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Evaluation of Quality and Mass Loss of Maize (Zea mays) Stored in Rigid Hermetic Storage Structure (Aluminum Metallic Container) in a Tropical climate.

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ABSTRACT*- This study evaluated the quality and mass loss of maize stored in rigid hermetic storage structure (Aluminum metallic container) in Minna, Nigeria for a period of 12 months. Carrying out this evaluation entailed the identification and purchase of freshly harvested maize hybrid 9021 single cross, which has not undergone any form of storage before sale at the market. The initial quality and mass characteristics were determined using standard methods, and was stored in 100kg capacity well sealed aluminum metallic container that was set up in a natural ventilated atmosphere under a mango shed. Samples were taken at 2 months intervals and any sampled metallic container was discarded due to the interference with the modified atmosphere. Analysis of variance (ANOVA) and Duncan's multivariate test was used for the statistical analysis of data generated. The result showed that most quality variables depreciated at different level/significance after 12 months of storage, except carbohydrate and energy values. The germination potential (g) depreciated from 98.60%-89.00%, moisture content (MC) 10.90%-7.20%, crude fibre (CF) 2.50%-1.00%,, crude protein (CP)10.00%-4.52%, bulk density (BD) 0.74g/cm^3-0.68g/cm^3 fat content (CFC) 4.96%-4.08%, ash content (AC) 2.04%-1.50% while carbohydrate and energy values appreciated from77.69%-78.58% and 379.99%-380.56%. There was no significant mass loss (p>0.05) (after the 12 months of storage (44.85kg per 1000kg). Aluminium metallic container retained germination potential and quality and mass characteristics especially when compared to other available non- hermetic storage structures in the tropics. More public awareness targeted at farmers, is needed to popularize this economical and zero chemical storage structure.*

KEYWORDS*-Hermetic storage structure, storage losses, maize, aluminium metallic container*

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I. INTRODUCTION.

Maize (Zea mays L.) is a cereal grain crop that is widely grown and stored in different continents of the world (South America, Europe, Asia and Africa). It is the most produced and stored annually in the grain family [1]; [2]. Maize is a member of grass family called Poaceae. There are about 50 known species of maize existing globally, which consist of different types used for different purposes in their various agro- adapted climates of the world. In developing countries, several millions of people derive their protein and calorie requirements from maize. With its high nutritive content such as carbohydrate, fats, proteins, essential minerals and vitamins, it stands out as one of the reputable cereal grains [3]. In many developing countries the bulk of maize produced serves as a major source of protein for weaning children, the sick, adult and children, or eaten during lean period of crop production cycle, has a biological nutritional value of 40% of that of milk [2]. Maize production, therefore, is of strategic importance to food security and the socio-economic stability of developing countries. Due to the exorbitant nature of animal protein, and the scarcity of other common human dietary elements, most people in sub-Saharan Africa especially from the rural poor areas who cannot afford the conventional source of these dietary elements, depend on maize and other cereal grains, avoiding numerous health problems such as kwashiorkor, underweight, weakened resistance to infections and impaired intellectual development [2]; [3] . Maize (Zea mays) is the most popular cereal crop planted and stored in Nigeria. 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 [4]. 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, quantity, available technology and culture, but are popularly stored in commercial quantity in metallic silos [5]. In Nigeria majority of the maize production is from the Guinea and Sudan Savannah climatic region known as the grain belt of Nigeria, and from mainly peasant farmers who use predominantly the traditional system of cultivation and storage. Guinea Savannah climate zone of Nigeria has average daily temperature range between 18–39^{0}C. 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.

