) arrangement that will enable individuals, corporate bodies, industries and farmers co-operative societies to rent space for the storage of grains and paddy crops.

However, due to land tenure system in Nigeria and subsistence nature of agriculture, the annual grain output of an average farmer is between 1 – 5 tonnes (Igbeka, 1990). Invariably, it is only the government farmer's cooperatives, sectors, private processors, industries and grain merchants that can lease government owned silos, which are ready for leasing and not the individual farmers.

According to Olumeko, (1989) the larger parts of food produced in Nigeria are retained on the farm for home consumption. Thus increase in yield through improved cropping system and introduction of high yielding varieties is necessary. The re-assessment and amendment of the land tenure system and the encouragement of state and federal government farmstead will solve the problem of low output (Alabadan, 2013). In line with this philosophy, the Nigeria Government in recent years in the agricultural transformation agenda is trying to provide agricultural inputs and incentives to farmers to boost agricultural production in the country.

2.1.5. Production/consumption

The worldwide production of maize is 785 million tons per year. The largest producer, worldwide is the United States of America (U.S.A) producing 42%. Brazil, Soviet Union and Mexico follows. Africa produces only 6.5% of world maize production with Nigeria the largest producer in Africa, followed by Tanzania and South Africa (IITA, 2009). Out of 158 million hectare of maize harvested yearly worldwide, Africa's total harvests is 29 million hectares, with Nigeria harvesting 3%. Maize is widely cultivated all over the world. It is the most popular, most cultivated and most stored among other grains all over the world (FAO, 1995). Increase in total production has been recorded in many countries of the world including Nigeria due to Research impact.

Worldwide consumption of maize is more than 116 million tons yearly. It is location specific, with Africa consuming 30% and SSA 21%. While most of the African countries uses its maize production for food, and other developed world regions uses most of its produced as animal feed. White maize consumption is in Africa and Central America stood at 90%, while yellow maize is preferred in most part of South America and Caribbean. It is also preferred by animal feed producers due to crop modelling, geographic information system and adaptive research may alleviate the constrain of location specificity, especially its yellow colour which enriches the egg yolk and animal fat.

2.1.6. Consumption and industrial uses of maize

Maize stored in metallic silos can be used for the following purposes

i. As staple food for man
ii. As feed for animal especially livestock
iii. As raw materials for industries
iv. Alternative medicine / orthodox medicine additive
v. Seed for planting
vi. Farm manure / bio-fuel
vii. Commodity for export

(i) Staple for man

Maize is used as a staple food in many parts of the world especially in South Africa and sub – Saharan Africa. In Nigeria it is eaten in various forms and it is loved for its high palatability. It could be eaten fresh as a vegetable. When roasted or boiled it is very tasty. Maize can be milled dried or fresh to produce different kind of raw materials for industries or finished products for immediate consumption e.g. starch, pap, corn meal, and pop corn. In many cultures it could be made into porridge alone or in combination with others from (Ogi or Akamu) in Nigeria to polenta in Italy, Angu in Brasil, Mamaliga in Romania and corn mush in the United States of America (IITA, 2009).

(ii) Feed for animals

Grain is a very important component of animal feed especially the biting and chewing grazes in the absence of fresh leaves that is their staple food (Vassal, 2000). Many farm animals have proven that they can survive with grain meal in the absence of their normal kind of food. Maize constitutes the most popular and the biggest amount concentrates / additives used in the production of animal/ livestock feed production, where they are processed into various kind of feeds ranging from poultry, piggery and baits for aquatic animals.

(iii) Raw material for industries

The importance of maize as a major source of raw materials for industries are numerous butt can be grouped into three namely, the dry, wet milling, and products of distillation and fermentation. Dry milled maize products include, grain flour, different forms of maize meals, maize flakes, biscuits and confectionaries. Products of wet milling of maize include, corn oil, corn starch, sugar and dextrin while the products of fermentation and distillation includes ethyl alcohol and whiskey. Starch can also be made into plastics fibres and adhesives

(iv) Alternative / orthodox medicine additives

Stigmas from maize flowers popularly called corn silk are sold as herbal supplement in many parts of the world especially in Asia. They could be used in the production of certain drugs or additives e.g. syrups. Maize could be used as medium for growing some micro organisms in many biochemical industries.

(v) Seed for planting

Maize stored in metallic silos could be used for the next seasons planting if it is preplanned or in emergency situations. The only limitation is the speak and the source which may not be known due to indiscriminate buying culture especially in Nigeria, else if it is pre – planned stocking could be done with desired species that can be used as seeds for next seasons planting. However, in emergency situation where species and source may be compromised it will serve.

(vi) Farm manure

Good grains, discoloured grains and caked grains has proven to be a good component farm yard manure or organic manure on its own. Research has shown that it decays easily and also absorbed leaving no side effect to soil or plants. There is equally an on – going research for its used in the production of bio – fuel.

(vii) Commodity

Maize is bought and sold by investors and price speculators as a tradable commodity. Even farmers, middlemen, co-operatives and organizations who engage in maize agri – business does that in expectation of making profits, gaining financial buoyancy and foreign exchange. In Nigeria grain farmers merchants / traders are one of the most prosperous as far as agri-business is concerned and the business flourishes year after year

2.2. Grain Storage Structures Used in Nigeria

The global perspective of grain storage structures is dependent on grain type, geo ecological zone, intended use and quantity, but grains are stored in commercial quantity worldwide with the use of control atmosphere system of storage and bulk storage in metallic silos. Most developed countries that has made remarkable improvement in grain storage uses both storage structures.

A survey of grain storage structures used in Nigeria shows that it can be classified as village, low - level or traditional structures, middle or improved storage structures and commercial, high – level or modern storage Structures (Alabadan, 2013). Since grain storage in Nigeria involves mainly traditional system/ technologies, the availability of local building material determines the type of structures used in a particular area. Other factors includes the environmental, duration, social, volume of grain, climate, transport or handling system, economic, level of literacy, cultural and otherwise (Mijinyawa, 2010). Furthermore, the need for storage structure for a farmer who has only 2 hectares of land cultivated with maize is different to a farmer that has 100 hectares and 1000 hectares. Consequently, the storage structures needed by a farmer who wants to store his crop on the farm is different from a middleman grain trader, grain merchant, Agro industrialist and Government agencies that can afford to store multi – million naira worth of grain. However, the primary function of any grain storage structure is keeping the grain stored dry at all times to provide protection against pest, pilferage water ingress, seepage, insects, and microorganism that cause deterioration of grains during storage. A storage structure may effectively preserve the quantity and quality of grain, but may have a profound disadvantage like being expensive, or a problem such as moisture and condensation in metallic silo. A storage structure that worked in the tropics may not necessarily work in other temperate regions. It is therefore imperative that adoption or modification, designing and selection of storage structures, should focus on issues such as location, adoptability, cost, type of crop to be stored, duration and other important indices should be considered for efficient and functionality of the storage structure. Hence efficient and effective storage structure made from affordable materials can ensure food availability, accessibility, stability and utilization (Alabadan, 2013).

2.2.1. Low level / traditional storage structures

Traditional grain storage structures are those grain storage structures that are indigenous to local farmers in the tropics and sub tropics in an age long tradition. The methods have been used for donkey years with little or no modification using inexpensive and locally sourced materials for its construction or framework. Design and capacities of these facilities are determined by the type of facility, type and quality of crop to be stored (Adejumo and Raji, 2009). Traditional grain storage structures are further grouped into three namely open air, semi – open air storage and storage in enclosed containers.

2.2.1.1. Open air storage

Open air storage is the storage of food in an unenclosed type of storage structure. It can be further classified into two types namely aerial storage and storage on the ground or on a platform.

(i). Aerial storage

Aerial storage method of storing grains is a system whereby grains are hung on horizontal cords/creepers, vertical poles/racks suspended from tree branches. The grains stored under this system are normally unthreshed and tied in bundles, for ease of suspension. The modification of this system was the suspension of pile on wooden rafters directly above the household cooking fireplace. The modification became imperative since the former provided no protection against weather (if outside), insects, rodents, buds, thieves and micro-organism that causes deterioration.(Alabi, 2001). Hanging under roof directly above fire place, makes the grains to be kept dry, while heat and smoke from the fire place will deter insect, rodents, birds and other pest from attacking it. Mould and other micro organism will not grow, and the grain will be dry maintaining low moisture content. Storage is much more effective using this system, but quantity stored is very low relative to other system. It is efficient for seeds preservation against next planting season.

(ii) Storage on the ground or platform / huts

Crops stored using this system are unthreshed grain and paddy crops. They are always in piles in a hut, farmhouse or unoccupied living rooms. It is a provisional method of storing grains where farmers may be compelled to stack grains awaiting processing / threshing transportation or evacuation to an agro processing mill, a farmstead or market (Ajani, 2001). In this system of storage, the grains are exposed to all the agents of deterioration and pilferage from even domestic animals and man. Storage is far relatively a short period of time but the quantity stored is relatively high. It can be piled in heals on a wooden platform made in a boxlike shape, in regular layers. To speed up drying or deter pest, a fire can be made underneath and detachable straw cover or roof will be provided to heat up the big box (FAO, 1995).

2.2.1.2. Semi – enclosed storage structures

Semi – enclosed storage structures are storage structures that are partially closed, are can be further classified into storage in cribs, thatched rhumbus and baskets

(i) Cribs/thatched Rhumbus

Cribs are normally rectangular in shape. It is an enclosed structure elevated far above the soil surface and supported on columns. The purpose of elevation is to guide against soil moisture and rodents, others are to provide a means of natural ventilation to help in drying of the crops stored. The material for construction includes wood, palm fronds, grasses, bamboo stem, wire nets, steel rods and pipes. Depending on the extent of woods used, metallic materials could also be used for its construction (Mijinyawa, 2010).

The roof is thatched with raffia and date palm leaves, while the floor is made of treated wood or bamboos closely aligned to each other. The walls are always covered with wire netting. It is important to note that cribs perform desirable functions of drying and storage. The choice of capacity depends on the volume / amount of crops to be stored. Cribs may be divided into compartments where many crops are to be stored together. The length above the ground is determined by its loading and unloading system, mainly done manually through the door. Its major advantage is that farmers can afford to harvest their product early at higher moisture content and allow it to dry while storing in the crib. It can also enable farmers to keep unthreshed crops as long as they want until they have time to thresh. Crib must be provided with enough foundation and stronger legs to withstand the weight. Problem associated with storage in cribs includes insect infestation, loading and unloading, bird and rodents and susceptibility to wild /domestic fire outbreak. The early cribs were originally meant for maize but at present, extended to include virtually all other crops (Mijinyawa, 2010).

Thatched rhombus is normally made of woven grass only. Local materials such as rope are used to weave around it serving as tension ring. They are not as durable as mud rhombus and are liable to rot within 2 – 3 years (Alabi, 2001; Adejumo and Raji, 2009), also confirmed to the majority of the capacity ranges from 500 kg – 8000 kg, depending on size, cost of construction is between ₦ 2,000 - ₦ 8,000 as at 2007. The roofs of thatched rhombus are usually made in two distinct shapes, one is conical in shape as shown in Plate 2.1, and consists of thatched grass normally built all the way from ground and raised into location on top of the bin. The others are built to overhang in order to protect mud or thatched walls from splashing effect from rain. Side doors, detachable caps or roofs provide access into the silo. Unlike mud rhombus, thatched rhombus, usually have external support ranging from 6 – 16 units depending on the size of the rhombus as shown in Plate 2.1. Physical defects associated with thatched rhombus includes, foundation, instability, low elevation, inadequate design and structure failure. Others include insect infestation, termite, problems and cleaning. The maintenance cost per year as at 2007 ranges from ₦ 500 - ₦ 3,000.

Plate: 2.1. Thatched Rhumbus

Source: Adejumo and Raji, 2007.

Fumigants are always applied but are normally ineffective due to the fact that the structure is not air tight, the percentage loss in quantity and economic value is between 10 % - 20 % which depends on duration of storage and other factors (Adejumo and Raji, 2007).

(ii) Baskets

Baskets are used for storage mainly in the humid areas of southern Nigeria, mainly because of the recognized need to ventilate crops during storage. Crops stored in basket are normally covered with straw or dry grasses and sometimes grain protectant such as dry pepper before covering with grass straw to scare insects. There are different types of baskets used in the storing of grains, all depending on choice and the availability of local construction materials at low cost and ease of construction. Storage baskets could be made of grass, reeds, bamboo strip, raffia palm leaves or small tree branches. Basket making is highly artistic job that needs a lot of skill. These baskets are kept inside the house while those for long term storage are kept in granaries and covered with mating palm leaves or banana leaves. Several studies including (Adejumo and Raji, 2007) have revealed the ineffectiveness of this kind of grain storage structures.

2.2.1.3. Enclosed storage structures

These are storage structures that are enclosed completely, such as calabash and gourds, Earthen pots and jars, bags/sack storage, pits and underground storage, storage in rhumbus and mud granaries.

(i) Calabash and gourds

They are containers though not necessarily air tight but closed; and have low capacities in terms of storage quantities. It is mainly to store grain used for seed storage as seed and for pulses that are susceptible to insect infestation. The opening (mouth) of some of the structures are blocked with clay, cow dunk or wooden stoppers. The major problem is the bodies of some of the structure are permeable to gases and insects and their covers are not tight, thus difficult to seal completely (Alabi, 2001) suggested sealing the body of the storage structures with linseed oil, pitch and or bitumen. This only reduces the problem and does not completely solving the problem.

(ii) Earthen pots and Jars

Earthen pots are large clay containers made in various pots – like shapes and sizes, used for grain storage. They are naturally like traditionally water pots with big body and very narrow neck. Traditional earthen pots can be made air – tight especially the body having only its mouth for loading and offloading. The mouths are normally closed with clay or lids and are kept indoors after loading. Some farmers use dry pepper as protectant to cover the grain surface inside the pot. Jars are also made of clay. The shape and sizes of jars varies from one region to the other. They also have narrow necks like earthen pots and are also used the same way, but afford bigger capacity for storage as most are quiet big unlike earthen pot. Grain protectant such as ash, sand as well as dry pepper is also used to cover the surface of the grain. The containers are porous naturally and the ease with which they crack is a source of worry (Osunde, Okusanya, Ajisegiri, 1996).

(iii) Sack / Bag storage

These are hand knitted sack made from local materials such as palm leaves or raffia leaves, jutes and cotton or leather strips for transportation and storage of grains. They may be used for subsequent stacking inside a hut according to (FAO, 1995). Why they are stacked off the ground or either in a platform is to prevent spoilage by translocation of moisture. Storage in bags inside box like platform can provide an extra protection against insects, rodents and other agents of spoilage. (Alabadan, 2013) highlighted its vulnerability to insect attack, tear and termite activity. Sacks of stored grains are normally covered with water proof material to protect the bags from rain water.

(iv) Pit or underground storage

These storage structures, dug as pits in variety of shapes and sizes, are specifically made for long term storage or large quantities of threshed and un threshed grains. According to (FAO, 1995) this method of storage is mainly practiced in dry regions where the water table does not endanger the stored products.(Igbeka,1990) also acknowledged that it is used in humid zones of Nigeria for storing tubers only. In North Eastern part of Nigeria (Borno, Yobe and Jigawa state), pit/underground storage structures are prevalent. The inner walls of the granaries are usually lined with straw mats and grasses to prevent the grain from soil moisture. After manual loading of the grains, its surface is covered with mat or strain and then soil. Result of research such as (Igbeka and Olumeko, 1996) shows that it provides protection against pest, insects, and theft, but the major impediment being the laborious nature of digging pits, difficulty in cleaning and offloading. There are limited records on the performance of underground granaries in Nigeria, however, (Igbeka and Olumeko, 1996) observed that after a long period of storage, the grains acquired fermented smell. An improvement on this structure is the use of bricks, cementing or casting the internal surfaces of the granary to solve seepage problems and moisture acquisition that can cause dampness and fermentation (FAO, 1995).

(v) Mud Silo, Mud Rhumbus, and Mud granaries

Rhombus and mud granaries are containers built with clay for grain storage. It is a popular type of storage structure used across Nigeria but mostly in the Guinea and Sudan savannah Areas. Sometimes rhombus can be made of thatched grass stack and are built into make shift storage silos as shown in Plate 2.2. It was found that 90% of farmers that store grains in Guinea and Sudan savannah area of Nigeria uses rhombus (Osunde *et al* 1996). According to (FAO, 1995), mud silos are used in all grain growing zones of Nigeria. Variation exists only in size, shape and other structural details.(Adejumo and Raji ,2007) also confirmed the rising popularity of mud silos especially in the Sudan savannah region of Nigeria.

However, smaller sized silo are predominant in the southern, part of Nigeria.(FAO, 1995) also suggested that it could be due to the fact that, the period of dry season in the south is very short and farmers generally do not habour any fears of famine. Generally such storage structures ranges from 0.4 to 10 tonnes capacity. The small sized rhombus is also popular in the Sahel savannah region of Nigeria. This is unconnected with the fact that, they are not within the grain production belt and as a result produces relatively lower quantity of grains per yearly harvest. Thatched grass materials are always used to roof rhombus, and loading of grains into mud rhombus is done by the removal of its roof, since no appropriate design for loading and unloading is provided (Adejumo and Raji, 2009).

The interior of rhombus are sometimes compartmentalized for storing different grains per compartment. For very tall ones, ladders could be used to climb. When only clay is used for the construction, the walls are about 15 – 20 cm thick according to. The construction is similar to the walls of a house, but when straw is mixed with clay, wall thickness may be less but very strong .This makes it possible for farmer to climb while loading grains. Mud rhombus are always cylindrical in nature which helps in the even distribution of pressure inside; thus rectangular and other sized mud rhombus do often come up with cracking problem as confirmed by (Alabi, 2001). The walls of a mud rhombus are normally rendered inside and outside in such a way that no corner, crack or uneven surface can offer refuge for insect and their larva. Fissures are sealed with liquid clay before each loading. Mud rhombus are normally built on a platform, far above the earth surface with as many legs that can withstand the intended pressures from the weight of the grains, the self weight of the facility and wind pressures. The platform also serves as anti rodent measure to ensure that they do not have access to the stored grain. The capacity of mud rhombus differs. According to (Adejumo and Raji, 2007) in Sudan savannah, the capacities ranges from 1000kg – 8000 kg and the construction cost ranges from ₦ 6000 - N 10,000 as at 2007. The prices are location specific and dependent on the availability of construction materials. Mud rhombus is built to be stable without external support or reinforcement as shown in plate 2.2. However, several physical defects associated with mud rhombus include attacks by termites and rodents, leakages of roof, wall cracks, and poor strength of material and structural failures. Others are defects resulting from insect infestation and the difficulty in loading and unloading. In addition fumigation is also ineffective.

The average annual maintenance cost of a typical mud rhombus ranges between ₦ 2,000 and ₦ 6,000 (Adejumo and Raji, 2007). In Nigeria generally, produce losses are up to 50% in storage where farmers store their farm produce underground pits, rhombus, local cribs, bag pot, calabashes, baskets and earthen pots (Igbeka and Olumeko, 1996). According to (Oyebanji, 1996) on – farm and postharvest losses alone accounts for about 25 – 40 % of the total crop yield in the country.

Similarly (Osunde *et al*, 1996) found that grain losses in Sudan savannah are as high as 43%. These are due to inefficient and ineffective use of traditional storage systems. According to (Alabi, 2001) the losses were estimated as high as 65%.(Mijinyawa, 2010) estimated 20 -30 % effort has still not yielded the desired best storage though there is a recorded improvement.

Plate 2.2: Mud Rhumbus
Source: Adejumo and Raji, 2007.

Storage losses estimated by (Oyebanji ,1996) stood between 25 – 40% while (Igbeka, 1990) is 50% and (Olumeko ,1989) estimated 35 – 50%.Whereas the earlier reporters of post harvest losses using traditional structure are high, there is a remarkable reduction in the losses recorded according to available results and values. it is advocated however that there is further need for improvement in structures, management, adaptation and otherwise, that will go a long way in improving the entire storage system in Nigeria.

2.2.2. Improved Traditional Storage structures

Today a wide range of improvement in storage structures has emerged at different level of storage. For the purpose of this paper review within the contest of this study, it suffices to note that there are alternative modern structures as well as improvement or modified traditional storage structures

2.2.2.1. Alternative modern storage structures

Alternative farm / urban storage structures includes those structures that evolved as an alternative to the existing traditional structures which have performed creditably in its aspect of storage. This include metal drums, circular metal bins, prefabricated steel bins with hopper bottom, plastic containers concrete / cement bins, masonry bins and wooden bins.

(i) Metal drums

They are metal containers or drums, originally designed for transportation of liquids such as petroleum products, but have been thoroughly cleaned with no perforations, thereby making it air tight. This attribute makes it very suitable for storing of grains / paddy crops. By filling the drums to the brim, oxygen should be excluded from the mass or may be present in a little quantity, thereby making it difficult for insect to survive after it has been sealed (hermetic storage). The containers are generally inaccessible to rodents, birds and are also difficult for human pilferage. Due to the difficulty of loading and unloading from the small drum hole, it was modified. This modification involves cutting the drum around its circumference on the top to create lids which are normally sealed with gum, and flash band to create the much desired air tightness as shown in Plate 2.3. Metallic drum can be used indoors or outdoors provided that it is well sealed. According to (Igbeka, 1990), As long as the grains stored are adequately dried, metallic drums shown in Plate 2.3, can store grains as long as five years.

Plate 2.3: Metallic Drum

Source-FAO,1995.

(ii) Circular metallic bins

Circular metallic bin are metallic containers designed and fabricated for storage of grain / paddy crops. They are modified metal drum, airtight, with good loading and unloading facilities but of higher capacity, for storing grains. They are made of welded sheets of mild steel which may be plain or corrugated.

According to (FAO, 1996), two basic design are available; the first has a flat bottom with sloping roof and the wall made of curved steel sheet bolted to each other and can be assembled on site. It has provision for aeration to prevent the development of temperature gradient that can lead to moisture migration. When not in use it can be taken apart and reassembled whenever it is required. The bin is made airtight by provision of neoprene washers and bolt.

The other type has a flat bottom and roof, with welded sheet, but has no provision for aeration. It has provision for loading and unloading. They are very effective for protection of stored grains against insects, rodents and water ingress / seepage and equally efficient for indoor storage. It can be made with a wide range of metallic / metallic alloys, such as aluminum, steel and corrugated iron sheets.

(iii) Prefabricated steel bin with hopper bottom

It is a bigger capacity steel bin fabricated with a hopper bottom, which makes it stand firm on a good framework of metal stand, with clearance of about 60cm above the soil. Fabricated and fixed beneath the steel silos are strong legs, enough to carry its self weight and or when it is fully loaded with grains. It is an outdoor structure, though putting under a roof may be a matter of choice. It has a sloping roof and a tapered bottom with opening / gate that could be used to discharge grains and as well a lock. The prefabricated steel silos can be dismantled and reassembled in another location (TechnoGrain, 2002). Some may have provisions for aeration but an internal ladder and manhole /

inspection chamber at the top is a necessity for effective use. The loading and loading can be done manually or motorized using different types of grain handling equipment.

(iv) Plastic bins / containers

Plastic containers / bin have proved to be a suitable storage structure especially for storing grains and paddy crops. It is suitable for both indoor and outdoor storage. Different sizes of plastic container found useful includes jerry can, that is airtight which is a popular application in Nigeria Others are drum sized plastic containers originally meant for transporting chemicals and liquid (FAO,2009). If properly washed and well sealed, could make a good storage structure. The opening at the top can be widened like in case of the metallic drum, to ease loading and unloading. Other higher capacity plastic containers with raised platform exist. They are purposely designed for storage of grains with good loading and unloading facilities. They are movable and could be dismantled. The advantage of plastic bins lies in its ability to maintain air tight, environment, protection against insects, rodents and ingress of water (Opit, 2010).

(v) Cement / concrete silo

They are circular weather roof structures made of concrete, which can be used for surface and underground storage. It has been built in several locations in Nigeria by the Federal Ministry of Agriculture, crop, processing and storage unit, and many individuals/private organizations (Olumeko, 1999). It can be built in variety of sizes but mainly in cylindrical form. Concrete silos are relatively cheap in view of high input of local materials. There are two main types namely the ordinary plain concrete type and the reinforced concrete type (R. C. C). The ordinary plain type consist of high concrete slab, strong enough to withstand load that will be exerted on it by the self weight and when fully loaded with grains. The covers is also precast and are usually raised into location after loading. In reinforced concrete types, the structure is cast on site with steel reinforcement rods. The joints of all concrete structures are sealed with cement mortar.

(vi) Masonry bins / brick silos

They are silos built with either sun dried brick or burnt bricks. They are usually strong and durable; the bricks are usually held into place with cement mortars. A spout at the bottom and a slanting floor makes it easy for discharge. Loading is done from the manhole at the roof. Locking arrangement for securing the manhole and discharge point is always necessary. In Nigeria, so many designs exist including the type introduced by FAO .It is designed to look like a modified traditional shaped rhombus. It is constructed with stabilized earth brick. The silo is built on a concrete pillars supporting a reinforced concrete slab. The inside is plastered with cement with a removable roof or cover. Result of works carried out to evaluate the performance of brick silo (Olumeko, 1989; Mijinyawa, 2010) indicated that there is a substantial reduction of temperature gradient as oppose to metallic silos. However, increase in bulk density of stored grain, moisture absorption, wall grain friction, and fissures still remain issues of great concern.

(vii) Wooden Silos

They are containers made of wood, for the purpose of storing grains / paddy crops. The wooden silo is not common in Nigeria, though several research work such as (Alabadan, 2002; Alabadan,2006; Alabi, 2001; Mijiyawa Y; Lucas E.B; Adegunloye, F.O, 2007) has tested its suitability as a silo construction material, in Nigeria. Wooden silos consist of a hexagonal body, built with panels of plywood sheets using African mahogany or (*Mansonia Altissima*). It has a sloping roof with a manhole at the body near the base and another up in the roof for unloading and loading. The entire structure is always mounted on a support that is firmly embedded in the ground with concrete.

However, the results of several trails show that it does well in terms of temperature gradients in the grain mass, but the durability remains a problem. The wood must be adequately treated, because as a biological material it is susceptible to decay and weathering. Treatment of wood should not be done with non-toxic chemicals. Apart from its several bottleneck, it would have been the most preferred choice due to its cost and availability (Mijinyawa, 2010).

2.2.2.2. Modified or improved traditional storage structures

These are structure which are naturally traditional but has been modified or improved due to the result of several research work carried out in that area. The modification is basically for improvement of its efficiency as a grain storage structure.

(i) Bag / sack

Several modifications have been done in the use of bag for storage by the manufacturing hermetic bags of sealing such as Purdue improved cowpea storage bags (PICS) bags. The bags are rodent repellant. The bags are air tight and kept indoors or out door under shade (McNeil, 2010). In Nigeria, it is not very popular unlike Asian countries. It can be used to store as much as 1,500 tonnes of grains in an open shade under roof.

(ii) Local cribs

Local crib is been improved upon with construction with treated woods. There are also improvements in the aspect of ventilation cribs. This is done by designing crib to face the direction of wind to facilitate fast drying as show in Plate 2.4. Galvanized iron roofs are being used as roof and the stand are now made of metals having anti-rodent guards for effective storage and prevention of rodents and other pest, especially termites.

Plate 2.4: Local Cribs

Source: IITA,2009.

(iii) Rhumbus

The modified Rhumbus structure is raised off ground and provided with stands that has anti-rodent guards. It has inlet and out let manhole for loading and unloading. It is also movable and for total evacuation of crops, the rhombus is slanted towards the door side, thick polythene sheets are incorporated to the body during construction to reduce or stop seepage and too, to also make the rhombus air tight, sealant and flash band are used to seal the inlet and out let doors. An improvement on the thatched rhumbus / cribs is indoor masonry brick structure and the outdoor which is reinforced to have more strength. Other types improved upon are the thatched rhombus made of thatched body but aligned with non pervious polythene inside, both at the floor; it is also used to cover the grain surface after loading. The stands are constructed with metal having anti-rodent guards and local grain protectant (pepper) is used to cover the surface (Ngamo,Ngassum,Mapongestem ,Maliasse,and Hance,2007; FAO, 2009). The roof is also made of zinc or aluminum, sloping downward covering almost the entire rhombus. The major shortcoming is that loading and offloading is still done manually (Olumeko, 1989).

(vi) Metallic drum

An improvement on metallic drums are of higher capacity, airtight metal containers used in hermetic storage circular bins, especially the type introduced by the crop processing units of the Federal Ministry of Agriculture. The sizes are enhanced with 2 manholes, one at the top and the other at the side bottom for easy loading and unloading. Lower capacities of 1 tonnes are very popular though other higher capacity exists (FAO, 2009).

(vii) Underground pits

Underground brick masonry structures are the improvement of the traditional underground pits. The floor and body are well rendered and double coated with cement mortar. Bigger capacity types are reinforced. The roof is made of reinforced concrete sloping downward towards the edge to drain away rain water as shown in figure 2.5. Bitumen and other sealing materials are applied to the external surfaces for perfect sealing. It comes in different capacities depending on the volume of the crop to be stored1. Loading and unloading is still manual though a moisture problem is highly reduced.

