Evaluation of nutritional characteristics of corn stored in metallic silos

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Abstract: This study assessed the nutritional quality attributes of maize (Zea mays) stored in metallic silos for a period of eight months in the humid tropics of Nigeria. The nutritional properties (NP) evaluated are percentage ash content (AC), crude fibre (CF), crude protein (CP), carbohydrate content (CHO), fat content (FC), and energy value (EV). The initial or control values were compared with the values obtained during storage. Statistical package for social sciences (SPSS 20) was used to determine the significant levels of data while the Multiple Analysis of Variance (MANOVA) and Duncan's multivariate test were used to determine the trend of deterioration ($P<0.05$) for all the values. The minimum and maximum average temperatures during storage were 29oC in July (wet season) and 34.7oC in April (dry season) respectively. The minimum and maximum average relative humidities during the storage period were 51% in March (dry season) and 71% in May (wet season) respectively. The mean deviation of FC, CP, AC, CHO, CF and EV are 7.25%±1.00%, 8.79%±0.87%, 3.5%±0.88%, 63.36%±0.99%, 6.25%±0.96% and 361.55%±1.00% respectively for the control in respect of the position of the grain in the bulk. FC, CP, AC, and CF decreases from 7.0% to 1.2%, 8.79% to 6.33%, 3.5% to 2.3% and 6.25% to 3.21% respectively during storage while the values CHO and EV increases from 63.36% to 83.2% and 360 kcal to 395 kcal during the storage.

Keywords: silo, corn bulk, storage, nutritional value

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1 Introduction

Maize or corn (*Zea mays*) constitutes a staple food in South America, South Africa and Sub Saharan Africa (SSA). It accounts for more than 50% of agribusiness in these regions (Akande and Lamidi, 2006; Olakojo et al. 2006; FAO, 2010; Mbuya et al., 2010).

Nigeria is the largest producer of maize in Africa with about 8 mmt per year and 85% of maize produced is consumed as food (IITA, 2009). Maize is rich in vitamins A, C and E, carbohydrates, essential minerals, protein, dietary fibres, and calories that are good source of energy (IITA, 2009). In Nigeria, the maize produced serves as a major source of protein for the people and has a biological nutritional value of 40% of that of milk (Bressani, 1992; IITA, 2009; Durojaiye, 2012). Maize grain accounts for about 15% to 56% of total daily calories in diets of about 25 developing countries particularly in Africa (Vasal, 2000).

The best qualities of maize are the ones from the present harvest irrespective of the intended use (FAO, 1995). 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).

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Maize (*Zea mays*) is hygroscopic and biologically active in storage. Temperature, humidity, rainfall or precipitation, solar radiation and wind are climatic variables that influence the storability of maize in metallic silos (Alabi, 2001). The 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 result to more moisture condensation on the silo walls (Alabadan, 2005), humidity affects the physiological response of stored grain and organism/pest in the storage bin, wind speed and the size of ventilation openings plays an important role in the thermal state/regime and stability of metallic silos temperatures (Ileleji, 2010) and the rainfall pattern plays an important role in the thermal stability of a metallic silos, especially during the raining seasons. However, with proper monitoring and control of these variables, enormous storage losses associated with maize storage can be minimized (Agodas, 2011).

Maize storage in Nigeria is often associated with high storage losses of 25% to 43% yearly (Osunde et al., 1996; Oyebanji, 1996; Adejumo and Raji, 2007; Ahmed, 2009) and as high as 65% (Mijinyawa, 2010). This is due to handling, inefficient and ineffective traditional storage structures and practices used by farmers (Igbeka, 1990). Food security can be achieved only if there is increased agricultural productivity, efficient storage system/structures and reduced pre and post–harvest losses. Efficient and effective storage structure made from affordable materials can ensure food availability, accessibility, stability and utilization (Alabadan, 2013).