Hermetic Storage technology

Hermetic storage technology refers to a system of storage whereby oxygen is depleted by natural or artificial means in an air tight storage structure, creating a non life sustaining modified atmosphere. This will enhance the gradual asphyxiation of insects and other micro organism that depends on the oxygen to live, thereby maintaining the quality of the stored products. Hermetic storage structures are naturally made of different materials and are built or made to be air tight by man. Apart from being air tight, the functional requirements for an efficient crop storage structure must also be fulfilled to enhance its primordial functions [6]. Hermetic storage structures could be classified as rigid or flexible, based on their structural rigidity. Rigid hermetic structures are hermetic storage structures that are made of non-flexible material such as metals, metallic alloys, plastics and glass. They are the fundamental hermetic storage structures used by man from cradle. Rigid hermetic storage structures have proved to be efficient storage structures for any type of hermetic storage, affording an air tight environment with almost 100% impermeability to the ambient air [7] . The most critical problems associated with flexible hermetic storage structures such as rodent attack, human pilferage and deliberate piercing of holes by mischievous person or domestic animals are practically inexistent with rigid hermetic storage structures. However, major issues associated with rigid hermetic storage structures include improper sealing of the edges, loading and the unloading points. Various rigid hermetic structures have other problems ranging from moisture condensation, to high cost of hermetic storage structures. Individual materials used for the construction of hermetic storage structures, differ in reactions to external climatic conditions. Rigid hermetic storage structures made of metallic materials are bound to have condensation problem which is also expected in plastic but not in glass containers, but glass and plastic containers are relatively expensive, and as such peasant farmers may not be able to afford them. However, according to research, if rigid hermetic storage structures are kept under a shade or roof during storage, better results are normally achieved [7]; [8]. Pressure decay tests (PDT) can be conducted on the structures to ensure that hermetic conditions are guaranteed or a more common test, which is to fill the storage structure with water, and check for leakages, especially if the material of construction is not water absorbent. Hermetic metallic containers are rigid storage structures made of metallic or metallic alloy materials. It is one of the storage structures promoted by FAO for low level and on farm storage in developing countries. The early metallic containers were not naturally made for hermetic storage, but were sealed to guarantee air tight conditions were the first type of hermetic structures used for this purpose. Recent technological developments have evolved different types of metallic structure purposely designed for hermetic storage with good loading and unloading points [8].

Plate 1: Metallic aluminum containers

II. MATERIALS AND METHODS

Hybrid single cross maize (Hybrid 9021) was purchased from Mariga market, a grain market near Minna and stored in 6 numbers 100kg capacity 2.5mm gauge aluminum metallic containers fabricated locally by artisans. The stored grains are from the present harvest and had not undergone any form of storage before sale at the market. The detail process of production, drying and threshing and handling was sought from the farmers before purchase to ensure this. The grains were properly cleaned and immature grains, broken and bad grains picked out before storage. The metallic containers were examined for leakage by pouring of water into them and allowing it to stay for 24 hours and examine for leakages. Samples of the grains were taken in triplicates with sampling bags that will not allow the alteration of the properties before laboratory analysis. Samples were analysis to determine its quality and mass properties before storage, as described in American Association of Analytical chemist [9]. The grains were loaded to the brim in the metallic silos. The loaded grains were agitated very well to reduce the void volume and lower the amount of air trapped in the loaded silos. The metallic containers were sealed properly and kept under shade in a naturally ventilated atmosphere for 12 months spanning through the two climatic seasons. Samples were collected on bimonthly basis from one metallic silo for 12 months. Any sampled silo automatically was withdrawn from the experiment due to the alteration of the modified atmosphere. Samples were taken in triplicate for analysis.

III. RESULT AND DISCUSSIONS.

Quality loss evaluation

The result of the quality evaluation is presented in Figures 1.2.and 3 respectively.

Crude protein (CP)

The result of the statistical analysis of crude protein over the observed period showed that there was depreciation of crude protein content of the stored maize, from 10.00 ± 0.23a to 4.52 ± 0.10 The crude protein content of maize recorded 54.8% percentage depreciation and 1% level of significance depreciation after 12 months of storage. This may be due to protein denaturation, grain respiration and or grain age due to long storage. The trend of depreciation is in agreement with [10]; [11], who reported decrease of crude protein during maize storage. [12]; [6]; [13] all reported significant depreciations. Higher values of depreciation were reported, for unsealed storage, where grain metabolic activity during storage is expected to be relatively high.

Crude fat content (FC)

The crude fat content of the stored maize depreciated at 1% level of significance after 12 months of storage with the following values, FC, 4.96 ± 0.11 to 4.08 ± 0.09. The statistical analysis also revealed that. FC for maize stored in had 17.7%, percentage depreciation and 1% level of significance after 12 months of storage. This implies that the FC content of stored maize is dependent on the duration of storage, having depreciated progressively from the control value in January at -0.76,-0.36,-0.18,-0.68, -0.72,-0.88 on bi-monthly basis. The downward progression as observed in Figure1, may be due to storage or drying process or burning off of other extract crude fats and fatty acids which occurs in grains. The direct implication is the reduction in the baking quality due to the release of unsaturated fatty acids as reported by [14].

Crude fibre content (CF).

