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STORAGE OF MAIZE (Zea mays) USING HERMETIC METHOD AND ANALYSES OF SOME QUALITY PARAMETERS

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ABSTRACT

In this study, samples of freshly harvested maize were obtained from a farm in Gidan Kwanu village, Minna, Niger State. They were dehusked and their moisture content determined to be 24.3%. The dehusked samples were sun dried for a week at an average temperature of 31°C and a relative humidity of 78%. The maize grains were removed from the corncobs after drying and the moisture content was found to be 12.1%. The percentage mould formation, insect infestation and broken grains were 0%. Other parameters analysed prior to storage were crude fat 6.74%, Crude fibre 1.58%, ash content 4.06%, protein content 9.11%, Carbohydrate content 66.41%, Dry matter 87.9% and hectoliter weight 66.83kg/hl. The maize samples were filled into hermetic bags and jars and some were put in a non-hermetic structure which served as the control; all of these were stored under the same atmospheric conditions. The average temperature and relative humidity for each day were recorded. Proximate composition of the grains were analysed every fortnight and the results obtained were analysed statistically. The Analysis of Variance (ANOVA) showed that the storage models have significant effects of on the quality of the maize. At the end of the eight week of storage, the quality parameters in the hermetic bag, jar and control were M.C (7.8%, 7.9%, 16%), crude fat (6.25%,7.42%,8.23%), crude fiber (9.89%, 10.45%, 20.23%), Ash content (3.17%, 7.51%, 2.91), Protein content (10.5%, 10.85%, 10.15%), Carbohydrate (62.39%,55.87%,42.49%), hectoliter weight (60.2, 62.2, 57.2) and dry matter (92.2%, 92.1%, 62.2%). In terms of nutrient retention, the hermetic bag and jar gave better results; as the carbohydrate, hectoliter weight and dry matter content for maize stored in both media were higher. There were no significant differences in the protein and crude fat content of the maize samples irrespective of the storage method. However, there was a significant difference in the moisture content of the stored samples; those in the control had higher moisture content than those stored in the other two. Low moisture content is desirable for longer and safe storage, thus the hermetic bag and jar medium of storage are better in this regard.

1. INTRODUCTION

Maize (*zea mays*) is the third most common cereal grain in the world after wheat and rice (De Groote *et al.*, 2013). It is being referred to as the cereal of the future due to its high nutritional value and utilisation of its products and by products (Lee, 1999). In Sub Sahara Africa, the major challenge to the storage of maize is insect attack, the dominant insect pest being the large grain borer (LGB); *Prostephanus truncates* and the maize weevil *Sitophilus zeamais* (Vowotor *et al.,* 2005); with the LGB the most dangerous to maize grains in small scale and on farm storage (Birkinshaw *et al.,* 2002). This challenge, led to the invention of various means by the farmers to tackle the LGB by shelling the maize earlier, and storing in polythene. Shelled maize happens to be less susceptible to LGB, but over time, this means also became ineffective in tackling the LGB attacks. Other farmers adopted the use of fumigants (phostoxin) and other pesticides but this could only protect the grains for 40 weeks. All these challenges led to the discovery of hermetic storage method in storing maize in hermetic bags, hermetic jars and cocoons (De Groote *et al.,* 2013).

Hermetic storage is a type of storage system for grains consisting of a modified atmosphere (Villers *et al.,* 2006) that is now being used for the protection of stored agricultural products (Jonifa-Essien *et al.,* 2010).This modified condition is developed by hermetic structure (airtight); the effect of low oxygen (O_2); and high carbon dioxide (CO_2); these have the capacity to prevent moisture from re-entering the grains, protect grains from insects, rodents and birds, have ease of loading and unloading and ease of maintenance (Villers *et al.,* 2006). According to Chakraborty and Sujeetha (2014) hermetic storage structure; can be classified into: Organic hermetic storage, Vacuum hermetic fumigation and Gas hermetic fumigation.

The World Health Organization and the Food and Agriculture Organization of the United Nations are discouraging the conventional use of chemicals in grain storage due to their numerous adverse effects on human health when not properly handled. Also, the improper application of these chemicals in the storage of food crops has led to avoidable deaths in the past due to poisoning. Presence of chemicals do not allow for the consumption of the grains at any time during storage, these chemicals must expire (i.e. the effect must wear off) before grains can be consumed.

Hermetic storage method serves as a better alternative because it does not involve the use of chemicals but rather offers a more biological approach to Integrated Pest Management (IPM) in storage and allows the grains to be consumed at any time. This study therefore focuses on the following; storage of maize hermetically using two hermetic storage models: hermetic bag, hermetic jar and a non-hermetic model as a control; assessment of some quality parameters of the maize before, during and after the storage period and comparing the results obtained from the hermetic storage models used and the control.

2. MATERIALS AND METHODS

Samples of matured freshly harvested maize were obtained from a farm in Gidan Kwanu village, Minna, Niger State. The moisture content of the freshly harvested maize was determined to be 24.3%, which was too high for storage purpose. The maize was sun dried for one week at an average temperature of 31°C and relative humidity of 78%. The maize grains were then removed from the corncobs and subjected to pre storage analysis; the moisture content after drying was determined to be 12.1%, which was safe for storage.

