Assessment of Quality and Mass Loss of Sorghum (Sorghum Bicolour L. Moench) Stored in Metallic Silos in Minna, Nigeria

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***Abstract*--This research assessed the quality and mass loss of sorghum stored in metallic silo, in Minna, Nigeria for a period of eight months. The grain stock in the silo facility was managed using integrated bulk grain management procedures (IBGM) in metallic silos. A 2,500 metric tonnes capacity metallic silo out of 10 numbers assembled in a battery form was loaded with red coloured sorghum (*Sorghum bicolour*) SAMORG-14 variety. Samples were taken randomly from the bulk and analysed before binning which will serve as control and subsequently on monthly basis, at designated depth and locations. The samples were analysed using standard methods. The quality and mass characteristics assessed within the period, include moisture content (MC), bulk density (BD),carbohydrate (CHO), crude fat (F), ash (A), crude protein (CP), crude fibre (CF), germinability (G), and Energy value (EV). Data generated were analysed to determine significant levels using Statistical package for social sciences (SPSS). Multiple analyses of variance (MANOVA) and Duncan's multivariate test was used to determine the trend of deterioration. Values obtained were compared with the control values. The result of this study shows that all the quality and mass characteristics evaluated are significant ($p<0.05$) with duration of storage. The following parameters depreciated from the control within the duration of storage, F (3.5%-1.4%), BD (98kg/m^3-91.3kg/m^3), CP (11.42%-6%), A (2%-1.15%), CF (4.76%-3.24%), MC (9.0%-6.98%), G (99%-86.4%) This may be due to fluctuations in storage conditions, grain respiration, age and shrinkage. The results also revealed that EV (366.6kcal-404.3kcal) and CHO (76.6% -79.2%) increased significantly ($p>0.05$) from the control within the 8 months duration of storage, probably due to continuous loss of moisture and the depreciation of other variables. The quality and mass characteristics of sorghum stored in metallic silos in Minna, Nigeria is significantly affected by duration of storage.**

Keywords: ***Metallic Silos, Sorghum, Storage Losses, Degenerating Changes In Storage, Stored Grain Ecosystem*.**

I INTRODUCTION

Sorghum (*Sorghum bicolour L. Moench)* is a major cereal grain that is widely grown and stored in Europe, America, Asia and Africa. It is an integral member of grass family called (*Poaceae*). It is the fourth most important world cereal and the second most important cereal after maize in Sub-Saharan Africa [1], [2]. Sorghum (*Sorghum bicolour*) seems to have originated from the Sahel/dry lands of Sub-Saharan Africa, and diffused to other areas such as the Middle East, Asia, Europe and America through the slave traders. It ranks second to maize as the most popular cereal grain planted and stored in Nigeria [3. Nigeria is the second largest producer of sorghum in the world, and highest producer in Africa with 10 million metric tonnes (mmt) per annum [1]. The world sorghum economy and storage consist of two distinct sectors; a traditional, subsistent smallholder farming sector where most production are consumed as food (mainly in Africa, Middle East and Asia) and modern mechanized large scale sector where output is largely used for animal feeds in the developed countries [4]. The grain consists of a naked caryopsis, made up of a pericap, endosperm and germ as shown in Plate 1, although there is a huge range of diversity. Sorghum is classified into four groups namely, grain sorghum, forage sorghum, grass sorghum, and Sudan sorghum. They are grouped using the colour of the pericap (white, yellow, or red) [20]. Sorghum is rich in protein and carbohydrate; other constituents include lipids, vitamins and minerals [5]. As one of the grains with huge protein content, it is being relied upon as a cheap source of plant protein for human consumption especially in the developing countries where animal protein is increasingly becoming unaffordable [6]. In Savannah and the arid region of Africa, millions of people consume sorghum in their daily diets. It constitutes a staple food high in energy. It is an environmental friendly and water efficient plant; its ability to be grown in extremely harsh climates with little or no amount of fertilizer and pesticide makes it peasant farmers friendly

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Plate 1: Sorghum *bicolour*
Source. [20]

Sorghum 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 [7]. At farmers' level in Africa where output is low, it is mainly stored with traditional storage structures while in developed countries where individual output is high, modern storage structures are used [8]. As a hygroscopic and biological active material, its interaction with the immediate environment during storage is ongoing. In bulk storage of sorghum in metallic silos, especially for long period in the tropics where moisture condensation and migration are imminent, certain degenerating changes are expected to occur that will certainly affect the quality and mass characteristics. Irrespective of the integrated bulk grain management strategies, the extent of the degeneration of the grains is largely dependent on the Grain storage factors such as physical, biological, and climatic [9]. Climatic variables known to influence storability of cereal grains in metallic silos include temperature, humidity, rainfall or precipitation, solar radiation and wind [10].