The Federal Government of Nigeria increased the total storage spaces in its silo complexes to 1.3 million metric tons to stabilize the nation's food stock and the price of food items during period of emergencies (Okolo, 2013). The need to investigate the effectiveness of the metallic silos located in every state of the nation through research on storage duration in relation to quality makes this study a worthy research. The main objective of this study is to evaluate the nutritional characteristic of maize stored in metallic silos in Minna, Niger State, Nigeria.

2 Materials and methods

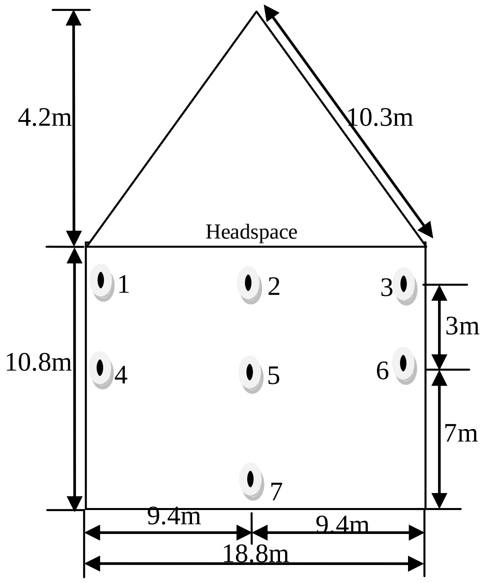
2.1 Raw material and sources

The research work was done in Federal Government of Nigeria owned National Strategic Food Reserve Silo Complex in Minna, Niger State, Nigeria. Minna is located in the Middle Belt 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^{o}C around the wet season of August to 38.9^{o}C in the dry season of February and March giving a range of 10.4^{o}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 in metallic silos (Alabadan, 2006).

The stock of maize used for this research work was delivered to the silo complex from December 2012 to January 2013. The type of maize *(Zea mays*) used is a mixed variety because of indiscriminate buying by different grain suppliers. The colour of maize (*Zea mays*) used for this research work is white only and was sourced within Guinea Savannah climatic zone in Nigeria.

2.2 Silos

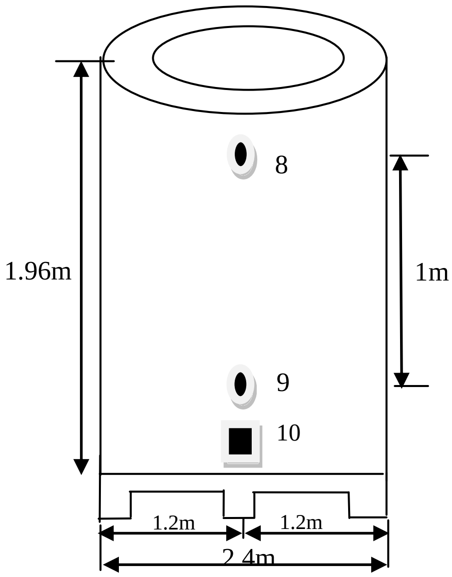
Two sizes of metallic silos, 2,500 mt galvanized steel and 1 mt aluminum silos shown in Figure 1 and Figure 2 respectively were used for the research. The 2,500 mt silo is the silo cell 9 of the 10 silo cells located in an out-door silo complex as shown in Figure 3. The 2,500 mt silo has two aeration fans in series, inspection window/manhole, internal ladders and roof vents. The one mt hermetic silo was installed under a tree shade alone in naturally ventilated position to store the grain hermetically.



Grain surface height = 3 + 7 =10m

Black hole, Point 7 is the manhole

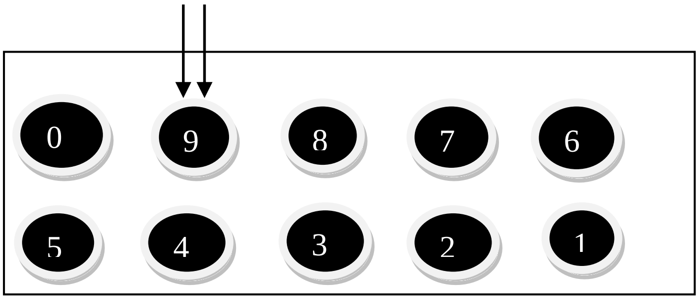
Figure 1 Dimensions of 2,500 mt silo



Black square, Point 10 is the unloading point

Figure 2 Dimensions of one mt silo

Silo used.