The percentage of mould formation, insect infestation and broken grains were zero percent. The maize samples were filled into the four hermetic jars (400 grams each) and bags (400 grams each) and kept under the same atmospheric conditions. The temperature and relative humidity values of the storage environment during the storage period ranged from 30±2^{0}C to 75±4% respectively. The control was a non-hermetic storage structure (of same size). The quality parameters where then assessed periodically during storage using standard methods.

AOAC (2012) methods of analysis was used to determine the proximate composition of the maize samples except the ash content which was determined using the method described by Sule *et al* (2014). The method described by Uchechukwu-Agua *et al* (2015) was used to estimate the percentage of dry matter. Percentage of insect infestation, broken grains and mould formation were determined according to the method described by Tiongson (1992). Analysis of Variance (ANOVA) method was used to analyse the data obtained.

3. RESULTS AND DISCUSSION

The results and discussions of the study are presented as follows:

3.1 Proximate Composition of Maize Stored in the Three Media over the Storage Period

The Proximate composition of Maize determined was crude fat, moisture content, crude fibre, protein and carbohydrate.

Table 1: Crude fat Composition of Maize Stored in the Three Media

Duration (weeks)	Crude Fat (%)		
	Hermetic bag	Hermetic Jar	Control
0	6.74±0.01a	6.74±0.01^a	6.74±0.01a
2	3.78±0.01^a	6.42±0.02^c	4.37±0.59^b
4	3.0±0.1^a	4.17±0.01^b	5.12±0.01^c
6	5.85±0.01^a	6.37±0.02^b	7.04±0.04^b
8	6.25±0.01^a	7.42±0.01^b	8.23±0.42^c

The values are given as means of triplicate determinations ± standard deviation. Different superscript in rows means a significant difference of ($p < 0.05$).

The crude fat content of maize stored in the hermetic models showed a significant difference during the storage period, it reduced from 6.74(pre storage value) to 6.25% after eight weeks of storage in the bag and increased to 7.42% in the jar, the control had an increase in fat up to 8. 23% (Table 1). Sule *et al* (2014) reported a range of 2.17 - 4.43% for fat content of maize during storage. Fig. 1 shows the crude fat content of the maize samples in the different storage structures over the storage period.