The characteristics and behaviour of the structural materials used for the construction of any silo, 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 walls of the silo, the head space and inside the grain mass. Higher temperature will invariably result to more moisture condensation on the metallic silo walls [11]. Humidity as a variable also affects the physiological response of stored grain and organism/pest in the storage bin. Wind speed and direction and size of ventilation openings also play an important role in the thermal state/regime and stability of metallic silo temperatures [12]. The rainfall pattern in any geo-ecological zone no doubt plays an important role in the thermal stability/regime of metallic silos, especially during the raining 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 silos directly and as well as the grain mass. However, with proper monitoring and control of all these variables mentioned, enormous storage losses associated with sorghum storage in metallic silos can be minimized [7].Minna is located in the Northern Guinea Savannah agro-ecological zone of Nigeria. The dry season lasts between November and March with the on-set of rain usually around April. The average monthly temperature ranges between 28.5°C around the wet season of August to 38.9°C in the dry season of February and March giving a range of 10.4°C. The corresponding average monthly rainfall is usually about 409 mm in August and none in February and March. These 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 [12].

Integrated bulk grain management in metallic silos (IBGM) includes the use of a wide range of grain management procedures to maintain the quality of stored grain in metallic silos [13]. The main objectives of IBGM are basically using the most cost effective ways of controlling insects/pests, maintaining the quality of grains in storage, without harming either the environment or the grains, and the grains still kept fit for human consumption [14]. The procedures as mentioned above include, non-compromise of standards during grain reception, sanitation of the grain facility, record keeping, monitoring and control of stored grain ecosystem, integrated pest management (IPM), regular physical inspection and analysis of grains, grain turning and workers health and safety.

Monitoring and control of stored grain ecosystem, entails monitoring variables like temperature, humidity with industrial measuring devices and controlling them using aeration fans, dehumidifiers, and grain turning. However, IPM can be defined as the use of all available methods/knowledge to keep pest population below economical damaging levels in a manner that is profitable and causes no harm to human health and the environment [14]. . IPM is the most important aspect of grain management due to the complex nature of insect morbidity, development of resistance to chemicals, the emergence of new species, and chemical residues left on grains as they are treated with insecticides.

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II METHODOLOGY

The experiment was carried out in Strategic Food Reserve Silos Complex in Minna, Niger State Nigeria. Red coloured variety, SAMSORG-14 (*Sorghum bicolour*) used for this research was sourced within local markets in Niger State, by Government accredited grain suppliers. The grains are from the present harvest (year 2014) and have not undergone any form of storage before supply to the silo facility. Standard procedures were followed during the grain reception, which include sampling, analysis of the grains to check if it meets up to the FAO standard, for bulk grain reception. The consignment may be accepted or rejected, after the analysis depending on the result. The accepted grains were cleaned and weighed using a set of cleaner, aspirator/cyclone and a weighbridge. Online fumigation was carried out on the grains using a tablet dispenser, before finally binning of the grains.

The accepted grains were loaded in 2,500 metric tons metallic silo cells using grain handling equipment such as elevators, augers, conveyors chutes and sprouts. The silo cells were assembled in a battery form in an open space as presented in Figure 1. Samples of the grains to be stored were taken at random, before loading (binning) to determine the initial properties of the red sorghum, which also served as control. Subsequent samples were taken on monthly basis for a period of eight months, with the aid of a sampling probe, 3 metres beneath the surface of the bulk, from 9 designated well-spaced positions/locations. The samples were mixed thoroughly to get a through representative sample. The experiment ran from January to August, 2015 spanning through the wet and dry season prevalent in Northern Guinea Savannah agro-ecological zone of Nigeria.