Plate 2. 5: Underground Pit

Source: IITA,2001

2.2.2.3. Commercial / large scale grain storage structures

The major reason for commercial and large scale storage is the need for increase in capacity which its essential purpose is to facilitate long term operational storage of grain providing a buffer in between harvest receive period and backups for markets and other users of grain during the learn periods.(FAO, 2010). Commercial storage is a multi million Naira venture that can be a source of financial independence for the government, organizations and individual who undertake the business. The main purpose of commercial storage is to serve as a nucleus for the attainment of food security (Alabadan, 2002). Commercial grain storage can be classified into warehouse and bulk/ silo storage

(i) Warehouse

Warehouse is a modern storage structure used for storage of grain and other crops in bags. The origin can be traced to the use of unoccupied rooms for storage of farm of farm produce (Mijinyawa, 2010). A good warehouse should be sited in an upland area or raised to a higher elevation in a low land to avoid seepage. It should have piled foundation and floor, depending on design. There are Lorries driven in warehouses in which case stronger foundation, building and floor element are needed. It should be rodent proof with air suction fans. Fan inlets could be sealed or left open with nets to prevent birds from having access. It should be a bit air tight, but must have closable vents for ventilation. Openings and must be sealable when closed, to encourage fumigation. There should be one or more entrance doors for access by trucks or otherwise. Depending on size, a good warehouse should have pallets for stacking and facilities for forced ventilation. This will prevent stored items from having direct contact with the floor to prevent heat and moisture problems.

(iii) Silo / Bulk Storage

It is the type of storage system where silos are used for storage of food crops. It is the commercial way of storing grains in bulk all over the world. Silo referred to as bin or tank is basically a huge container used for the storage of free flowing and granular solid material. The most common types in Nigeria are the conventional or proprietary metallic silos (Alabi, 2001). Silo could be made of different material ranging from plastic, sandcrete, wood, metal, masonry/brick and stone or ceramics. Silos can be used to store multimillion quantities of grains depending on its capacity.. Only the Government and few organizations, such as breweries, feed mills, beverage/confectionery companies and selected individuals use this kind of bulk storage structure in Nigeria.

2.3. Metallic silos

Metallic silos are containers in form of towers or pits made of metal for storing grains or other free flowing granular materials (Hornby, 2010). As a multipurpose storage container, a wide range of agricultural material/grains ranging from flour, liquids, oil seeds, cereal paddy crops, coal and mineral ores could be stored in metallic silos. The most popular type of metallic silos in use worldwide is cylindrical type with sloping roof, made of the new, high performance corrugated steel sheets, with protective coatings. The magnesium based chemical composition of this coating, makes it ten times more resistant to adverse condition than the traditional galvanized steel, because the composition of its coating has been optimized to provide resistance to adverse conditions. It is also adapted to high volume prefabrication manufacture because it is relatively light in weight, impervious to vapour and requires no sealing.

Metallic silos can be made in a variety of shapes and sizes depending on its use, and desired capacity. It can store thousands of tonnes of granular material. Its variety of shapes ranges from boxes, square, octagonal, rectangular and most commonly cylindrical types, above or beneath the earth with either flat or conical bottom (TechnoGrain,2002). While metallic silos with conical or hopper bottom, mounted on a frame of steel structure discharges by gravity, the flat bottom metallic silos need a form of grain handling transport equipment to aid its discharge. Though some flat bottom silos can be discharge by gravity, if the transport system is under the discharge point, it has no self cleansing discharge effect and will need a sweep auger for efficient and complete discharge of the material it holds.

Plate 2.6 : Metallic Silo

Source: Okolo,2013.

A metallic silos as shown in Plate 2.6 are normally designed to have loading and unloading facilities, a manhole at the top and the middle and or near the silo base, which serves as an aperture for having access inside the silo to effect a task or for inspection. Monitoring and aeration facilities, internal ladder, roof vents are also necessary especially the big capacity flat bottoms silos that holds grains for relatively longer periods for the control of temperature and relative humidity (Ajani, 2001).

Silo could be indoors or outdoors depending on choice, capacity and purpose. Grain stored in outdoor silos is subject to greater temperature changes causing deterioration in quality in long storage, especially in warm humid climate. There is also the risk of moisture migration or condensation on the internal surfaces/walls of silos especially if the material of construction is metal (Alabadan, 2013). Different materials used for construction of silo have different advantages and disadvantages; none of them has proved absolutely satisfactory all over others (Mijinyawa, 2010). There is no doubt that metallic silos has proven to be efficient in reducing storage losses recorded in bulk storage over the years, with efficient integrated grain management techniques (Okolo, 2013).

2.3.1 Silo Classification

Silo can be classified based on aeration method/ system, material of construction, level of technology sophistication and structural stability

Based on the aeration method, silo can be classified as, mechanical ventilated silo, controlled atmosphere silo, hermetic silo and gas (nitrogen, oxygen, etc) silo

Based on the material of construction, silo can be classified as: metal (aluminum, steel, etc) silo concrete silo wooden silo mud silo composite silo and plastic silo

Based on the level of technology, silo can be classified as, conventional silo,instrumentalized silo, computerized/ automated silo

Based on structural stability, silo can be classified as, deep silo and shallow silo

2.3.2 Metallic silo construction

Metallic silo construction is a highly technical / professional job which needs training and strict adherence to the design, including the distribution of load. After clearing, excavation and compaction of a given area earmarked to be the silo base, the area is casted or pilled with reinforced concrete to a given strength and height above the earth surface according to the dictate of design. This is to prevent any form of seepage and to provide for enough strength to withstand the self weight of the facility, the lateral and the wall pressure that will act on it when the bin is empty or fully loaded (Technograin, 2012).

During the silo base casting, channels are created emanating from the aeration duct depending on the adopted floor layout design for effective aeration. After the completion of the silo base, stanchions are erected with, and corrugated galvanized steel sheets which have been rolled to a curve corrugated steel sheets are bolted together to form a vertical cylinder. It is anchored on a floor – level ring which is fixed to the silo base. The cylinder of sheets supports itself with stiffening ring only at the base which are held tight together with bolts and nuts. The sheets are heavy gauge at ground level and are progressively lighter as it goes up to higher level. According to(FAO,2009) recent improvement in silo construction has evolved silos with same gauge steel sheets, whereby vertical stiffeners, fitted inside and outside the silo cell bear the vertical load. However, different silos are designed and are built for different purposes; hence strict adherence to design dictates which is determined by intended load must be observed. Each sheet is sealed to its neigbour with a sealant if the assembly of corrugated metal sheet is completed a light metallic trapezoidal element in metal sheet is galvanized and ribbed steel plate sloping roof made of aluminum will be used to cover the silos without imposing excessive vertical load on the structure. The base is always sealed accordingly, with bitumen and flash band to prevent water seepage into the silo cell. Special electro plastic material and PVC washers permit to have a perfect sealing of the panels and the bolts (Technograin, 2002).

2.3.3. Economic Importance of metallic silos

Since world population has been predicted to reach 9.1 billion by 2050 and this will require invariably a 70% increase in food production especially grains (FAO, 2009). There is no doubt that, the enormous challenge that will be posed by storage of grain in the near future is imminent. Since most of this population explosion will occur in developing countries especially in Africa where grain crops are staple food, more grains storage structure will be needed. Presently Africa is suffering from 20 – 30% post harvest losses valued at 4 billion dollars annually according to (FAO, 2009). The problem of inadequate and inefficient storage structures will deter the ease of achieving the increase storage capacity, to complement the expected increase in production.

At present, traditional storage practices in developing countries lacks the integrity to guarantee protection of stored food against major pest, micro-organisms and other agent of deterioration due to the lack of suitable and efficient storage structures and absence of storage management technologies. These situations often force the small holder farmers to sell their product immediately after harvest (FAO, 2009). Consequently, farmers receive low market prices for any surplus they produce because of inability to store. Certainly the importance of metallic silo in meeting challenge is encouraging, considering its ability to reduce post harvest and storage losses recorded over the years. However the only impediment is the cost of construction, and the technical expertise for its management. Thus imminent expected capacity in storage due to increase population and development can only be met with such a capacity a metallic silo can provide. Metallic silo can store multi thousand of tonnes of grains with relatively minimized storage losses, thus major boost and break through for commercial and capacity agriculture worldwide (FAO, 2010).

The main interesting aspect of metallic silo storage is its lucrative nature and opportunities for employment, for teeming youth in who may either be employed by companies that constructs metallic silos, or organization that runs a metallic silo complex or grain elevators. Naturally Prices of grain can appreciate to almost twice during the lean period to be compared to the price it was sold during the harvest period, especially in the developing countries where there is inadequate and inefficient storage facilities (FAO, 1995).

2.3.4. A review of silo construction materials

Silo construction materials include, metal, sandcrete, wood, plastics, bricks and stone. The proprieties of a construction material refer to those qualities possessed, characterized and exhibited by the material either in its material state or processed for use (Mijinyawa, 2010). These properties are very vital because the influence the strength, durability, stability and aesthetic values of the final structure in which they are used. Various materials have been used in silo construction in Nigeria. Some are readily available locally like clay and wood while others are manufactured or processed into form. The materials used for silo construction are generally exposed to the environment, and their performances under these conditions are dependent of their properties (Alabadan, 2009). For example, the ability of a storage structure to protect the grains stored from external environment, which includes (Moisture, temperature, wind, insect, rodents, fungi etc).

These properties are categorized into physical, mechanical, chemical and biological properties. Physical properties are those characteristics exhibited by the material that describes the response to water vapour, gases, heat, cold and radiation. This includes porosity, water absoptivity, thermal resistance, thermal conductivity and thermal transmittance (Mijinyawa 2010). Mechanical properties describes the materials ability to resist deformation and failure under the action of external and internal forces, while biological properties describes a materials response to attack by fungi, insects and their larva, rodents and birds. Chemical properties of silo construction material include the structure of the material and its formation. The properties are normally measured in the laboratory and not by mere vision for example acoustic properties, corrosive and reaction with the atmosphere, and other elements and compounds (Mijinyawa, 2010). Although steel, aluminum, concrete, wood and rubber are commonly used in the construction of silos, none has proved absolutely satisfactory as a construction material over others. The all have advantages and disadvantages, but according to (FAO, 1996) the choice of construction materials for grain silos is between steel and concrete for developed countries but for developing countries other materials like wood masonry, clay, raffia and thatched grasses are popular because of cost.

(i) Steel

Steel is believed to be most common among the building materials used for silo construction all over the globe. (FAO, 1996) justified this claim by giving the reason that it's easily adaptability to high volume pre-fabrication manufacture. Steel used in silo construction may be in small or big panels. It is relatively light in weight. It has good workability factor that makes it easy to be fabricated into different shapes and sizes. It has high strength and impermeability, which makes it easier to protect stored grains against insects, water ingress, pest and rodent except at the joints which requires special sealing. Steel exhibits high heat aborsorbity, conductivity and specific heat capacity. This accounts for high temperature gradients that result to moisture migration and condensation which are the major problem of grain storage in metallic silos (Alabadan, 2013). Based on this peculiar problem, steel bins generally required a lot of monitoring to control moisture migration and would amount to high over head cost, coupled with the fact that steel sheets must be protected against corrosion. Steel bin are most desirable. They have smooth walls, less friction between grain and wall and very low maintenance cost.

(ii). Aluminum

Some metallic silos are made of pure aluminum especially the low capacity ones and could be constructed with aluminum alloys for big capacity silos for example (Aluzinc) which is an alloy of aluminum and zinc (Technograin,2002). Its physical characteristic is almost the same with steel silos only that the pure aluminum made silos lacks strength and rigidity and is lighter, whereas aluminum alloys are heavier and stronger. However, thermal conductively, absoptivity, specific heats are as high as in steel and wall to grain friction is also low. Moisture migration is also prevalent. It has high impermeability to ward of insect, rodents, wall and roof leakages which is a quality of a good storage structure. Necessary monitoring and are key to successful storage in aluminum silos due to moisture problem, (FAO, 1995).

(iii) Concrete or sandcrete

Concrete silos are classified under pure concrete and reinforced concrete silos. Concrete is an artificial building materials made from cement, sand, gravel and water. Its strength depends largely on the composition of each of the conglomerates. Reinforced concrete was introduced due to the brittle nature of ordinary concrete that has lead to failing of silo structures. However silo engineers on noticing the problems with pure concrete silos, decided to reinforce it with steel, iron rods, wire mesh to make it stronger and more collective. Concrete generally has low thermal conductivity and absoptivity according to (Igbeka and Ajisegiri, 1986). But has high moisture absoptivity and permeability which makes its durability an issue especially in the tropic or humid climates.

Concrete has a high grain to wall friction; it can be constructed with pre-cast concrete form, but requires high technical expertise (Olumeko, 1989). Concrete silos have a high compressive strength, and are cheaper than steel silo in view of high inputs of local raw materials used for its construction. However, they are also susceptible to moisture problems though it is less pronounced than in metallic silos. Cleaning in concrete silos is problematic as its walls are not self cleansing. (FAO, 1996) had recommend sandcrete silos to coastal areas and high humid areas due to corrosion problems in metallic silos. Apart from the sandcrete silos built for research purposes, and the one owned by Dangote groups of companies, they are rarely used in Nigeria.

(iv) Wood

The initial use of wood for the construction of grain storage structures was primarily for maize cribs and thatched rhombus, because of the locally availability and relatively low cost. However research evolved new use of wood as a silo construction material (.Alabadan, 2005). They are normally treated with anti termite / pest chemical and surfaces well rendered, for the construction of surface / tower silos for storage of grains. Various advantages of wooden silos include low thermal conductivity and absoptivity, low cost of local materials mainly used in its construction (Alabi, 2001). It major problems includes vulnerability to deterioration by weathering and biological agents like fungi, insects and rodents. Others are poor wall vapour pressure resistance and susceptibility to wild fire. Its abnormal capacity of absorbing moisture and water when it decays can impact odour in the stored grains. Human theft of grain is easier in wooden silos than any other type. However several researchers (Mijinyawa, 1999; Alabadan, 2002) concluded that wooden silos are more efficient in reducing the moisture migration and condensation, and development of hot spots that arises during periods of elevated temperature, than metal silos in the tropics. In Nigeria, the majority of the wooden silos that were constructed in several occasions are for research purposes, thus there are no records of operational existing wooden silos in Nigeria.

(v) Clay

Clay silos are largely made of fired earth, consisting of materials such as illite, kaolinite and monotonrilonite used for silo construction. Fired bricks are also form of clay which is also used for a lot of underground and surface grain storage structures. The initial structure made from clay used in grain storage was mud rhombus and the improved rhombus reinforced with wood husk, lime, ash and cement to stabilize the mud and strengthen the structure. It is one of the ancient building materials in the word and its use is dated from 5000 or 4000 BC according to (Igbeka and Olumeko, 1989). Clay has low heat conductivity and absoptivity and works well in solving moisture condensation problems. However, it has high moisture absoptivity and wall to grain friction. Its durability, insect / rodent attack and human theft are high. In Nigeria, clay grain storage structures made up 80% of the whole grain storage structures according to available records as it is mostly used by peasant farmer for domestic and on-farm storage. (Adejumo and Raji, 2009)

(i) **Plastics**

Plastics materials such as polyvinyl chloride (P. V. C) polypropylene and polyethylene are low – density materials whose main quality is their moisture proofing properties. They have very high puncture strength and drums of tank made from it are now being used as grain tanks according to (Alabi, 2001). Plastics silo comes in a wide range of low and high density. However the more popular plastics used in grain storage are plastic sheets, they have low initial and maintenance cost. They are used as weather proof covers for stacked bags of grain and as water proofing materials for bin walls and floor or as bags for grain storage. Research has also shown that it worked well in hermetic storage for example, the Purdue Improved Crop Storage (PICS) bags. They have low heat conductivity and absoptivity, temperature condensation is not a problem, but it has generally low tear resistance. Insects and rodents may attack plastic sheets. Prolong exposure to weather may cause the deterioration of the sheets or tanks. However, the most popular of all types of plastic containers is butyl rubber but is largely unpopular way of storage especially in Nigeria and most parts of the tropics.

2.4. Review of Operative factors in grain storage.

Operative factors affecting grain storage can be classified into, environmental factors, biological factors, and technical factors.

2.4.1. The grains and grain bulk

A grain bulk is the assembly of biological active materials that is living. As living materials, grains respires given out heat which involves complete body activity. However, its activity tends to slow down or becomes dormant when equilibrium moisture content is attained (Brooker, Bakker-Arkema and Hall, 1990). It is a man made ecological system in which living organisms and their non-living environment interact with each other (Alabadan, 2013). These variables can be grouped into physical, biological and chemical include temperature, grain moisture, relative humidity, CO_2 and O_2 gasses, solar radiation and precipitation, physical, chemical and biological controls, mould and mycotoxin, contaminants, frass and feaces, insects, termites and rodents and other plant materials. This variable can act seldom or interact with grain and or each other to affect grain quality as shown in Figure 2.2.

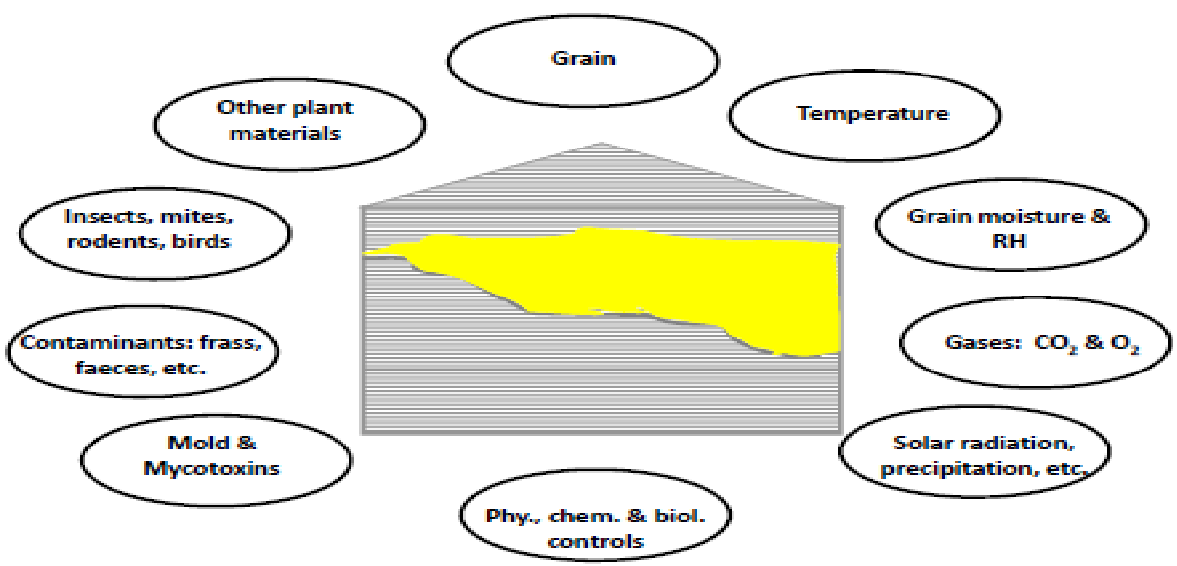


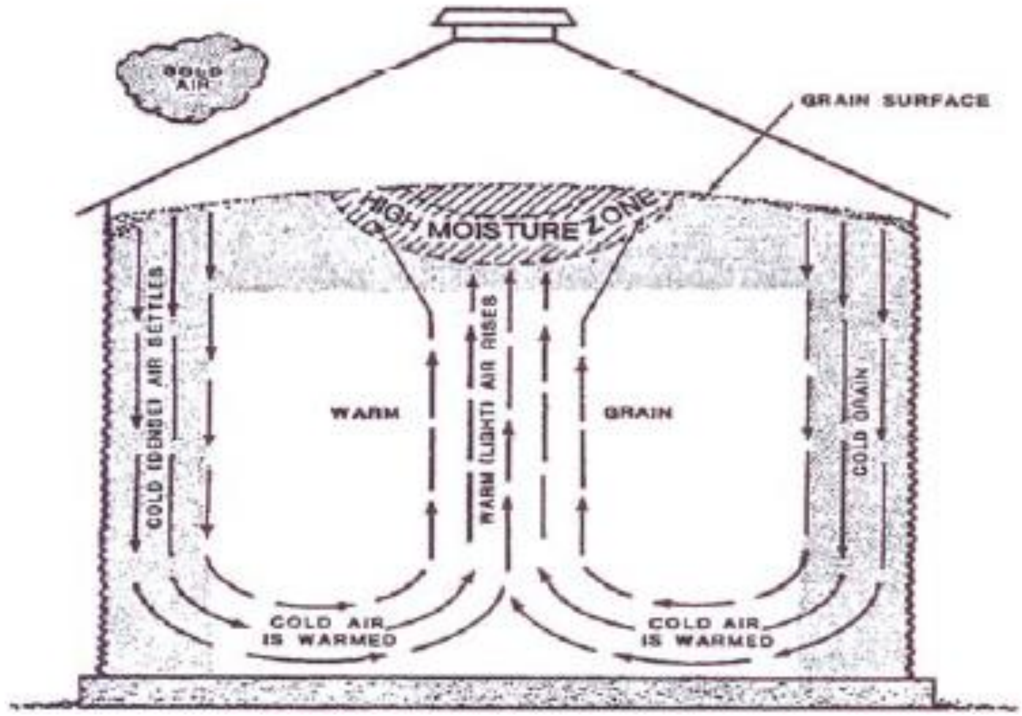
Figure 2.2: Stored grain ecosystem

Source: McNeil, 2010.

2.4.1.1. Moisture Migration and Condensation

Grains are stored at relatively high temperature. As the fall proceeds, the average temperature outside the grain storage decreases, causing a temperature differential or gradient across the walls of the metallic silos. This in turn lowers the air and grain temperatures near the storage walls and their density decreases. There is always a downward movement of air along the walls due to natural convection as shown in Figure 2.3. This air flows along the bottom of the silo upwards through the centre of the warmer grain mass, leaving the grain mass near the central area of its cold surface. During its path through the bulk it picks up moisture which may be condensed in the upper 1 to 2 ft at the top of the bin and the silo walls spoilage may occur if counter measures are not taken (McNeil, 2010). During the early dry season the reverse will be the case. This means low grain temperatures in the storage and higher ambient temperature. The air in this case flows down the centre of the grain mass and rises along the storage walls picking up moisture equally. Moisture accumulation may take place in the bottom or top or the walls of the metallic silos especially if there are no adequate aeration within the period.

Moisture condensation and migration is the greatest problem encountered in the storage of maize in metallic silos. However, the intensity of the problem of moisture migration depends on the climatic variables of the area



.**Figure 2.3: Moisture Migration**

Source: Ileleji,2010.

2.4.1.2. Physical properties / characteristics of maize

Physical properties of maize grain can be defined as those properties that can distinguish one grain from another. These properties have a standard for every individual grain and can be used to grade any grain (Ileleji, 2010). In the determination of grain quality, physical properties are considered along with other variables / properties, but largely depend on the intended use of the grain. For instance if a grain is to be used for ethanol production, the chemical composition of the grain such as starch content will be considered in classification of its quality.

Physical properties of maize seed include moisture content, test weigh tor bulk density, size, shape, colour, porosity, viability, percentage damage and broken grain, percent mould and foreign matter, flow and hygroscopicity. The physical properties can be classified into natural or intrinsic and induced or extrinsic properties (Brooker, *et al* 1990).

(i) Moisture content

Moisture content which could be intrinsic and extrinsic is one among important factors in grain properties / quality. It denotes the quantity of water per unit mass of grain expressed in percentage basis, either wet or dry. Moisture content does not affect grain quality directly but indirectly since grains will naturally spoil at moisture content above that recommended for its storage.

(ii) Test weight / bulk density or specific or bushel weight

Test weight is known as volumetric weight. It is a good criterion used to determine quality of grain and bulk density. It is an indication of the overall quality. The higher the test weight, the higher the quality of the grain. It is measured in Kilograms per hectoliter (kg/hl). Certain grains like maize and wheat has shown that the bulk densities is a reasonable indicator to milling yield (FAO, 1996) defined it as the weight per standard volume. It is the weight of 100 litres (i.e. one hectolitre) of grain. Other physical properties of the grain that affects the bulk density according to Alabi, (2001) are namely varieties, maturity, harvesting / growing condition and drying condition. Thus a decrease in the value of bulk density of maize from 72 kg to 62kg / hl will amount to an increase of about 10% in the storage volume in order to store the same quality of dry matter (Brooker *et al.*1990).

(iii) Colour

Colour is an important physical property of grains that is most common to determine. What is required is a visual identification and differentiation between the good and bad within one variety or species (Alabi, 2001). Maize seed occurs in different colours but in Nigeria the most popular, are white and yellow species. The colour which the maize is based on is the colour of the endosperm and pericap. Each variety of maize has its peculiarities and different intended purposes because of its biochemical uniqueness. Maize seed can be discoloured. Discolouration is mainly because of the activity of micro organism like fungi and sometimes by overheating during drying. Certain chemicals are also known to taint maize kernels and change their colours. However, some discolouration may be due to mould growth, which could produce some poisonous aflatoxins harmful to human and animals. Discoloured grains generally yield very poor quality products when processed and do not germinate if planted (FAO, 2009).

(iv) Kernel, size and shape

Maize kernel or seed vary in shape and sizes, all depending on variety, planting/growth condition. They may be only 2.0cm in length and near round to a half inch long in some species and a flattened cylinder shape. A typical Nigeria white maize kernel is about is between 1 – 1.5 cm long and between 0 – 1cm in width. It has a protruding mouth known as the germ, which tappered to a pointed mouth. Its body is flattened on both sides showing an imperfect oval shape if the germ is pointing down wards. The Nigeria white corn is creamy in colour with the germ or pulp area looking brighter than its entire body (Ileleji, 2010). Other species in other agro ecological zone will definitely vary from what is obtained in Nigeria. The maize kernel consists of the following, outer thin covering made up of outer pericap and inner seed coat or testa. The endosperms which consist almost entirely starch except in sweet corn and the embryo or the germ, as shown in Plate 2.7, which contain miniature plant structure that development into a new plant.

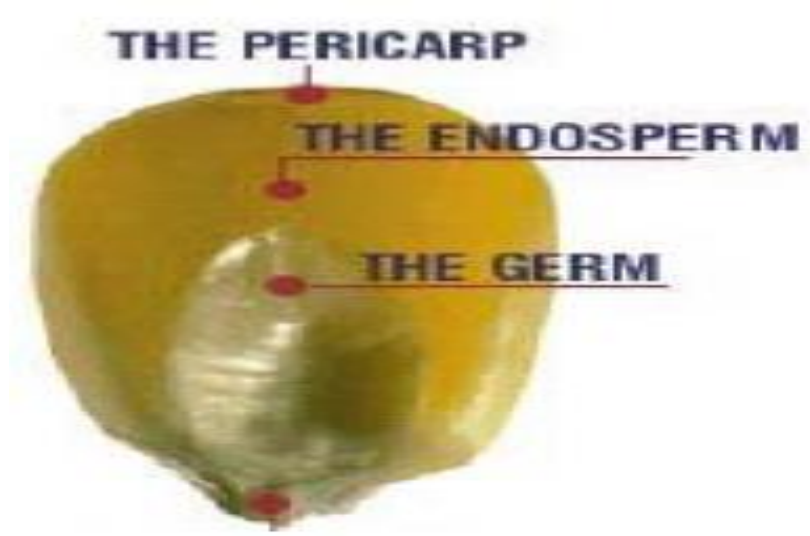


Plate 2.7: Maize Kernel

Source: Ileleji,2010.

(v) **Porosity**

Porosity of any grain mass is the amount of void or space in between the kernels in the bulk. It is due to the colloidal nature of the kernel itself and the presence of inter granular spaces with the grain in bulk (Ajani, 2001). Porosity depends heavily on shape and size of the kernels. An irregular kernel will have more void volume, the more regular and roundish it is the less amount of void. It is very important indices in air and heat flow studies in bulk grain storage. It also depends on the grain particle size, dockage level and its distribution, loading method, moisture content, bulk weight and compaction (Greg and Maler, 2001). The porosity and other flow indices of a typical maize bulk grain determined using a gas pycnometer is shown in Table 2.4.

Table 2.4: Data for true kernel density, porosity and particle size of maize bulk grain

Species – white, bojae hybrid

Moisture content %	11.8 %

True kernel density g/cm^3	1.452
Apparent kernel density g/cm^3	1.258
Interior kernel porosity %	13.3
Pore spaces inaccessible %	92
Particle size distribution in $< (\mathbf{250})\mathbf{\mu m}$	18
Particle size distribution in $< (\mathbf{500})\mathbf{\mu m}$	54

Source: McNiel,2010.

(vi) Angle of Repose

Angle of repose or critical angle of repose of any granular material is the steepest angle of descent or dip of the slope in relative to horizontal plane, when the material on the slope face is on the verge of sliding between (0 - 90^0) as shown in Figure.2.4.

When bulk granular material is poured onto a horizontal surface, a conical pile will form the internal angle between the surface and the pile is called angle of repose. It is an important physical properties of grain related to density, surface area, shape and particle size and the coefficient of friction. Its application in design is numerous for example in hopper design and generally in all grain handling and drying equipment, in design of silo head space and flow dynamics of granular solid grains and paddy crops.

