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Cocoon Storage: A Better Alternative to the Use of Inorganic Insecticides/Pesticides in Middle Level and Large Scale Storage, in the Tropics

Okolo, C. A.[1], Chukwu, O.[2], Adejumo, B. A.[3], Haruna, S.A.[4]
[1&4] *(National strategic Food Reserve Department, .Federal Ministry of Agriculture and Rural Development, Nigeria)*
[2&3] *(Department of Agricultural and Bioresources Engineering, Federal University of Technology Minna, Nigeria)*

Abstract: *This paper reviews the economics and efficacy of hermetic cocoon storage as a preferred alternative to use insecticides and pesticides for middle level and large scale storage of cereal grains, paddy crops, oil seeds and pulses in the tropics. Also assessed and evaluated is the ability of hermetic storage cocoon to maintain the quality attributes of stored grains, and control most of the causative agents, or issues responsible for enormous storage losses, as far as grain storage is concerned in the developing countries. White coloured hybrid 9021 maize stored in cocoon was evaluated for physical and proximate characteristics for a period of 2 years. Grain samples were taken randomly at inception of storage and on quarterly basis during storage. Data collected was analysed using Statistical Package for Social Sciences (SPSS) and Duncan multivariate test were used to determine how significant the changes that occurred in the grain within the period. The variables evaluated were both quality and mass characteristics which includes Moisture content wet basis (MC), Bulk density(BD), Insect damaged grains (ID), Mould infested grains (MD), Cores and fines(FM), Crude protein (CP), Crude fat content (CF), Ash content (AS), Carbohydrate value (CV), Energy value (EV), and Germinability (G). Most of the physical properties of the grains remained almost unchanged. The proximate characteristics, depreciated, but most variables were not significant within the 2 years of storage. Only carbohydrate and energy value appreciated slightly within the duration. The general quality of stored grain was excellent and above average within the acceptable standard and limit for stored cereal grains.*

Keywords: *Hermetic cocoon storage, storage losses, insecticides and pesticides, cereal grain*

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I. Introduction

Cereal grains are edible seeds of specific grasses belonging to the botanical family *Poaceae*, otherwise known as *Gramineae* [1]. Cereal grains are grown in greater quantities all over the world, providing more food energy than any other food crop. They are important dietary components as they provide substantial amount of nutrients such as proteins, vitamins, minerals, and carbohydrates for human and animal consumption. Cereal grains account for about 15 to 56% of the total daily calories in diets of people in more than 50 developing countries, particularly in Latin America and Africa, where animal protein is expensive and consequently unavailable to a vast sector of the population [2]. They consist of staple food and comprise of 80% or more of the average diet in Asia and Africa, 50% in Europe and 20 –25% in the United States of America [3]. They account for more than 70% of agribusiness, employments and major source of raw materials to agro-allied industries in Sub-Saharan Africa (SSA) [4]. Though cereal grains storage is dated back to the prehistoric era, hitherto it is still associated with huge storage losses, which are estimated between 25%- 46%, in most developing countries and in Sub-Saharan Africa. This is due to inefficient and ineffective storage system, climatic factors, and agricultural practices used by farmers [5]. This situation often forces millions of rural peasant farmers/small producers of cereal grains to sell their grains at the time of harvest, with the disadvantage of low market prices, [6].

Losses after harvest which are of both quantity (weight losses) and quality (proximate) deprive farmers of the full benefits of their labours. In hot humid climates such as SSA, insects, rodents, and mould can cause storage losses up to 25% [7]. Weigh losses in grain storage, generally ranges from 5 per cent to 40 per cent of total production, averaging about 13.5 per cent. It has been suggested that for Eastern and Southern Africa alone, the value of this weight loss amounts to about 1.6 billion United States dollars (USD) per annum, or possibly about four billion USD for all of sub-Saharan Africa. This exceeds the value of total food aid received by SSA in the decade 1998–2008, equates to the value of cereal import to SSA in the period 2000–2007, and is equivalent to the annual calorific requirement of at least 48 million people in SSA [8]. This protracted generic storage losses could be avoided or minimized if the right technology and approach are adopted as far as grain storage is concerned.