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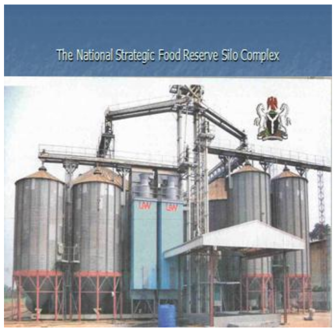

b

Figure 3 Silo arrangements

2.3 Experimental design

A complete randomized block design of one factor, six variables and three replications were used and the mean of the three replications were taken as the true value. The experiment ran for eight months from 10th January to 15th August, 2013. The period was selected taking into consideration the wet and dry seasons prevalent in humid tropics.

The ambient temperature and relative humidity and the silo headspace temperature were measured daily by 12:00 noon, using a Jenway 5105 digital psychrometer (Chief Industries Incorporated, Nebraka, USA) and a dry bulb thermometer and further confirmed by using a mobile temperature/relative humidity digital apparatus. Other material handling equipment such as elevator, cleaner, chutes, sweep augers, discharge augers and chain conveyors are from Alvan Blanch, UK.

The integrated pest management (IPM) procedure was strictly followed for the silo bin during the experimental period. Insecticide was applied inside the silos during the preparation of silo bins for grain reception. Grain management practices followed also included adherence to grain reception standards, monitoring and the control of stored grain ecosystem through aeration, grain turning and fumigation. Also, grain releases are done according to standards. Grains were fumigated twice during the period using phostosin as the fumigant. No insecticide was used during the storage period. The silo was aerated with the two aeration fans at the airflow rate of 0.30 cfm for one hour twice a week.

2.4 Experimental Procedures

2.4.1 Sampling collection technique

Samples were taken at random from the silos stored with maize in January, 2013 to determine the initial properties that serve as a control. All samples for the assessment of storage variables were taken monthly from the positions one to 9 shown in Figures 1 and Figure 2 for a period of eight months spanning the wet and dry season prevalent in Nigeria. About one kg of corn was taken per sample.

Samples from positions 1, 2, 3 and 8 were taken without the aid of a sampling probe, samples in positions 4, 5 and 6 were taken with the big sampling probe and samples 7 and 9 were taken by unloading the bulk to get sample.

Samples were taken at 28th of every month in triplicates with laboratory double layered minute sample bags to forestall alterations in the properties due to adverse weather conditions on transit and the analysis of the nutritional characteristic were carried out 6 h after the samples were taken due to the non-proximity of an efficient laboratory to run the analysis.

2.5 Analysis of samples

The nutritional analyses were done in National Cereal Crop Research Institute, Badeggi Niger State using the standard methods in accordance with AOAC (2012) guideline for food analysis. The nutritional compositions evaluated include ash content, crude fat content, carbohydrate content, crude fibre, crude protein and energy value. Samples were analyzed twice for comparison and the average of the two values was upheld as values for the given sample. The general linear model, multivariate test and graphs used for these illustrations were derived from the analysis of data using SPSS 2.0 Multiple Analysis of Variance (MANOVA).

3 Results and discussion

3.1 Ambient temperature and relative humidity

Table 1 contains the monthly average temperature and relative humidity for the storage period. The daily average maximum temperature records of the head space of the 2500 mt silo and the ambient recorded for the period of the experiment are presented in Figure 4.

Table 1 Monthly average temperature and relative humidity data during the storage period

Month	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG
R.H., %	55	53	51	52	71	68	69.8	69
TEMP., °C	34.5	34.2	34.2	34.7	32.0	30.0	29.0	30.0

The minimum and maximum average temperatures during storage were 29°C in July and 34.7°C in April respectively. The minimum and maximum average relative humidities during the storage period were 51% in March and 71% in May respectively. The recorded ambient and silo temperatures showed a similar pattern but the values at the headspace were consistently higher than the ambient. At the period of regular rainfalls in April, the humidity increased while the temperature decreased significantly but the reverse was the situation during extreme dry conditions in first three months of storage. The implication is that during the dry season storage will be less problematic as compared with rainy season.