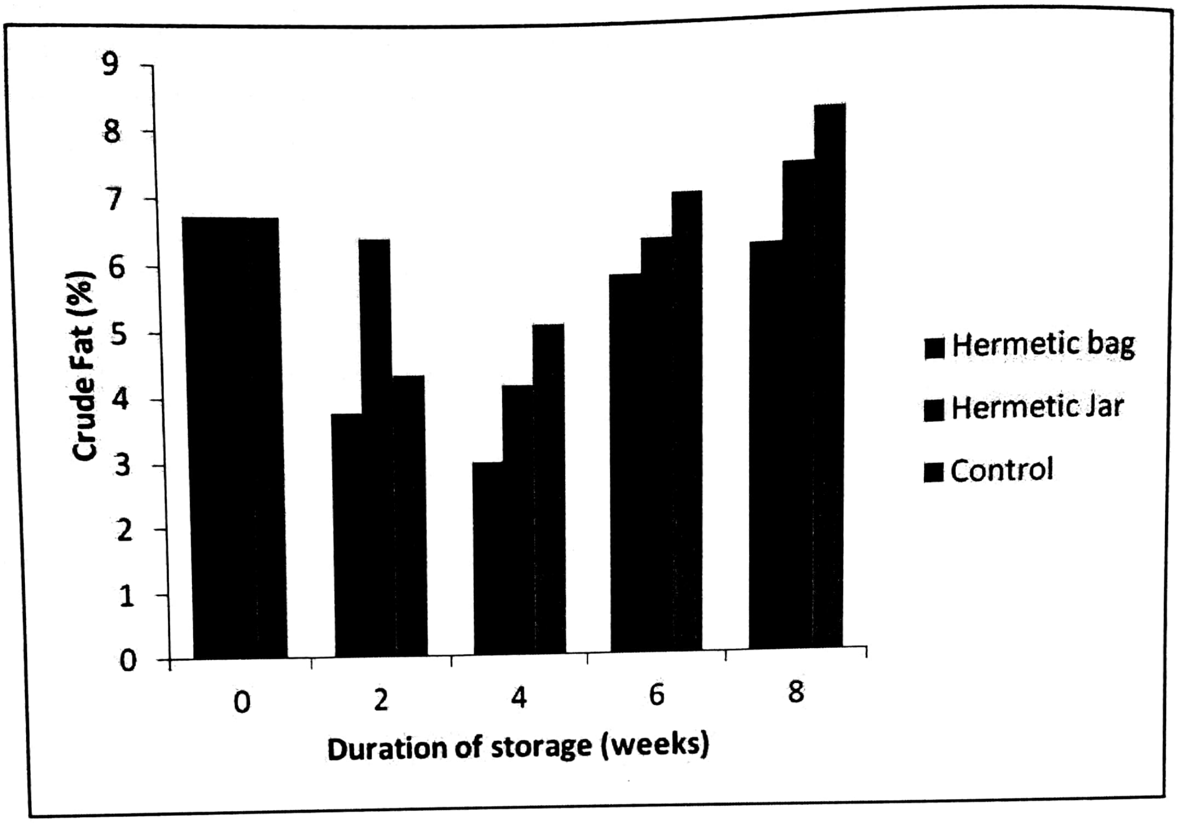

Fig. 1: Crude Fat Content of the Maize samples in the storage media

Table 2: Moisture content of Maize Stored in the Three Media

Duration (weeks)	Moisture Content (%)		
	Hermetic bag	Hermetic Jar	Control
0	12.09±0.02[a]	12.09±0.02[a]	12.09±0.02[a]
2	10.5± 0.2[a]	10.37± 0.01[a]	13± 0.02[b]
4	8.17±0.01[a]	8.53±0.03[a]	14.33±0.03[b]
6	8.1 ±0.1[a]	8 ±0.02[a]	15.2±0.2[b]
8	7.8 ±0.1[a]	7.9 ±0.1[a]	16 ±0.1[b]

The values are given as means of triplicate determinations ± standard deviation. Different superscript in rows means a significant difference of ($p < 0.05$).

The moisture content reduced from a pre storage value of 12.1% to 7.8 and 7.9% in the hermetic bag and jar respectively; while the control increased from 12.1% to 16%; this agrees with the findings of Yakubu *et al;* (2011) who reported that hermetic storage reduces the moisture content of stored maize, while non-hermetic increases it. Fig. 2 shows the moisture content of the maize samples in the different storage structures over the storage period.

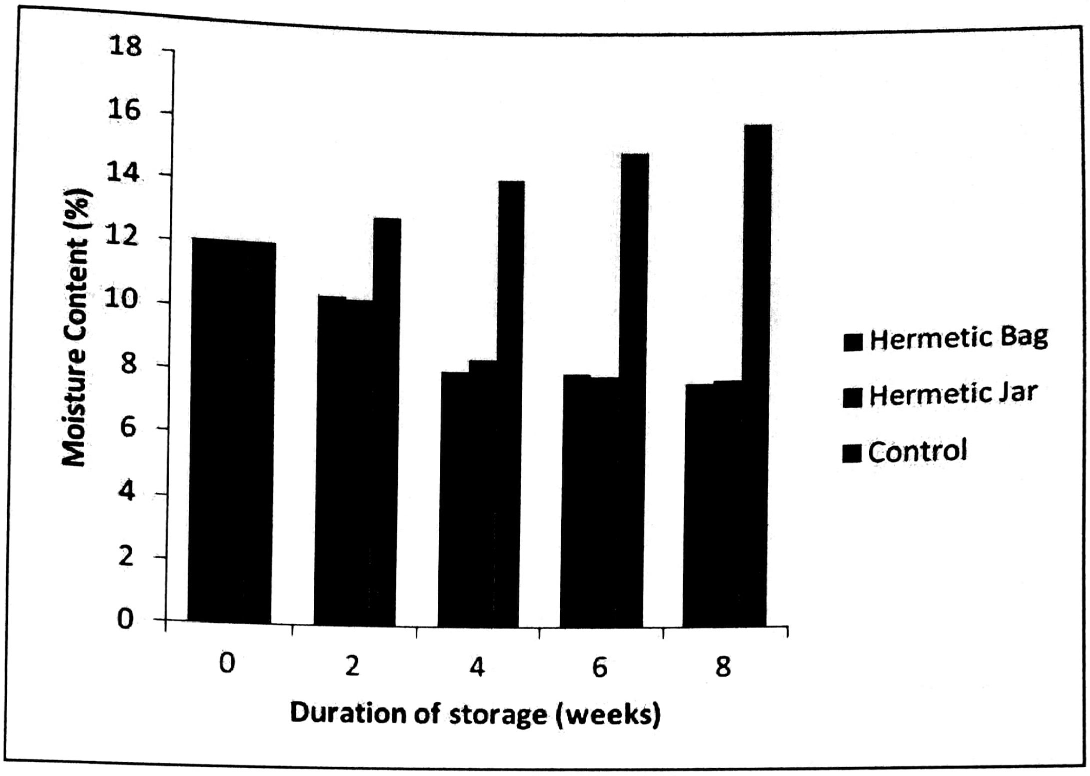

Fig. 2: Moisture Content of the Maize samples in the storage media

Table 3: Crude Fibre content of Maize Stored in the Three Media

Duration (weeks)	Crude Fibre (%) Hermetic bag	Hermetic Jar	Control
0	1.58±0.02[a]	1.58±0.02[a]	1.58±0.02[a]
2	2.74±0.01[a]	16.36±0.01[b]	16.51±0.01[b]
4	9.9±0.1[ab]	8.6±0.1[a]	25.12±0.02[c]
6	19.6±0.1[a]	19.46±0.01[a]	18.6±0.3[a]
8	9.89±0.01[a]	10.45±0.01[a]	20.23±0.01[b]

The values are given as means of triplicate determinations ± standard deviation. Different superscript in rows means a significant difference of ($p < 0.05$).