Hermetic storage (HS) technology is a non-chemical based system of storage, which provides an air tight, safe and pesticide- free means of storing dry crops [7]. Its basic principle is the generation of low oxygen and enriched carbon dioxide and or nitrogen interstitial/ modified atmosphere, achieved by either natural metabolic activities of living organisms in the bulk, or through artificially enhanced and accelerated means in an air tight storage structure [9]. A sufficiently low oxygen and elevated carbon dioxide or nitrogen, could either be created through a natural internal metabolic process based on insect respiration and respiration of food material if they are living, and other micro-flora in the bulk such as moulds, and other micro organisms (Organic hermetic storage (OHS)). It could also be achieved through the deflating/sucking out of oxygen rich air from an air tight storage structure with the aid of a vacuum pump creating a partial pressure of air inside the structure, that will lead to depletion of oxygen (Vacuum hermetic fumigation (VHF)), and through an artificial mechanism such as enriching the air tight storage structure with carbon dioxide or nitrogen by the use of pumps, generators and scrubbers (Gas hermetic fumigation (GHS) These are the three major types of hermetic storage [10] [11]. These methods creates a low oxygen modified atmosphere which results in 100 % insect mortality of all life stages in a few days to two weeks as well as preventing mold development [12]. It will also lead to the asphyxiation of the entire living organisms in the bulk, who are normally agents of deterioration, and the crops will store well and its quality preserved [11].

In organic hermetic storage system, natural disinfestation of stored crops depends on, the time taken for depletion of oxygen to non –life sustaining levels in the bulk. The total depletion of oxygen in the bulk also depends on the level of metabolic activities which takes place in the bulk after storage, and the available volume of air entrapped in the air tight storage structure from the inception of storage. This has thus emphasized the importance of stocking organic hermetic storage structures to the brim during storage, allowing for minimum volume of entrapped air (oxygen), as well enhancing quick disinfestation of the stored crops. However we can assert that the time taken for total disinfestation of stored crops in an organic hermetic storage system is a relative term but in VHF and GHS systems, the reverse is the case, since they are generated and accelerated through artificially means and used mostly where rapid disinfestation is required. The ability to retain the fresh aroma of crops, by preventing the formation of free fatty acids (FFA) is a major millstone in hermetic storage. Major research in this area has also revealed that hermetic storage can help double the lifespan of stored seeds; maintain good milling quality of stored grains [7].

Grain Storage Cocoon is a flexible hermetic plastic storage structure/enclosure, which serves as gas and air barrier when assembled and closed, used for storage of dry sensitive and non-sensitive crops. Available capacities are mainly between 5 to 300 Metric tonnes but in the recent past capacities up to 15,000 tonnes were introduced [9]. They are basically made of reinforced poly vinyl chloride material designed for middle and large scale storage. Some are made of single layer high density polypropylene thermo elastic material which naturally inhibits the permeability of both air and micro organism maintaining an air tight environment. They could be assembled indoor or outdoor depending on the prevailing circumstances, environmental condition and choice. Grain storage cocoon is a total enclave, which is highly flexible and can be folded to just a sample pad, but takes the shape of grains stored in it, if assembled [11]. The grains cocoon is basically made of two major components carefully sewed rectangular thick, blind polypropylene material that can be attached or detached by a means of plastic zippers designed on its outside surface for each component for the purpose of zipping/sealing. The two basic polypropylene components are the head and the tail. They are joined with the male and female zippers attached to respective covers as shown in Plate 1 and 2.

It was designed with 2 holes that have plastic tight covers; one for oxygen and carbon dioxide sensors insertion point, and the other is a one-way in-valve for sucking out of air from the cocoon during storage [11]. After the tail has been spread on a clean well drained soft floor preferably on a sandy base, bagged grains are stacked to take the shape of the sewed polypropylene cocoon. After stacking to the designed horizontal recommended length and width, it will be further stacked up to the vertical length and width. While the tail is worn up the stacked grain, the top cover will be worn from the top and both will be attached together by means of an original zipper developed and used by astronauts [9]. After sealing of the zipper point, any of the three types of hermetic storage, can be used alone or in combination, for the crop storage and management [13]. It is widely used across the globe for storage of grains and pulses in places like the Philippines, China, Sri-lanka and Rwanda and best suited for middle level and commercial storage [14]. They became commercially available in the 1990's and today in use in 38 countries of the world. Hermetic storage cocoon is highly movable and easy to transport and set up in another location. Its technology is not too cumbersome and all the 3 basic types of hermetic storage technology can be practiced effectively in a grain storage cocoon [11]. Once it is procured and set up in its location, it will further take little or no expenses to manage until the evacuation of the stored crops. It is probably the only hermetic storage structure which can guarantee such feet. It retains moisture and prevents the formation of free fatty acids during storage, thus a desired characteristic, considering the consequence of loss of aroma and weight during storage. It is highly suited for keeping of emergency relief food items/ stock that may be needed to evacuate to areas where there are emergencies and relief items needed in matters of hours. Countries could also assemble there cocoons with grains already bagged with relief in scripted bags to facilitate swift response to cases of emergency.