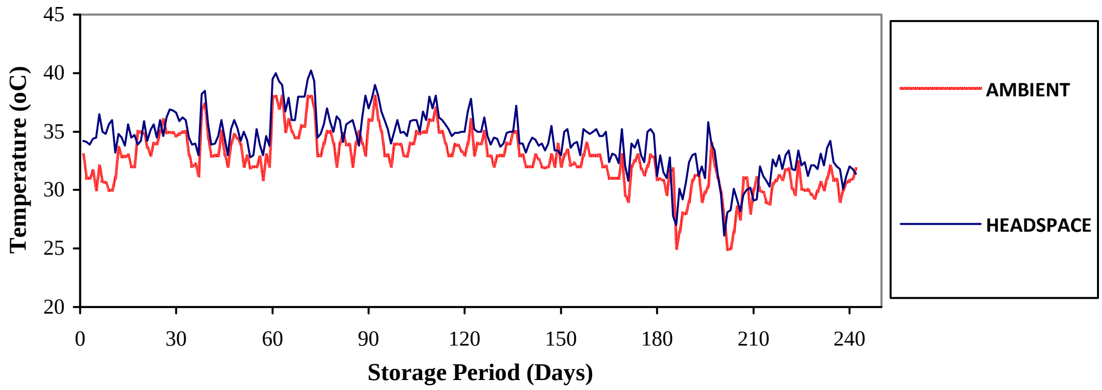

Figure 4 Silo and ambient temperatures

3.2 Moisture content of the stored maize

The moisture content of the stored maize is shown in Figure 5. The initial moisture content of 11.24% in January decreased gradually to 8.0% for position 1 in August. The stored maize moisture decreased during the dry season of the first three months but absorbed various degrees of moisture during the wet season from April to August.

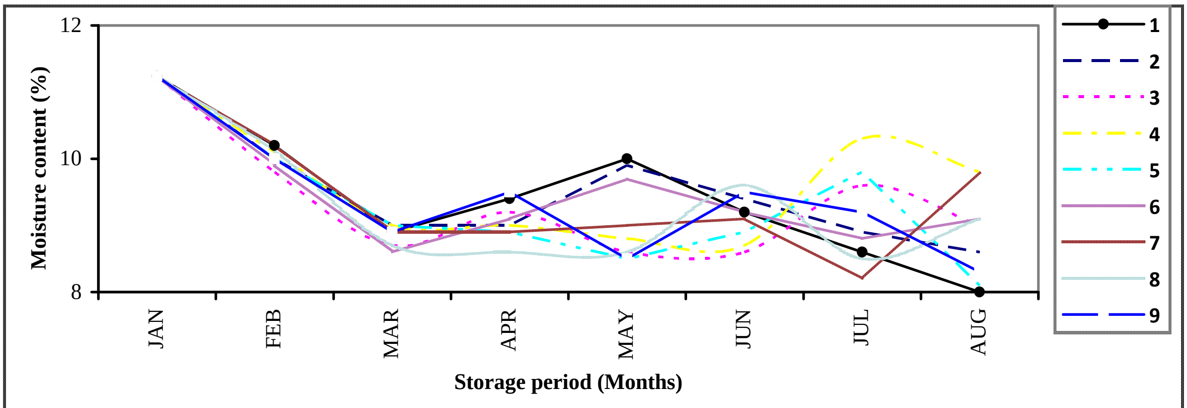

Figure 4: Moisture content of stored maize in the silos

3.3 Nutritional characteristics

The result of the average mean deviation of the nutritional properties from the control values during the eight months of storage are presented in Table 2. The summary of level of significance for various nutritional characteristics of maize stored in metallic silos, in respect to the duration of storage, the position of the grain in the bulk, and the control values are presented in Table 3. The statistical analysis showed that all the nutritional proximate characteristics were significantly dependent on the duration of storage irrespective of the size of the metallic silos with 0.00 significant levels ($p<0.05$) and varying deviations from the control. The nutritional variables relative to sample position remained insignificant since their various level of significance are higher than 0.05 ($p>0.05$) irrespective of the size of the metallic silos. The size of metallic silos did not have any significant effect on the nutritional characteristic of maize stored in metallic silos.