Samples were analysed using standard methods, in triplicates and the mean was taken as the tentative value. Destructive method of analysis was used to analyse the samples in National Cereal Crop Research Institute, laboratory Badegi, Niger State. All the reagents used for the analysis are analytical grade. The temperature and relative humidity of the storage environment were also monitored within the period. The position of the silo cell used in the battery arrangement, the sampled position and the dimensions of the silos used are illustrated in Figures 1, 2a and b. statistical analysis of data from was done using Statistical Package for Social Sciences (SPSS). Multiple Analysis of Variance (MANOVA), and Duncan's multivariate test was used to determine levels of significance of variables, and trends of deterioration or appreciation from the control, for all the values obtained in respect of duration of storage.

Immediately after bining, the grains inside the silo were levelled for easy access, performance of various tasks and or silo inspection, and the reduction of the grain surface area prone to insect attack in accordance with IBGM. The height of the grains in the metallic silo is 8 m from the silo base. Each silo cell has aeration facilities, temperature monitoring and control systems, inspection window/manhole, internal ladders and roof vents. Within the period of this research work, the grains were fumigated thrice and each time with fumigant (phostosin) and grain surface protectant (coopex dust) used to protect the grain surface from in-flight insects. The 2,500MT metallic silo is the galvanized steel type, a product of Chief industries Nebraska USA installed in 1989, Aeration of the sorghum was carried with two non-mobile centrifugal aeration fan with air flow rate 0.03 cfm (cubic feet air per minute) installed in parallel position in a double (T) silos floor layout. The aeration was carried out at irregular intervals, especially whenever grains temperature reading indicates abrupt increase, but averagely twice in a week and for 30 minutes each time.

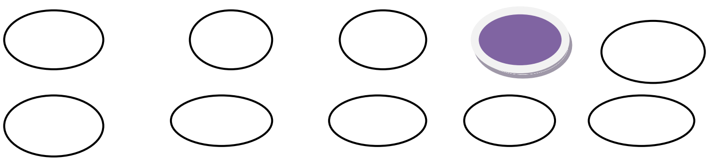
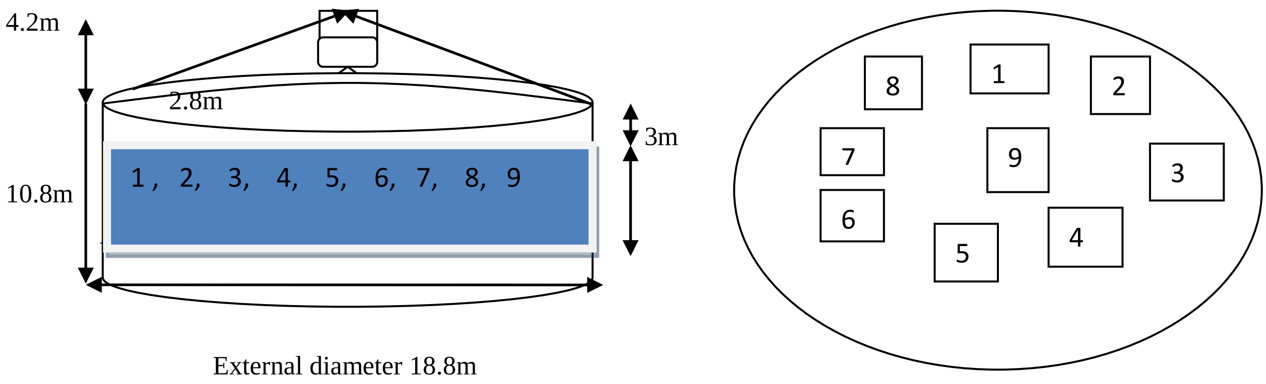


Figure 1: Position of the 10 silo cells in battery and the shaded one, used for the research



(2a) (b)

Figure: 2a Dimension of the silo used, shaded portion is the area occupied by grains. (b) The sampling positions inside the metallic silo.

(III) DETERMINATION OF QUALITY AND MASS CHARACTERISTICS OF THE STORED SORGHUM.

(A) Determination of mineral content

The mineral content of the stored sorghum was determined by using the method described by [15]. The ash obtained from the ash analysis earlier was used in the determination of the minerals content. The ash was placed in porcelain crucibles, and then few drops of distilled water were added and 2ml of concentrated hydrochloric acid. 10 ml of 20% HNO_3 were also added and evaporated on the hot plate. The samples were filtered through Whatman filter paper into 100 ml volumetric flask. The mineral elements; iron, magnesium and calcium were determined by atomic absorbance spectrophotometer.(AA800 perkin-Elmer, Germany). The phosphorus in the sample filtrate was determined using Vanadomolybdate reagent at 400 nm using colorimetric method (Colorimeter SP20, Bausch and Lamb).