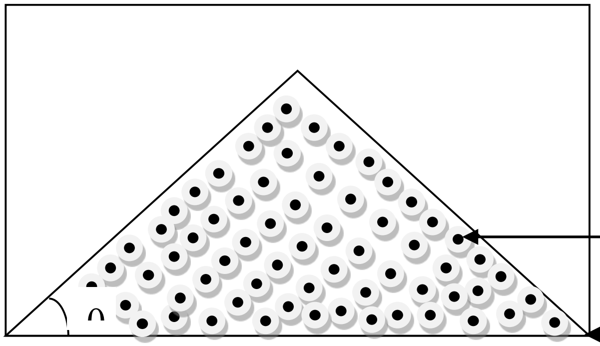


Figure 2.4: Angle of repose of a granular solid material

Source: (Ojha and Michael, 2010)

(i) Co-efficient of Static Friction of grains

It is that amount of force that need to be overcome, before any granular solid can flow or move. It could be between particles of grains itself, or grains against any other object or material. Co-efficient of static friction of grain could be affected by the following, temperature, humidity, operating techniques and moisture content of material, therefore specific condition should be considered while determining the co–efficient of friction values of agricultural products (Alabi, 2001). Its relevance is in the design of different grain transport equipment is enormous. It is basically the interaction of grain with surfaces. Thus the magnitude of force required to move the grains in bulk, determines the power requirements of its grain handling equipment, and generally determines flow patterns both in hopper and in binning

(ii) **Flow**

Grain properties which facilitate flow include coefficient of friction, angle of repose and internal angle of friction. Flow is generally referred to the ability to move in bulk. These parameters are important considering it usefulness in the designing of grain handling equipment / storage systems.

(iii) Germinability and viability

Viability is the ability of a seed to be alive, viability test is the act of determining the proportion of the seed that is alife (Glosing, 2010). Germinability is the ability of a seed to germinate and develop into strong and healthy plant. It can be defined as a measure of capability of seed to germinate according to Ajani, (2001). While germinability is a measure of performance, it depends on the condition of the germ and the favourable conditions for germination.

Viability is the greatly influenced by mechanical damage during harvesting and handling. The ease of mechanical damage to grains is dependent on the moisture content and temperature of the grain and handling. Other variable that affect viability include, field fungi and storage mould, insect infestation, age of the grain seed, dry temperature and condition and system of drying, and the condition of storage.

The effect of storing grains in high relative humidity is also obvious. According to (Brooker, *et al* 1990), serious damage occurred to the germinability of seeds stored at 70oF and 90% relative humidity or higher for less than 1 month. The same grain was stored for 3 years at 70^{0}F and 57 – 61% humidity showed only small decrease germination. The germ contains the embryo and cotyledon. It is rich in protein and fat, so the effectiveness of the grain kernel as a seed depends on its condition. The germ is most susceptible to insect attack because it is bitter in taste and contains protein and fats. The germ is also the weakest part of grain. When fungi attacks germ, the grains will decay or becomes discoloured.

Age affects germinability. This is due to long biochemical reactions e.g. hydrolysis, respiration that stresses the germ, sometimes resulting in the lost of dry matter. Germination of seed will be reduced if wet grains are frozen before moisture removal. This is because act of freezing distorts the internal tissue arrangements of the food materials, which will naturally not go back to its exact locations after defrosting.

Viability does not mean germinability. This is because viable seed are not necessarily capable of germinating into normal seeding. (Glosing, 2010). External appearance is virtually no guide to seeds age or its integrity so a test will be more definite. For the purpose of this study the both types of test were combined as viability test.

2.4.1.3. Extrinsic and induced properties of grains,

(i) Insect damage / broken grains

Insect damage/ broken grains are always expressed as percentage of the whole bulk. It is however a very vital factor to grain storability, germinability and general grain quality. Percentage insect damaged grains can be defined as that percentage of grain that is damaged by insect from the farm to the point of analysis. Insects basically bore holes and lay eggs inside a whole grain, or simply eating up the dry matter (Opit, 2010).

Broken grains are those grains that have physical damage and are broken. It may be due to manual or mechanical harvesting/handling.(FAO,1995). Broken grains always leaves the internal structures of grains exposed to insect attack and other agents of grain deterioration. Either insect damaged or broken grains are sign of bad quality, they exposes grain seeds to deteriorate. They are generally counterproductive as far as storability is concerned.

(ii) Mould infested grains

Mould infested grains are normally expressed as a percentage. It connotes the actual percentage of the grain bulk affected by mould. Mould growth is caused by dampness which gives rise to increase respiration producing heat. This condition is favours mould growth, which uses the grain nutrient for its own growth (McNeil, 2010).Major mould species that grows in grains includes, Aspergillus, Fusaruim and penicillin which may produce mycotoxin and aflatoxins, fumonism and zearalenane. These micro-organisms if consumed by human beings or animals can cause death. Mould attacked grain are easy to identify. It is characterized by colour charge, dullness, mustiness dampness and high temperature and moisture content. Mould attacked grain losses quality on viability and storability (McNeil, 2010).

(iii) Foreign matter, cores and fines

Dockage / fines / foreign material are amount of non grain material present in grain. Apart from whole grain and broken grains.(Ileleji,2010) They may be inform of grain dust, husk, grain cops, insect parts, chaff insect feaces, and other foreign material which accomplish grain either from farm, make shift grain depots, from silo complexes and or other storage structures. Cores and fines are reduced to a minimal level with efficient and effective cleaning. However, foreign matter accompanying grains from harvest depends largely in the system of harvest, threshing and the agro-ecological zone of grain production (Ajani, 2001).

The higher the foreign matter in grains, the higher the insect activity. This is because external feeders can breed rapidly in presence of fines which it uses as nest for breeding. Higher percentage of cores and fines reduces grain porosity thereby making aeration more difficult. It also encourages hot spots, moisture migration and condensation (Brooker *et al* 1990). The greater the percentage of cores and fines in grains, the lower the storability. Clean dry grains are the most storable types of grains. Foreign material prevents uniform grain flow and always accumulates in one side of the bin during loading serving as a safe haven for insect breeding and reduces the effectiveness of aeration.(McNiel,2010)

(iv) Grain Age

The age of grain after harvest is a serious factor in terms of quality, germinability and storability. No matter how well the external conditions are controlled during handling and storage, it is difficult to control internal reactions in the grain kernel (Ajani, 2001). Rather than enzymatic reaction to cease after harvest, it is believed to be intensified. Enzymatic reactions in kernel are controlled and balanced by nature before harvest but immediately after harvest, it is normally upset due to changes in both climatic parameters and conditions for handling and storage. The upset causes a serious of reaction that continues to weaken the grain and make it vulnerable to micro-organism and other agents of deterioration. Even at dormant stage, due to different temperature gradients, enzymes continue to initiate biochemical reactions in stored grain resulting to changes over time. Thus that will bring about decrease in carbohydrate content.

Other changes orchestrated by age, includes loss of dry matter due to years of respiration leading to decrease in the protein content .Enzymatic degradation and break down of protein in protelytic reactions, over time also causes the changes in Organoleptic properties of grain but some enzymes are also desirable to keep the seed alive and enable respiration to continue. However, Old or aged grains, look old, and off colour because it has depreciated in quality and lost its fresh look, thus the best form of grain for storage is good quality from present harvest.

(v) Immature grain

Immature grains are those categories of grains found with weak or without endosperm but not as a result of insect activity. Many have immature endosperm which makes them falls short of the grain integrity standard. This condition makes such grains to have lower hardness, more susceptible to insect and microorganism infestation, and breakage during handling. Immature grains are mainly caused by early harvest or drought. Storage of such grains will lead loss of resources, because they will deteriorate easily in storage. Immature grain will naturally not germinate. This is because the genetic and biochemical process that will make them nature grain was short-lived and not complete (Ajani, 2001).

2.4.1.4. Biochemical composition of maize grain

Maize grains are made up of living cells that are basically carbohydrates, fats, protein materials, vitamins, fibres and water. The relative proportion of these elements differs from one type of grain to another. Their constituents are broadly grouped into two namely dry matter and water (Alabi, 2001).

(i) Water

Water constitutes a vital and active part of any living grain. The amount of water present in any grain determines the rate of chemical reaction activity, enzyme activity and microbial growth decrease in amount of water decreases activity towards a dormant state called equilibrium condition in storage. However, moisture and water are synonymous, thus volume of water present in a material makes up terminology called moisture content

Moisture content

The amount of water contained in a product is expressed in term of its moisture content. Moisture content is the ratio (in percent) of moisture contained in a given sample of material to either the initial (total) weight, or the dry weight of the material. When it is considered in relative to total weight, it is said to be in wet basis, but if the basis of consideration in dry weight of the material it is called moisture content dry basis.

$$Mw = wet\ basis = \frac{w-d}{w} \times 100\ \%$$

$$Md = dry\ basis = \frac{w-d}{d} \times 100\ \%$$

Where w = wet weight,

$d = dry\ weight$

M = moisture in percentage.

(ii) Moisture content determination

Moisture content determination procedure is classified as primary or direct and secondary or indirect. A major problem is securing of a sample before analysis. Since maize sample can absorb or loss moisture, if exposed to the atmosphere before analysis. Standard metal containers or form sample bags are prescribed. For some of moisture determination grinding of the sample is recommended especially when the moisture content is near equilibrium with the atmosphere. In primary and direct method, the moisture is removed from the sample and the quality is determined by weighing or measuring.

Secondary and indirect procedures depend upon certain characteristics of the material which is related to moisture content and must be calibrated against the official primary methods. Direct methods include, oven methods, distillation method, while indirect methods include electrical resistance and dielectric method.

(iii) Dry matter

The dry matter (or water free portion) of maize kernel contains about 77 % starch, 2% sugar, 9% protein, 5% fat, 2% ash and 5% pentose. More than 70% of maize kernel is carbohydrate, which are present as sugar and fibre (cellulose) (Alabi, 2001). They are broken down during grain respiration to obtain energy. The starch is found mainly in the endosperm and sugar in the germ and the fibre in the bran. The fibrous framework of the kernel is made of cellulose. In the maize kernel about 80% of protein is found in the endosperm and the remainder in the germ. Research work in the past revealed that there are variations of the internal constituent of the dry matter depending on varieties. The quality of protein in maize is poor due to the low content of (lysine and tryptophan) two essential amino acid. The oil in maize is contained in the endosperm.

2.4.1.5. Intrinsic properties of grains

They are these self made properties of grains which came to be as a result of their genetical composition. They are by any means induced. Such properties include hydroscopicity, carbon dioxide and oxygen content and respiration.

(i) Hygroscopicity

Hygroscopicity is defined as the ability of a material to lose or gain moisture from the immediate environment. Most grains are hygroscopic and as a result have the propensity to exchange moisture with the ambient air. This property of grain is called sorption, it consist of two processes namely absorption and adsorption. While absorption is moisture is gained while in adsorption moisture is lost to the immediate environment. Moisture is exchanged between a material and its surroundings until the material reaches an equilibrium moisture content at which there is no gain or loss of moisture. The equilibrium moisture content is a function of temperature and relative humidity.

(ii) Oxygen / carbohydrate content / respiration

In a storage ecosystem, factors such as oxygen and carbohydrate content of the grain mass are very important. Oxygen support life in the grain mass and the presence of oxygen makes it easier for micro-organisms like fungi, bacteria and other insects / pest to survive in the grain mass. This is the main principle of hermetic storage. Alternatively the amount of CO_2 present in the grain mass is an indicator to the grains respiratory activities, loss of dry matter, fungi development and grain quality (Brooker, *et al* 1990). Respiration is physio-chemical reaction that involves the decomposition of organic matter to produce energy.

It can be either takes place in the presence of oxygen (aerobic respiration) or in the absence of oxygen (anaerobic respiration). Aerobic respiration involves oxidation of carbohydrates, usually in form of sugar, to generate carbon-dioxide water and energy in form of heat. On the other hand, in anaerobic respiration the carbohydrate are not completely decomposed so that ethyl alcohol is formed instead of water.

The heat librated during respiration raises the grain temperature and generally contributes to the heating of the grain bulk thus the quality of oxygen decreases as quantity of CO_2 increases

2.4.2. Environmental factors in maize / grain storage

Environmental factors in grain storage include temperature, relative humidity / moisture precipitation/ rainfall and oxygen content.

2.4.2.1 Temperature

Temperature is an important factor in grain storage because; it dictates the pace of biochemical reaction drying, grain respiration, morbidity of insects and moisture migration and condensation (Ajani, 2001). Temperature in this contest is in two variables namely, the ambient temperature and the internal temperature of the grain bulk, (inside the silos). Temperature has direct influence on the speed of development of mould, yeast and bacterial and on the premature and unseasonal germination of grain (Ileleji, 2010). Temperature gradient does not only exist inside the silo bin but also between the internal and external surfaces of the silo. Prevalence of diurnal fluctuation of temperature, localized heat due to insect activities and porosity of structure causing water ingress, grain respiration heat produced, are several sources of temperature inside grain bulk (Alabi, 2001). The temperature of the grain bulk is always higher than the ambient temperature especially in during dry/hot seasons. Thus higher temperature mainly favours fungi growth but not insects.

However, grain stored at a low moisture content of between 10 – 13 % most appropriate for maize storage at average temperature between 20 –$30^{0.}$ Temperature affects the growth and development of insect and mould. The optimum temperature for the development of most fungi is less than 50^0C except the thermophilic fungus. Higher temperature also does not favour insect morbidity as shown in Table 2.5. Insects could raise grain temperature as far as 42^0C but their activities, and if it hot spot becomes uncomfortable; the insect would either move to a cooler part or the grain bulk or remains in the spot and die. Alabadan, (2006) in a similar research confirmed that large diameter bins maintained warmer centers than small diameters. Temperature can be controlled through aeration.

Table 2.5: Temperature influence on insects / insect morbidity

Temperature (^0C)	Effect on insect	Effect in Morbidity
< 0	Death in minutes	Unfavourable
5 – 15	Death in days	Unfavourable
19 – 25	Sub – optimum	Slightly favourable
23 – 33	Optimum	Highly favourable
35	Development steps	Unfavourable
55	Death in minutes	Unfavourable

Source: (Opit, 2010)

2.4.2.2 Relative humidity

Relative humidity can be defined as the percentage measurement of the amount of moisture contained in the air compared to the maximum amount it can hold at the same temperature and pressure. When it is containing the maximum amount of moisture, it will be said to be saturated, relative humidity at the point is 100%. If further water is added to saturated air it will appear as liquid. Relative humidity is an important factor in grain storage because it affects all the agents' of deterioration of grain. High relative humidity will definitely favour the growth of micro-organism and will encourage grain decay and spoilage except if controlled. Humidity can be controlled by aerating with dehumidifier.

The reserve is the case above insect survival and morbid. Insect activities are reduced when the humidity is high, but the fungi and other micro-organisms that cause spoilage of grains stored in metallic silos thrives.

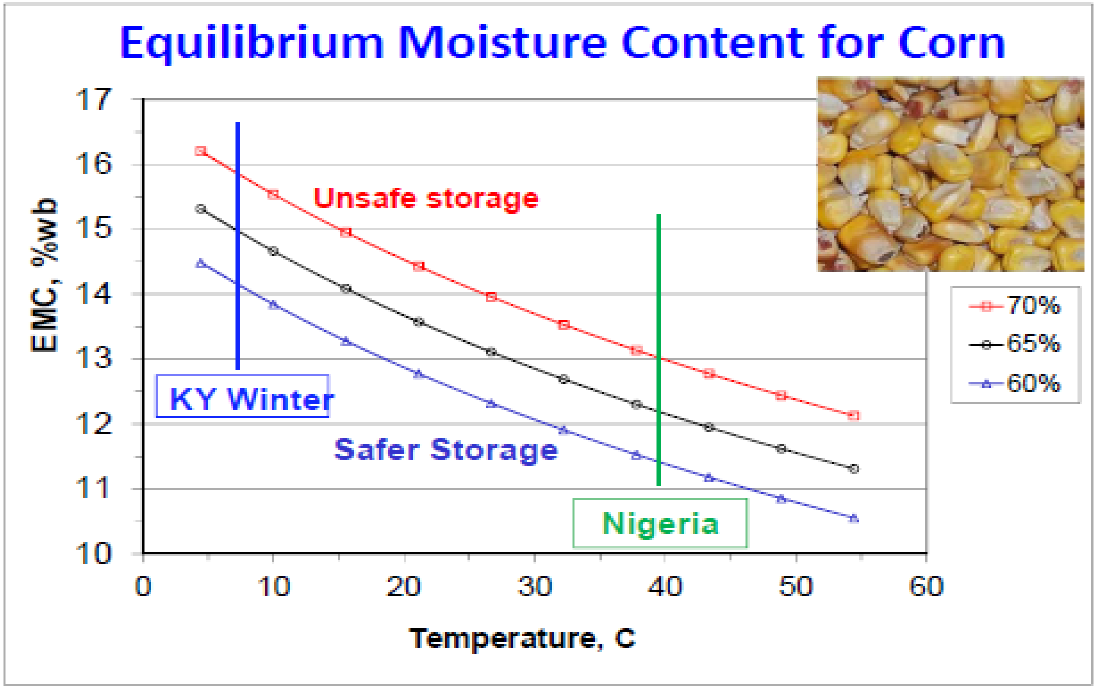


Figure 2.5: Equilibrium Moisture Content for Corn

Source: McNiel, 2010.

2.4.2.3. Equilibrium moisture content (EMC) for storage of maize

It is condition in grain storage ecosystem which the grain in storage attains a moisture content in equilibrium with its surrounding at a given vapour pressure of water (Ileleji, 2010). The interplay between grains in storage and environment is enormous especially maize because of its high water activity (hygroscopicity). The equilibrium moisture content of corn at different values temperature and relative humidity in Nigeria as shown in Figure 2.5 shows the safe and unsafe storage values.

(i) Moisture movement pathway in a Maize seed

Moisture movement into a maize seed is during developmental stages of the seed and wetting due to atmospheric condition (Brooker *et al* 1990). The flow of moisture from a wet kernel is as follows, maize seeds are enclosed by a thin pericap, under which lies the seed coat. The aleuronic layer lies under the seed coat and through it that moisture leaves the grain seed to outer layer and then vaporizes into the air.

Cell ⟷ Aleuron ⟷ Seed ⟷ Crosswal ⟷ Mesocar ⟷ Epidermi

In food material moisture are held in varying degrees of bonding. Water is held by forces whose intensity ranges from weak surface retaining surface moisture to very strong forces holding chemically bond water in the cytoplasm. In drying, the loosely held surface water will be lost easily as free water (constant rate of drying), after this stage comes the H_2O held by strong forces, which is more difficult to remove.

2.4.3. Biological factors in grains storage

In grain storage in metallic silos, grain remains the major source of nutrients for microorganisms, insect, rodent and birds. Even in the field, these organisms have proved to be enemies of grain. It will be pertinent to mention that after attack from all these agents of deterioration it usually leaves the grain in the most unsuitable conditions (FAO 2009). Apart from the differences in how they attack grains, these pests have specific conditions under which they thrive. It is therefore very important to discuss the individual pest and how they affect stored grains.

2.4.3.1. Micro-organisms

Micro-organisms which affect grain stored in metallic silo include bacteria, fungi and yeast. These micro-organisms are mainly parasitic. They grow on the grain dissolving nutrients and making use of them for their requirement (Mc Neil, 2010). Whereas some micro-organism may be useful, majority are harmful to grain itself and secrets toxin, that are harmful to man and animals called mycotoxins. However, various micro-organisms differ in their thermal requirements and are commonly classified as psychrophiles, mesophiles and thernophiles (Opit, 2010).

2.4.3.2. Fungi

Fungi are multi cellular plants which consist of branching intertwined filament called hyphea. Collection of hyphea is known as mycelium. When present on a cereal grain it is referred to as mould, (Alabi, 2001; Brooker, *et al* 1990). Fungi are plants without roots leaves or chlorophyll, thus parasitic in nature. There reproduction type is asexual by means of spores which are easily spread by wind. Over 100 species of mould has been isolated from cereal grains. The optimum temperature for its development is between 20 and 50^0C. (Opit, (2010) confirmed that mould can thrive from – 5 – 50^0C as shown in Table 2.6. Fungi differ considerably in humidity and moisture requirement, but it is believed that the lower the moisture / humidity and temperature, the less mould activity / growth in a substrate (Alabi, 2001). The minimum air humidity that supports mould growth can be as low as 65% but for some mould 93%. The presence of moisture within the inter – granular air in the grain mass is sometimes adequate enough to meet moulds demand.

The major losses caused by fungi to stored grains includes discoloration, mustiness, biochemical changes, loss of dry matter, loss of viability and germinability and possible production of harmful toxins called aflatoxins. Fungi affecting cereal crops can be classified as field fungi and storage fungi. While field fungi attacks or attaches itself on the grain from field, storage fungi only affects grain in storage. Conditions that affect mould growth during storage includes, grain presence of extraneous organisms and percentage broken grains (Opit, 2010). However, mould development can be controlled by chemical and physical means. Propionic acids and acetic acid are used as chemical mould preventives. Physical mould control in stored grain can be achieved by storing clean dry grain and controlling moisture content of the grain, temperature, humidity, insect activity through integrated grain management in metallic silos.

2.4.3.3. Mould and mycotoxin

They effect of mould colorization of grain can be lead to the secretion of chemical substances called mycotoxin, that are toxic to man and / or animals. They are metabolites which are produced by moulds species like Aspergillus, Fusarium and Penicillium, if the storage environment favours them. Mycotoxin such as aflatoxins, fumonism and zearaleone can cause serious illness or even death when consumed by man or animals (FAO, 1996). That's why best practices suggest, that before again should be released for consumption from any bulk storage structure, samples should be taken for analysis in a standard and independent laboratory. However, the presence of mould in stored grain does not mean that mycotoxin will be present; even more frustrating is that the absence of mould does not guarantee mycotoxin free commodity.

2.4.3.4. Insects

They are the most common storage pest. They are characterized with six legs and a hard outer skeleton. Their body is divided into head, thorax and abdomen

For most insect their life cycle is appropriately 3 weeks to one mouth, if temperatures, moisture content of the grain and oxygen supply are favourable (Opit, 2010). Grain insects have biting jaws that enable than to piece and break grain kernels. Most insects feed on the germ portion of the grain kernel which is relatively soft. Major stored grain insects include lesser grain borer, India meal moth, Rice weevil, maize weevil, Angoumois grain moth and Redflour beetle. The characteristic of major storage insects includes ability to reproduce rapidly, migration, causing extensive damage to grains in no time and ability to develop resistance to storage chemicals. The optimum temperature for insect development is between 23 – 33^0C as shown in Table 2.7.

According to (Alabi, 2001), temperature above 45^0C are total for all storage insects and they would die in matter of hours. Complete eradication in insect can be also achieved through chilling, for example at temperature of 16^0C all insects will die in matter of hours.

Other factors that influence insect development in stored grains include oxygen supply, increase in temperature, and amount of foreign matter in the stored grain.

However, insects can adapt to low oxygen levels as low as 1% or evolve strains can develop a resistance and adapt to difficult conditions. The damage caused by insects to grains are categorized as boring of holes and the disappearance of a large percent of the kernel, injury to germs, heating, condensation, moulding of the grain mass and contaminating the grain with excrements and webbing. However, the damage caused to grains, largely depends on the type of insect.

Different insect control measures exist, like aeration, grain turning, fumigation and biological control. Each control measure depends on the kind of insect and population. Inquest into insect history and population using insect trap is very efficient. Integrated pest management (IPM) remains the solution to insect control. This involves the use of available options, singly or combined that will be cost effective and keep the insect population low, without causing any necessary harm to personnel and the immediate environment. (Opit, 2010).

2.4.3.5. Rodents

Rodents and mites have continued to pose challenges to success in stored grains managements. Rodents especially rats and mice inflict enormous and direct losses in stored product by consuming it (FAO, 1995). They often travel distances, burrow or climb into storage structures if not well protected against rodents. While feeding on the grains they contaminate the grains with their droppings, urine and hair, leaving an offensive smell on the grain and reducing its market value. They may also carry rodenticide which are poison, fungi or other micro-organism into the grain. Rodents also eat up wire in silo complexes causing potential dangers to silo workers and discontinuity of wires in control panels. Effective rodent control includes biological control (the introduction of a male and a female cat in the environment). Others are using rodenticide and traps to control their population. Rodents have been known to transmit disease to man, such as rabbit and rat transmitted swine fever, rabies and cattle plague diseases (Opit, 2010)

2.4.3.6. Birds

Birds especially, the granivorous types are always attracted to grains either on the field or in the store houses. If these birds get access, they feeds on the grain and in the process contaminate the grain with their dropping and feathers (Opit, 2010). However, they are relatively easy to control in the store houses. Control measures for birds in store houses include preventing them from having access to the facilities by closing all openings/vents, or using wire mesh to protect them if they are ventilation openings.

2.4.4. Technical factors affecting grain deterioration/spoilage

Technical factors affecting grain deterioration includes length of storage, the grain condition before storage, integrity of the grain storage structure, technical know – how and grain management strategies of the grain managers.

2.4.4.1. Length of storage

It is known that the longer grains stay in storage, the higher dry matter losses. This is due to the breakdown of carbohydrate during respiration of the grains giving out energy. According to (Ileleji, 2010) the complete consumption of a typical carbohydrate in aerobic condition is represented by

$$C_6H_{12}O_{16} + 6O_2 \longrightarrow 6CO_2 + 6H_2O + (677.2\ Kcal) \text{ --------------------- } (2.1)$$

This translates into 1.47g of CO_2, 0.6g of H_2O and 6.772 Kcal of heat, which is produced from each gram of carbohydrate that is consumed (decomposed). During the course of a lengthy storage, it is expected that moisture content may fluctuate and thereby giving rise to the growth of fungi and bacteria that also metabolizes the nutrients in the grain for their own use (Brooker,*et al*,2000). This will definitely bring about deterioration of grain, irrespective of the magnitude. Prolong storage generally increases the risk of insect infestation, pilferage, water ingress, fungi and bacteria growth and other agents of deterioration. It also affords the opportunity of management lapses that can give way to any of the agents of grain spoilage and deterioration.

2.4.4.2. Initial Grain Condition

You cannot increase the quality of grain in storage, but you can only maintain it. According to (Ileleji, 2010) grain reception standards should not be compromised for efficient and effective storage. The condition of grain to be stored is very vital to safe storage. It is widely accepted that for grains to store well, it must be clean and dry. It must be free from insects, broken kernels, straws, husks, wastes, dockage and fines. These materials are collectively known as foreign matters and they contaminate good grains thereby constituting centre of insect infestations in storage of grains (Alabi, 2001). If the initial condition of grain meets the standard for good storage, the grains are relatively easy to manage. Thus, the cost of storing such grains will be economically, encouraging and profitable to farmers.

2.4.4.3. The integrity of the grain storage structures

The primary functions of a grain storage structure are basically maintenance and improve the storage stability of grains and protection of the grains from all agents of deterioration (Mijiyawa,2010). The design and construction of a grain storage structure is a serious factor in the maintenance of the grains quality. They are the easiest to control of all other factors, the choice of a site for citing a grain storage structure is the first challenge followed by its design. The strength and choice of materials for construction, the geo-ecological climate of the area and the technical know – how of the technicians that will construct the storage structure is another vital factor. To a large extent, all these factors determine the vulnerability of grain intended to be stored to deterioration or spoilage.

According to (Alabadan, 2013) the structural requirement and choice of storage structures should vary according to climates, crop type and dominant pest species of country or its geographical area. However, most storage structures are likely to reduce the activities of agents of deterioration like insect, if they minimize heat and moisture loss from the granary to the environment. Thus, a good storage structure should have adequate control over the thermal and moisture conditions in the internal environment (Ajani, 2010). Different materials have different ways of reacting to weather fluctuations which to a large extent influences the immediate storage ecosystem.

2.4.4.4. Managerial skills of the manager

Grain management is a very risky profession, considering the financial value of bulk storage. It is a multi million Naira investment, and as such, any form of mismanagement may be suicidal. There is no doubt that, even if all other factors are guaranteed, without good management techniques nothing will be achieved. Good management technique is primarily the act of using best management practices to control the activities of insects, pests, grain moisture content, temperature of the grain and as well as the activities of bacteria and fungi that causes grain spoilage (Okolo,2013). The secondary aspect is the health and safety of workers considering the occupational hazard involved. The ability to manipulate the storage eco-system to reduce storage losses is also a major challenge in bulk storage (Brooker,*et al*,1990). The manager's training and his ability to put what he/she has learnt into practice is very important. However a good training understanding of the job makes storage easier and a very big profitable venture. Necessary important tools / techniques includes records keeping of activities which include the use of Integrated grain Management practices (I. G. M),Integrated Pest Management (I. P. M) and the observation of all safety and preventive measure to ensure that grain storage work are safe and healthy

2.4.4.5 Integrated grain management/Integrated pest management

Integrated grain management (I G M) is simply the act of using different grain management techniques/system collectively, to minimize storage losses, in the storage of grains in metallic silos (Okolo, 2013). These includes sanitation, record keeping, aeration, grain turning, leveling of grains, monitoring, the use of I P M, cleaning and adhering to grain reception standards. I G M actually start during grain reception and stop when the grain is released or given out.