Table 2 Monthly mean deviation of nutritional proximate from the control in January

Month	MC	FC	CP	AC	CHO	CF	EV
January	10.85	7.25	8.79	3.50	63.36	6.25	361.55
February	-0.81	-0.66	-0.92	-0.51	+2.50	-1.22	+4.43
March	-1.98	-2.37	-2.10	-0.80	+8.31	-1.84	+12.60
April	-1.78	-3.61	-2.27	-1.56	+14.94	-2.36	+25.00
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	-2.30	-1.33	+19.91	-2.63	+35.11
August	-1.98	-5.95	-2.46	-1.07	+19.93	-3.08	+33.80

Note: Positive value means that there is increase in value away from the control and vice versa

Table 3 Summary of level of significance for various nutritional characteristics

Nutritional characteristics	Duration of storage	Remark	Sample positions	Remark	Control
Crude fat content (FC)	7.25±0.00%	*	7.25±1.00%	NS	7.25%
Crude protein content (CP)	8.79±0.00%	*	8.79±0.87%	NS	8.79%
Ash content (AC)	3.50±0.00%	*	3.50±0.88%	NS	3.50%
Carbohydrate content (CHO)	63.36±0.00%	*	63.36±0.98%	NS	63.36%
Energy value (EV)	361.50±0.00%	*	361.50±1.00%	NS	361.55%
Crude fibre (CF)	6.25±0.00%	*	6.25±0.96%	NS	6.25%

Note: * = Significant difference ($P \leq 0.05$) and NS= Not significantly different ($P \geq 0.05$)

3.4 Crude fat content

There is a significant and progressive decrease in the average fat content from 7.0% to 1.2% during the storage period as is shown in Figure 6. The result of the study indicates that the fat content is significant at 7.25%±0.00% with respect to the duration of storage and irrespective of the size of the metallic silos. Since $p<0.05$, it implies that the duration of storage has significant effect on the fat content. In respect to the different positions of grains in the bulk, 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 the position of the grain in the bulk has insignificant effect on the fat content.

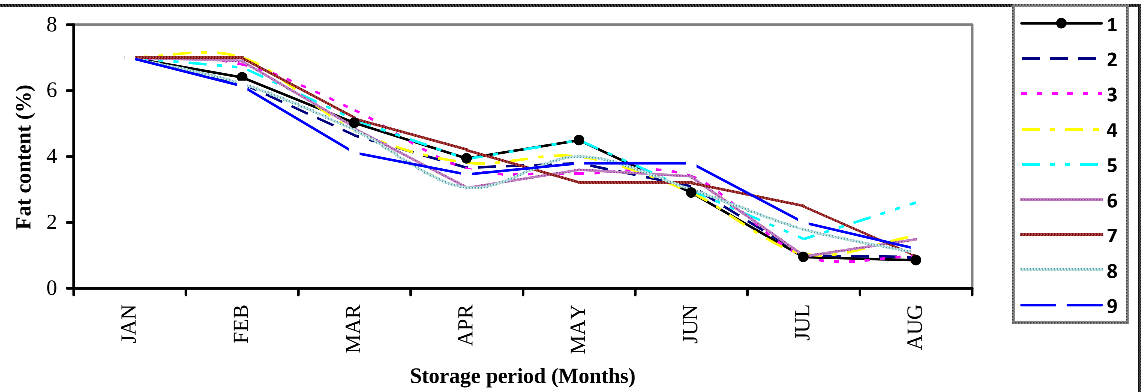

Figure 5: Fat content of stored maize in the silos

The irregular downward decrease in fat content observed with the duration of storage may be due to the burning off of other extract of crude fat and fatty acids which occurs in the grains during the storage and drying process. The direct implication is the reduction in the baking quality due to unsaturated fatty acid release during long storage as reported by Richard et al. (1990).