(b) Determination of moisture content

The moisture content was determined using oven method as described in [15]. An empty crucible was weight and 2g of crushed stored sorghum the sample was transferred into the crucible and re-weighed. The crucible and the sample was transferred to an oven and dried for 24hours at 100^{O}C. The crucible and its content were cooled in a desiccators and re-weighed. The loss in weight before drying and after drying is expressed as a percentage and regarded as the moisture content.

$$\%\ \text{moisture} = \frac{weight\ loss}{weight\ of\ sample} \times 100$$

***(c)** Determination of crude ash content*

5g of samples of crushed stored sorghum were weighed in a crucible in duplicates and incinerated in a muffle furnace at 550 ^{O}C until a constant weight is attained and a light grey ash was observed. The sample was cooled in a desiccator and re-weighed to obtain the ash content as described in [15].

$$\text{Ash}\ (\%) = \frac{weight\ of\ ash}{weight\ of\ sample} \times 100$$

(d) *Determination of crude protein content*

The crude protein content of stored sorghum was determined using Kjeldahl method as described in [15]. 2g of the sample of crushed stored sorghum was put in a digestive flask 10g of copper sulphate and sodium sulphate catalyst were added in the ratio of 5: 1, and concentrated sulphuric acid were also added to the digestion flask. The flask was futher placed in a distillation apparatus and 10ml of 40% of sodium hydroxide were added. The released ammonia by boric acid was treated with 0.02 of hydrochloric acid until the green colour changes to purple. The percentage of nitrogen present in the sample is calculated using the formular below.

$$\text{Nitrogen}(\%) = \frac{Titre - Blank \times 14.008 \times Normality}{weight\ of\ sample} \times 100$$

$$\%\ \text{crude protein} = \%\ \text{Nitrogen} \times 6.25$$

(*e*) *Determination of crude fibre content*

5g sample of the crushed stored sorghum was weighed into a 500ml and transferred in a porcelain dish. After drying of the sample at 105 ^{O}C for 24hours the sample was transferred in a desiccator and weighed as w_1. The sample was then burnt in a muffle furnace for 6 hours at 500 OC and allowed to cool and re-weighed as w_2. The crude fibre was calculated using the formular below according to [15].

$$\%\ crude\ fibre = \frac{w1 - w2}{wo} \times 100$$

w_1=weight of the crucible+ fibre +ash
w_2= weight of the crucible + ash
w_o= Dry weight of food sample

(*g*) *Determination of crude fat content*

The Soxhlet extraction method was used for the determination of the fat content according to [15]. 3g of the crushed stored sorghum was weighed in a flat bottom flask with an extractor mounted on it. The thimble was held half way into the extractor. The thimble was held half way into the extractor and the weighed sample. Extraction was carried out using (boiling point 40-60C). The thimble was plugged with cotton wool. At completion of extraction which lasted for 8 hours, the solvent was removed by evaporation on a water bath and the remaining part in the flask was dried at 80C for 30 minutes in the air oven to dry the fat and then cooled in a desiccator. (Igbabul *et al*,.2014).The flask was reweighed and percentage fat calculated as

$$\%\text{Fat} = \frac{weight\ loss}{weight\ of\ sample} \times 100$$

(h) Determination of carbohydrate content

The carbohydrate content is calculated by adding the sum of (moisture +ash+ crude+ crude fat+ protein +crude fibre) subtracted from 100, according to [15].