The crude fibre content after 12 months of storage showed 1% significant deprecation with the following values, CF 2.50 ± 0.06 to 1.00 ± 0.02e for the stored maize from the inception to the end of storage. The study also revealed that the crude fibre CF had high 60% percentage depreciation over the storage period. The monthly change in the crude fibre content of the stored maize in rigid structures on bi-monthly basis are as follows -0.40, -0.50, -0.80, -0.70, -1.00, -1.50, The implication of the results presented, is that the crude fibre content is dependent on the duration of storage. However, this result is in agreement with [11] who also reported the progressive decrease of crude fibre of wheat during long storage. The result of this finding supported an initial claim by [13] about decrease crude fibre content of maize, though lower values were reported in his findings between (2.03% to2.5%), while [15] reported slightly higher values (2.07% to 2.77%) during storage

Crude ash content (AC)

The crude ash content of the stored maize depreciated after 12 months of storage with the following values, 2.04 ± 0.05 to 1.50 ± 0.03, The study also revealed that AC had high percentage depreciation over the storage period as presented in Figure 1, from 26.47%, to 8.87 and 1% level of significance. From the above results crude ash content of the stored maize is dependent on the duration of storage. The fluctuations noticed in the depreciation may be due to experimental errors. The result is in agreement with Chemeda et al. (2016) who reported progressive decrease in ash content of stored cereals. [16] reported increase in crude ash content value for wheat after 3 months of storage [17]; [18]; [19] all reported non- significant decrease in ash content of wheat stored for different storage periods less or equal to 6 months, .

Carbohydrate content (CV).

The result indicates that, there is a slight, non significant ($p > 0.05$) increase in carbohydrate value for the maize after 12 months of storage from 77.69% in January to 78.58% in December. The study also revealed that the CV had relatively low percentage appreciation over the storage period 1.15%, The monthly change in the carbohydrate content of the stored maize in on bi-monthly basis are as follows 5.64, 6.69, 5.95, 6.11, -1,15, 0.89. The implication of the results presented, is that the CV content is not significantly dependent on the duration of storage, though a little progressive increase was observed. 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 [20]. The result of this study is in agreement with [13]; [21] who all supported claims that carbohydrate content increases during storage.

Energy value (EV)

The result of the statistical analysis of this study indicates that, there was a slight, non significant ($p>0.05$) increase in energy value after 12 months duration of storage, of the stored maize from 379, 99g/kcal in January to 380,56g/kcal in December. The study also revealed that the EV had relatively low percentage change in composition over the storage period (0.15%). The monthly change in the energy value (mean deviation) of the stored maize on bi-monthly basis is as follows 27.93, 31.03, 3.59, -3.19, -2.63. The implication of this result is that the energy value of the stored maize may even be better than the newly harvested ones especially if the energy value is what is desired . The result obtained is in agreement with [19] who reported no significant decrease in energy content of stored wheat after 12 months of storage. [22] reported that duration of storage does not affect energy content of stored cereal grains.

Lysine and Tryptophan content

Amino acids are the building blocks of protein, and are essential parts of cereals. Though they are present in relatively small quantities to be compared to other nutrients, they are important, and must be supplied by diets, or be made by the body. Lysine and tryptophan are essential and limiting amino acids in maize, sorghum and most cereals [23] . This informs their choice among other amino acids, for this study. From the result lysine content of the stored maize showed 44% depreciation, which is significant at 1% level after the 12 months of storage, from 0.025mg/g to 0.014 mg/g. The tryptophan content for the stored maize showed the same depreciation pattern with lysine. Percentage depreciation is 8% from 0.046 mg/g to 0.0423mg/g and was significant at 1% level. The decrease buttresses the fact that stored grains utilize amino acids for metabolic activities and also through non-enzymic browning. Cereals are naturally deficient in lysine and drastically losses it in event of long storage [24]. It is also due to the fact that maize storage proteins contains less glutamine and proline and more of hydrophobic cross-linked zien which are very soluble on heating or after reduction of disulphide bonds [24; [25].

Riboflavin and Niacin

Riboflavin and niacin are important components of vitamin B, which are essential parts of cereals. They are vital for the balance of diets for both human being and animals. From the result presented in riboflavin and niacin content depreciated at 1% level respectively within the storage duration. Riboflavin and niacin content of the stored maize depreciated from 0.700 ± 0.02 to 0.012 ± 0.001 and 0.341 ± 0.002 to 0.0198 ± 0.000**,** after 12 months of storage. The result is in agreement with [26] who reported that some vitamins are more soluble (less affected by processing and storage) than others. Water soluble vitamins (B-group and C) are more unstable than fat-soluble vitamins (K, A, D, and E) during food processing and storage. The implication is than other fat soluble vitamins may have more tendencies not to depreciate during long storage than the water soluble which niacin and riboflavin is one of them [22]; [18] .