Integrated pest management (I P M) is basically the use of all available knowledge /methods to keep pest population below economically damaging levels in a manner that is profitable and causes no harm to human and the environment (Opit, 2010) .This simply means the most effective way or ways of bringing insect population low to economical non-damaging level in a storage facility, which is cost effective and without causing a health and environmental hazard. It includes using of all pest control methods singularly or collectively to achieve this aim. Pest population can be reduced using a wide range of activities such aeration, grain turning, fumigation, application of pesticide, sanitation/cleaning. Identification of the pest in question, the population and characteristic, will make the choice of its control relatively easier and adequate.

2.4.4.6 Sanitation

Sanitation plays an important role in grain storage, especially in the deterioration, due to the ability bushes and dirty environment to become breeding ground for insects and other pest that will attack stored grains. Insect can breed rapidly in a dirty environment, especially the ones that had dockage, old/bad grains and grain dust. This is why the advocacy of Integrated Pest Management (I. P. M) is seriously recommended for every grain storage facilities. Pest and insect infestation may be continuous if the breeding ground of the pest and insect is not identified and destroyed by the grain storage facility managers. (Opit, 2010).

Insect re infestation will be difficult if the source, type of insect and population is identified and effective treatment and preventive measures taken. Thus sanitation leads to a clean environment that will make it difficult for insects to breed and generally is an important tool to keeping the insect population within the economically non-damaging level in any grain facility. Effective sanitation includes, cutting bushes around the silo, cleaning of any dirt, dust, left over grain, both in the conveyors, elevator, cleaners, chutes and in the tunnels and disposing them in a proper manner that they will not breed insect or pest (McNeil, 2010).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Raw Material and Sources

This research work was carried out at the National Strategic Food Reserve Silo Complex in Minna Niger State, Nigeria. Permission was sought and granted for use of the facility, from the National Strategic Food Reserve Department Abuja. The stock or consignment of maize used for this research work was delivered to the silo complex from December 2012 to January 2013. According to the grain reception standard of Minna Silo Complex, all supplied maize must come from the current year's harvest (2012 harvest). The specie of maize *(Zea mays.L*) used is White coloured Open pollinated variety TZB (FARZ 34), sourced within Guinea Savannah climatic zone in Nigeria.

During grain reception proper in the above mentioned grain facility, Consignments that met up with the standard of the silo complex which is the same with FAO standard for intending stored grains, were accepted after analysis at the Silo Complex, or otherwise rejected. This research work was carried out using two sizes of metallic silos namely 2,500 metric tonnes (MT) galvanized steel and 1 (MT) Aluminum silos. While the 2,500 (MT) silos was assembled in an open space along with other nine silo cell in a battery arrangement as shown in Figure 3.2, the 1 (MT) silos was put under a tree shade, alone in naturally ventilated location, for variation in storage conditions, capacity or quantity stored.

The 2,500 MT silo cell used for this research work is one of the 10 silo cells of 2,500 MT domicile in the silo complex. As shown in Figure 3.2, its location in the battery arranged silos cells is 9, its choice is based on the silo that was having grains as at the time of the experiment.

While the 2,500MT silos has aeration facilities, inspection window/manhole, internal ladders and roof vents, the 1 MT has none and was rather designed for hermetic storage. All samples and measurement of storage / variable were done in silos 9 as shown in Figure 3.2. Samples were taken from the designated points, as shown in Figure 3.1.

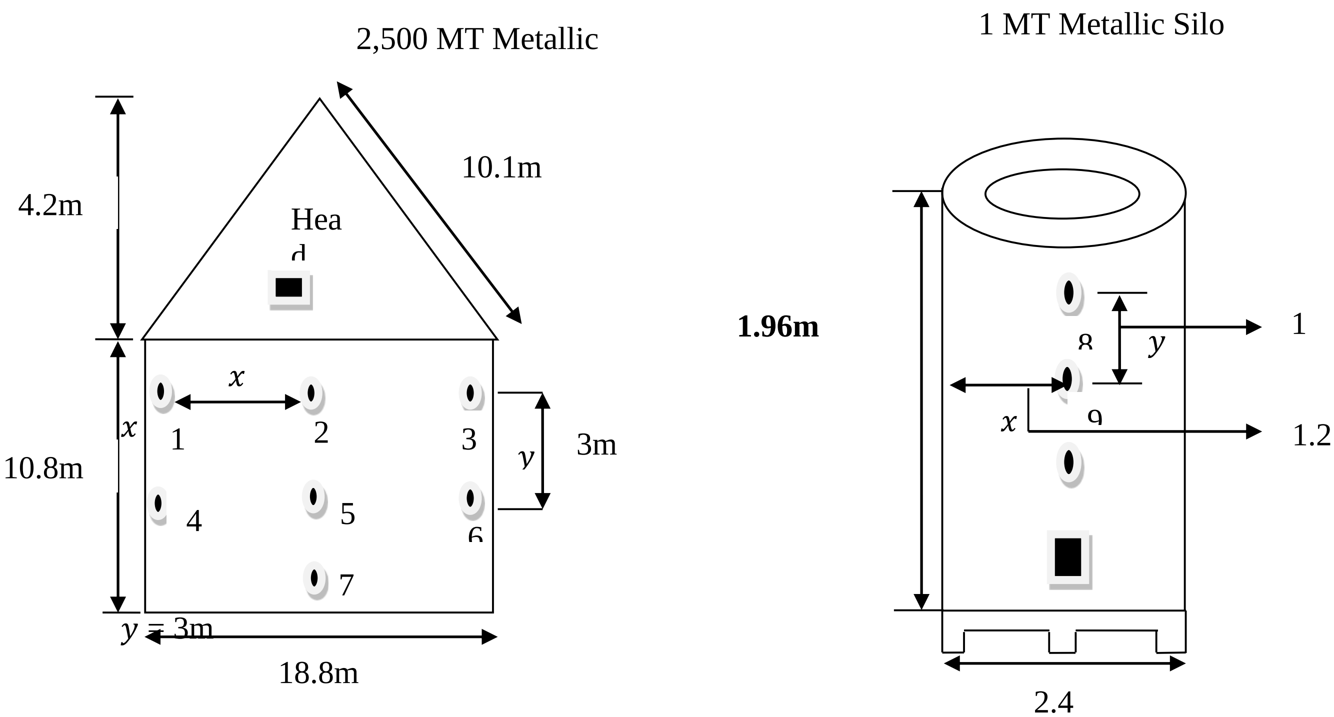


Figure: 3.1. Dimensions of Silos used

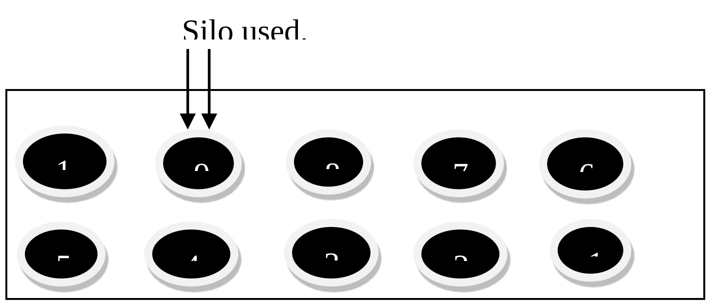


Figure: 3.2. Silo arrangement

Minna Silo complex is a standard silo facility. It has equipment like augers, elevators, conveyors, for transporting grain from one point to another within the complex for the purpose of grain reception cleaning, loading and unloading of the silo bins. It has an efficient laboratory for grain analysis, a digital weighbridge for weighing of consignment in bulk, a bagging plant for bagging of grains before release, a 2500MT capacity warehouse all confined within the same environment. It has 10 silo cells of 2500MT capacity and a total capacity of 25000 MT grain storage spaces of silo cells as shown in figure 3.2**.** The silo cells have grain monitoring and aeration facilities. Grains were regularly monitored for ingress of water, insect infestation, and temperature fluctuations. The normal Integrated Grain Management procedure in metallic silos which includes IPM (integrated pest management) that has been the practice of the silo complex was strictly used within the period. Other monitoring and control methods of integrated grain management such as aeration were done regularly as the need arises and the grains in storage were in good conditions throughout the period

During the period of this research work, ambient temperature and relative humidity around the silo environment and inside the silo headspace were measured once daily by 12 o clock, using a Jenway 5105 digital psychrometer and a dry bulb thermometer and further confirmed using a mobile temperature / relative humidity digital apparatus. This is to enable the researcher to have a good knowledge of the immediate prevailing atmospheric conditions.

The experimental analysis used is complete randomized block design, made up of 13 variables, 9 sample points and 3 replications. The mean of the 3 replications were taken as the true value as presented in Appendix B. A total of 351 samples were used. The variables includes, Carbohydrate content, Energy value, crude Fibre, Fat content, crude Protein content and Ash content, others are Moisture content wet basis, Hectolitre weight, Insect damaged grains, Mould infested grains, Foreign matter, Broken and Germinability The experiment ran for eight months from January 2013 to August 2013.

3.3. Reagents and instrument/equipment used

The reagents used for the laboratory analysis were all analytical grade and most of the equipment used for the analysis are sophisticated and automated.

3.3.1 Reagents

The reagents used for the laboratory analysis are

1. Acetone
2. H2So4 solution (Tetraoxosulphate(VI)acid)
3. NaOH solution (sodium hydroxide solution)
4. Petroleum ether
5. Copper catalyst
6. Methyl indicator
7. CuSo4 solution (Copper sulphate)
8. Phenolphthalein
9. Potassium oxalate solution
10. Distilled water
11. Hcl solution
12. Boric acid (H3Bo3)
13. Carbonate free NaOH

3.3.2 Instruments and Equipment

The instrument and equipment used are

1. Dickey John’s (2000) moisture meter Apparatus
2. Fibrertec Hot/ Hydrolysis unit, Model: 1020.
3. Fibrertec cold extraction unit, Model: 1021.
4. Soxtec weighing apparatus.
5. Carbolite Muffle Furnace, Model: PF 800.
6. Uniscope Laboratory oven, Model: SM 9023.
7. Kjeltec Auto nitrogen distillation and digestion apparatus connected to external titrator,
8. Tecator Digester, Model: 801.
9. Hanna magnetic stirrer, Model: HI300.
10. Electronic weighing balance (Analytic balance machine)
11. Fritted crucibles
12. Air ventilated oven capable of operating at 105 ± 2^{o}C.
13. Desiccators
14. Cyclotec 1093, general purpose sample milling machine.
15. Table top dispensing bottle
16. Incineration or muffle furnace 525 ± 15^{o}C
17. Aluminum extraction cups
18. Thimble adapters
19. Crucibles
20. Crucibles tongue
21. Spatula
22. Petri dishes
23. Digestion Tubes

24. Desiccators Crucibles

25. Electric hotplate; Model CB 300/12 OV/60.

26. Masking – Tape

27. Table top dispenser bottle(automatic addition of petroleum ether)

28. Set of sieves.

29. Moisture analyzer; Model: ML – 50 with super hybrid sensor (SHS).

3.4. Experimental Procedures

3.4.1. Samples collection Techniques / Analysis

3.4.1.1. Samples collection technique

Immediately after the loading of the 2,500MT and 1MT silos with maize, samples were taken at random in January to determine the initial properties which serve as a control to the subsequent samples that will be taken. After the determination of the initial properties, the identified locations of interest for the research were marked inside the silos. Samples were taken monthly from January to August,2013 from the locations, for a period of eight months, spanning the wet and dry season prevalent in Nigeria.

Samples were collected in triplicates with sample bags. These are laboratory double layered minute bags, specially made for samples on transit in other to forestall alterations in the properties due to adverse weather conditions. The samples collected were analyzed to determine the Nutritional and Physical characteristics using standard methods. Physical characteristics evaluated include, percentage Moisture content, Wet basis (wb), Hectoliter weight, percentage Foreign matter, percentage Insect damage, percentage Broken grains, percentage Mould infested grain and Germinability. The Nutritional/Proximate composition evaluated include Ash content, crude Fat content, Carbohydrate content, crude fibre, crude Protein and Energy value. Samples were collected from the sample locations 1 – 9 as illustrated in Figure 3.1.

The sampling techniques used are sampling with the use of big sampling probes and manual taking of samples from unloading point in the both silos. While sample 1, 2, 3 and 8 were taken without the aid of a sampling probe, samples 4, 5, 6 and 8 were taken with the use of a sampling probe and Samples 7 and 9 were taken by unloading the bulk to get sample.

During the research period, samples were taken at 28th day of every month at the designated points and the analysis were carried out the same day to determine Physical characteristics while the Nutritional characteristic were carried out 4 hours after the samples were taken, due to the non-proximity of an efficient laboratory.

3.4.1.2. Analysis of samples

The Physical characteristics were determined in National Strategic Food Reserve Silo Complex Laboratory in Minna Niger State Nigeria, while the Nutritional / Proximate analyses were done in National Cereal Crop Research Institute, Badeggi Niger state. Samples were analysed trice for comparism of results, and the averages of the three values were upheld as values for the given sample. Data was further subjected to statistical analysis. Statistical package for Social Sciences (SPSS 20.0) for Windows evaluation version package was used to determine the level of significance ($p<0.05$) for values obtained for both the Nutritional and Physical characteristics.

3.5. Test Procedures for analysis of Samples

(i) Proximate Analysis

. Destructive method of measurement was used for the proximate analysis. The details procedures of the destructive method of measurement of all the above listed proximate composition are attached in Appendix A.

(ii) Physical Characteristics

For the determination of physical characteristics, each sample was properly mixed and poured into a large rectangular plastic container. Two sub-samples of each 500g were taken from each composite sample and weighed in a mini-laboratory in Jenway weighing apparatus to re-confirm their weights.

Each 500g sub sample was poured into a set of laboratory sieves and was thoroughly shaken. All other material that is not maize was separated by the sets of sieve remaining a clean grain. The clean grain was weighed and poured into TR 400 auto device hectoliter equipment.

It gave a result via its readout mechanism in less than one minute. Test weight is expressed in kg/m^3 or per hectoliter. The amount of fines and dockage sieved out from the 500g sub sample was weighed to determine its percentage of the whole sample of 500g. The clean grains which has been weighed to be 400g was divided in out to two (2) portions and pour into the surface of an illuminator to enhance visibility. The maize kernels were sorted into two groups namely, damaged and undamaged whole grain. Damaged grains were sorted between insect damaged grains and broken grains with the aid of magnifying glass. Undamaged or whole grains were also sorted between the ones in good condition and mould affected grains. Each of these sorted type of grains were weighed in a mini weighing laboratory scale and are expressed as a percentage of the initial total quantity of grains (500g) which was the initial weight before sorting.

$$Percentage\ x\ sorted = \frac{weight\ of\ x\ sorted\ grains}{Total\ initial\ quantity\ of\ grain\ (including\ dockage)} \times 100$$

Where x is either, insect damaged, broken grains, mould infested / discoloured grain or undamaged whole grain.

Grain moisture content was measured using a Dickey John's (2000) moisture meter apparatus and further confirmed using a multi-grain analyzer. A given quantity of the grain was poured into the apparatus and energized. In a moment it displays the grain moisture content via its digital output display.

(iii) Test for viability/Germinability of maize seed

Different type of seed viability test exist which include, cutting the seed open to examine the content especially the germ. Major seed bank in developed countries used X- ray analysis and /or tetrazoluem chloride (TZ) staining, test floating method and visual inspection. Local and traditional way of carrying out seed viability tests is by inspection and planting in a local green house. However for the purpose of the research work the seed viability test system used is cellophane / rag system

A 500g of maize seed are mixed properly and divided into 20 samples. One sample is further divided into two. A piece of napkin or towel is dampened with water and is used to wrap the seeds. The wrapped dampened cloths with the seeds are further enclosed in a plastic wrap well closed and kept in a relatively warm place like the top of refrigeration and not on direct sunlight. Check from 4 -6 days for germination and sprouting. Normally the majority of the germination will occur within 4-5 days. When germination has stopped after the fifth day, and no more new seeds have sprouted, the percentage viability will be determined using simple calculations. However, seed viability decrease over time and especially under poor storage conditions, so expected reduced germination of old seeds compared to fresh seeds is obtainable. Every system of testing viability has its advantages and disadvantages and also depends on the type of seed, its shape and size and other variables (Royal Tasmania Botanical Gardens, 2009).

3.6. Precaution taking in the experimental procedures

i. All samples were collected with sample bags and the bags are tied to close the mouth against spillage and interaction of the grain sample and the immediate environment.

ii. The samples were analyzed as quickly as possible to forestall the effect of several factors that can affect the above named characteristics.

iii. The probes are cleaned properly before use to avoid left over grains inside contaminating the fresh samples.

iv. Precautions were taken while taking measurements in the silo to minimize heat exchange that would naturally occur as a result of opening of the doors.

v. The weighing equipment is regularly tested for accuracy with known weights.

vi. As soon as a sample is taken, it is labeled immediately.

vii. All form of ventilation devices both natural and forced are turned off before any analysis is carried out in the laboratory.

viii. All analyzed samples are kept safe for purpose of reference especially in case doubtful results.

ix. Sampling probes are always used keeping in straight locations while taking samples rather than slanting to be able get to the estimated depth.

x. Enough time has to be given once sampling probes aperture are opened to enable maize to flow in and fill the grove since maize has a poor flow characteristics.

3.7. Limitations

The apertures in sampling probes are designed all through the entire length. The implication is that a sample taking at a particular depth will not be only from the depth but also at other shorter distances within the bulk since the probe is inserted from the top and its aperture is all way down the groove as shown in Figure 2.3

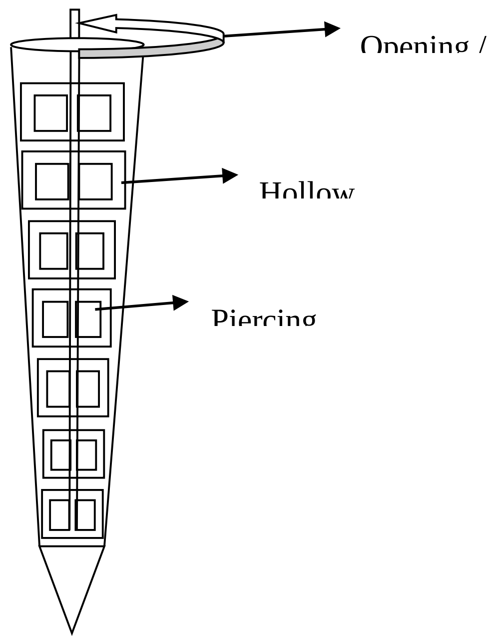


Figure 3.3: Sampling probe

CHAPTER FOUR

4.0. RESULTS AND DISCUSSION

4.1. Results.

TABLE 4.1 Summary of level of significance for Various Nutritional and Physical Characteristics in Respect to Duration of storage and Location of the Grain in the Bulk, the Control and the end values for both sizes of the metallic silos combined.

Parameters	in respect to duration of storage.	Remarks.	in respect to Sample Locations.	Remarks	Control Values	Final values
PHYSICAL CHARACTERISTICS						
• MC =Moisture Content	10.0 ± 0.00%	*	10.0 ± 0.56%	NS	10%	92%
• HC=Hectolitre Weight	72.9 ± 0.44%	*	72.9 ± 0.98%	NS	72.9Kg/h	70.4kg/h
• ID=Insect Damaged Grains	0.29 ±0.00%	*	0.29 ±0.03%	*	0.29%	1.03%
• BG=Broken Grains	0.55 ± 0.05%	NS	0.55 ±0.09%	NS	0.55%	0.7%
• M=Mould Infested Grains	0.00 ± 0.209%	NS	0.00 ± 0.01%	*	0.00%	0.2%
• V= Viability / Germinability	100 ± 0.03%	*	100 ± 0.00%	*	100%	92.3%
• FM = Foreign Matter	0.80 ± 0.20%	NS	0.80 ± 0.60%	NS	0.80%	0.7%
NUTRITIONAL CHARACTERISTIC						
• FC = Fat Content	7.25 ±0.00%	*	7.25 ± 1.0%	NS	7.25%	1.3%
• C.P= Crude Protein	8.79 ± 0.00%	*	8.79 ± 0.87%	NS	8.79%	6.3%
• A.C=Ash Content	3.5 ± 0.00%	*	3.5 ± 0.88%	NS	3.5%	2.3%
• CHO=Carbohydrate Content	63.36 ± 0 .00%	*	63.36 ± 0.98%	NS	63.36%	83.2%
• Energy = Energy Value	361.5 ± 0.00%	*	361.5 ± 1.0%	NS	361.55%	395cal
• C.F= Crude Fibre	6.25 ±0.00%	*	6.25 ± 0.96%	NS	6.25%	3.1%

*** = Significant difference ($P \leq 0.05$) NC= Not comparable NS= Not significantly different ($P \geq 0.05$), N/A=Not Available**

Average Climatic Condition

Table 4.2 Average monthly temperature and relative humidity data within the period of the experiment from January to August 2013.

MONTH	JANUARY	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUGUST

R.H	55	53	52	52	71	68	69.8	69
TEMP T(^{O}C)	34.5	34.2	34.2	34.7	32	30	29.0	30.0

. The summary of level of significance for various Nutritional and Physical characteristics of maize stored in metallic silos, in respect to duration of storage, the location of the grain in the bulk, the control and final values and average climatic conditions are presented in Table 4.1 and 4.2 respectively. The data for Nutritional and Physical characteristics of maize (*Zee mays*) stored, in two different sizes of metallic silos domicile in different environmental conditions, and systems of storage, in respect different location of the grains in the bulk and duration of storage are presented in Appendix B

The result of the average mean deviation of the variables from the control values at the inception of the experiment, for both Nutritional and Physical properties during the eight months of storage are also presented in Tables 4.3 and 4.4, respectively. The general linear model, multivariate test and graphs used for these illustrations were derived from the analysis of data using S.P.S.S, 20.0 Multiple Analysis of Variance (MANOVA).

Graphical representation of variables for Nutritional and Physical/ proximate characteristic for both sizes of metallic silos, in relation to duration of storage and the location of grains in bulk are also presented in Appendix D. The daily average maximum and minimum temperature and relative humidity records of the head space, and the ambient temperature recorded for the period of the experiment are presented in Appendix C.

Table: 4.3 The monthly mean deviation of Nutritional proximate from the control in January to August 2013

Month	MC	FC	CP	AC	CHO	CF	EV
January	10.85	7.25	8.79	3.5	63.36	6.25	361.55

⇩

Month	MC	FC	CP	AC	CHO	CF	EV
February	-0.81	-0.66	-0.92	-0.51	+2.5	-1.22	+4.43
March	-1.98	-2.37	-2.1	-0.8	+8.31	-1.84	+12.6
April	-1.78	-3.61	-2.27	-1.56	+14.94	-2.36	+25
May	-1.23	-3.37	-2.22	-1.28	+14.56	-3.25	+22.39
June	-1.72	-4.07	-2.25	-1.30	+16.95	-3.08	+27.96
July	-1.76	-5.91	-2.3	-1.33	+19.91	-2.63	+35.11
August	-1.98	-5.95	-2.46	-1.07	+19.93	-3.08	+33.8

(Positive value means that there is increase in value away from the control and vice versa)

Table: 4.4. The monthly mean deviation of Physical properties from control in January to August 2013.

Month	MC	HC	ID	BG	M	FM	V
January	10	72.9	0.29	0.55	0.00	0.80	100.0

⇩

Month	MC	HC	ID	BG	M	FM	V
February	-0.78	-1.8	+0.45	-0.12	+0.06	-0.17	-1.1
March	-0.91	-2.64	+0.50	-0.14	+0.08	-0.13	-1.44
April	-0.66	-1.72	+0.59	-0.13	+0.08	-0.12	-4.22
May	-0.16	-0.6	+0.61	-0.33	+0.01	-0.10	-3.0
June	-0.66	-1.67	+0.63	-0.24	+0.06	-0.10	-5.56
July	-0.3	-1.09	+0.88	-0.21	+0.08	-0.11	-6.56
August	-0.38	-2.17	+0.74	-0.28	+0.29	-0.13	-7.67

NB. (Negative values means that there is decrease in value away from the control and vice versa.)

4.2. Discussion of Result

4.2.1. Temperature and Relative humidity of the storage environment.

Within the period of the experiment from January to August 2013, the recorded temperature and relative humidity fluctuated due to the prevailing climatic conditions, as shown in Appendix C. However, temperature was measured only at the head space and not inside the bulk. At the period of regular rainfalls, the humidity appreciated while the temperature decreased significantly and the reverse during extreme dry conditions. The implication is that during the dry seasons storage will be less problematic to be compared with rainy season. Maximum Average Temperature (T^{o}C) during storage was in April 2013 at 34 T^{o}C while the minimum was in July 2013 at 29 T^{o}C. Maximum Average (RH) during the storage period was at 70 in May 2013 with minimum at 51 in March 2013.

4.2.2. Nutritional characteristics.

The result of the statistical analysis shown in Table 4.1, shows that all the nutritional proximate characteristics are significantly dependent on duration of storage irrespective of the size of the metallic silos and are significant at 0.00%, thus ($p<0.05$) , with varying deviations from the control. Table 4.4, shows at a glance the variations of various nutritional proximate characteristics from the control as follows, Crude Fibre, CF. Crude Protein, CP. Ash Content, AC. Carbohydrate Content, CHO. Energy, EV and Crude Fat Content, FC. The nutritional variables in relative to sample location remained, insignificant since their various level of significance are higher than 0.05 ($p>0.05$) irrespective of the size of the metallic silos. All their values were far above 0.05. The average monthly deviations from the control in January to August are presented in Table 4.3. The size of metallic silos did not have any significant effect on the nutritional characteristic of maize stored in metallic silos.

4.2.2.1. Crude Fat content

The result of the study indicates that the fat content is significant at (7.25±0.00%), in respect to duration of storage, irrespective of the size of the metallic silos. Since ($p<0.05$) it implies that duration of storage has significant effect the fat content. There is a significant and progressive decrease in the average fat content over observed period from the graphical presentation in Figure 4.1 below. The values of the average fat content from January to August, decreased from7.0% to 1.2, % with monthly deviation from the control as follows,-0.66, -2.37, -3.61, -3.37, -4.07, -5.91, -5.95, respectively. In respect to the different locations of grains in the bulk, as shown in Figure 4.2 the average fat content is significant at (7.25±1.00%), irrespective of the size of the metallic silos ($p>0.05$). This implies that location of the grain in the bulk has insignificant effect on the Fat content as shown in Appendix D.