Osipitan et al. (2012) reported that the 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, the increase popularity in genetically modified maize (GM) and improved seeds available to maize farmers.

3.5 Crude protein content

The average value of the crude protein January (the control) was 8.79% but in August it depreciated to 6.33% as is shown in Figure 7. It shows that there is a downward progression with duration of storage. The result of crude protein during the storage period was 8.79%±0.00% and 8.79%±0.87% with respect to the position of the grains in the bulk and irrespective of the size of the metallic silos. Since $p<0.05$, it implies that sample positions is insignificant but the duration of storage has a significant effect on the crude protein content of maize stored in metallic silos.

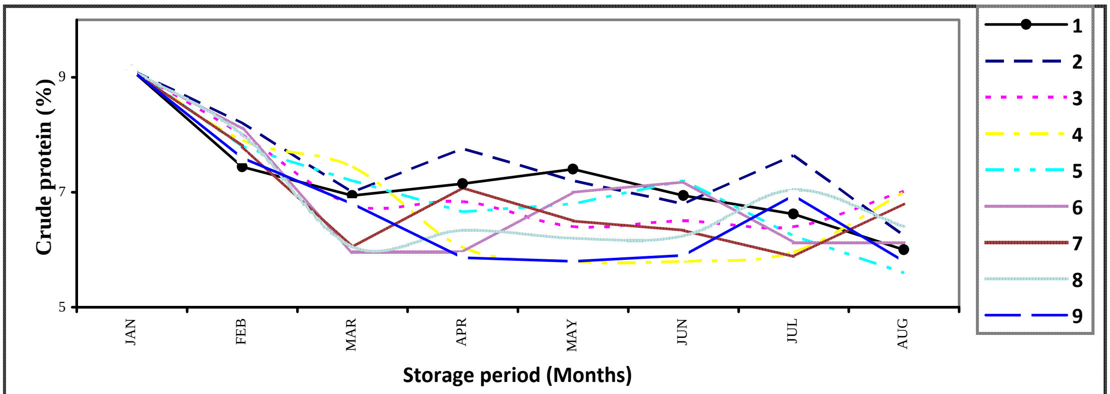

Figure 6: Crude protein of stored maize in the silos

The pattern noticed may be attributed to high storage temperature in some months especially during hot dry periods. The implication is that at longer storage and exposure to higher temperature will lead to the degradation of gluten which is responsible for the development of extensibility and elasticity in dough (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 insolubility of protein. Notwithstanding the crude protein depreciation, the fitness of maize for industrial processing remained impressive throughout the storage period (Osipitan et al, 2013). The average percentage crude protein obtained in this study is in agreement with similar studies by Osipitan et al. (2013) and Pelhate and Theriault (1989).

FAO (2010) believes that the protein content of cereal grain stored under good condition that prevent insect infestation and mould growth is not appreciably altered by seed respiration over long period. The difference in all the studies is probably the meaning of good condition because it cannot be quantified.

3.6 Ash content

The ash content of the stored maize decreased from 3.5% to 2.3% during the storage period as is shown in Figure 8. The analysis showed 3.5%±0.00% significant levels for the variable with respect to duration of storage. Since $p<0.05$, it can be concluded that the duration of storage affects the ash content in both metallic silos. The result of the analysis of the positions 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 position does not affect the variable.

The fluctuations of values of ash content within the months could be attributed to the effect of high temperature. 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.