The crude fibre is the undigested carbohydrate which decreases the risk of heart diseases, obesity and other diseases. It increased during the storage period in the hermetic bag, Jar and the control but was highest in the control. It ranged from 1.58% - 9.89%; 10.45% in the jar and 20. 23% in the bag, jar and control respectively. Sule *et al* (2014) gave a range of 2.1-26.7% for crude fat content of maize during storage. Fig. 3 shows the crude fibre content of the maize samples in the different storage structures over the storage period.

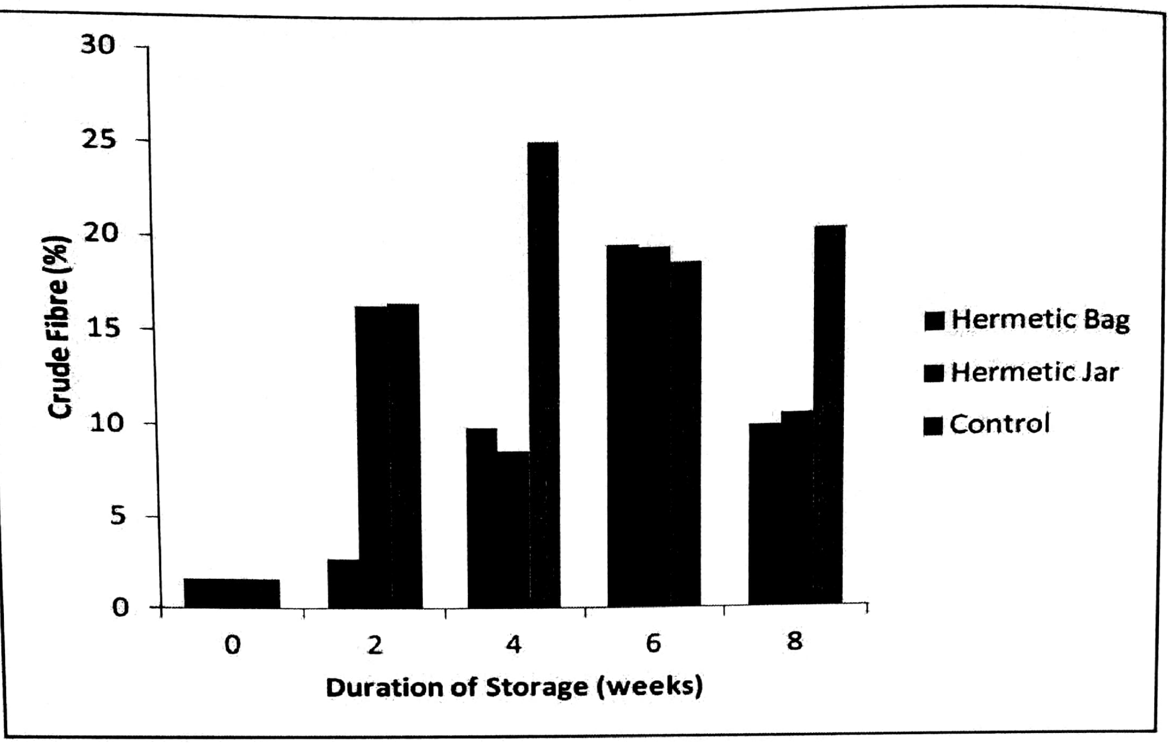

Fig. 3: Crude fibre content of the Maize samples in the storage media

Table 4: Ash content of Maize Stored in the three Media

Duration (weeks)		**Ash (%)**	
	Hermetic bag	**Hermetic Jar**	**Control**
0	4.06±0.01[a]	4.06±0.01[a]	4.06±0.01[a]
2	5.87±0.01[a]	9.54±0.01[b]	5.41±0.02[a]
4	2.14±0.01[a]	1.45±0.02[a]	2.09[a]
6	3.08±0.01[b]	3.03±0.02[b]	2.64±0.01[a]
8	3.17±0.23[a]	7.51±0.01[b]	2.9±0.1[a]

The values are given as means of triplicate determinations ± standard deviation. Different superscript in rows means a significant difference of ($p < 0.05$).

Ash content is the total amount of minerals present in the maize. There was significant difference in the ash content of the stored maize samples. It reduced from 4.06 (pre storage value) – 3.17% in the bag but increased from 4.06 - 5.87%, in the hermetic jar. There was also a reduction in value in the control from 4.06 – 2.9%. Fig. 4 shows the ash content of the maize samples in the different storage structures over the storage period.