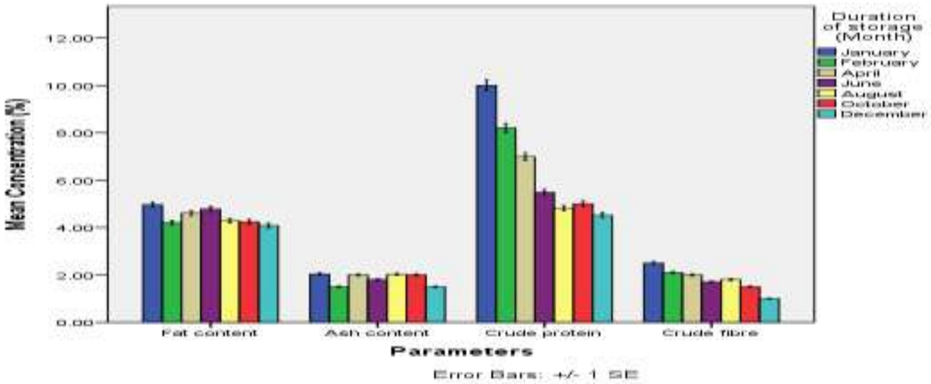

Figure 1.Crude fat, ash, protein and fibre content of the stored maize after 12 months of storage.

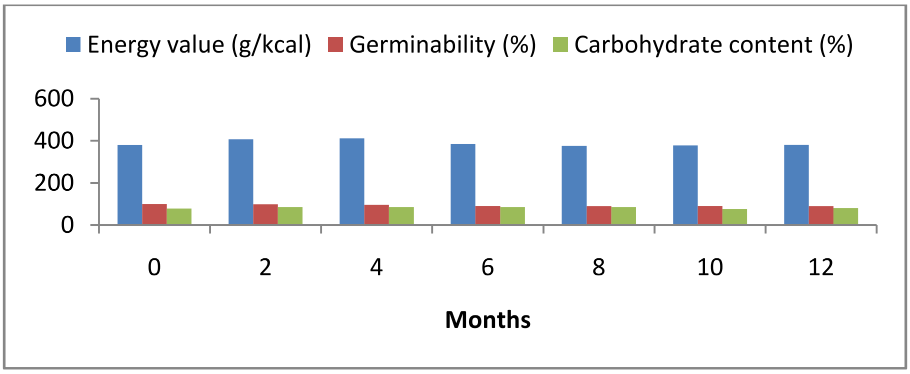

Figure 2. Energy value, germinability and carbohydrate contents of the stored maize after 12 months of storage

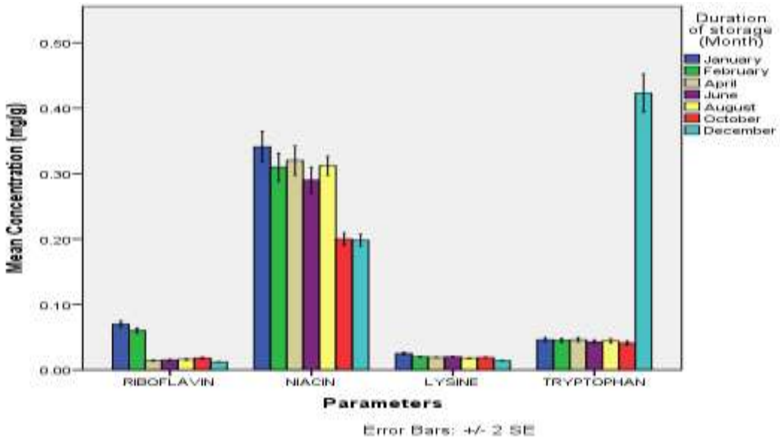

Figure 3. Riboflavin, niacin, lysine and tryptophan content of the stored maize after 12 months of storage

Mass losses of the stored maize.

The result of the quality evaluation is presented in Figure 4. The mass characteristics/loss could be estimated using bulk density (BD) or moisture content (MC) wet basis (wb). Mass losses in stored grains are due to grain shrinkage, loss of moisture, loss of dry mater due to insect/pest damages, grain deterioration, and biochemical activities such as grain respiration [6].