(i) Determination of bulk density

The bulk density was determined by simple weighing of grains inside a known volume container in the laboratory and as well as determining the weight, in accordance with the standard approved by (AOAC, 2005). The values were further confirmed using multi grain analyzer and hectolitre meter.

$$\text{Bulk density} = \frac{mass\ of\ the\ container\ with\ the\ grain}{volume\ of\ the\ containet}$$

RESULT AND DISCUSSIONS

Within the period of this experiment, temperature and relative humidity of the immediate environment fluctuated due to prevailing unstable climatic conditions as presented in Table 1. At period of regular rainfall the humidity increases while temperature decreased significantly and the reverse was the case during extreme dry conditions. The monthly deviation of each variable from the control is presented in Table 2

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Table 1: Average monthly temperature and relative humidity data within the period of the experiment from January to August 2015

MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG
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 result of this research and the graphical illustration in Figures 3 and 4 shows that the following variables, CFAT, BD, CP, AC, CF, MC, Na and Mg decreased with duration of storage while EV and CHO increased with duration of storage. They are significantly dependent on the duration of storage with varying deviations from the control ($P < 0.05$) for all the values obtained for each variable. The Crude fat content had a downward progression which may be due to degradation of fatty acids during storage or drying process as reported by [9]. The direct implication is the reduction in baking quality. The Bulk density reduction has direct effect on the mass and weight of the grain, and this is due to the reduction of moisture content and continuous drying of grains during storage, and grain respiration which use up internal nutrients of grains. BD is a critical factor, especially when the basis of sales and grading of grains are done on weight basis.

The mass loss of the stored sorghum could be quantified and calculated in terms of monetary value using any of the two important variable namely, MC and BD or by determination of the weight before and after storage This can be done using simple equations.

The Crude protein content also showed a significant decrease with the duration of storage. The high storage temperature inside the silo bin and the immediate environment may be responsible. This is also expected to facilitate the denaturation or degeneration of amino acids which are the building block of proteins [17].

Table 2: Monthly mean deviation of variables from the control

	MC	BD	CP	CA	EV	CHO	CFAT	CF	G	Na	Mg
Control	9	98	11.42	2	366.6	76.6	4.76	3.5	99	3.12	1.96
JAN	0.1	0	1.21	0.1	-17.4	0.5	0.09	0.3	0	0	0.36
FEB	1.8	1.5	2.22	0.2	-22.4	0.6	0.64	0.7	2	0.82	0.44
MAR	2.1	4.8	3.26	0.4	-22.6	-0.4	0.64	0.6	2.7	0.82	0.48
APR	2.08	5.2	1.72	0.5	-24.7	-1.2	0.95	2	7	0.97	0.58
MAY	2.5	7.2	2.62	0.75	-25.2	-1.2	0.85	1.5	8.8	0.97	0.56
JUN	2.2	7	4.72	0.7	-25.5	-1.3	0.76	1.9	8.6	0.97	0.56
JUL	2.08	6.4	4.71	0.75	-25.8	-1.9	0.76	2.02	8.9	1.01	0.56
AUG	2.02	6.7	5.42	0.85	-37.7	-2.6	1.52	2.1	12.6	1.01	0.55

Positive values means there a decrease from the control while Negative values means there is an increase from the control

However, [16] upheld that crude protein content of cereal grains stored under good condition, devoid of insect infestation and mould is not altered by seed respiration during long storage. The result of the statistical analysis also shows that crude ash content and germinability of the stored sorghum are significantly affected ($P < 0.05$) by duration of storage at (2.0%-1.15%) and (99%-86.4%). What could be responsible is insect infestation, in which appreciable percentage of the grains are eaten up by insects. Germinability could depreciate due to insect, mould activity and heat (Faure, 1988). The result of germinability of the grains after 8 months of storage shows a significant reduction in germinability with mean deviation of 12%. Apart from insect and mould activity, other may be the presence of immature grains or moisture sorption cycle could also affect germinability as well, reported by [21].

The effect of higher temperature inside the silo bin and head space could also reduce thiamine content (important vitamin which acts as co-enzyme in various energy transfer biochemical reaction during metabolism) [17], [7].

Crude fibre content reduction from 3.5% to 1.4% during the 8 months of storage is very significant, and may be attributed to lipid hydrolysis, due to oxidation, seed respiration and other enzymatic processes/actions; Energy value and Carbohydrate content are significantly affected by duration of storage, considering the difference between control value and the values of variables after 8 months of storage (366.6 kcal-404.3kcal) and (76.6%-79.2%) as shown in Figure 3. This may be due to the reduction of MC/shrinkage and or other variables since they are expressed as percentage of the whole [18]. The assessed mineral contents Na and Mg also evaluated also depreciated within the 8 months of storage as illustrated in Figures 3 and 4, and this could be due to high temperature, inside the bulk of grain and the head space. It could also be inferred that stored sorghum could be better than freshly harvested ones especially if flour and energy is what is desired [19].