II. Materials And Method

A 100 metric tonnes (MT) capacity "Grain Pro" hermetic storage Cocoon, supplied to Federal ministry of Agriculture, silo facility in Minna, Nigeria by Ruton Enterprises Limited, a Grain Pro agent, was used for this study. The hermetic storage cocoon was delivered to the Silo facility in June 2015. The cocoon was set up inside the silo facility perimeter fence for a pilot phase trail in July, 2015. It was set up in a prepared artificial sandy surface/ platform, bordered by a block work, thus creating an artificial well drained surface, devoid of sharp objects that could puncture the Cocoon when it is set up with grains. The Cocoon was set up outside, not under shade but under direct sunlight with a protective cover made of reflective materials laid over and above the cocoon to prevent direct sun rays. 98.20 metric tonnes (MT) of hybrid 9021 (white maize) supplied in 100kg bags, by Government grain suppliers/agents, was used to set up the 100MT capacity cocoon for the trails. The supplied bags of grain were opened, and the grains were manually cleaned, picking out cores and fines, mould infected and immature grains. Samples of the grains were collected at random, and analyzed using standard procedures to determine its initial properties which will serve as control. The grains were finally re-bagged in a strong and desired new bag, and stacked in alternate pattern, inside the Cocoon as shown in Plates 1. The upper and lower parts of the Cocoon were zipped as final form of closing, after stacking and arrangement of the grains inside as shown in Plate 2. After setting up, of the cocoon, a hand evacuation pump/blower was finally used to create a partial pressure of the trapped air inside, by sucking out the air through a designed aperture (one way valve) , in the body of the Cocoon, which only allows air out.

Plate 1: An assembled un-zipped grain storage Cocoon in National Strategic Food Reserve Silo Complex, Minna, Nigeria.

When these processes of were completed, the level of oxygen inside the cocoon was read via an oxygen meter from "Grain pro" and allowed to undergo natural bio-generated disinfestation. At the inception of storage, the oxygen analyzer dictated 15% oxygen level inside the bulk. After one month of storage, it was re-read and the level of oxygen inside the cocoon has been depleted to 6%, which was recommendable. Subsequent samples of the stored grains were collected from the cocoon for analysis on quarterly basis for a period of 2 years.

Data collected were analyzed to evaluate the efficacy, and the ability of hermetic storage cocoon to preserve the quality stored food grains, for the duration of storage. The analysis of data was done using Statistical Package for Social Sciences (SPSS) multiple analysis of Variance (MANNOVA) and Duncan's multivariate test, was used to determine the trend and significance of appreciation or depreciation of the variables. This include Moisture content wet basis (MC), Bulk density (BD), percentage broken grains (BG), percentage mould infected grains (MD), percentage Insect damaged grains (ID), crude protein (CP), crude fat content (CF), ash content (AC), carbohydrate value (CV) and energy value (EV). Significance was accepted at 5%. The climatic variables were also monitored and recorded within the period of this experiment. The research was designed as a single factor experiment with 12 levels 3 replications. Proximate Analysis Sample of the maize stored in hermetic storage cocoon were analyzed using standard procedures [15] for ash, crude protein, fat and moisture content (wet basis). The nitrogen was determined by Micro-Kjeldahl method as described by [16] and the percentage nitrogen was converted to crude protein by multiplying 6.25. The carbohydrate content was estimated by the difference in value obtained when all the chemical composition values were subtracted from 100%. All determinations were in triplicates and values of each constituent were expressed in percentage. Destructive method of analysis was used for all analysis. The physical characteristics were analyzed using mini weighing digital scale and calculating the variable based on percentage of the whole. The BD was calculated by division of the mass of the grain divided by the volume it occupies.

Plate 2: An assembled grain storage Cocoon in National Strategic Food Reserve Silo Complex, Minna, Nigeria.

III. Result and Discussion

The statistical analysis of the variables assessed within the period of storage and Average monthly temperature and relative humidity data in Minna, within the period of the experiment from June 2015 to July 2017 are presented in "TABLES" 1 and 2 respectively.