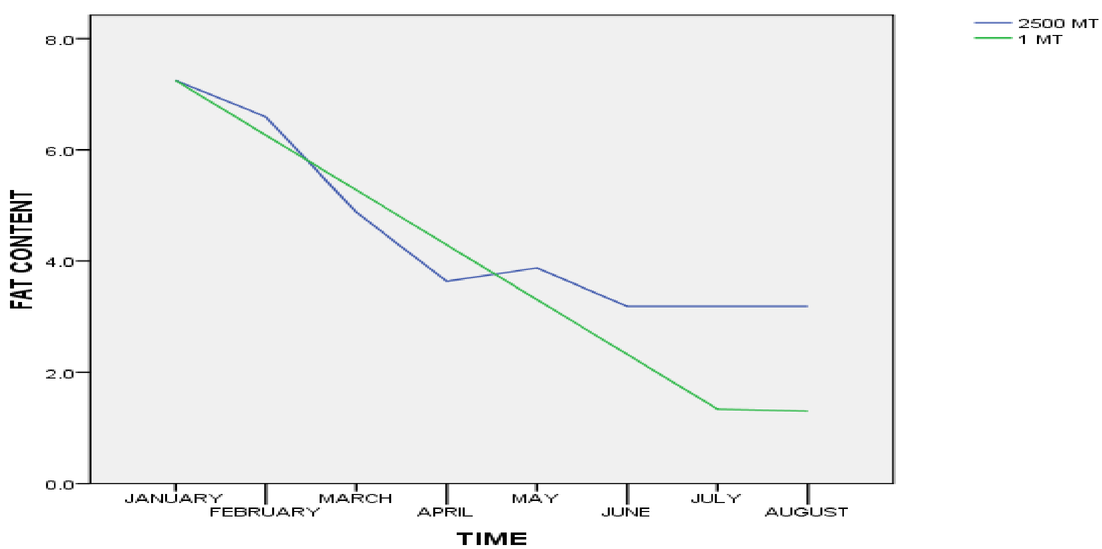


Figure: 4.1.Avarage percentage Fat content in respect to duration of storage for both silos

The irregular downward progression/decrease of Fat content observed with duration of storage, as shown in Fig 4.1, may be due to the storage and drying process which may have affected the Crude fat content degradation during storage or drying process, due to the burning off of other extract of crude fat and fatty acids which occurs in the grains. The direct implication is the reduction in the baking quality due to unsaturated fatty acid release during long storage as reported by (Faure J,1986; Richard, Cahagnier and Multon, 1990). However, in a previous study by (Osipitan,Olaifa and Lawal, 2012), average Fat content in maize grown in Nigerian was estimated to be between 4.77% to 5.0% but the results of this study showed higher values. This may have to do with species and the increase popularity in genetically modified maize, (GM) and improved seeds being distributed to maize farmers from Federal Government of Nigeria under Agricultural Transformation Agenda

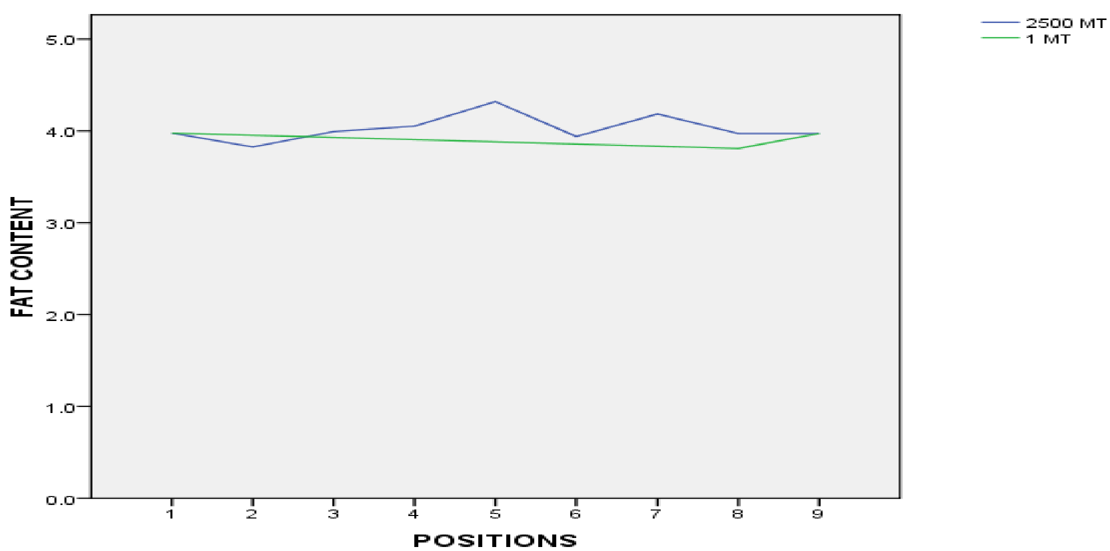


Figure: 4.2.Avarage Fat content in respect to sample locations for both silos

4.2.2.2. Crude protein content:

The result of the statistical analysis of crude protein over observed was significant at (8.79 ±0.00%) significant levels, with duration of storage and (8.79±0.87%) in respect to the location of the grains in the bulk, irrespective of the size of the metallic silos, as shown in Figure 4.1. Since($p<0.05$) ,it implies that sample locations is insignificant as shown in Appendix C, but the duration of storage has a significant effect on the crude protein content of maize stored in metallic silos, with monthly mean deviation as follows.-0.92, -2.1, -2.27, -2.22, -2.25, -2.3, -2.46. .

The average value of the crude protein January (the control) was 8.79% but in August it depreciated to 6.33%. as shown in Appendix C. It shows that there is a downward progression with duration of storage. The depreciation noticed may be attributed to high storage temperature in some months especially during hot dry periods. The location of the metallic silos, for instance if is standing alone or in between other silos, may also be a factor, but the size of the metallic silos did not affect the crude Protein content.

The implication is that at longer storage and exposure to higher temperature gluten which is responsible for development of extensibility and elasticity in dough may be limited, due to the fact that higher temperature, will lead to the degradation of gluten (Osipitan *et al* 2012),. This conforms to the earlier evaluations by (Gupta *et al* 2013).

The depreciation in protein content could also be due to progressive acidification of the grains by organic acid (fermentation) leading to a partial insolubilization of protein. Such a change has already been reported by (Wrigley *et al* 1990), but values were not given. Nevertheless the crude protein depreciation, the fitness of maize for industrial processing remained impressive throughout the storage period. (Osipitan *et al*, 2013). The average percentage CP obtained in this study is in agreement with similar studies by (Osipitan, *et al* and Pelhate and Theriault, 1989) who observed between (7.71 to 14.6%).

However (FAO, 2010) believes that protein content of cereal grain stored under good condition, preventing insect infestation and mould growth is not appreciably altered by seed respiration over long period. The difference in all the studies and results are probably the meaning of good condition because it cannot be quantified. The size of the metallic silos did not have any reasonable impact as the two graphs showed a lot of similarity for both variables.

4.2.2.3. Ash Content:

From the experimental result, it could be asserted that there is a change in the Ash content in the both size of the metallic silos with duration of storage as shown in Appendix C. The analysis shows that it is significant (3.5±0.00%) Since ($p<0.05$), it can be concluded that duration of storage affects the ash content in both size of the metallic silos with mean deviation values from February to August as follows,0.51, 0.8, 1.56, 1.28, 1.30, 1.33, 1.07 as shown in Table 4.3. However the decrease from 3.5% to 2.3% within the eight months of storage implies a progressive decrease which fluctuates in between months as shown in Appendix C. The result of the analysis of the locations of the grains in the bulk as it affects Ash content is significant, at (3.5±0.88%). Since ($p<0.05$) it implies that sample location does not affect the variable. The fluctuations of values of Ash content within the months could be attributed to the effect of high temperature, since the temperature inside the bulk is higher than that of head space. Higher temperatures could denature or reduces thiamine content which is an important vitamin and acts as a co-enzyme in various energy transfer biochemical reaction during metabolism (Gupta *et al* 2013).

However the size of metallic silos and system of storage did not necessarily affect the ash content of the stored maize as the graphs followed a similar pattern of depreciation as shown in Appendix C.

4.2.3.4. Carbohydrate Content:

The result of this study shows that there is a change in carbohydrate content in respect to duration of storage and sample locations. The statistical result showed that they are significant at (63.36±0.00%) and (63.36±0.98%) respectively. This implies that the variable is influenced by sample locations in the bulk and duration of storage as shown in Figures 4.3 and 4.4. The effect of different sizes of metallic silos during eight months of storage on carbohydrate content of the stored maize is negligible as both followed a

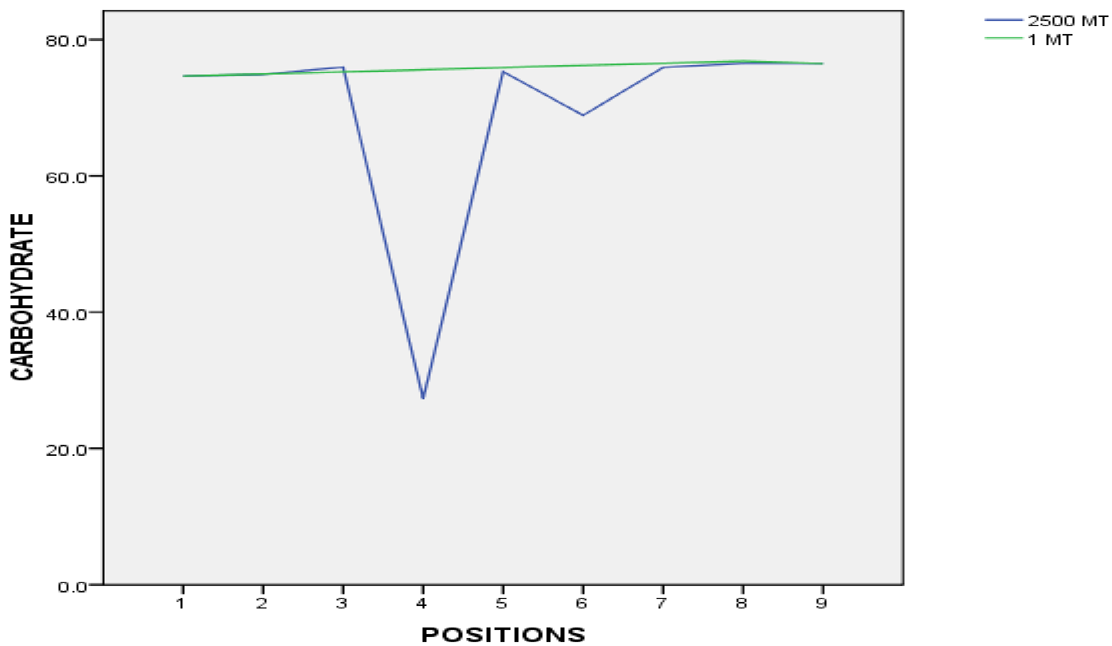


Figure: 4.3. Average Percentage Carbohydrate content in respect to sample locations

similar pattern with a depression in location 4 which may be due to experimental error as shown in Figure 4.3. Its monthly mean deviation from the control values in January, as shown in Table 4.3. as follows +2.5, +8.31, +14.94, +14.56, +16.95, +19.91, +19.93. The result of this experiment shows that there is a little progressive increase in carbohydrate content for the stored grains, over the observed period, in the both sizes of the metallic silos from 63.36% in January to 83.2% in August. The progressive increase noticed in both cases, may be due to soluble sugar compromise. As important component that protects grains membrane/ integrity during dry condition, it naturally tends to increase its total soluble sugar at temperature less the 45^0C during grains storage (Pelhate, and Theriault, 1989).

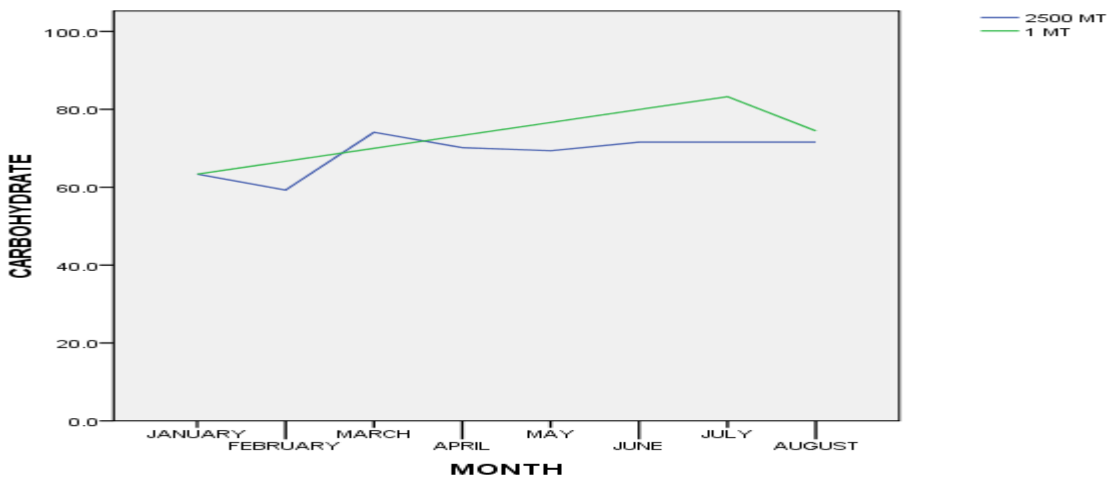


Figure: 4.4. Average carbohydrates content in respect to duration of storage for both silos

This result is in agreement with (Osipitan,*et al*,2012; Wrigley, Grass and Bason,1994; Gupta,*et al* 2013; Ranjana, and Hari,2013) who all supported claims that CHO content increases during storage. The control value of CHO in this study which is (63.3%) agrees with (Durojaiye, 2012) which was (68.8%). The slight differences in value may be due to experimental error, sugar plus carbohydrate content, such as composition of carbon, hydrogen and oxygen and or other varietal component of different species of maize.

The starch value may also be constant but will naturally seem increasing due to the reduction in moisture content. The implication is that stored maize grains may be more fit and suitable for industrial milling purposes than fresh grains.

4.2.2.5. Crude Fibre:

From the result of this experiment, the crude fibre was significant at (6.25±0.00%) in respect to duration of storage, irrespective of the size of the metallic silos. Hence ($p<0.05$). Based on this result, it can be concluded that the crude fibre content is dependent on time and duration of storage. However, the average monthly mean deviation from February to August as shown in Table 4.3. are as follows,- 1.22, -1.84, -2.36, -3.25, -3.08, -2.63, -3.08. There is a progressive decrease in the values from 6.25% to 3.21% from January to August as shown in Appendix C. The sample locations or different location of the grains in bulk has no significant effect on the average crude fibre over observed period, but tends to decrease with longer time of storage for the both sizes of the metallic silos. It is significant at (6.25±0.964%). Since ($p>0.05$) The average crude fibre recorded at the sample locations (1 – 9) also follows the same trend as shown in Appendix C .

However the result of this finding supported an initial claim by (Osipitan *et al* 2012) about decrease crude Fibre content of maize, though lower values were reported in his findings between (2.03% to2.5%), while (Wrigley *et al* 1990) reported slightly higher values (2.07% to2.77%)during storage. This may be due to lipid hydrolysis that occurs during storage, due to respiration, oxidation and process of enzymatic action. The difference and fluctuations in the graph or in the reported values may be due to experimental errors or due to improvement in breeding activities or the species involved.

The findings of (Gupta *et al* 2013; Ranjana and Hari, 2013) upheld that storage duration has no apparent effect on crude Fibre. It may still be in order, since storage conditions and the storage structure also determines the rate of deterioration of these properties. The implication is that maize stored for longer period in a good storage structure and condition still retains its dietary Fibre content, and could still be fit to nourish the body or used industrially.

4.2.2.6. Energy value

The result of this study shows that energy content is significant at (361.55± 0.00%) with duration of storage as shown in Table 4.1. Since ($p<0.05$). It implies that storage duration has significant effect on the energy content of stored maize after 8 months of storage, irrespective of the size of the metallic silos as shown in Figure 4.5. From January to August there was a slight increase from (360kcal to 395kcal) with monthly mean deviation as follows, +4.43, +12.6, +25, +22,39, +27.96, +35.1, +33.8 as shown in Table 4.3. The result of the effect of different locations of the grains in the bulk was also insignificant as shown in Figure 4.6. However, it showed (361.55±1.0%) level of insignificance during analysis.

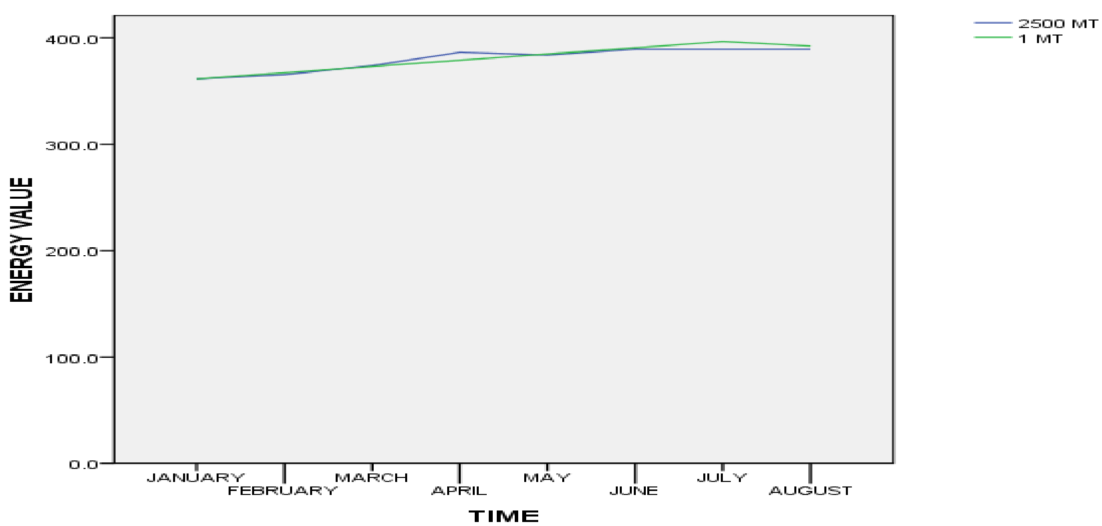


Figure:4.5. Average Energy value in respect to duration of storage for both silos.

Thus ($p>0.05$) which implies that stored maize energy value is not affected by the location of the grain in the bulk. From the illustration in Figure 4.6, it implies that stored maize, may even be better than the newly harvested ones especially if the energy value is the what is desired (Faure,1986). In a similar study by (Richard,*et al* 1990) where stored dry maize and fresh maize were used to feed pullets, the result is in agreement with the result of this study. The stored maize performed as much as the fresh harvest did. However, (Osipitan *et al*,2012) upheld that energy value does not change with storage duration, but it may be factual since the finding of this study is slight increase. The difference may be due to experimental errors or storage structure/condition.

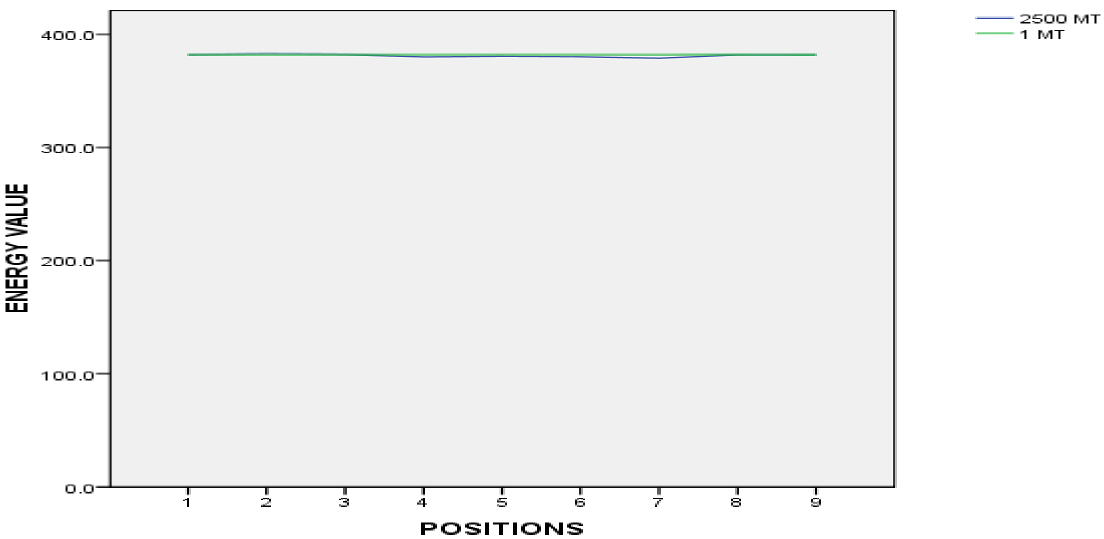


Figure:4.6. Average Energy value in respect to sample locations for both silos.

4.2.3. Physical characteristics.

The result of various physical characteristics presented in Table 4.1 shows that most of the variables are time dependent, irrespective of the size of the metallic silos. Since their level of significance, Wilks' lambda are less than 0.05, ($p<0.05$) then, for all the variables, we can conclude that they are significantly dependent on duration of storage. This includes moisture content, MC, Hectolitre weight, HC, Insect damaged grains, ID, Viability / Germinability, V, and Foreign matter, FM. For variables like Broken grain, BG, and Mould infested grains M, their Wilks' Lambda values (p) are higher than 0.05, ($p>0.05$), and are not significantly affected by storage duration. The result of the physical characteristic in relative to sampling location, irrespective of the size of the metallic silos shows that only three variables (ID, V and BG) were affected by the location of the grains in the bulk. Since Wilks' lambda for the three variables are less than 0.05. However the remaining variables are insignificant in respect of the sample locations and their level of significance are higher than 0.05, and are not affected by the location of the grains in the bulk.

4.2.3.1. Moisture content

The result of this study shows that the average moisture content over the observed period decreases, and it is significant at (10.0± 0.00%), with duration of storage, with average mean deviation from the control on monthly basis as shown in Table, 4.4 as follows-0.78, -0.98, -0.91, -0.66, -0.16, -0.66, -0.30 and -0.38 from February to August, irrespective of the size of the metallic silos. Since Wilks Lambda ($p<0.05$), it shows that moisture content is significantly affected by the duration of storage.

Figure 4.7 shows slight decrease of the moisture content in the two sizes of the metallic silos, especially in the first few months of storage. This may be as a result of initial loss of moisture, until equilibrium moisture content is attained with the environment. The fluctuation noticed in the values especially in the bigger silo may be attributed to the hygroscopic nature of maize as a food material, and or the instability in the climatic conditions of the area, because moisture was gained during high humidity and lost during extreme dry conditions. . The implication is that may be equilibrium moisture content was attained shortly after binning, and frequent aerations helped to even out moisture build up inside the bulk. As earlier reported by (Kenneth and Hellevarg 1995), there is insignificant sorption and adsorption as climate changes during storage of maize, which may weaken the integrity of maize seed in long storage but no values were given. It also implies that, economic returns could be affected, since it can impact positively or negatively on the test weights, inform of shrinkage or moisture absorption. However the 1 MT metallic silo shows more stability with climatic conditions, which may be due to its size, hermetic nature and short storage duration.

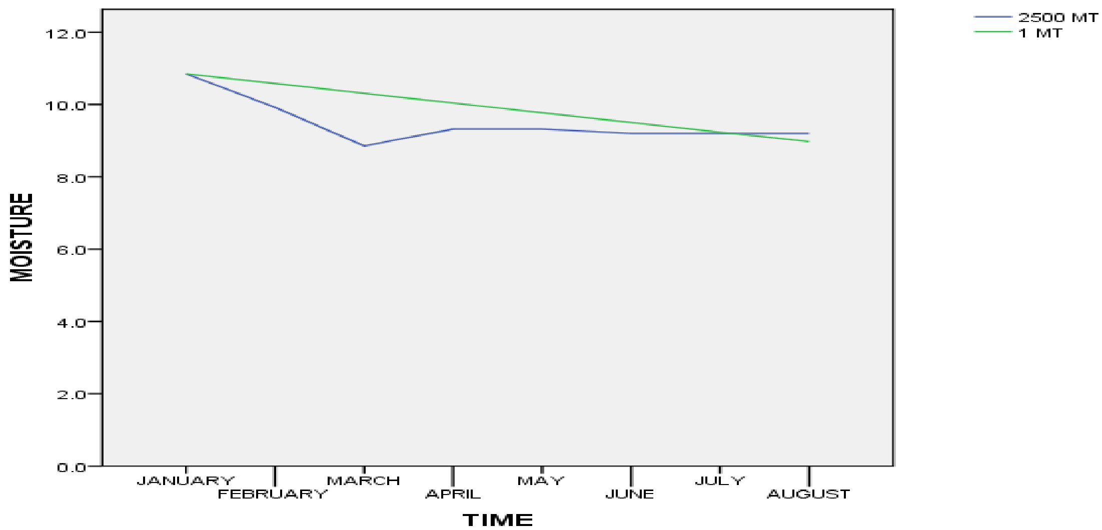


Figure 4.7.**Avarage percentage Moisture content in respect to duration of storage for both silos**

The result of moisture content in respect to different locations of the grains in the bulk as showed in Table 4.4. showed (10.0 ±0.569%) level of significance. Since, ($p>0.05$), it shows that the variable is independent of the sample locations of grains in the metallic silos. Figure 4.7 and 4.8 also shows that size of metallic silos does not have significant effect on moisture content of the stored maize considering the overlapping and similarity in the graphical representation of the two silos.

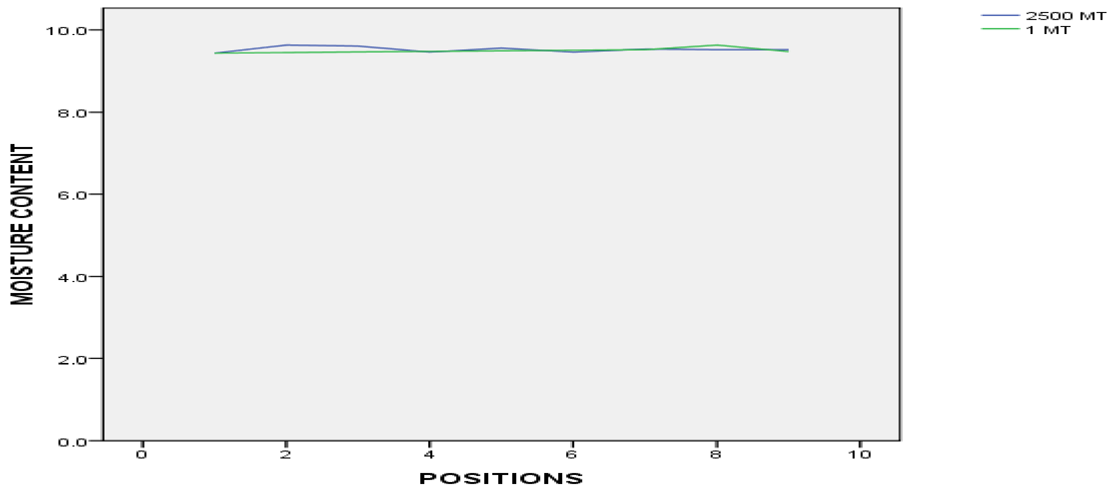


Figure 4.8.**Avarage percentage moisture content in respect to sample location for both silos**

4.2.3.2. Hectolitre weight

From the result of this study, the average test weight in respect to storage duration, was significant at (72.9±0.04%) irrespective of the size of the metallic silos. The result also shows that the average test weight was significant at (72.9±0.098%) in respect to the sample locations in the bulk, irrespective of the size of the metallic silos, with monthly deviation from the control as shown in Table 4.4. The values from February to August are as follows, -1.8, -2.64, -1.72, -0.60, -1.67, -1.09, -2.70. Since Wilks Lambda ($p<0.05$) in respect to storage duration of the grains, and ($p>0.05$) in respect of location of the grains in the bulk, it can be concluded that the HC is significantly affected by duration of storage, while it is insignificant and not affected by the locations of the grain in the bulk as shown in Appendix C. The behavior of hectolitre weight is synonymous with moisture content, supporting earlier claims by (Brooker et al, 1990; McNeil, 2010) that a change in moisture content of a grain will affect the test weight.

After the initial decrease in values of the hectolitre weight, it remains almost constant with minute fluctuations, which may be attributed to the water activity of the grains. In a similar research by

(Chukwu and Ajisegiri, 2005), it was demonstrated that sorption cycle affects some Nutritional and Physical characteristics of agricultural grains including the test weight but values were not given. The direct implication is that if grains are evacuated during high humidity period, there is the likelihood of gaining weight. There were no significant changes of hectoliter weight in respect of location of the grains in the bulk during for both silos, throughout the period of the experiment. It can also be concluded that no matter the location of grain in the bulk, if the integrity of the storage structure is good the grain will have almost the same test weight. The size of metallic silos did not affect the test weight of the grains as the graphical representation shows in Appendix C.

4.2.3.3. Insect damaged/broken grains

The result of the analysis showed (0.29± 0.00) and (0.29±0.03%) significant levels in the percentage Insect damaged grains in respect to duration of storage and location of the grains in the bulk, irrespective of the size of the metallic silos as shown in Table 4.2. The monthly mean deviations from the control are shown in Table 4.4 are as follows, +0.45,+0.50+-0.59,-+0.61,+0.63,+0.88+0.74. Since Wilks Lambda ($p < 0.05$) in respect of storage duration and locations of the grain in the bulk, it can be concluded that both variables are significantly affected by the storage duration, especially in the bigger silos. The result of the analysis also shows that percentage broken grains is at (0.55±0.058) significant level, in respect to duration of storage with monthly mean deviations as follows,-0.12, - 0.14,- 0.13, -0.33, 0.24, 0.21, 0.28. from February to August. The implication is that the variable is not significantly affected by duration of storage, since Wilks Lambda (p.=0.058) and(0.058>0.05)

In respect of location of grains in the bulk, there were (0.29±0.00%) significant levels observed in the analysis. Since ($p < 0.05$) it implies that percentage broken grains are significantly affected by the locations of grains in the bulk. From graphical representation in Appendix C, it is observed, there is increase in insect damaged grains at locations 1, 2, 3 at the head space especially for the big metallic silos where insect and human activity is high in relative to other locations.

As suggested by (FAO, 1995) percentage broken grains is mainly a factor of the prevalent handling and processing system which the grain had undergone before storage. Locations 4, 5, 6, recorded a low percentage of the both factor due to their locations in the grain bulk. Similar trend was observed with previous evaluation but no values were given (Opit 2010). Insect activity at the head space are probably due to high presence of oxygen which the insect needed for survival and easy asses of insects through metallic silo vents for the bigger silo. In the smaller silo, the principle of hermetic applies as it is sealed after loading and has no aeration facilities. The existing insect in the grain bulk dies after the exhaustion of the oxygen in the bulk. The implication is that the integrity of the grains at location 1, 2, 3, in the bigger silos is more in doubt and will not perform well if used as seeds, when compared to other locations in the both silos. From the result of this study, as shown in Appendix C, the size of metallic silos has a significant effect in the control of insect damaged grains but has no effect on the percentage broken grains

4.2.3.4. Mould infested grains:

The values of mould infested grains obtained from the analysis shows that mould activity in both silos are significant at (0.00±0.659%) with duration of storage, with average monthly mean deviation from February to August, as follows,+0.06, +0.08, +0.08, +0.01, +0.06, +0.08, +0.29.as shown in Table 4.4. Since ($p>0.05$) as shown above, it implies that duration of storage has no significant effect on percentage mould infested grains. As shown in Appendix C, the values obtained for the eight months of storage are negligible, Infact they are totally inexistence from January to April in the bigger silo.