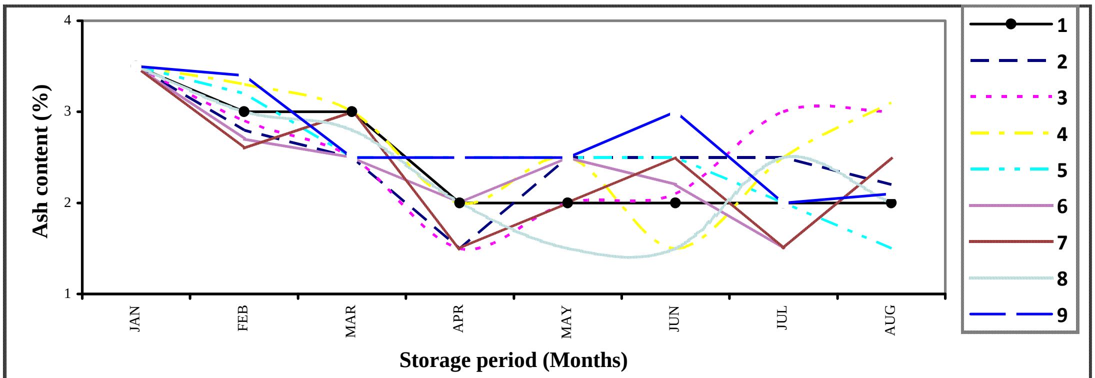

Figure 7: Ash content of stored maize in the silos

3.7 Carbohydrate content

The result of this study shows that there is a change in carbohydrate content in respect to the duration of storage and sample positions. The statistical result showed 63.36%±0.00% and 63.36%±0.98% significant levels respectively. This implies that the variable is significant and is influenced by storage duration, but not by sample positions as is shown in Figure 9. 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 similar pattern similar pattern.

The result shows that there is a little progressive increase in carbohydrate content for the stored grains in the both metallic silos from 63.36% in January to 83.2% in August. The increase 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 than 45^{0}C during grains storage (Pelhate and Theriault, 1989). This finding is in agreement with Osipitan, et al., 2012; Gupta et al, 2013; Ranjana and Hari, 2013 who all supported the claim that CHO content increase during storage. The control value of CHO in this study which is 63.3% agrees with 68.8% that was done by Durojaiye (2012).

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.

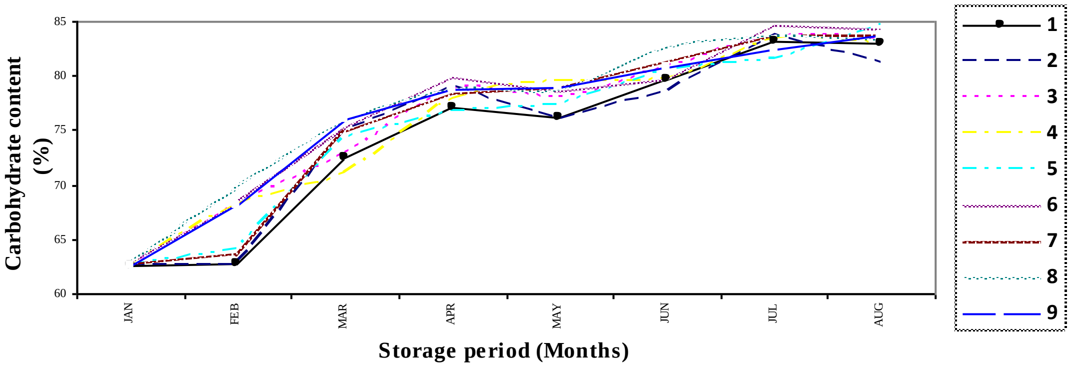

Figure 9 Carbohydrate content of stored maize in the silos

3.8 Crude fibre

There is a progressive decrease in the values from 6.25% to 3.21% from January to August as is shown in Figure 10. The crude fibre has 6.25%±0.00% significant level in respect to the duration of storage and irrespective of the size of the metallic silos. Since $p<0.05$, the crude fibre content is dependent on time and duration of storage. The sample positions of the grains in bulk have no significant effect on the average crude fibre during the storage period but tend to decrease with longer time of storage in both metallic silos. It has 6.25%±0.964% significant level with $p>0.05$. The average crude fibre recorded at the sample positions (1-9) also follows the same trend.