Table 1: Statistical Analysis of the variables assessed within the period of storage. (Jun, 2015 –Jul, 2017)

Time	Jun - 15	Sep - 15	Jan - 16	May - 16	Aug - 16	Nov- 16	Apr - 17	Jul - 17
MC %	10.4 ± 0.18^{a}	10.3 ± 0.18^{a}	10.15 ± 0.18^{a}	10.25 ± 0.18^{a}	10.2 ± 0.18^{a}	10.1 ± 0.17^{a}	10.12 ± 0.18^{a}	9.8 ± 0.17^{a}
AC%	1.32 ± 0.04^{a}	1.32 ± 0.04^{a}	1.24 ± 0.04^{a}	1.21 ± 0.03^{a}	1.22 ± 0.04^{a}	1.2 0± 0.03^{a}	1.2 0± 0.03^{a}	1.21 ± 0.03^{a}
CP%	7.9 ± 0.18^{b}	7.8 ± 0.18^{bc}	7.82 ± 0.18^{bc}	7.21 ± 0.17^{d}	7.30 ± 0.17^{cd}	7.20 ± 0.17^{d}	9.50 ± 0.22^{a}	7.31 ± 0.17^{cd}
CF%	4.50 ± 0.08^{a}	4.50 ± 0.08^{a}	4.53 ± 0.08^{a}	4.00 ± 0.07^{bc}	4.20 ± 0.07^{b}	4.12 ± 0.07^{bc}	3.96 ± 0.07^{c}	3.67± 0.06^{d}
ID %	0.22 ± 0.01^{ab}	0.21 ± 0.01^{bc}	0.18 ± 0.01^{d}	0.19 ± 0.01^{cd}	0.22 ± 0.01^{ab}	0.21 ± 0.01^{bc}	0.24 ± 0.01^{a}	0.24 ± 0.01^{a}
M %	0.11 ± 0.00^{bc}	0.12 ± 0.00^{b}	0.09 ± 0.00^{d}	0.09 ± 0.00^{d}	0.21 ± 0.01^{a}	0.1 ± 0.00^{cd}	0.12 ± 0.00^{b}	0.12 ± 0.00^{b}
FM%	0.20 ± 0.01^{c}	0.20 ± 0.01^{c}	0.10 ± 0.00^{d}	0.30 ± 0.01^{a}	0.20 ± 0.01^{c}	0.10 ± 0.00^{d}	0.24 ± 0.01^{b}	0.30 ± 0.01^{a}
CHO	78.69 ± 0.91^{a}	78.5 0 ± 0.91^{a}	78.50 ± 0.91^{a}	78.60 ± 0.91^{a}	79.3 ± 0.92^{a}	79.40 ±0.92^{a}	79.90 ± 0.92^{a}	79.82 ± 0.92^{a}
EV	379.99±4.39^{bc}	370.90±4.28^{c}	380.00±4.39^{bc}	370.80±4.28^{c}	389.40±4.50^{ab}	370.9 ±4.28^{c}	390.3 ±4.51^{ab}	396.02±4.57^{a}
G%	98.90 ± 1.71^{a}	98.00 ± 1.70^{a}	98.40 ± 1.70^{a}	98.10 ± 1.70^{a}	98.00 ± 1.70^{a}	97.60 ±1.69^{a}	98.10 ± 1.70^{a}	96.60 ± 1.67^{a}
BD	0.72 ± 0.02^{a}	0.71 ± 0.02^{a}	0.71 ± 0.02^{a}	0.70 ± 0.02^{a}	0.71 ± 0.02^{a}	0.70 ± 0.02^{a}	0.74 ± 0.02^{a}	0.69 ± 0.02^{a}

Table 2: Average Monthly Temperature and Relative Humidity Data for Minna, within the Period of the Experiment from June 2015 to July 2017

Month	Jun 15	July	Aug	Sept	Oct	Nov	Dec	Jan 16	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec	Jan 17	Feb	Mar	Apr	May	Jun	July 2017
Temp T (°C)	29	30	30	30.2	31	33	33.2	34.5	34.2	34.6	34.8	32.4	30.1	29.0	30.0	31.2	34.0	34.2	34.3	34.0	34.3	34.5	34.8	33.0	31.0	29.0
R.H	68	69.8	69	70	68	60	56	55	53	52	52	71	69	69.5	69.6	69	68	61	58	54	53	53	52.5	72	70	69