In respect of the sample locations in the bulk, it was significant at (0.00±0.015%), which implies that sample location in the bulk may influence mould growth as shown in Appendix C especially in location 7, which is the base of 2,500MT silos and locations 8, 9 in the small silos which showed a sign or the likelihood of mould growth. It is observed that in locations 1 – 6 in the big silos, it is totally inexistence unlike locations (8 and 9) in the smaller silo as shown in the graphical representation in Appendix C. This could be attributed to build up of moisture due to non aeration of the smaller silos, or that the integrity of the storage silos does not support longer storage due to the absence of ventilation and aeration facilities for proper thermo stability of the structure. This is in line with the submission of FAO 1995 that very low capacity of metallic silos are not too good for longer storage due to the lack of aeration facilities. And that any metallic silos without aeration facilities should be for make shift storage activities.

4.2.3.5. Foreign matter or Cores and Fines

The result of this experiment shows that percentage cores and fines are not affected by storage duration, irrespective of the size of the metallic silos. However, it was insignificant at (0.80±0.209%) with mean deviations from February to August as shown in Table 4.4 as follows, 0.17, 0.13, 0.12, 0.10, 0.10, 0.11, and 0.13. since ($p>0.05$), it implies that storage duration has no effect on percentage cores and fines during eight months storage of maize in metallic silos. It is important to note that it may be significant with longer storage duration and or with poor grain management.

The effect of sample locations to cores and fines was insignificant at (0.80±0.060%), as shown in Table 4.1. This implies that the percentage cores and fines is not affected by different sample location, since ($p>0.05$). However it is expected that there will be an increase at the bigger silos especially in locations 1, 2, 3, as shown in Appendix C, due to insect activity and the application of grain protectant by the grain workers as earlier reported by (Opit, 2010; Faure, 1986). Percentage cores and fines in respect to duration of storage and sample locations may be negligible because of short period of storage, but may become prominent in longer storage.

The percentage of cores and fines in location 4, 5, 6 seemed constant as shown in Appendix C.. This may be due to low insect and human activity in these areas. Locations 7, 8, 9 also seemed constant because of low insect and human activity to further support reports of assertion by (Brooker, *et al* 1990; Ileleji, 2010). However most of the studies are empirical and has no values. The size of metallic silos may not have effect on the cores and fines for eight months of storage as shown in Appendix C, but may have an effect in longer storage duration,

4.2.3.6. Viability and germinability.

The viability/ germmability of the grains analysed in respect of the size of the metallic silos and locations of the grains in the bulk are significant at(100± 0.03%) and(100± 0.00%) respectively, with mean deviation from the control from February to August as follows, -1.1, --1.44, -4.22, -3.0, -5.56, -6.56, -7.67,as shown in Table 4.4. The implication is that, in the both cases viability and germinability are significantly affected, since Wilks Lambda ($p<0.05$). From Figure 4.9 and 4.10 below, there is a progressive decrease in germinability especially during longer storage, but increases from sample locations (1-9) in the both silos.

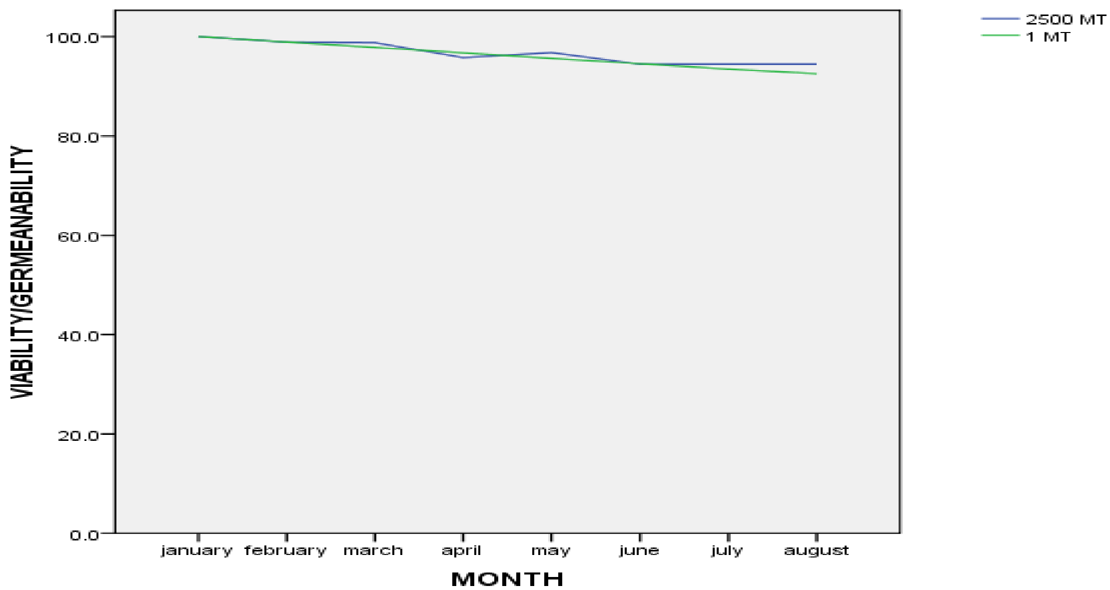


Figure: 4.9. Average percentage Germinability in respect to duration of storage in both silos

While locations 4, 5, 6,7,8,9 remained almost the same within the eight months of storage location 1, 2, 3 showed a slight decrease in viability / germinability as shown in Figure 4.4.

However, this can be attributed to insect and human activity, grain respiration, sorption cycle which may cause alteration of chemical composition of stored grains, as well as chemical residue in the head space especially for the bigger metallic silos. The implication of this finding is that smaller hermetic silos appear a better storage structures in terms of seed storage.

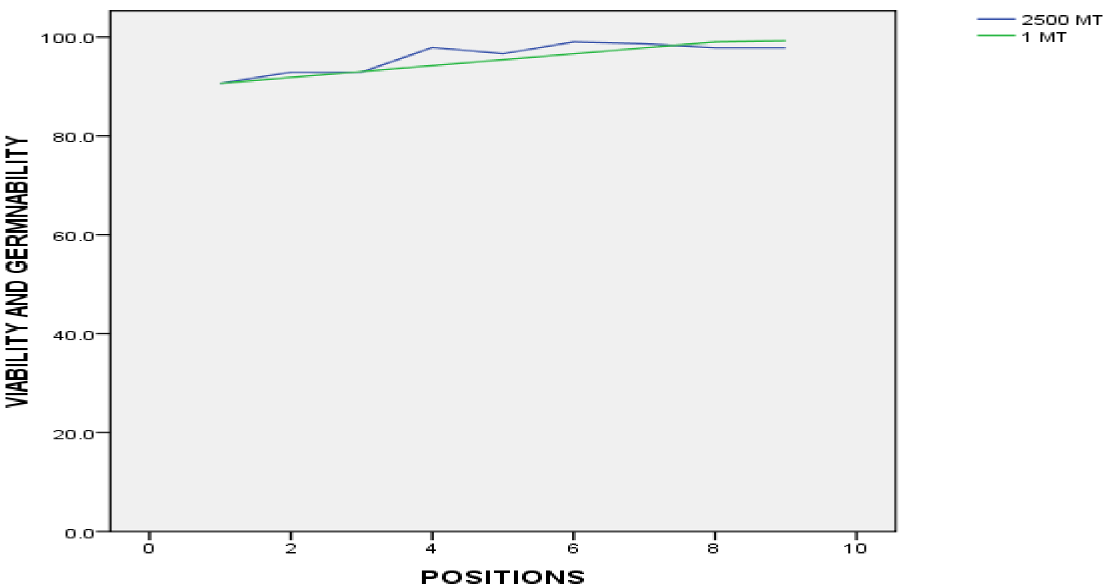


Figure: 4.10. Average percentage Germinability in respect to sample locations

The integrity of the grains below the surface in bigger metallic silos is also not in doubt as they could also be used for seeds in an emergency situation. In a similar research carried out by (Chukwu and Ajisegiri, 2005) on the effect of sorption cycle on some physical properties of agricultural grains, maize showed a reduced germination, which is in line with the findings of this research work, but no values were given. Thus the size of metallic silos has significant effect on the germinability of stored maize in metallic silos.

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The basic information about the Nutritional and Physical characteristics of maize stored in metallic silos, especially in relation to size of metallic silos, location of the grain in the bulk and duration of storage will be invaluable information to processing and storage as a discipline and as a business, due to the huge potential of maize as a grain crop and for the fact that it is stored in commercial quantity all over the world in metallic silos.

The result of this study shows that all the Nutritional/ Proximate characteristics assessed, are significantly dependent on duration of storage irrespective of the size of the metallic silos, but with varying deviations from the control. The location of the grain in bulk, or sample locations, did not affect the Nutritional/Proximate characteristics within the eight months of storage.

After eight months of storage, some of the Physical characteristics were found to be time dependent, irrespective of the size of the metallic silos. They include Moisture content, MC, Hectolitre weight, HC, insect damaged grains, ID, Viability / Germinability, V. However, Broken grain, BG, Foreign matter, FM, and Mould infested grains M, are not significantly affected by storage duration. The location of the grains in the bulk affected some of the Physical characteristic like Insect damaged grains, ID, Broken grains BG, and Germinability V, especially in sample location 1, 2, 3, at the surface of the big silos where insect activity is high. However, the storage duration, size of metallic silos and the location of the grain in the bulk, all have significant effect on Germinability/viability.

5.2 Recommendations

(1) It is recommended that the intended use of grain should be considered while deciding the storage duration of maize or other grains as this research work has shown that Nutritional and Physical characteristics are mostly time dependent.

(2) More laboratories should be established and equipped with modern equipment in the Universities and Research institutes by the Federal Government, to alleviate the sufferings of researchers in this area, and for better result and output.

(3) More extensive work is still recommended in the area of depreciation of Nutritional and Physical characteristics of maize and other grain crops stored in metallic silos, especially with a longer period of storage and the information communicated to farmers through Government Agricultural extension workers for effective management and to enhance the economics of stored grain.

(4) It is also recommended that more research work should be carried out with different sizes of silos that are not in battery different species of maize, and sampling periods reduced to two weeks interval to improve on the result of this research work.

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APPENDICES

APPENDIX A

Destructive Method of the Determination of Proximate Composition Moisture Content Determination

Percent moisture content determination in the samples analyzed, two methods were used as listed below:

Procedure 1: for percent moisture content determination in each sample, non-destructive method i.e. Auto moisture Analyzer, model: ML-50 was used as follows:

1. The moisture analyzer equipment was switched on for about 10 minutes.
2. The drying temperature was set to 130^0C
3. The tarred weighing pan was placed on the analyzer, 1.0000 gramme of well grind samples was added onto the pan
4. The startup button on the equipment was pressed.
5. The equipment automatically measures the moisture content of the sample and displays it result on the screen in percentage.

In the second method used, AOAC (2006) guideline on food analysis scheme for the determination of proximate composition of cereal grains was followed:

Procedure 2

Moisture content of sample was carried out using destructive method in accordance with the standard approved method (AOAC,2006).

1. The empty petri dishes were dried in the oven at 105 ± 5^0C for 30 minutes to get rid of moisture present in the dishes.
2. The Petri dishes used was transferred into desiccators and was allowed to cool at room temperature for about 20 minutes.
3. The weight of the empty dishes were taken and recorded as (W_0).
4. The sample of maize, sorghum and wheat were grind, one after the other using cyclotec multipurpose sample mill.
5. Using an analytical balance, the weight of 1.0000g of sample was weighed into the petri dish and recorded as (W_1) and then the sample was dried in the oven at 105 ± 5^0C for two hours.
6. The petri dishes containing each samples was allowed to be cold for about 10 minutes the oven.
7. Using crucible tongue, the petri dishes containing each sample was transferred into the desiccators and was allowed to be cooled at room temperature for about 30 minutes.

The final weight of the petri dishes and content was taken and recorded as (W2)

Calculations

$$\%\ Moisture\ Content = \frac{(W_0+W_1)-(W_0-W_2)}{W_1} X100$$

Where:

W_o =weight of empty dishes (g)

W_1= Initial weight of samples + weight of petri dishes (g)

W_2= final weight of samples + weight of petri dishes (g)

Procedure for the Determination of Crude Protein (CP)

Crude protein (CP) was estimated using standard Kjeldehl block digestion and steam distillation operation procedure (AOAC, 2006) as follows:

Preparation of Receive Solution

1. 0.1 gramme of methyl red ($C_{15}H_{15}N_3O_2$) indicator was dissolved in 100ml 95% methanol.
2. 0.1 gramme of bromocresol green indicator ($C_{12}H_{14}Br_4O_5S$) was also dissolved in 100ml methanol (ethanol could also be applicable)
3. Solution of 4% boric acid (H_3BO_3S) was also prepared by dissolving 400 grammes of the powder in about 5 – 6L of the solution , this is very hot. The solution was allowed to cool to room temperature and 100ml of bromocresol green and 70ml of methyl red solution was added. 10L of the solution was diluted with deionized water and mix carefully.

Procedure

1. 1 gramme of well prepared sample was weighed to an accuracy of 0.1mg into a 250 ml digestion tube.
2. 2 Kjeltabs Cu of 3.5g was added into the digestion tube.
3. 12ml of concentrated H_2SO_4 was carefully added and gently shake to dissolve the sample with the acid.
4. The exhaust system was attached to digestion tube in the rack and the water aspirator was set to full effect.
5. The samples were digested for 1hr at 420^0C.
6. The tubes was removed from the rack and placed in a stand and then allowed to cool for about 10 – 20 minutes.
7. The tube was inserted into the distillation unit and the safety door been automatic closes immediately.
8. 80ml of deionized water was carefully added into the tubes.
9. 25-30ml receiver solution was added into the conical flask and placed into the distillation unit while the platform of the distillation outlet is submerged in the receiver solution.
10. 50ml of 40% of NaOH was dispensed into the tube (Note: step 8 – 9 and 10 will be done automatically).
11. The solution was allowed to distill for about 4 minutes.
12. The distillate was titrated with standardized HCL (usually 0.1 0r 0.2N) until the blue grey end point is achieved.
13. The volume of acid consumed in the titration was recorded.

Note: blank valve was run through every batch of the sample.

Calculation

$$\% \, Protein = \frac{(T-B) X \, N \, X \, 14.007 \, X \, 100}{W_1} X \, F$$

Where:

$$(g \, {}^{N}/_{L}) = \frac{(T-B) X \, N \, X \, 14.007}{Volume_{Sample}}$$

Where:

W_1=Sample weight
T= Titration volume of sample (ml)
B=Titration volume of blank (ml)
N= Normality of acid to 4 decimal places
F= Conversion factor for nitrogen to protein = 6.25 for food and feeds
(g $^{N}/_{L}$*)* = grammes nitrogen per litre

Procedure for Determination of % Crude Fat

Crude fat was determined by Soxtec extraction (ether extract/fat analysis) standard method (AOAC, 2006) as follows:

1. Thimbles fitted with the adapters was placed on a balance and tarred.
2. 1.000gramme of well prepared sample was weighed into the thimble and tarred; this was moved to the thimble stand using the thimble handler.
3. The Soxtec extraction unit was switched on by pressing "MAIN" button (The switch lamp was ensured to be shown/ seen to indicate the light up).
4. The temperature was set according to the solvent used to achieve a reflux of solvent which is 3 – drops/second.
5. The proper programme was selected with respect to the time to check (boiling / rinsing / evaporation) pre – drying on the control unit.
6. The cold water tap for the reflux condensers was opened, with cooling water at approximately 15^{0}C, the flow was adjusted to 2 litres/ minutes to prevent solvent evaporation from the condensers.
7. A thin layer of defatted cotton was placed on the top of the sample.
8. The thimble handler was used to move the thimbles as it was inserted into the extraction unit and this was attached to the magnets.
9. The cup holder was used to insert the aluminum extraction cups loaded with 40- 60^{0}C petroleum ether. Sample was also loaded with petroleum ether dried at 103 ± 2^{0}C.
10. The RUN / STOP key were pressed on the Soxtec extraction equipment. The Soxtec auto fat extraction system now starts performing automatically.
11. The cups was removed and dried at 103 ± 2^{0}C for 30 minutes to obtain constant weight.
12. The cups were weighed.

The extractable crude fat was calculated as:

$$\% \ Fat = \frac{W_3 - W_2}{W_1} \ X \ 100$$

Where:
W_1= Weight of sample (g)
W_2= Weight of empty extraction cups (g)
W_3= Weight of extraction cup + residue weight (g)

Procedure the Determination of % Crude Fibre

The standard adopted for the operation of Fibertec Hot/ Hydrolysis unit equipment and Fibretec cold extraction unit (model: 1020 and 1021 respectively) as prescribed by AOAC, 2006 were followed as given below:

Crude Fibre (CF) determination was by digestion of the defatted sample followed by drying of the residue obtained from washing with boiling distilled water in an oven to constant weight. Nitrogen free extract (NFE) was determined by difference as:

%NFE= 100 – (%MC - %CP + %Ash + %CF + %CF)

Total carbohydrate was obtained by summation of crude fibre (CF) which represents the insoluble carbohydrate and the nitrogen free extract (NFE) which is the soluble carbohydrate as in %CF + %NFE.

Fibertec Hot Extraction Operation Procedure for Crude Fibre (CF) Determination

1. The fritted crucibles were pre-dried at 103 ± 2^0C for 30 minutes.
2. The pre-dried crucibles were placed on a balance and tarred, were 1.000g of celite was weighed to simplify filtration and 1.000g of well – prepared samples was weighed into the crucibles containing the celite.
3. Fibertec hot extraction unit was switched on while 1.25% of H_2SO_4 solution was prepared and heated on the hot plate.
4. The crucibles was inserted in the extraction unit using crucible holder and then lock into the location in front of the radiator of the fibertec hot extraction unit ensuring that the safety latch was engaged.
5. The reflector was placed in front of the crucible.
6. All valves were allowed to be in closed location.
7. Cold water tap opened (1 -2 litre/ minutes) for reflux system.
8. Reagent (150ml of pre-heated 1.25% H_2SO_4) was added into each column on the fibertec equipment (Reagent 1).
9. 2 – 4 drops of n-octanol was added to prevent foaming and then the HEATER was switched on; while the heater control was adjusted to moderate boiling limit as the reagents started boiling.
10. The boiling point period was measured from the time when the solution has reached the boiling point as the regulation gives 30 minutes.
11. The heater automatically switched off immediately the 30 minutes elapse time for the extraction has reached.
12. The valves was placed in “VACUUM” location and the cold water tap was open to full flow rate for water suction pump while filtration commences immediately (automatically).
13. Reversed pressure system was used to wash the sample as the washing was conducted three times with hot deionizer water. 30ml portion of water was used for the process.
14. 150ml of pre-heated 1.25% NaOH solution was added into each column (Reagent 2).
15. Step 9 – 13 mentioned above was repeated for the operation.
16. The crucibles were released with safety hook.

17. Using the crucible holder, the crucibles were transferred to the fibertec cold extraction unit.

Fibertec Cold Extraction Operation Procedure

18. The crucibles were locationed in the fibretec cold extraction unit and valves were closed.
19. 25ml of acetone was added to each crucible. The solvent were extracted and filtered out by placing the valve in "VACUUM" location, while the process is repeated thrice.
20. Crucibles were removed and transferred to the crucible stand, at this location, the crucible and sample remains at room temperature until acetone has been evaporated. Otherwise there is a risk of burning the fibre during the drying process.
21. The crucibles were allowed to be dried for about 2 hours at 130 ± 2^0C.
22. The crucibles were cooled at room temperature in a desiccators and 0.1mg of sample was accurately weighed and recorded.
23. The samples were ash in the crucibles for about 3 hours at 525 ± 15^0C while the crucible were heated and allowed to be cooled with caution.
24. Crucibles were allowed to be cooled slowly to room temperature in the desiccators and 0.1mg of sample was accurately weighted.

$$\% \; Crude \; Fibre = \frac{W_2 - (W_3 + C)}{W_1} X \; 100$$

Where:

W_1=sample weight (g)

W_2= crucible + residue weight after drying (g)

W_3=crucible + residue weight after ashing (g)

C = blank

Where blank is given by C= $W_2 - W_3$

Determination of %Ash in Samples

Ash content (%) determination was carried out according to standard procedure provided for the operation of carbolite sophisticated machine (model:- PF800) by AOAC (2006) using the following procedure:

PROCEDURE:

1. Empty crucibles were dried in the oven at 130 ± 15^0C for 30 minutes to get rid of moisture present in the crucibles.
2. The crucibles were transferred into desiccators and allow cool at room temperature for about 20 minutes.
3. The weight of each empty crucible were weighted and recorded as W_0.
4. The sample which was grind into powder using cyclotec sample mill were weighed.
5. Using analytical balance, 1.0000g of samples were weighed into the crucibles and recorded as W_1 after which the sample were ashed in the furnace at 500 ± 15^0C for 5 – 6 hours.
6. The crucibles containing the samples were allowed to cool for about 30minutes in the furnace.

7. Using the crucibles tongue, the crucibles containing the samples were transferred into the desiccators and allow to be cooled at room temperature for about 45 minutes.

8. The final weight of crucible and its contents are taken and recorded as W_2.

The % ash content was calculated as:

% Ash Content = $\frac{W_2 - W_0}{W_1}$ X 100

Where:

W_0=Weight of empty crucibles (g)

W_1= Initial weight of crucibles + samples (g) before ash

W_2= final weight of crucible + sample (g) after ash

APPENDIX B
NUTRITIONAL/ PROXIMATE AND PHYSICAL ANALYSIS DATA FOR MAIZE STORED IN METALLIC SILOS.

NUTRITIONAL/ PROXIMATE DATA

MC= Moisture Content FC = Fat Content C.P= Crude Protein
A.C=Ash Content CHO=Carbohydrate Content Energy = Energy Value
C.F= Crude Fibre

Control (January)

Location	M.C%	F.C%	C.P%	A.C%	C.HO%	C.F	Energy
1	11.24	7.0	9.12	3.5	62.64	6.5	360.64

February
2,500 MT

Locations	M.C%	F.C%	C.P%	A.C%	C.HO%	C.F	Energy
1	10.20	6.40	7.44	3.00	62.80	4.80	365.00
2	10.00	6.20	8.20	2.80	62.50	4.80	362.40
3	9.80	6.80	8.00	2.90	68.08	4.90	363.20
4	10.10	7.00	7.90	3.30	68.10	5.00	371.20
5	10.00	6.70	7.80	3.20	64.00	5.60	370.00
6	9.90	6.90	8.10	2.70	68.00	5.20	368.00
7	10.20	7.00	7.80	2.60	63.50	5.00	360.00

1MT

8	10.12	6.20	8.00	3.00	69.60	4.90	369.00
9	10.00	6.14	7.60	3.40	68.00	5.10	361.20

March
2,500 MT

Locations	M.C%	F.C%	C.P%	A.C%	C.HO%	C.F	Energy

1	8.9	5.02	6.94	3.00	72.42	4.50	372.22
2	9.0	4.64	7.00	2.50	74.92	4.00	381.24
3	8.7	5.40	6.78	2.50	72.80	4.50	373.82
4	9.0	4.80	7.44	3.00	71.10	4.20	370.56
5	9.0	5.12	7.20	2.50	74.42	4.50	372.34
6	8.6	4.86	5.96	2.50	75.04	4.50	373.24
7	8.9	5.16	6.04	3.00	74.76	4.50	374.04

1MT

8	8.7	4.80	6.05	2.80	75.60	4.50	373.20
9	8.9	4.12	6.80	2.50	76.00	4.48	376.00

April
2,500MT

Locations	M.C%	F.C%	C.P%	A.C%	C.HO%	C.F	Energy
1	9.4	3.94	7.15	2.0	77.09	3.5	388.47
2	9.0	3.66	6.76	1.5	79.00	4.0	389.08
3	9.2	3.63	6.84	1.5	78.81	3.5	391.32
4	9.0	3.82	6.04	2.0	77.78	4.5	380.76
5	8.9	3.92	6.66	2.5	76.80	4.0	383.82
6	9.1	3.04	5.96	2.0	79.74	3.5	384.76
7	8.9	4.20	7.08	1.5	78.24	3.5	393.48

1MT

8	8.6	3.06	6.34	2.0	78.60	4.0	386.18
9	9.5	3.46	5.86	2.5	78.66	3.5	381.22

May
2,500MT

Locations	M.C%	F.C%	C.P%	A.C%	C.HO%	C.F	Energy
1	10.0	4.50	7.40	2.0	76.10	3.5	392.60
2	9.9	3.80	7.20	2.5	76.00	3.5	384.00
3	8.6	3.50	6.40	2.0	78.10	3.5	384.00
4	8.8	4.00	5.80	2.5	79.40	2.5	373.80
5	8.5	4.50	6.80	2.5	77.20	2.5	388.00
6	9.7	3.60	7.00	2.5	78.30	3.0	390.60
7	9.0	3.20	6.50	2.0	78.80	2.5	373.70

1MT

8	8.6	4.00	6.20	1.5	78.50	2.5	385.80
9	8.5	3.80	5.80	2.5	78.90	3.5	383.00

JUNE
2,500MT

Locations	M.C%	F.C%	C.P%	A.C%	C.HO%	C.F	Energy
1	9.2	2.90	6.940	2.0	796.20	3.0	391.20
2	9.4	3.10	6.80	2.5	78.50	3.1	386.42
3	8.6	3.40	6.50	2.10	80.70	3.5	389.90
4	8.7	2.89	5.80	1.5	79.70	2.50	390.60
5	8.9	2.96	7.20	2.5	80.56	3.5	391.40
6	9.2	3.40	7.18	2.20	79.40	3.20	384.90
7	9.1	3.20	6.34	2.5	81.20	3.20	389.40

1MT

8	9.6	3.00	6.24	1.5	82.46	3.0	391.50
9	9.5	3.80	5.90	3.0	80.70	3.5	390.30

JULY
2,500MT

Locations	M.C%	F.C%	C.P%	A.C%	C.HO%	C.F	Energy
1	8.6	0.95	6.62	2.0	83.23	3.0	396.30
2	8.9	1.00	7.64	2.5	83.76	3.5	402.40
3	9.6	0.98	6.40	3.0	83.50	4.0	395.52
4	10.3	1.05	5.96	2.5	83.39	3.5	391.40
5	9.8	1.50	6.24	2.0	81.56	4.5	388.40
6	8.8	0.96	6.12	1.5	84.52	3.10	397.00
7	8.2	2.50	5.88	1.5	83.52	4.0	397.00

1MT

8	8.5	1.08	7.04	2.5	83.48	3.5	401.60
9	9.2	2.0	6.94	2.0	82.46	3.5	400.30

AUGUST
2,500MT

Positons	M.C%	F.C%	C.P%	A.C%	C.HO%	C.F	Energy
1	8.0	0.85	6.00	2.0	83.00	4.0	389.40
2	8.6	0.95	6.24	2.2	81.20	3.5	398.60
3	9.0	0.98	7.02	3.0	83.40	2.5	400.10
4	9.8	1.60	7.00	3.1	82.90	3.0	401.20
5	8.1	2.60	5.60	1.5	84.60	3.5	390.60
6	9.1	1.50	6.12	2.5	84.00	2.5	382.11
7	9.8	0.96	6.80	2.5	83.60	2.0	406.24

1MT

8	9.1	1.08	6.40	2.0	83.10	3.0	388.10
9	8.3	1.20	5.80	2.1	83.80	4.5	402.40

DATA FOR PHYSICAL PROPERTIES OF MAIZE STORED IN METTALLIC SILOS

R.H =RELATIVE HUMIDITY, MC =MOISTURE CONTENT
HC=HECTOLITRE WEIGHT OR TEST WEIGHT
ID=INSECT DAMAGED GRAINS, BG=BROKEN GRAINS
M=MOULD INFESTED GRAINS, V=VIABILITY / GERMMABILITY
T=TEMPERATURE (^{0}C) AMBIENT

Januay – Control

M.C%	H.CKg/h	I.D%	B.G%	M%	F.M%	V%
10.0	72.90	0.29	0.55	0.00	0.80	100.0

Feburary
2,500MT

Locations	M.C%	H.CKg/h	I.D%	B.G%	M%	F.M%	V%
1	8.9	70.2	0.64	0.49	0.10	0.58	98
2	9.4	72.8	0.74	0.72	0.10	0.83	98
3	9.0	71.3	0.52	0.78	0.00	0.49	97
4	9.0	70.4	0.99	0.52	0.00	0.78	99
5	8.8	69.7	0.84	0.74	0.00	0.81	100
6	9.1	70.0	0.86	0.34	0.00	0.53	100
7	9.6	72.3	0.34	0.56	0.10	0.43	100

1MT

8	9.4	71.4	0.65	0.67	0.00	0.68	100
9	9.7	71.8	0.85	0.57	0.20	0.61	98

MARCH
2,500MT

Locations	M.C%	H.CKg/h	I.D%	B.G%	M%	F.M%	V%
1	8.8	70.6	0.92	0.84	0.00	0.72	99
2	9.0	69.8	0.84	0.79	0.00	0.64	98
3	8.9	70.0	0.83	0.54	0.00	0.69	98