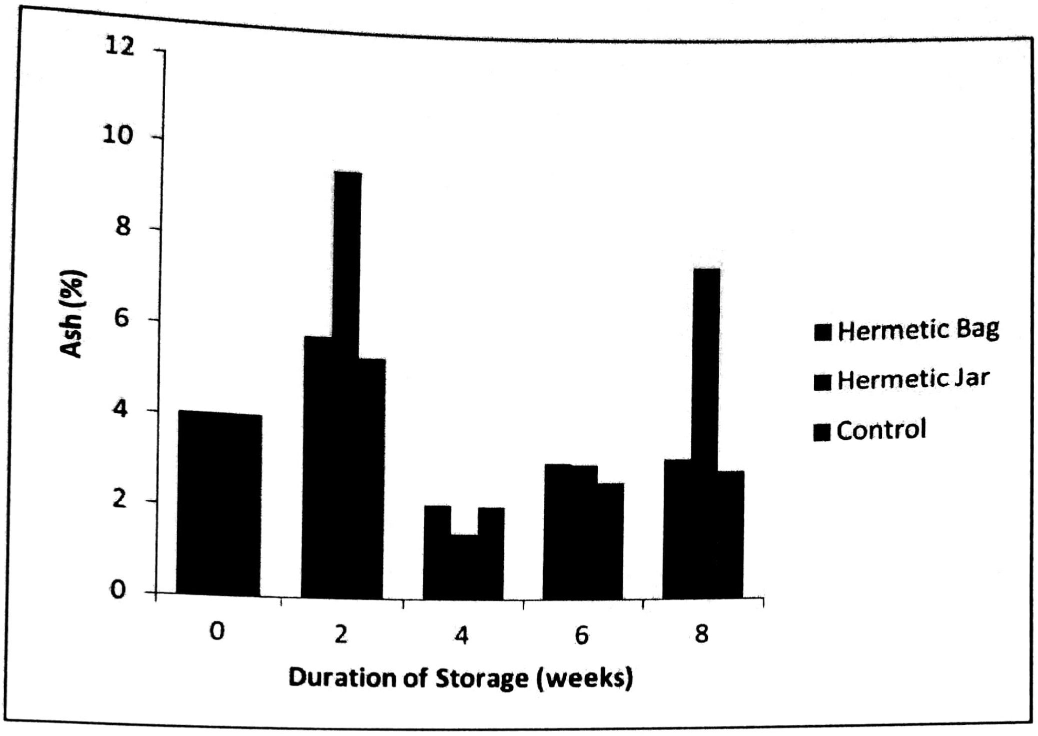

Fig. 4: Ash content of the Maize samples in the storage media

Table 5: Protein content of Maize Stored in the three Media

Duration (weeks)	Protein (%) Hermetic bag	Hermetic Jar	Control
0	9.11±0.01[a]	9.11±0.01[a]	9.11±0.01[a]
2	10.15±0.01[a]	9.8±0.1[a]	9.98±0.01[a]
4	10.33±0.03[a]	10.16±0.01[a]	9.98±0.02[a]
6	10.5±0.1[ab]	9.98±0.02[a]	9.45±0.03[a]
8	10.5±0.01[a]	10.85±0.01[ab]	10.15±0.01[a]

The values are given as means of triplicate determinations ± standard deviation. Different superscript in rows means a significant difference of ($p < 0.05$).

Protein is a macronutrient needed by the body for production of enzymes and it is important building block for bones. The protein content increased slightly during storage from 9.11% (pre storage value) to 10.5, 10.85 and 10.15% in the bag, jar and control respectively. But there was no significant difference among the maize samples in the different storage structures after the storage period. Fig. 5 shows the protein content of the maize samples in the different storage structures over the storage period.