3.1 Carbohydrate (CHO) and Energy values (EV)

The result of this study shows that there is non- significant increase in carbohydrate and energy values in respect to duration of storage for the stored maize, if the value at inception is compared to the values at the end of the storage as presented in "TABLE" 1. Carbohydrate value (CHO) appreciated from 78.69 ± 0.91 to 79.82 ± 0.92 after 24 months of storage. Within the same period the energy value (EV) of the stored maize also appreciated from, 379.99 ± 4.39 to 396.0.2 ± 4.57. The reasons may be due to the unique storage conditions. However in between months during the storage period, they were fluctuations which are progressive and retrogressive at different instances. The issue of not following a definite pattern as observed in the data generated, and as presented in "Fig" 1 may be due to experimental errors, or the interaction between storage structural material and the prevalent climatic conditions, or may be that the variables neither increases nor decreases during the storage duration.

Others reasons for appreciation of CHO and CV during storage may be due to grain shrinkage, negligible moisture sorption and desorption, and or loss of moisture considering the fact that the variables are calculated as percentage of the whole grain. It is in agreement with [6] [17] [18] [19]. Though different values were reported, due to different storage conditions, grain species/ varietal differences or experimental errors, the trends remains the same. The implications of this result is that, the milling value of stored cereal grains will even get better after long duration of storage in hermetic storage cocoon.

3.2 Germinability (G)

The result of this research shows that germinability is one of the greatest attributes of cocoon storage when compared to other storage systems. From "TABLE" 1 and "Fig" 1, they were slight decrease in the germination potentials, which was at 1% significance, from 98.90 ± 1.71 to 96.60 ± 1.67 within the storage duration (24 months). This is because cocoon storage is very efficient in the eradication of insects and other micro organisms such mould, which naturally attacks the embryo where germination chemistry normally originates in seeds. The high percentage of germination potential may also be attributed, to the ability of cocoon storage to maintain relatively constant moisture of the stored grains, devoid of several moisture sorption and desorption that occurs in other conventional storage systems which naturally affects the germination potential of seeds [20]. Consequently, hermetic cocoon storage, maintains constant climatic condition in the bulk, which guarantees low metabolic activities of the near dormant stored grains, saves grain energy and momentum that is normally used during germination.

3.3 Crude protein (CP)

There was significant depreciation of crude protein for the stored maize, from 7.9 ± 0.18a to 7.31 ± 0.17from the inception to the end of the 24 months storage duration as presented in "TABLE" 1. The depreciation may be due to protein denaturation, and or grain age. However the depreciations were only at 1% level of significance, at the end of the 24 months of storage in hermetic cocoon storage structures. There was no constant trend of depreciation month wise, which may be due to experimental error. The result is in agreement with [6], [19]. Though higher values of depreciation were reported, the various researches were for unsealed storage, where grain metabolic activity during storage is high, [21] observed significant reduction of protein content of cereal during long storage, and inferred that variations are largely dependent on the length of storage, crop and variety, and storage conditions, thus also in agreement with this research findings of [11], who also observed the significant reduction of protein content and starch digestibility of cereal grains during storage.

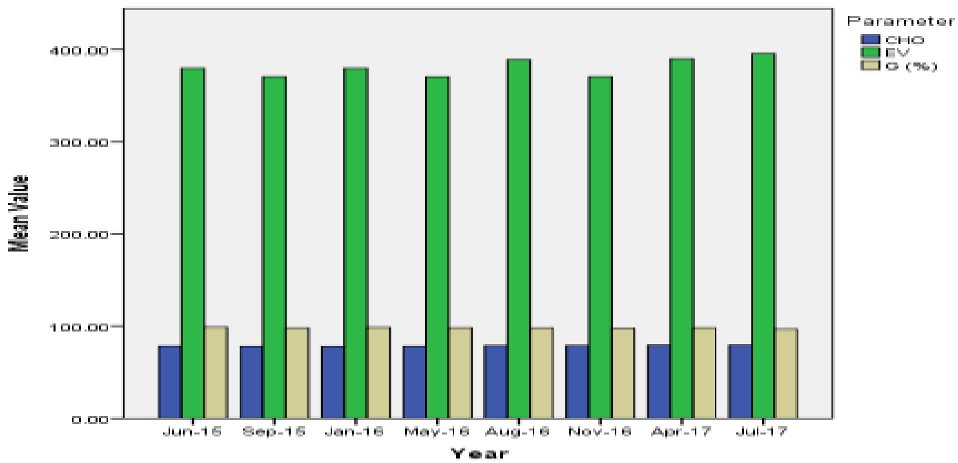

Figure 1: Graph of mean values of CHO, EV and G within the storage duration..