4	9.2	70.4	0.55	0.68	0.00	0.49	100
5	9.0	70.3	0.59	0.64	0.00	0.70	96
6	9.3	71.2	0.64	0.72	0.00	0.84	98
7	9.1	70.8	0.78	0.69	0.00	0.84	100

1MT

8	8.7	69.4	1.09	0.42	0.08	0.61	98
9	8.9	69.8	0.88	0.49	0.68	0.64	100

APRIL

2,500MT

Locations	M.C%	H.CKg/h	I.D%	B.G%	M%	F.M%	V%
1	9.4	71.4	0.88	0.54	0.00	0.63	92
2	9.2	70.8	0.83	0.48	0.00	0.72	94
3	9.5	70.4	0.89	0.49	0.00	0.68	90
4	9.0	70.9	0.82	0.73	0.00	0.64	96
5	9.3	70.0	0.69	0.58	0.00	0.47	98
6	9.1	70.2	0.58	0.75	0.00	0.84	96
7	8.9	71.6	0.95	0.84	0.00	0.79	98

1MT

8	10.4	73.4	1.25	0.87	0.00	0.74	100
9	10.0	72.9	0.99	0.58	0.68	0.93	98

MAY

2,500MT

Locations	M.C%	H.CKg/h	I.D%	B.G%	M%	F.M%	V%
1	10.0	72.4	1.35	0.94	0.00	0.91	92
2	9.9	70.9	1.02	1.34	0.00	0.84	93

3	10.3	72.0	1.00	0.82	0.00	0.91	95
4	10.0	73.0	0.90	0.65	0.00	0.91	98
5	10.2	72.2	0.98	0.69	0.00	0.73	100
6	9.7	73.2	0.88	1.00	0.00	0.67	100
7	10.0	72.0	0.94	0.84	0.00	0.72	97

1MT

8	9.6	73.5	0.92	0.77	0.00	0.84	100
9	9.8	73.0	0.83	0.85	0.12	0.58	98

JUNE

2,500MT

Locations	M.C%	H.CKg/h	I.D%	B.G%	M%	F.M%	V%
1	9.2	73.0	0.99	0.82	0.00	0.68	86
2	9.4	70.8	0.87	0.84	0.00	0.82	88
3	9.2	71.3	1.23	1.04	0.00	0.84	90
4	9.0	70.2	0.92	0.75	0.00	0.78	94
5	9.6	68.8	0.48	0.79	0.00	0.86	96
6	8.9	72.0	1.02	0.74	0.00	0.65	100
7	9.1	70.4	0.63	0.81	0.00	0.84	98

1MT

8	9.6	72.4	1.09	0.39	0.00	0.52	98
9	10.0	72.4	1.05	0.45	0.58	0.62	100

JULY

2,500MT

Locations	M.C%	H.CKg/h	I.D%	B.G%	M%	F.M%	V%
1	9.6	70.6	1.48	0.85	0.00	0.77	80
2	10.3	72.0	1.02	1.06	0.00	0.88	84

3	10.0	71.9	1.87	0.91	0.00	0.83	88
4	9.8	70.7	0.78	0.49	0.00	0.83	98
5	10.3	70.9	0.89	0.78	0.00	0.88	95
6	9.8	72.0	0.89	0.58	0.00	0.64	100
7	9.8	73.0	0.89	0.68	0.00	0.72	98

1MT

8	9.7	73.0	0.84	0.34	0.42	0.44	98
9	9.2	73.2	1.82	0.41	0.33	0.68	100

AUGUST

2,500MT

Locations	M.C%	H.CKg/h	I.D%	B.G%	M%	F.M%	V%
1	9.6	70.4	1.56	1.085	0.00	0.86	78
2	9.9	71.0	1.21	0.81	0.00	0.87	88
3	10.0	70.5	1.72	1.05	0.00	0.71	85
4	9.7	70.2	0.88	0.58	0.00	0.88	98
5	9.3	72.0	0.71	0.68	0.00	0.58	88
6	9.8	71.2	0.88	0.75	1.81	0.64	98
7	9.8	69.0	0.79	0.77	0.00	0.48	98

1MT

8	9.1	69.9	0.86	0.81	0.80	0.75	98
9	9.3	70.4	0.67	0.20	0.00	0.88	100

APPENDIX C

MAXIMUM AND MINIMUM AMBIENT AND HEAD SPACE TEMPERATURE ($T^{O}C$) AND RELATIVE HUMIDITY DATA FROM JANUARY TO AUGUST IN MINNA SILO COMPLEX

AMBIENT TEMPERATURE DATA

JANUARY 2013 **FEBRUARY 2013**

DATE	MAX TEMP(^{O}C)	MIN TEMP (^{O}C)	R.H (MAX)	R.H (MIN)		DATE	MAX TEMP (^{O}C)	MIN TEMP (^{O}C)	R.H (MAX)	R.H (MIN)
01-01-13	33.0	24.0	29.0	22.0		01-02-13	35.0	25.0	22.0	19.0
02-01-13	31.0	23.0	29.0	18.0		02-02-13	35.0	25.1	22.0	19.0
03-01-13	31.0	22.0	30.0	18.0		03-02-13	33.0	22.0	20.0	18.0
04-01-13	31.6	22.0	25.0	17.0		04-02-13	32.0	22.2	26.0	20.8
05-01-13	30.0	21.9	32.0	20.0		05-02-13	32.2	21.9	24.0	21.4
06-01-13	32.0	22.8	31.0	20.0		06-02-13	31.2	22.0	21.0	19.6
07-01-13	30.8	20.8	30.8	16.0		07-02-13	37.0	21.0	21.0	20.0
08-01-13	30.6	21.8	30.6	16.0		08-02-13	37.3	21.8	23.0	20.6
09-01-13	30.0	20.8	31.9	17.0		09-02-13	34.4	22.9	22.7	20.0
10-01-13	30.0	21.0	32.0	19.0		10-02-13	32.9	23.0	22.9	21.0
11-01-13	31.0	21.0	28.0	17.0		11-02-13	33.0	22.0	21.0	19.2
12-01-13	33.6	22.0	29.0	17.0		12-02-13	33.0	22.0	21.0	19.8
13-01-13	32.9	22.6	28.8	18.0		13-02-13	35.0	22.9	23.0	20.0
14-01-13	32.9	22.9	30.0	20.8		14-02-13	33.0	22.2	28.0	22.0
15-01-13	33.0	23.0	31.0	20.0		15-02-13	32.0	22.0	24.0	21.9
16-01-13	32.0	23.0	32.0	21.0		16-02-13	34.0	23.0	25.0	20.0
17-01-13	32.0	22.0	31.9	21.6		17-02-13	34.7	23.0	29.0	20.0
18-01-13	35.0	22.0	31.6	20.0		18-02-13	34.4	24.0	28.0	22.0
19-01-13	35.0	20.9	31.0	21.0		19-02-13	33.9	25.0	29.4	22.0
20-01-13	34.8	20.2	29.0	21.4		20-02-13	32.0	23.0	28.8	21.0
21-01-13	33.6	21.0	29.0	19.8		21-02-13	32.9	23.0	27.4	21.5
22-01-13	33.0	22.0	29.0	19.0		22-02-13	31.9	20.9	25.0	21.6
25-01-13	35.0	22.0	27.8	20.0		25-02-13	32.8	20.8	25.9	22.0

26-01-13	36.0	22.8	30.0	20.0		26-02-13	30.9	21.9	26.0	23.0
27-01-13	34.9	23.0	31.0	22.0		27-02-13	33.0	22.0	26.0	20.8
28-01-13	35.0	23.0	29.0	21.0		28-02-13	32.0	22.0	26.0	20.6
29-01-13	34.9	23.0	28.0	22.0						
30-01-13	34.6	23.2	30.2	22.4						
31-01-13	34.8	23.7	30.4	23.0						

MARCH 2013 **APRIL 2013**

DATE	MAX TEMP (^{O}C)	MIN TEMP (^{O}C)	R.H (MAX)	R.H (MIN)		DATE	MAX TEMP (^{O}C)	MIN TEMP (^{O}C)	R.H (MAX)	R.H (MIN)
01-03-13	38.0	26.0	49.0	19.0		01-04-13	36.0	25.0	60.3	18.60
02-03-13	38.0	26.0	50.0	20.8		02-04-13	36.0	25.3	60.8	18.70
03-03-13	37.0	24.2	49.9	20.0		03-04-13	38.0	25.0	57.5	19.0
04-03-13	38.0	23.9	49.6	20.0		04-04-13	36.0	25.9	63.8	20.0
05-03-13	35.0	23.6	49.0	19.0		05-04-13	35.0	24.5	63.0	20.0
06-03-13	36.0	22.4	48.0	19.0		06-04-13	33.0	24.5	60.0	21.0
07-03-13	35.0	23.0	50.0	19.8		07-04-13	33.0	24.0	61.0	22.0
08-03-13	34.5	23.9	50.5	20.0		08-04-13	32.0	23.6	61.0	19.0
10-03-13	35.5	23.0	50.0	19.5		09-04-13	33.9	23.4	64.0	19.0
12-03-13	38.0	23.0	48.0	22.0		10-04-13	34.0	22.9	60.5	18.0
13-03-13	38.0	23.9	48.0	21.0		11-04-13	33.9	23.4	60.0	18.0
14-03-13	37.0	24.0	49.0	21.0		12-04-13	33.0	22.8	58.0	20.0
15-03-13	33.0	22.0	48.0	22.0		13-04-13	32.9	25.0	61.0	19.0
16-03-13	33.0	22.2	50.0	22.0		14-04-13	34.0	23.0	59.0	19.6
17-03-13	34.0	23.0	50.0	22.0		15-04-13	34.0	22.0	60.0	20.4
18-03-13	35.0	23.2	49.9	21.0		16-04-13	35.0	24.0	63.0	19.2
20-03-13	34.0	20.9	48.0	23.0		17-04-13	34.8	23.0	63.0	18.5

21-03-13	32.0	21.0	46.0	22.5		18-04-13	35.0	24.0	62.0	20.0
22-03-13	34.0	21.9	49.0	22.0		20-04-13	36.0	22.0	61.6	20.5
23-03-13	34.8	22.0	49.9	21.9		22-04-13	37.0	21.0	62.4	20.0
24-03-13	33.9	23.0	50.0	22.2		23-04-13	35.0	22.0	63.0	21.0
25-03-13	33.9	23.0	49.0	22.8		25-04-13	34.0	24.0	60.0	21.0
26-03-13	32.0	22.0	49.0	22.8		26-04-13	33.0	24.5	60.0	22.0
27-03-13	34.0	23.0	49.0	22.0		27-04-13	33.0	23.6	58.0	22.0
28-03-13	35.0	24.0	48.2	19.0		28-04-13	33.9	23.1	57.0	21.0
29-03-13	34.0	22.0	48.0	19.0		29-04-13	33.8	23.0	58.0	21.0
30-03-13	33.0	22.0	48.8	19.0		30-04-13	33.3	22.0	58.0	22.0

MAY 2013 **JUNE 2013**

DATE	MAX TEMP (^{O}C)	MIN TEMP (^{O}C)	R.H (MAX)	R.H (MIN)		DATE	MAX TEMP (^{O}C)	MIN TEMP (^{O}C)	R.H (MAX)	R.H (MIN)
01-05-13	33.0	20.0	68.0	33.0		01-06-13	33.0	22.3	77.8.	35.0
02-05-13	34.0	20.0	69.0	32.0		02-06-13	33.4	22.0	75.2	34.5
03-05-13	36.0	22.0	75.0	32.0		03-06-13	32.1	22.7	76.8	44.5
04-05-13	33.0	21.0	75.0	35.0		04-06-13	32.3	25.2	77.5	50.0
05-05-13	34.0	20.0	72.0	34.0		05-06-13	32.0	23.6	80.0	53.0
07-05-13	35.0	19.5	73.0	32.0		06-06-13	32.0	23.9	81.0	53.5
08-05-13	33.0	21.8	74.0	33.0		07-06-13	33.0	22.0	79.0	60.0
09-05-13	32.9	22.5	73.0	35.0		08-06-13	34.0	22.0	76.5	55.0
10-05-13	32.0	23.2	72.0	32.0		09-06-13	33.0	21.9	77.0	53.0
11-05-13	32.9	22.0	72.6	33.0		11-06-13	33.0	22.0	77.0	54.0
12-05-13	33.0	23.0	73.2	33.0		12-06-13	33.0	23.0	78.4	54.0

14-05-13	34.0	23.0	71.0	31.0		13-06-13	32.0	22.8	77.8	53.0
16-05-13	35.0	23.0	68.0	33.5		15-06-13	31.0	23.0	75.6	53.0
17-05-13	35.0	22.0	68.0	33.0		16-06-13	31.0	23.0	76.0	37.0
18-05-13	33.0	22.9	67.5	32.0		18-06-13	31.0	22.9	76.0	38.0
20-05-13	32.0	21.0	69.0	29.9		19-06-13	33.0	22.8	78.0	39.0
21-05-13	32.0	21.0	69.0	29.0		20-06-13	29.5	22.6	79.0	41.0
22-05-13	32.0	19.8	71.0	31.0		21-06-13	29.0	21.9	80.0	41.0
23-05-13	33.0	19.9	72.0	31.0		22-06-13	32.0	22.0	79.9	42.0
24-05-13	32.6	19.0	72.0	31.0		23-06-13	32.5	22.0	79.6	43.0
25-05-13	32.0	22.0	71.0	31.0		24-06-13	33.0	21.8	79.8	44.0
26-05-13	31.9	22.0	68.0	28.8		25-06-13	31.8	22.0	80.0	49.0
27-05-13	32.0	22.0	68.0	29.0		26-06-13	31.3	22.9	80.0	50.0
28-05-13	33.0	21.0	69.9	29.0		27-06-13	32.0	23.0	77.8	51.2
29-05-13	32.0	21.0	67.9	30.5		28-06-13	33.0	23.0	77.5	50.0
30-05-13	33.9	22.0	69.2	29.5		29-06-13	32.8	22.8	77.9	49.9
31-05-13	32.0	23.0	69.0	29.0		30-06-13	30.9	23.0	80	53.0

JULY 2013 **AUGUST 2013**

DATE	MAX TEMP (^{O}C)	MIN TEMP (^{O}C)	R.H (MAX)	R.H (MIN)		DATE	MAX TEMP (^{O}C)	MIN TEMP (^{O}C)	R.H (MAX)	R.H (MIN)
01-7-13	31.0	25.3	67.0	63.0		01-8-13	30.0	22.6	85.0	80.0
02-7-13	30.8	25.0	68.2	62.9		02-8-13	29.8	22.5	82.0	78.0
03-7-13	29.6	23.6	70.2	65.0		03-8-13	29.0	22.6	85.0	81.0
04-7-13	31.6	22.7	64.0	60.0		04-8-13	28.8	21.9	81.0	76.0
05-7-13	31.8	21.9	65.3	60.2		05-8-13	30.5	23.9	83.7	80.0

06-7-13	25.0	22.0	72.0	66.8		06-8-13	30.8	22.6	82.9	79.2
07-7-13	26.4	22.4	71.8	65.0		07-8-13	31.2	22.4	85.0	81.0
08-7-13	28.0	22.6	70.6	64.8		08-8-13	30.9	22.2	83.8	79.2
09-7-13	28.0	23.0	70.0	65.3		09-8-13	31.7	22.6	83.8	79.8
10-7-13	29.0	23.0	70.6	65.3		10-8-13	31.8	22.5	82.0	79.8
11-7-13	30.8	24.6	69.8	63.6		11-8-13	30.1	21.8	81.0	78.0
12-7-13	31.2	25.0	69.8	64.8		12-8-13	29.6	21.6	82.8	77.0
13-7-13	31.4	25.0	67.5	61.4		13-8-13	32.4	22.6	82.9	78.6
14-7-13	29.0	23.9	70.0	64.0		14-8-13	30.1	22.4	81.0	79.0
15-7-13	29.8	22.8	70.3	64.4		15-8-13	30.0	22.0	84.0	78.0
16-7-13	30.3	23.0	68.3	62.9		16-8-13	30.0	22.0	83.9	80.6
17-7-13	34.0	23.0	64.8	60.9		17-8-13	29.6	22.4	83.9	78.6
18-7-13	32.0	24.0	66.0	60.0		18-8-13	29.3	22.8	83.0	80.0
19-7-13	31.0	24.5	67.0	63.5		19-8-13	29.9	21.8	82.9	80.0
20-7-13	29.8	24.3	65.9	60.0		20-8-13	30.6	20.9	82.8	74.2
21-7-13	27.6	23.9	69.8	64.5		21-8-13	30.0	22.3	81.8	76.8
22-7-13	24.9	23.9	73.0	67.8		22-8-13	31.0	22.6	83.0	78.4
23-7-13	25.0	22.0	72.0	68.8		23-8-13	32.0	22.4	82.0	79.0
24-7-13	26.4	22.0	70.9	64.5		24-8-13	30.9	21.9	83.4	78.4
25-7-13	28.5	23.0	71.0	65.0		25-8-13	30.9	21.8	83.6	80.6
26-7-13	27.5	23.1	71.0	66.8		26-8-13	29.0	21.8	85.0	81.0
27-7-13	31.0	25.0	68.6	63.0		27-8-13	30.0	22.8	85.6	81.6
28-7-13	31.0	25.0	69.0	63.4		28-8-13	30.6	23.0	85.0	81.0
29-7-13	28.0	23.5	68.0	65.0		29-8-13	30.8	22.8	84.0	80.0
30-7-13	30.0	23.0	69.0	64.8		30-8-13	31.0	22.7	82.8	80.0
31-7-13	31.0	22.0	70.0	65.0		31-8-13	31.8	22.6	83.0	81.0

HEAD SPACE TEMPERATURE DATA FOR 2500MT SILO

JANUARY 2013 **FEBRUARY 2013**

S/N	MAX TEMP (^{O}C)	MIN TEMP (^{O}C)	MAX R.H	MIN R.H		S/N	MAX TEMP (^{O}C)	MIN TEMP (^{O}C)	MAX R.H	MIN R.H
01-01-13	34.2	25.2	28.4	21.2		01-02-13	36.2	26.4	21.3	18.1
02-01-13	34.1	24.8	28.2	17.8		02-02-13	36.0	27.0	21.8	18.2
03-01-13	33.9	23.0	29.1	17.9		03-02-13	34.5	23.8	19.7	17.8
04-01-13	34.4	23.2	24.3	17.0		04-02-13	33.9	24.0	24.6	19.2
05-01-13	34.5	22.9	31.0	18.5		05-02-13	34.0	22.3	22.9	20.0
06-01-13	36.5	24.0	30.2	19.0		06-02-13	33.0	23.0	20.0	18.0
07-01-13	35.0	22.4	29.0	16.0		07-02-13	38.2	22.5	20.0	19.5
08-01-13	34.8	22.8	29.1	15.8		08-02-13	38.5	23.0	22.4	19.2
09-01-13	35.6	21.3	29.8	16.2		09-02-13	35.6	23.8	21.7	19.0
10-01-13	36.0	23.2	30.1	18.3		10-02-13	33.9	24.5	21.0	20.0
11-01-13	33.2	22.1	27.2	16.0		11-02-13	34.0	23.6	21.0	18.0
12-01-13	34.8	23.0	28.3	16.1		12-02-13	34.6	24.5	19.1	19.0
13-01-13	34.5	22.30	27.5	15.9		13-02-13	36.0	24.0	19.2	19.4
14-01-13	33.8	23.9	29.0	18.2		14-02-13	34.5	23.8	22.5	21.2
15-01-13	35.6	24.0	30.0	19.0		15-02-13	33.0	23.9	25.6	20.9
16-01-13	34.5	24.2	31.2	19.2		16-02-13	35.2	24.0	23.8	19.3
17-01-13	34.7	23.8	30.0	20.1		17-02-13	36.0	24.5	24.0	19.00
18-01-13	33.9	23.0	30.4	20.0		18-02-13	35.3	26.0	28.0	21.2
19-01-13	34.2	23.2	30.6	18.9		19-02-13	34.2	26.6	27.1	20.3
20-01-13	35.9	21.9	29.8	18.6		20-02-13	35.0	24.2	27.6	20.0
21-01-13	34.2	22.0	29.2	19.2		21-02-13	34.3	24.0	26.9	20.6
22-01-13	35.1	22.8	28.5	19.5		22-02-13	32.8	21.2	27.0	21.0
25-01-13	36.0	24.1	28.1	18.8		25-02-13	33.9	22.4	24.0	21.3

26-01-13	34.6	23.0	27.0	19.8		26-02-13	33.0	22.0	23.9	22.4
27-01-13	36.2	22.8	29.4	18.0		27-02-13	34.6	23.5	25.0	21.7
28-01-13	36.9	23.4	30.1	19.0		28-02-13	33.8	23.7	25.1	20.0
29-01-13	36.8	24.2	28.3	18.9						
30-01-13	36.6	32.4	29.0	20.3						
31-01-13	35.9	30.5	28.0	20.1						

MARCH 2013 **APRIL 2013**

S/N	MAX TEMP (^{O}C)	MIN TEMP (^{O}C)	MAX R.H	MIN R.H		S/N	MAX TEMP (^{O}C)	MIN TEMP (^{O}C)	MAX R.H	MIN R.H
01-03-13	39.5	28.0	48.2	18.0		01-04-13	37.0	26.1	59.0	17.6
02-03-13	40.0	27.8	49.6	19.0		02-04-13	37.8	26.8	59.1	17.7
03-03-13	39.3	25.6	47.3	18.8		03-04-13	39.0	26.0	56.2	18.0
04-03-13	39.0	25.0	48.0	19.0		04-04-13	38.1	26.2	62.4	19.6
05-03-13	36.7	25.7	47.5	18.0		05-04-13	36.7	25.6	62.5	19.8
06-03-13	37.9	23.8	47.2	18.4		06-04-13	36.0	25.0	59.1	20.2
07-03-13	36.0	25.0	49.2	18.8		07-04-13	35.2	25.1	58.9	20.0
08-03-13	36.0	24.3	49.0	19.4		08-04-13	34.0	24.7	58.5	18.2
10-03-13	38.0	24.2	49.3	18.0		09-04-13	35.0	24.6	62.0	18.1
12-03-13	39.5	24.0	47.2	21.0		10-04-13	36.0	23.4	59.0	17.2
13-03-13	40.2	24.9	47.0	21.0		11-04-13	34.9	24.9	58.9	16.2
14-03-13	39.3	24.8	46.5	20.2		12-04-13	35.0	23.8	56.2	18.4
15-03-13	34.5	23.2	46.2	20.0		13-04-13	34.6	26.0	60.0	18.2
16-03-13	34.8	23.4	47.2	20.0		14-04-13	35.9	24.0	58.1	18.0
17-03-13	35.6	22.5	45.6	21.1		15-04-13	36.0	23.7	58.7	18.6
18-03-13	37.0	23.0	48.8	20.5		16-04-13	36.0	25.2	62.0	18.0
20-03-13	35.8	19.6	49.0	21.0		17-04-13	35.0	24.5	61.8	16.9

21-03-13	36.3	19.7	47.8	20.0		18-04-13	36.7	26.2	61.8	19.4
22-03-13	36.0	19.0	47.0	22.5		20-04-13	38.0	24.0	60.0	20.0
23-03-13	34.1	19.2	45.6	20.8		22-04-13	38.1	22.3	61.2	19.4
24-03-13	35.6	19.8	46.9	20.4		23-04-13	36.2	24.1	62.5	20.0
25-03-13	35.8	21.2	47.8	20.8		25-04-13	35.6	25.2	59.6	20.2
26-03-13	36.0	22.4	49.0	21.2		26-04-13	35.2	25.2	59.00	21.00
27-03-13	35.0	21.5	48.2	21.4		27-04-13	34.6	25.2	57.00	20.7
28-03-13	33.8	23.0	48.0	20.8		28-04-13	34.9	24.3	56.2	20.1
29-03-13	36.2	22.0	48.2	21.3		29-04-13	34.9	24.0	56.2	20.1
30-03-13	38.1	22.4	48.0	22.0		30-04-13	35.0	23.0	57.0	21.0

MAY 2013 **JUNE 2013**

S/N	MAX TEMP (°C)	MIN TEMP (°C)	MAX R.H	MIN R.H		S/N	MAX TEMP (°C)	MIN TEMP (°C)	MAX R.H	MIN R.H
01-05-13	35.0	21.00	67.0	31.2		01-06-13	35.0	23.6	75.8	34.0
02-05-13	36.7	21.20	67.2	30.4		02-06-13	35.2	24.0	72.9	32.0
03-05-13	37.8	23.2	74.2	30.5		03-06-13	33.6	24.1	75.0	42.1
04-05-13	35.2	22.3	73.8	31.0		04-06-13	34.0	26.7	76.0	49.2
05-05-13	35.0	23.4	70.2	32.1		05-06-13	34.1	24.2	78.0	52.1
07-05-13	36.2	22.4	72.1	31.8		06-06-13	33.0	25.2	80.0	51.3
08-05-13	34.6	20.8	73.1	31.2		07-06-13	35.2	23.4	77.9	58.6
09-05-13	33.9	23.0	72.0	30.8		08-06-13	35.0	23.2	76.0	54.2
10-05-13	34.5	23.2	70.5	30.6		09-06-13	34.8	22.9	76.0	52.4
11-05-13	34.4	23.0	70.4	29.2		11-06-13	35.2	24.0	76.1	52.3
12-05-13	33.7	25.0	70.2	31.0		12-06-13	34.6	25.0	76.4	52.5
14-05-13	34.9	29.0	72.0	32.1		13-06-13	34.6	23.0	76.2	52.4
16-05-13	35.0	25.6	70.4	30.1		15-06-13	32.4	24.2	74.0	50.8

17-05-13	37.2	24.5	67.2	31.8		16-06-13	33.1	25.0	74.2	35.1
18-05-13	34.0	23.7	65.2	31.3		18-06-13	32.3	25.9	76.5	37.0
20-05-13	33.2	24.7	67.2	28.4		19-06-13	35.2	23.4	76.0	38.1
21-05-13	34.0	23.0	68.0	27.2		20-06-13	31.2	23.4	76.8	40.0
22-05-13	34.5	23.7	70.0	30.1		21-06-13	30.8	22.4	79.0	40.2
23-05-13	34.3	23.3	71.1	30.3		22-06-13	34.0	23.4	78.0	41.0
24-05-13	33.8	24.6	70.5	30.2		23-06-13	33.6	23.1	78.0	42.0
25-05-13	34.0	21.2	68.0	27.3		24-06-13	34.3	23.4	78.0	43.1
26-05-13	33.4	22.1	67.5	28.0		25-06-13	33.0	23.0	79.0	46.8
27-05-13	34.0	21.5	69.5	30.2		26-06-13	32.4	23.2	79.8	48.2
28-05-13	35.5	23.2	71.2	30.0		27-06-13	35.0	24.0	76.0	49.2
29-05-13	33.4	24.2	70.1	30.0		28-06-13	35.2	25.0	76.10	48.9
30-05-13	33.4	25.0	70.0	30.0		29-06-13	34.8	23.8	75.80	48.1
31-05-13	33.0	22.6	66.2	28.0		30-06-13	31.2	24.0	78.10	50.2