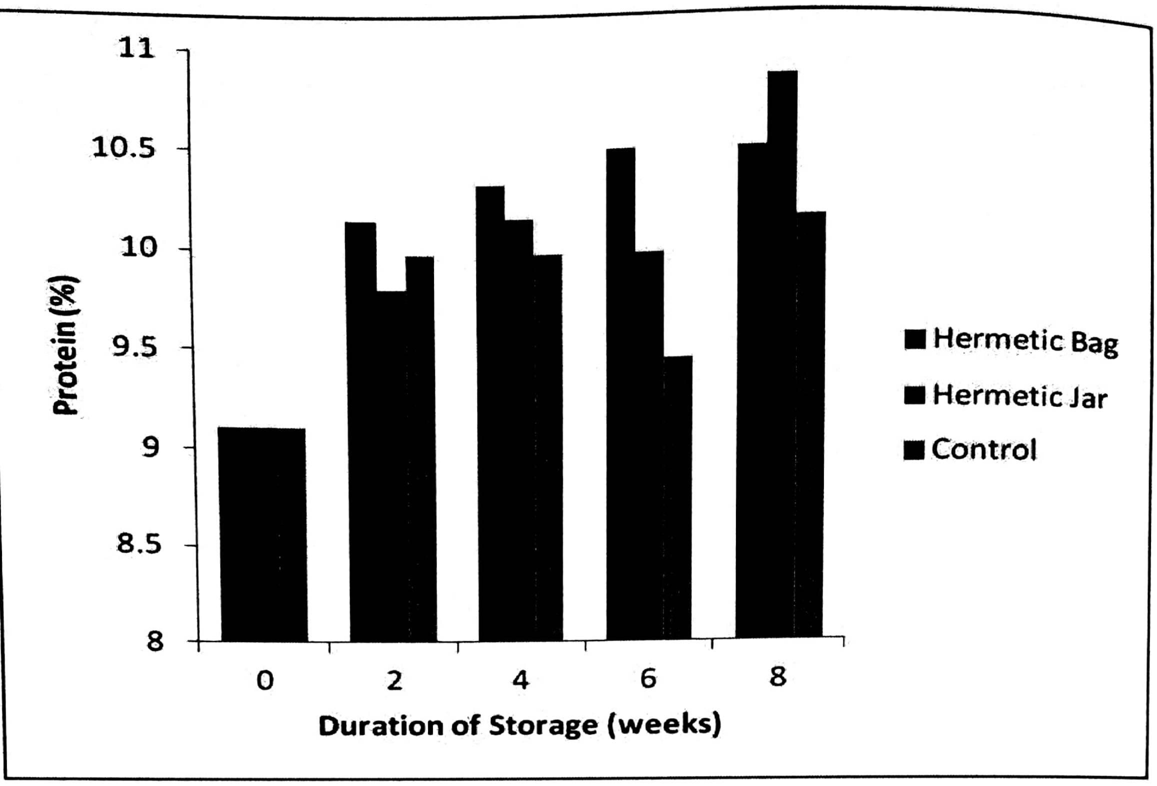

Fig. 5: Protein content of the Maize samples in the storage media

Table 6: Carbohydrate of Maize Stored in the three Media

Duration (weeks)	Carbohydrate (%)		
	Hermetic bag	Hermetic Jar	Control
0	66.41±0.03[a]	66.41±0.03[a]	66.41±0.03[a]
2	66.96±0.21[c]	47.51±0.09[a]	50.73±0.54[ab]
4	66.46±0.25[b]	67.09±0.01[b]	43.36±0.06[a]
6	52.87±0.1[b]	53.16±0.03[b]	47.07±0.58[a]
8	62.39±0.33[c]	55.87±0.12[b]	42.49±0.42[a]

The values are given as means of triplicate determinations ± standard deviation. Different superscript in rows means a significant difference of ($p < 0.05$).

Carbohydrate is the nutrient needed by the body in large quantity because it is the body's main source of fuel found mainly in grains; maize is a major source of carbohydrate. A significant difference was seen at the end of the storage period in all methods used. Carbohydrate content reduced slightly from the pre storage value of 66.41% to 62.39% in the hermetic bag but reduced significantly in the hermetic jar (66.41-55.87%). A significant decrease was observed in the control throughout the storage period from 66.41% - 42.49%. Sule *et al* (2014) reported a range of 44.6%-69.605% for carbohydrate content during storage. Fig. 6 shows the carbohydrate content of the maize samples in the different storage structures over the storage period.