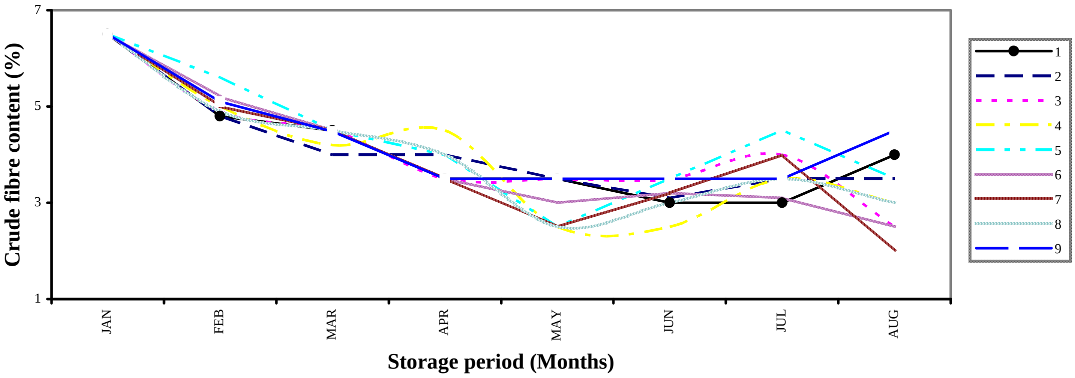

Figure 9: Crude fibre content of stored maize in the silos

The result is in agreement with similar research by Osipitan et al. (2012). This may be due to lipid hydrolysis that occurs during storage due to respiration, oxidation and process of enzymatic action. 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.

3.9 Energy value

There was a slight increase from 360 kcal to 395 kcal during the storage period as is shown in Figure 11. The energy value is 361.55%±0.00% and 361.55%±1.0% level of significance during analysis with respect to duration of storage and position respectively. The duration has significant effect on the energy content of stored maize irrespective of the size of the metallic silos but the effect of different positions of the grains in the bulk was insignificant.

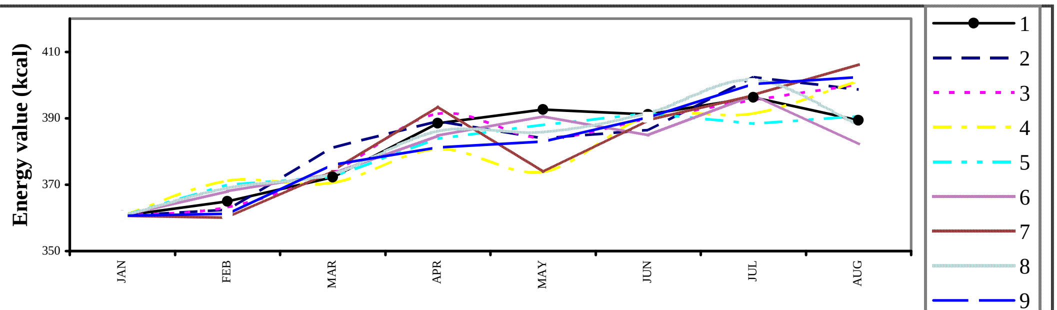

Figure 10: Energy value of stored maize in the silos

It implies that stored maize may even be better than the newly harvested ones especially if the energy value is 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 the storage duration but it may be factual since the finding of this study is slight increase.

4 Conclusions

The nutritional characteristics of the stored maize assessed are significantly dependent on the duration of storage. There is a significant and progressive decrease in the average fat content, crude fibre, ash content and crude protein content but slight increase in energy value and carbohydrate content during the storage period. The size of metallic silos did not have any significant effect on the nutritional characteristic of maize stored in metallic silos. The position of the grain in bulk did not affect the nutritional characteristics during the eight months storage period. The grains can be stored longer without losing their nutrient value further processing and utilization of maize as a grain crop.

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