3.4 Crude Fat (CF) and Ash content (AC)

Variables such as fat content (CF), ash content (AC), depreciated significantly at 1% level, within the 24 months duration of storage comparing the values at the inception and the end of the storage, with the following values, CF, 4.50 ± 0.08 to 3.67 ± 0.06 and 1.32 ± 0.04 to 1.21 ± 0.03. However the flocculation of values observed within the duration of the storage, may be due to experimental errors or temperature variations. Higher temperature could denature or reduce thiamine content, an important vitamin which acts as a co-enzyme in energy transfer reaction during metabolism [18]. Grain age, slight grain metabolic activities, and sorption and desorption also are expected to affect CF and AC especially during long storage. Higher values were reported by [6] [19], though for unsealed storage, where grain metabolic activities are high, but the trend remains the same.

3.5 Bulk Density (BD) and Moisture Content (MC)

The bulk density (BD) and moisture content (MC) wet basis (wb), of the stored maize, showed no major significant difference after 24 months of storage in hermetic storage cocoon as shown in Table 1, Figures 2 and 3. At the end of 24 months of storage BD depreciated from 0.74 ± 0.02 to 0.69 ± 0.02 and MC from 10.4 ± 0.18 to 9.8 ± 0.17. from the values BD was not significant ($p > 0.05$), while the MC was significant only at 1% level ($p < 0.05$). The result of these two variables are excellent, especially when compared to other systems of storage and other storage structures in Minna, and considering the many intrinsic natural physical properties which pre-dispose maize to easy loss of moisture. However, cocoon storage possesses good potentials in terms of mass retention. This may be due to reduced respiration and metabolic activities of the stored grains, and little or no interaction with the ambient air, with the modified atmospheric condition of hermetic storage system. The low thermal conductivity of the cocoon material facilitated low heat and mass transfer between the stored grains and the ambient air. The result of this research work in agreement with [6] [17], though higher values were reported for unsealed storage. Conditions of storage, variety of the crops, temperature variation, modified atmospheric conditions of hermetic storage, and or experimental errors are prevailing factors that could vary results. The result of the mass assessment will interest organization or individual who engage in grain storage as a business or responsibility, especially where the weight of the grain is the basis for payment or grading.

3.6 Insect Damaged grains (ID), cores and fines (FM) and mould infected grains (MD)

The result of this research shows that (ID, (FM) and (MD) was totally eradicated by cocoon storage with the following values from the inception and the end of the storage as follows ID 0.22 ± 0.01 to 0.24 ±0.01, FM 0.20 ± 0.01 to 0.30 ± 0.01, and MD 0.11 ± 0.00 to 0.12 ± 0.00. None of the values for the 3 variables are significant ($p > 0.05$). Though they were irregular trends of depreciation and appreciation within the respective months, but it can be attributed to experimental errors especially in sampling and analysis. The slight increase in ID and MD noticed may be due to long period of total disinfestation, and because the insects were totally eradicated at the end of the disinfestation process FM values were also reduced [6]. Eradication of insects and other micro-organisms normally agents of deterioration is one of the greatest attributes of hermetic storage technology.