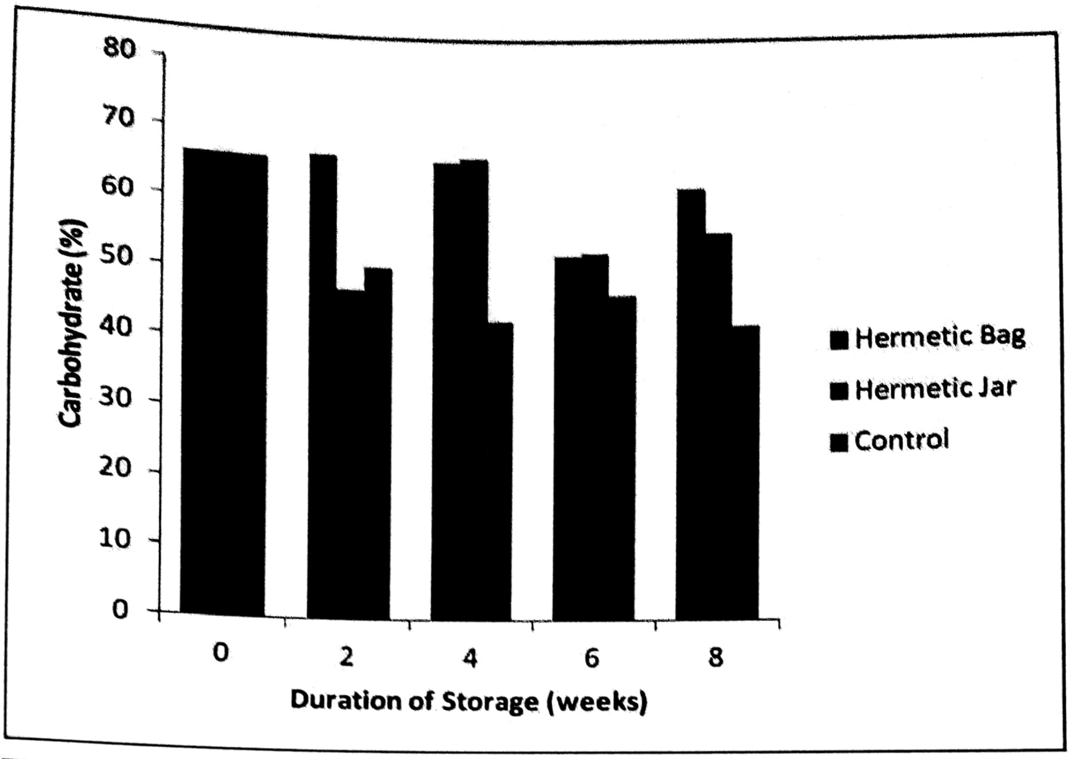

Fig. 6: Carbohydrate content of the Maize samples in the storage media

3.2 Other Quality Parameters Assessed in the Three Media over the Storage Period

Other parameters assessed were hectoliter weight, dry matter, percentage of Insect Infestation, broken Grains and mould formation.

Table 7: Hectolitre weight

	Hectoliter weight (kg/hl)		
Duration (weeks)	**Hermetic bag**	**Hermetic jar**	**Control**
0	66.83±0.06[a]	66.83±0.06[a]	66.83±0.06[a]
2	74.9±0.1[a]	76.5±0.1[a]	63.6±0.1[b]
4	53.78±0.01[a]	87.73±0.01[c]	60.63±0.01[b]
6	59.07±0.06[a]	92.03±0.02[c]	60.07±0.06[b]
8	60.82±0.1[b]	92.1±0.1[c]	57.2±0.1[a]

The values are given as means of triplicate determinations ± standard deviation. Different superscript in rows means a significant difference of ($p < 0.05$).

There was a significant decrease in the hectoliter weight of the maize grains during storage in the bag (66.83 - 60.82 2kg/hl) and control (66.83-57.2kg/hl). While there was significant increase in the hectoliter weight of samples stored in the jar from 66.83- 92.01kg/hl. Fig. 7 shows the hectoliter weight of the maize samples in the different storage structures over the storage period.

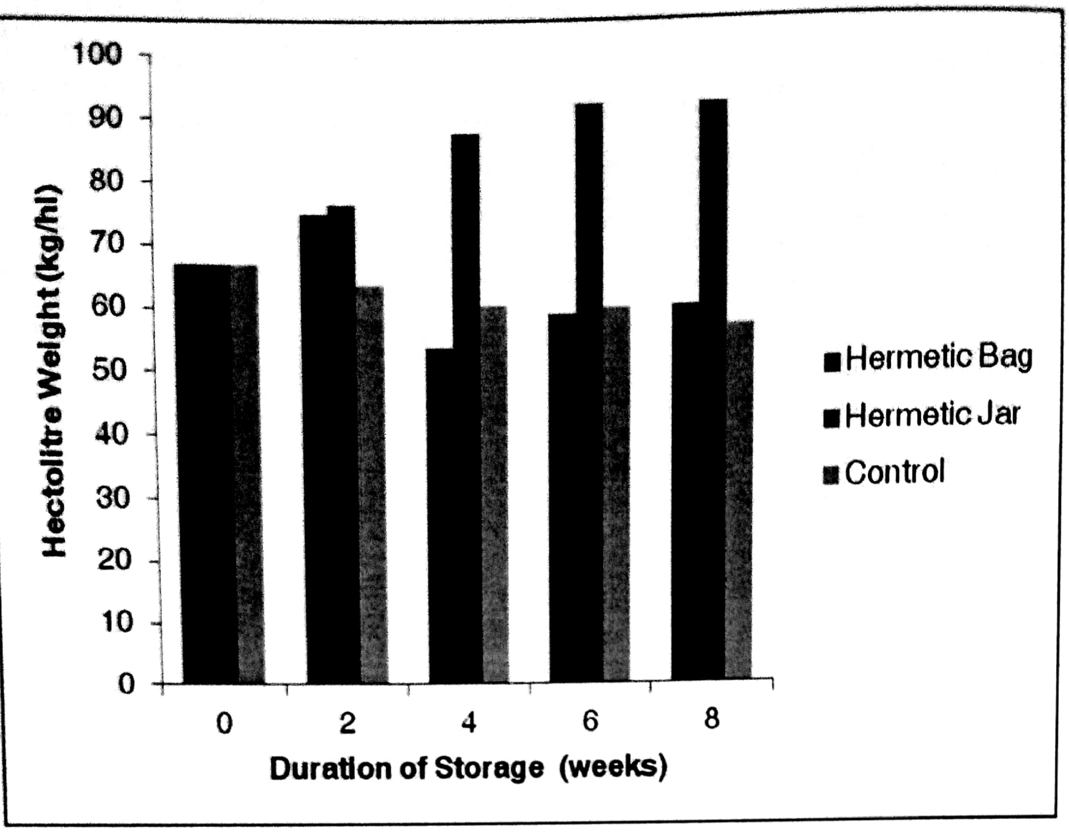

Fig. 7: Hectolitre Weight of the Maize samples in the storage media

Table 8: Dry Matter

	Dry matter (%)		
Duration (weeks)	**Hermetic bag**	**Hermetic jar**	**Control**
0	87.9±0.04[a]	87.9±0.04[a]	87.9±0.04[a]
2	89.5±0.2[a]	89.63±0.01[a]	87±0.02[b]
4	91.83±0.01[a]	91.47±0.03[a]	85.67±0.02[b]
6	91.9±0.1[a]	92±0.1[a]	62±0.1[b]
8	92.2±0.1[a]	92.2±0.1[a]	62.2±0.1[b]

The values are given as means of triplicate determinations ± standard deviation. Different superscript in rows means a significant difference of (p < 0.05).