Bulk density (BD).

The result of the statistical analysis indicates that, the stored maize had a non significant ($p>0.05$) decrease in bulk density after 12 months duration of storage, from 0.74g/cm^3 in January to 0.68 cm^3 in December. The result also revealed that the BD had relatively low percentage depreciation of 8.11% over the storage period. However the non significant depreciation observed may be due decrease in bio-chemical activity of stored grains, relatively low moisture, dry matter and shrinkage losses in observed in sealed storage structures. The result obtained is in agreement with [12]; [26]; [5] , though higher values were reported, conditions of storage or systems were unsealed storage. Variety of the crops, modified atmospheric conditions of hermetic storage, may be responsible for the different values reported.

The bulk density which is the test weight has a direct relationship with moisture content, and the magnitudes of the two variables are determinants to the rate of mass loss in stored grains. The behaviour of bulk density is synonymous with moisture content, supporting claims by [27 that a change in moisture content of a grain will affect the test weight. After the initial decrease in values due to constant rate of moisture loss/ drying, the bulk density or hectolitre weight remained almost constant with minute fluctuations, which may be attributed to the water activity of the grains. In a similar research [27] demonstrated that sorption cycle affects some physical and nutritional characteristics of agricultural grains including the test weight and germinability though values were not given.

Moisture content (MC)

The result of the statistical analysis of this study indicates that, there was a significant (p>0.05) decrease in moisture content of the stored maize at 1% level after 12 months duration of storage. The MC stored maize depreciated from 10.90% in January to 8.90% in December. The percentage depreciation over storage period is 33.9% The monthly change in the moisture content from the control in January (mean deviation) of the stored maize in both rigid and flexible storage structures on bi-monthly basis are as -1.00, -2.14, -1.50, -2.00, -2.98, and -3.70, The moisture content is significantly affected by duration of storage. This may be due to moisture reduction and continuous drying of grains during storage, moisture sorption and desorption and or the fluctuation to attain equilibrium moisture content. The result is in agreement [6]; [12], where significant losses of moisture were reported. The graphical presentation of moisture loss using moisture content wet basis (wb) is presented in Figure 4. The numerical calculations of mass loss show that 39.80kg/1000kg was the total mass loss after the 12 months of storage using moisture content calculations.

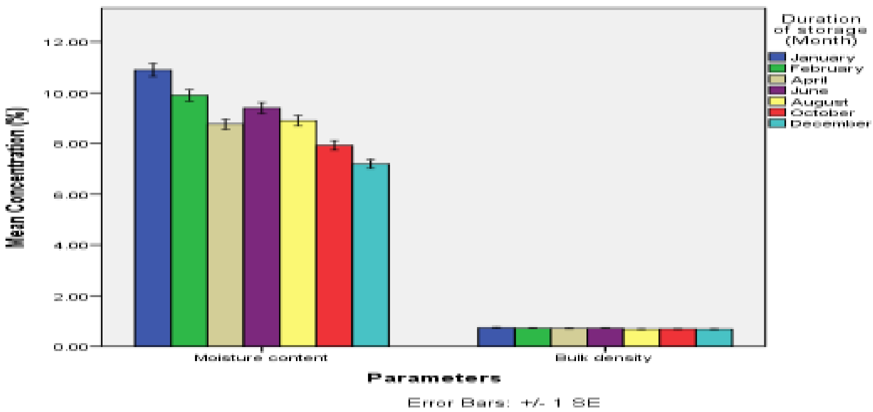

Figure 4. Moisture content and bulk density of the stored maize for 12 months storage duration

IV. CONCLUSION AND RECOMMENDATION.

Based on the findings of this study aluminum metallic silos retained quality and mass characteristic of the stored grain, especially when compared with other storage system and structures**.**

The potentials of hermetic storage aluminum container are enormous, as one of the storage structures promoted by FAO for the replacement of traditional storage structures. Its ability to reduce the protracted storage losses recorded annually in developing countries is not in doubt.

Since the future of cereal grain storage globally lies with non-chemical form of storage It is recommended that the Government should do more in the area agricultural extension services and public awareness to enhance the introduction, publicizing and promotion of hermetic storage technology for use at all levels of grain storage in the country.

Recommended modifications for effective storage include the sloping of the silo shoulders during construction to enhance self cleansing characteristics especially against water seepage which could find its way into the grain after settling in the shoulders of the silos for a long period of time

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