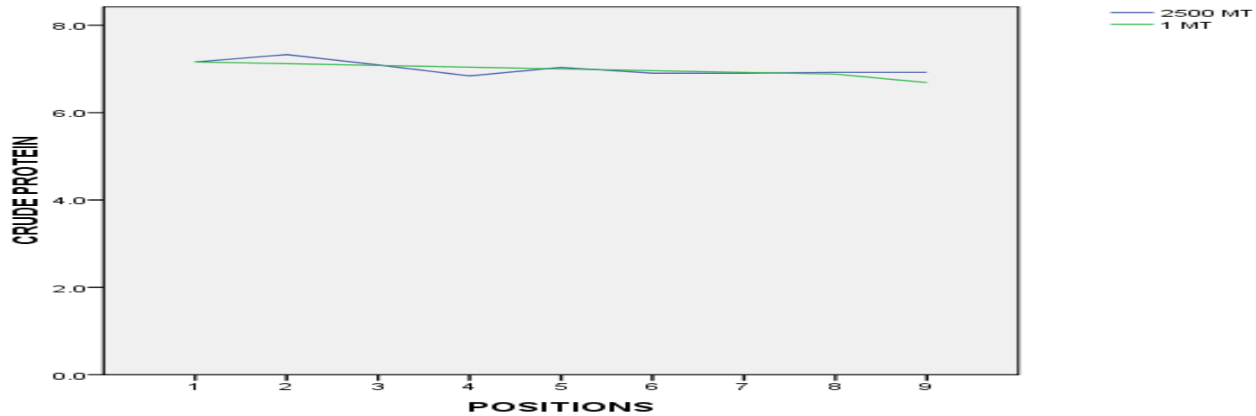
JULY **AUGUST**

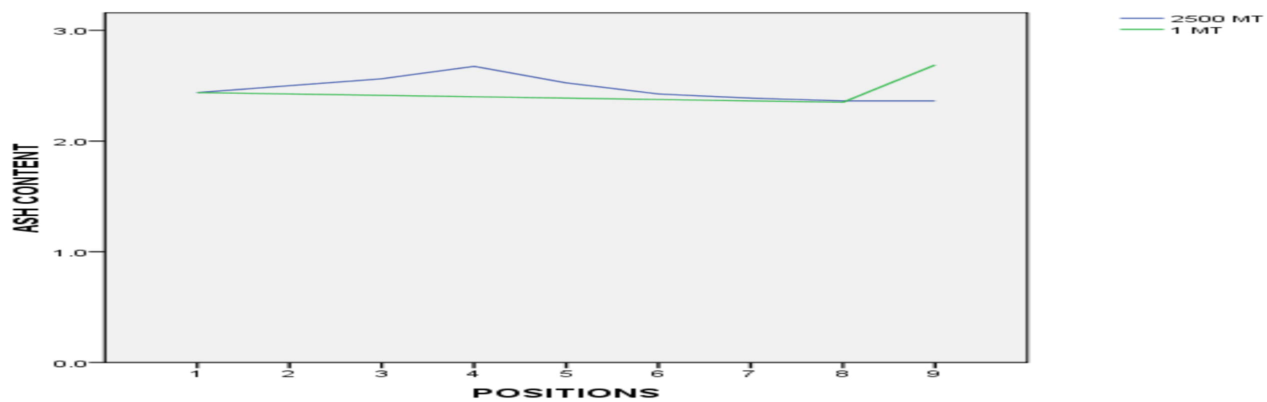
S/N	MAX TEMP (°C)	MIN TEMP (°C)	MAX R.H	MIN R.H		S/N	MAX TEMP (°C)	MIN TEMP (°C)	MAX R.H	MIN R.H
01-7-13	33.0	26.1	66.2	62.3		01-8-13	32.0	24.6	84.0	78.1
02-7-13	31.5	26.0	66.0	61.2		02-8-13	31.2	23.4	80.1	77.2
03-7-13	31.0	24.1	68.5	64.0		03-8-13	30.8	24.0	82.5	80.2
04-7-13	32.8	23.2	62.5	58.9		04-8-13	30.3	22.9	80.0	74.0
05-7-13	27.8	22.8	64.2	59.5		05-8-13	32.6	25.0	80.4	78.3
06-7-13	27.0	23.2	72.1	64.8		06-8-13	32.0	24.1	80.8	78.0

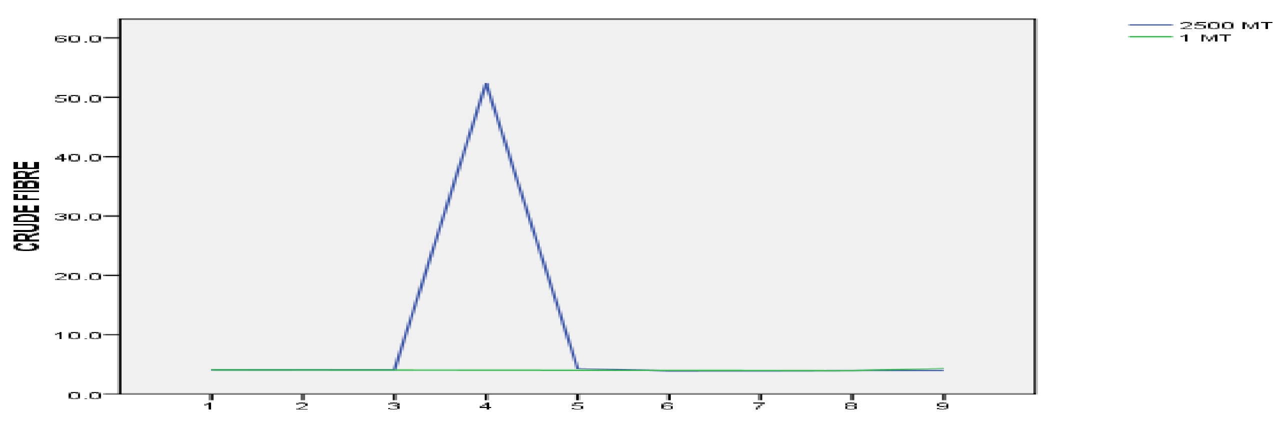
07-7-13	30.1	23.1	70.1	63.2		07-8-13	33.0	25.0	82.1	81.0
08-7-13	29.2	23.2	69.0	51.2		08-8-13	31.8	23.0	81.2	78.1
09-7-13	30.6	34.0	68.5	63.2		09-8-13	33.0	24.1	82.0	76.8
10-7-13	32.4	23.7	69.2	63.1		10-8-13	33.4	23.6	80.1	77.2
11-7-13	33.0	25.0	68.0	60.1		11-8-13	31.8	22.8	79.2	76.0
12-7-13	33.1	26.1	68.2	62.5		12-8-13	31.7	22.8	80.1	77.0
13-7-13	31.2	26.2	66.0	60.0		13-8-13	33.4	24.6	80.7	78.0
14-7-13	32.0	24.8	69.0	62.1		14-8-13	32.1	23.4	80.00	77.0
15-7-13	31.0	24.1	68.8	62.0		15-8-13	32.4	24.0	83.1	79.2
16-7-13	35.8	24.2	67.1	60.3		16-8-13	31.2	23.4	82.0	77.1
17-7-13	34.0	25.9	63.1	58.8		17-8-13	32.1	24.4	80.2	79.0
18-7-13	33.4	25.6	65.1	59.3		18-8-13	32.1	24.2	82.00	79.0
19-7-13	31.3	25.0	66.0	60.4		19-8-13	31.8	23.1	80.9	72.0
20-7-13	29.6	24.8	64.9	60.0		20-8-13	33.1	21.2	81.0	76.0
21-7-13	26.1	24.1	68.1	63.0		21-8-13	32.1	23.0	80.0	77.1
22-7-13	28.1	24.9	70.2	65.5		22-8-13	33.6	24.6	81.7	77.8
23-7-13	28.3	23.2	71.3	67.6		23-8-13	34.2	24.3	80.1	79.6
24-7-13	30.1	23.0	69.2	62.8		24-8-13	32.4	23.8	81.6	78.7
25-7-13	29.2	24.2	69.0	64.1		25-8-13	32.0	22.0	81.5	79.2
26-7-13	28.2	24.0	70.1	65.2		26-8-13	31.8	22.0	80.1	80.2
27-7-13	29.6	22.1	69.8	62.8		27-8-13	30.1	22.8	84.1	80.3
28-7-13	30.0	23.8	68.0	63.4		28-8-13	31.2	22.8	84.00	81.20
29-7-13	30.2	24.1	69.2	60.8		29-8-13	32.0	23.1	84.00	81.30
30-7-13	29.1	24.0	69.5	62.4		30-8-13	31.8	22.9	84.00	81.20
31-7-13	29.2	22.0	68.4	62.0		31-8-13	31.4	22.6	84.20	81.40

APPENDIX D

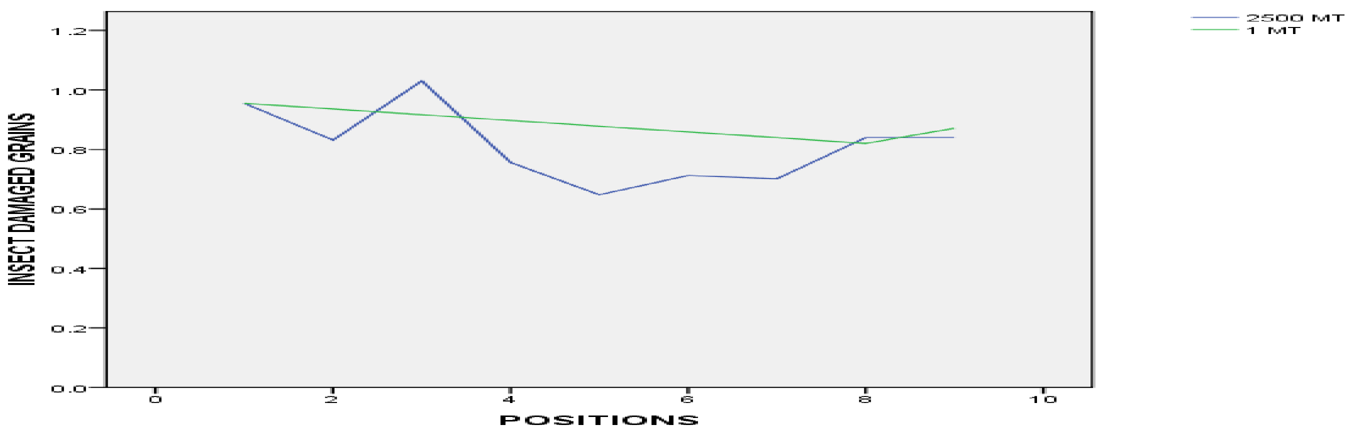
(NP) PROPERTIES IN RESPECT TO SAMPLE LOCATIONS

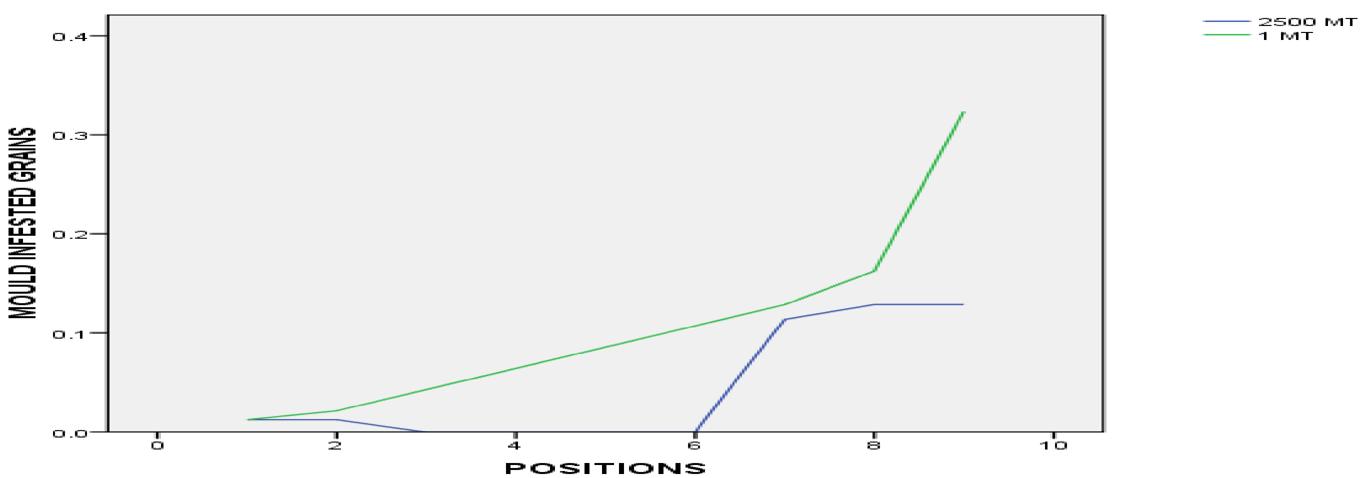


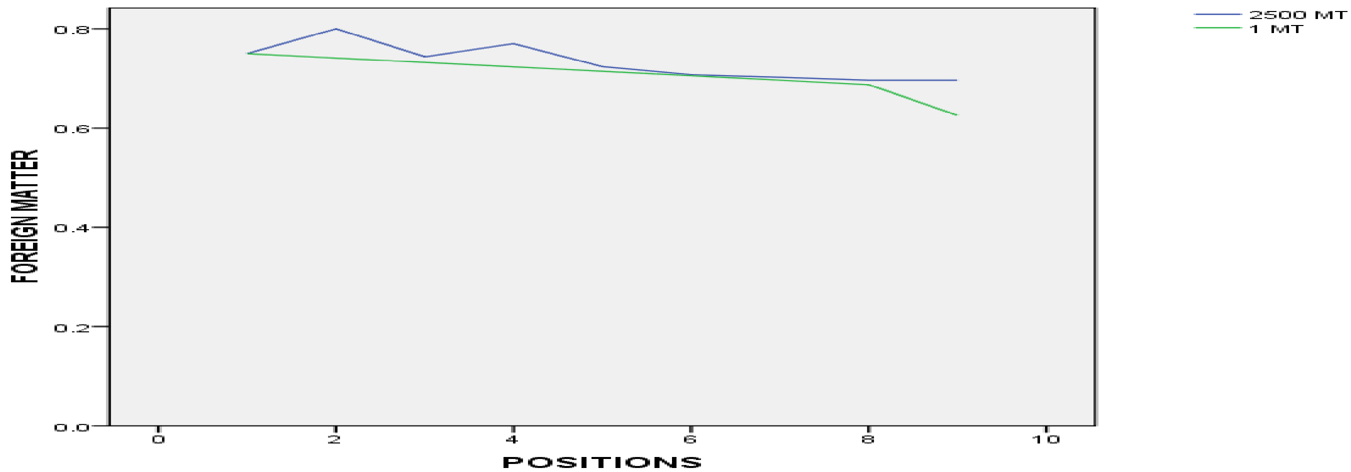


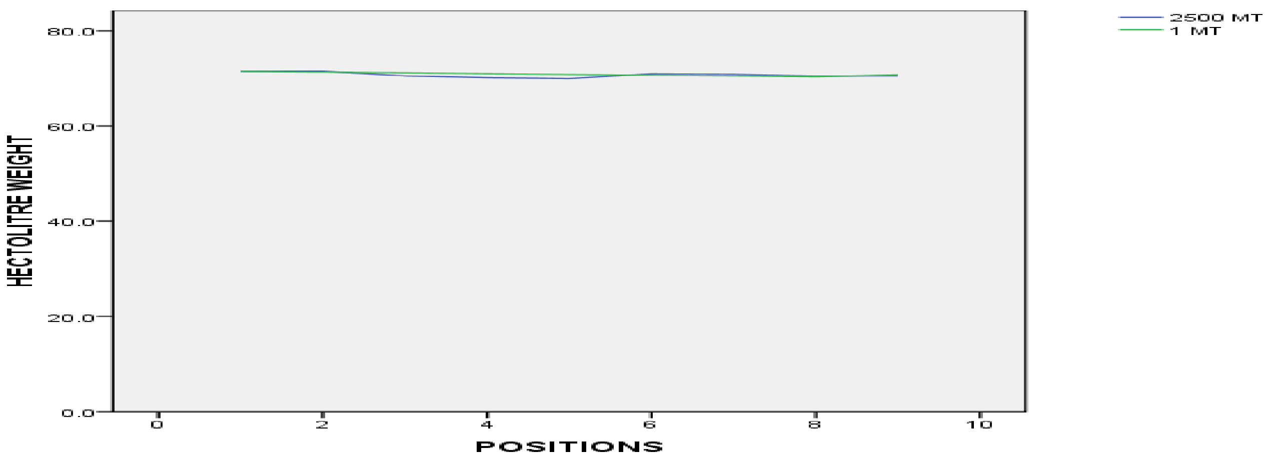


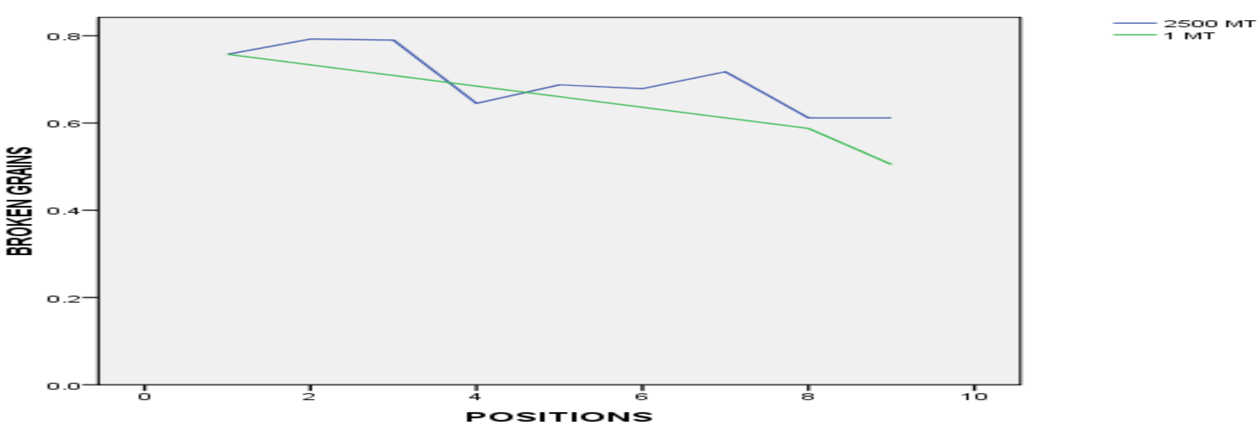
(PY) PROPERTIES IN RESPECT TO SAMPLE LOCATIONS



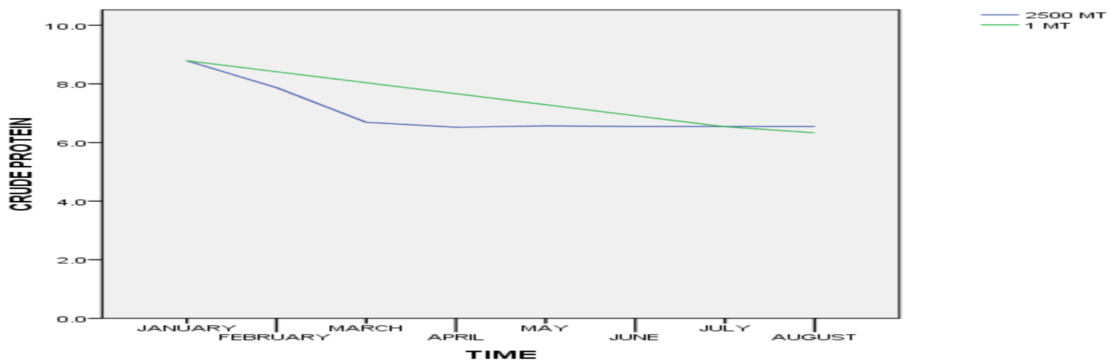


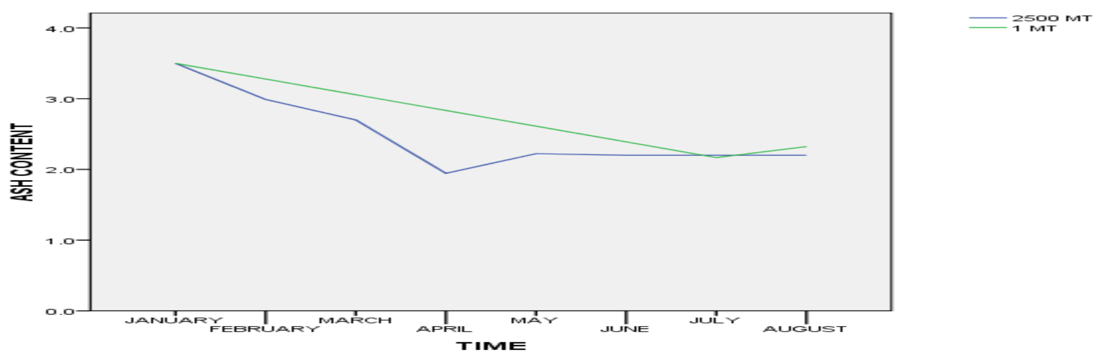


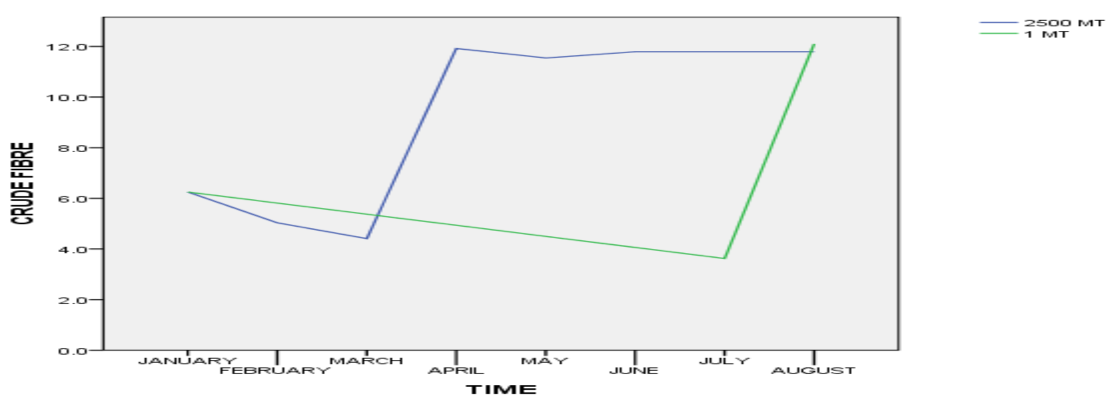




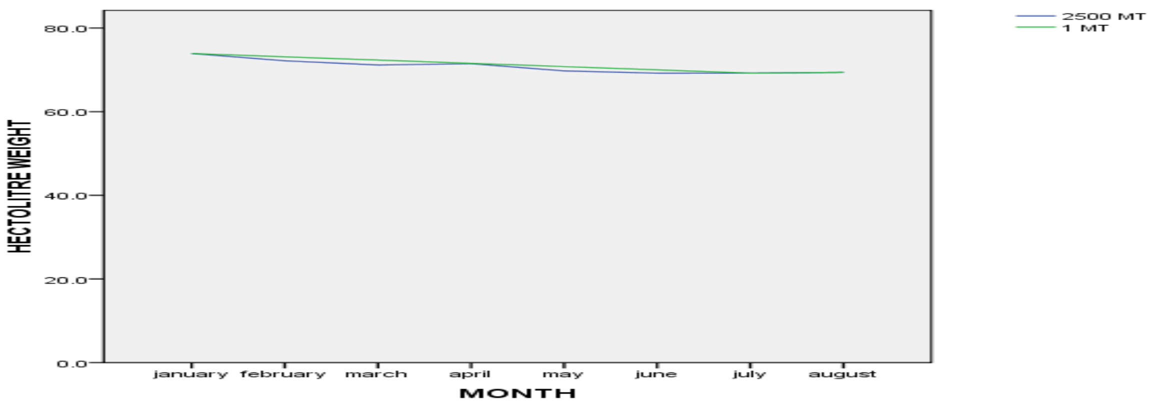
(NP) PROPERTIES IN RESPECT TO DURATION OF STORAGE



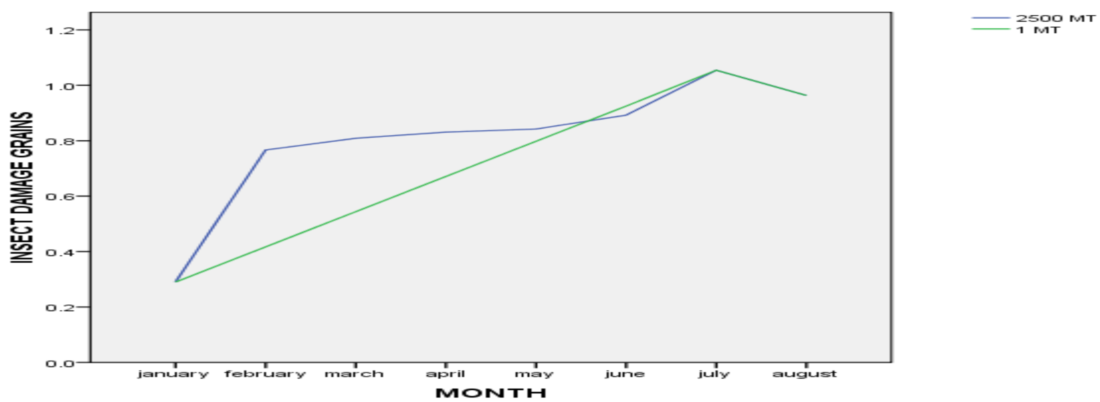




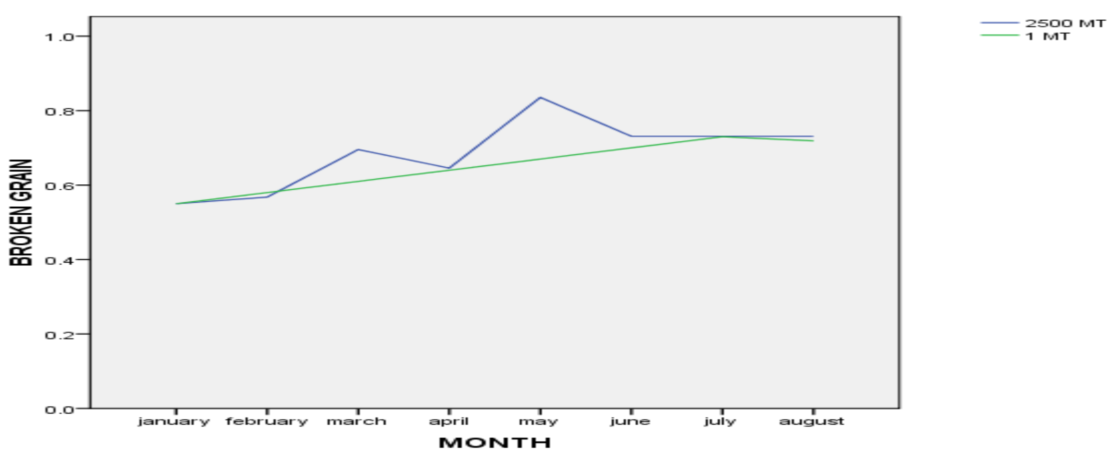
(PY) CHARACTERISTICS IN RESPECT TO DURATION OF STORAGE



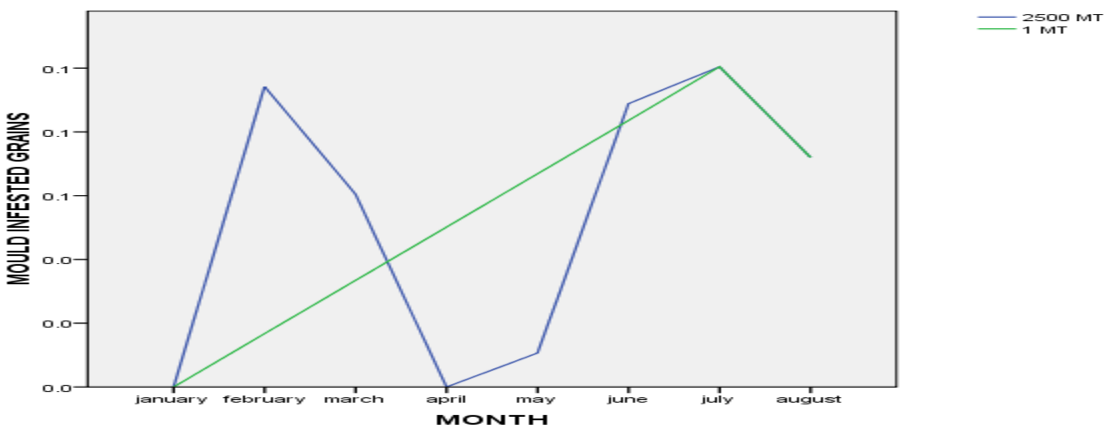
2500 MT
1 MT
HECTOLITRE WEIGHT
80.0
60.0
40.0
20.0
0.0
january february march april may june july august
MONTH

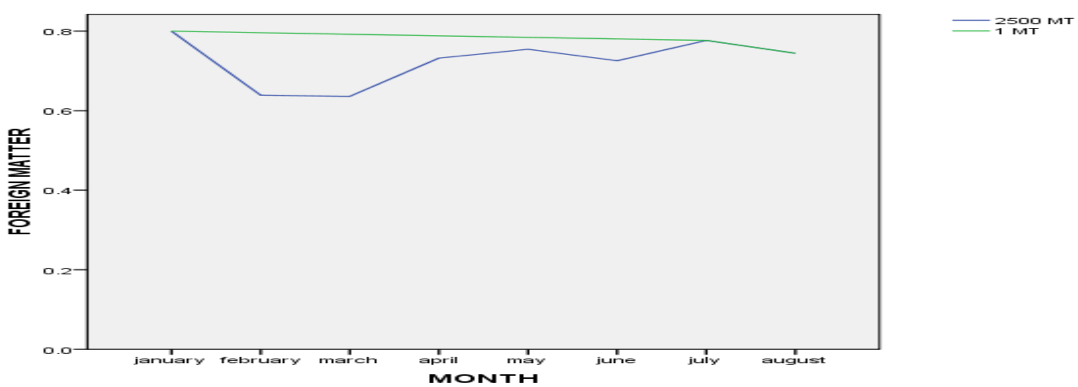


2500 MT
1 MT
INSECT DAMAGE GRAINS
1.2
1.0
0.8
0.6
0.4
0.2
0.0
january february march april may june july august
MONTH



2500 MT
1 MT
BROKEN GRAIN
1.0
0.8
0.6
0.4
0.2
0.0
january february march april may june july august
MONTH


2500 MT
1 MT
0.1
0.1
0.1
0.0
0.0
0.0
MOULD INFESTED GRAINS
january
february
march
april
may
june
july
august
MONTH


2500 MT
1 MT
0.8
0.6
0.4
0.2
0.0
FOREIGN MATTER
january
february
march
april
may
june
july
august
MONTH