The dry matter content of maize in the hermetic bag and jar showed an increase and this can be attributed to the decrease in the moisture content of maize in the hermetic storage models. Increase in moisture content leads to a decrease in dry matter and vice versa. Hermetic bag increased from 87.9% - 92.2%; an increase of 87.9%-92.1% was observed in the jar. The control decreased in dry matter content from 87.9% -62. 2%; this is in agreement with Uchechukwu-Agua *et al* (2015). Fig. 8 shows the dry matter content of the maize samples in the different storage structures over the storage period.

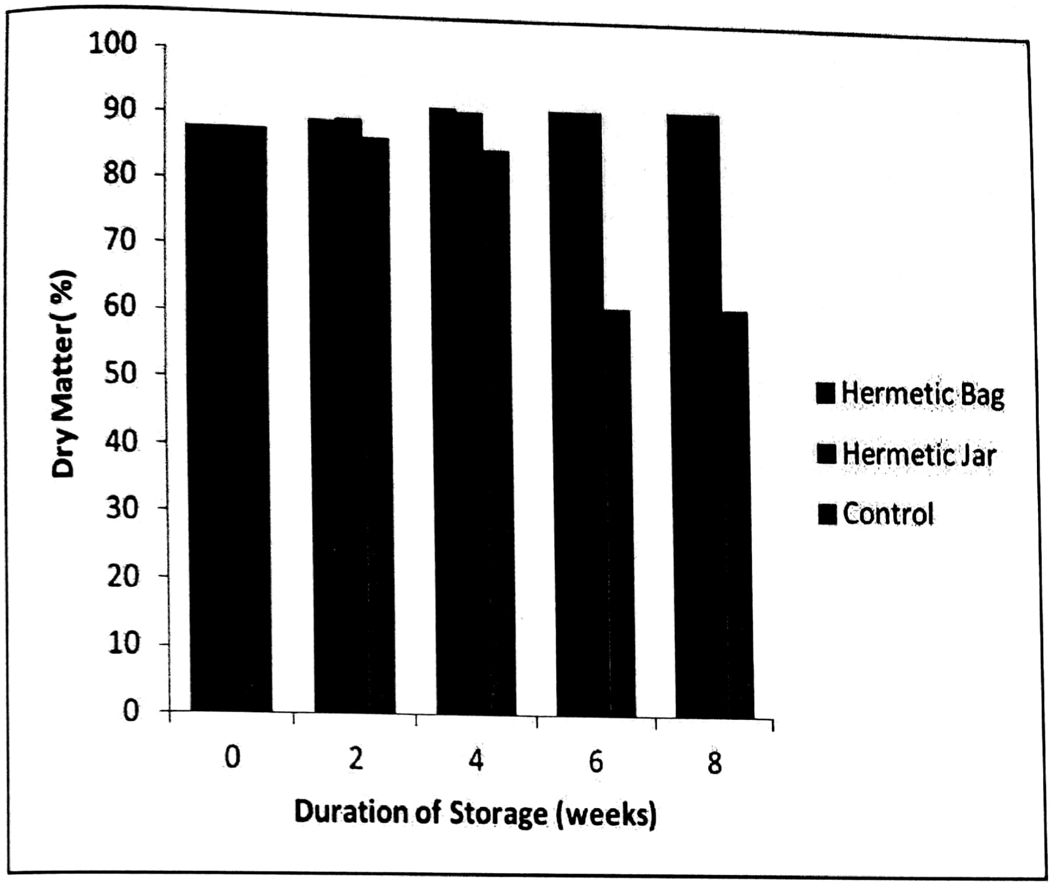

Fig. 8: Dry Matter of the Maize samples in the storage media

There was no incidence of insect infestation, broken grains and mould formation throughout the period of storage for all the methods used: this could be due to the fact that freshly harvested and dried maize grains were used in this study and also the duration of storage.

4. CONCLUSIONS

It can be concluded from the study that the hermetic storage models had a significant effect on the quality parameters of maize analysed, the carbohydrate content, dry matter, hectoliter weight and ash content increased in the course of storage in the hermetic structures while crude fat and moisture content decreased. The samples in the control had higher crude fibre and moisture content than the samples in the hermetic storage models. There were no significant differences in the protein and crude fat content of the maize samples irrespective of the storage method.

There was no insect infestation, broken grains and mould formation during the period of storage for all. Hermetic models should be adopted for maize storage as it reduced the moisture content (a desirable factor in storage) and most of the quality parameters were not negatively affected.

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