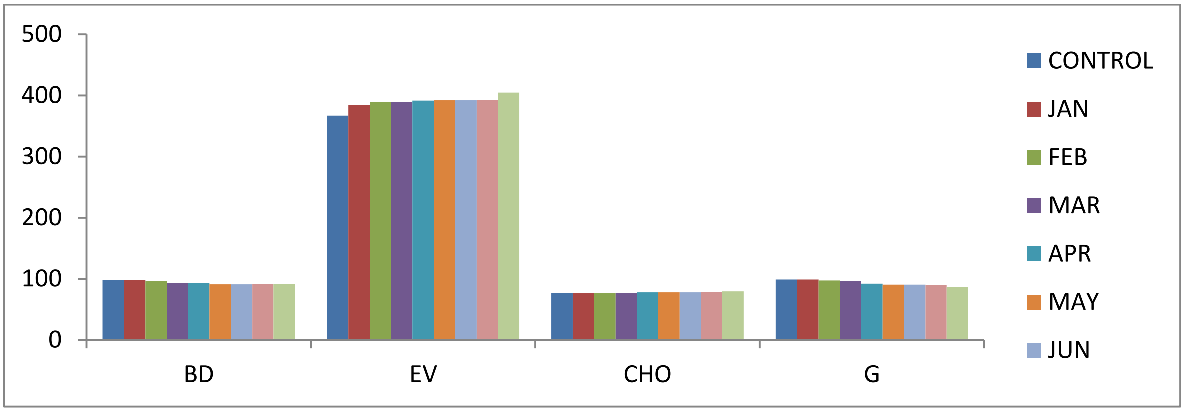

Figure 3: Average monthly percentage BD, EV, CHO, and G in respect to storage duration

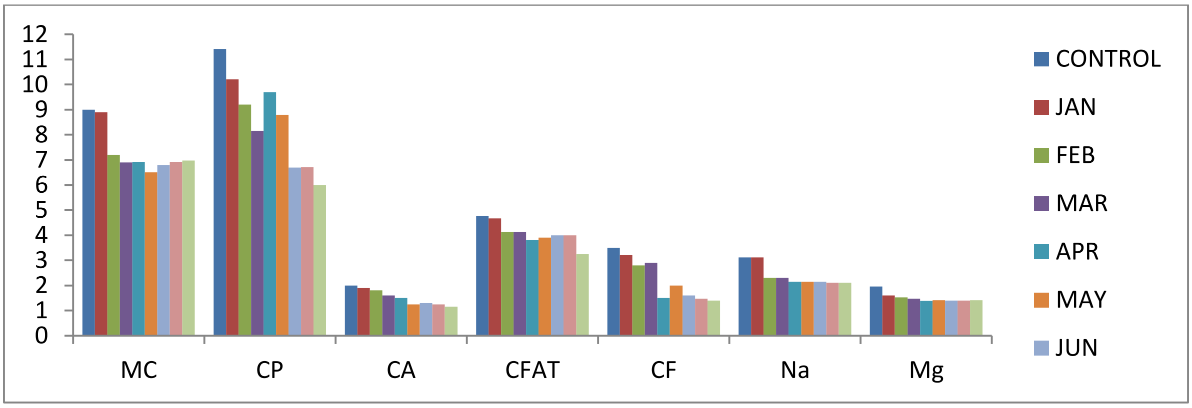

Figure 4: Average monthly percentage MC, CP, CA, CFAT, CF, Na, Mg, with respect to storage duration

CONCLUSION

The results of this research shows that quality and mass characteristics of sorghum stored in 2500 metric tonnes metallic silo, in Minna, Nigeria are significantly affected, by the duration of storage. Apart from the Carbohydrate and Energy value in which significant increase were recorded, all other mass and quality characteristics depreciated significantly within the 8 months duration of storage. The efficiency of metallic silos for bulk storage of sorghum in the tropics, as well as its impact in the quality and mass characteristics is largely dependent on storage conditions and its management, due to prevalent moisture migration and condensation issues. However with the provision of good storage conditions and management, the use of metallic silos for bulk storage will go a long way to aiding agricultural independence, storage of enormous paddy/cereal agro-raw material as well as enhancing food security in the developing countries.

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