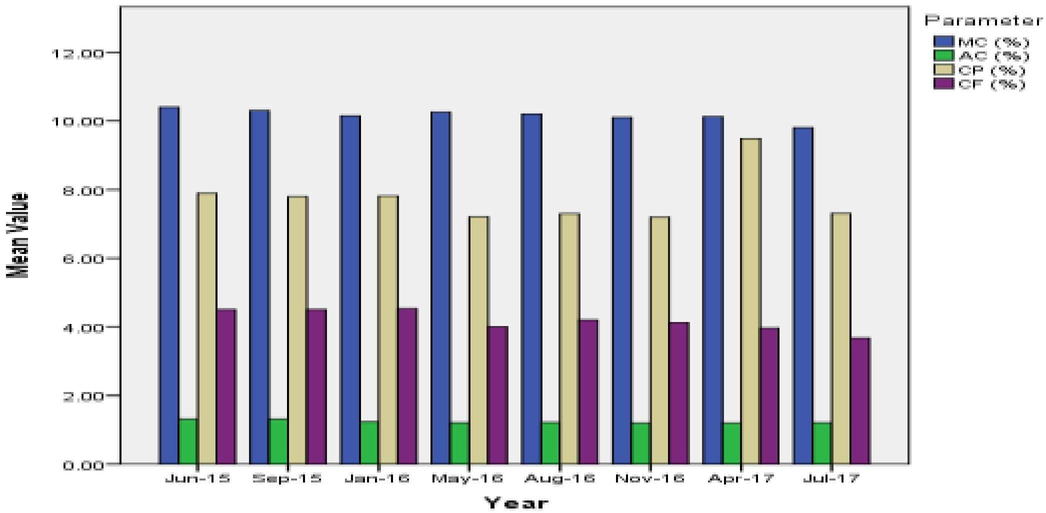

Figure 2: Graph of mean values of MC, AC, CP, and CF within the storage duration'

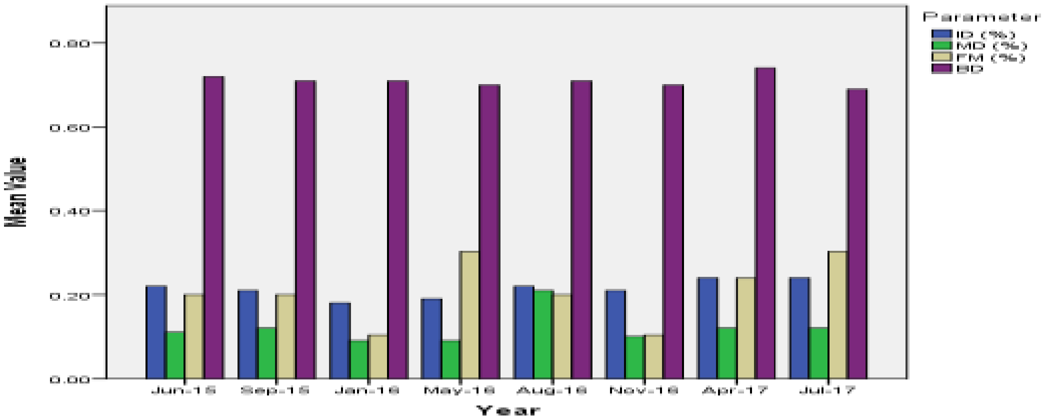

Figure 3: Graph of mean values of ID, MD, FM, and BD within the storage duration.

IV Recommendation and Conclusion

4.1 Gains of hermetic cocoon storage

1. Stabilization/retention of the ever flocculating moisture content and bulk density of the stored Grains. Cocoon not only keeps the grains in good condition, but maximizes farmers profit especially where grain grading is practiced and or where grains are marketed based on weight.
2. Eradication of insects and micro-organisms, who are naturally agents of deterioration is total and efficient.
3. The physical characteristics of grains stored in hermetic cocoon are excellent.
4. There is relatively less labour and resources involved in the grain management when compared to other system of storage, and can be rolled to a simple pad and moved to another location.
5. It is a non-chemical type of storage, no aeration, fumigation, and grain turning or recycling is required.
6. Total elimination of huge storage losses associated with other non-sealed storage structures.
7. With hermetic storage cocoon precious and delicate crops that hitherto been problematic to store could be now stored at ease.
8. It may be used to hold Government buffer reserve/stocks, which can be moved in a matter of hours to emergency locations, since the grains are bagged already in cocoon storage.

4.2 Shortcomings of Hermetic Storage Cocoon

1. Capacity/space remains one of the greatest impediments of Cocoon storage. It is like stacking grains in a warehouse where high altitude stacking is difficult. A lot of space occupied by the bags used in the packaging of the grains, and in between stacked grains. This makes it a space demanding type of storage.
2. Material used for the manufacturing of cocoon is not very durable, and largely non bio-degradable.
3. Major threats include security concern such as, pilferage, fire outbreak, Termite and rodent attack beneath, via the cocoon base, is susceptible especially in area of high prevalence, and generally in tropical climates.
4. Loading and unloading of grains is manual and critical, though mobile conveyor can be used, but it's affordability in developing countries is also an issue.
5. It is a bit technical form of storage that needs training; its affordability is still a problem.
6. Bigger capacities of Cocoon could be problematic in handling/management considering the size but smaller capacities may be relatively easily managed.

4.3 Recommendation

1 Routinary checks, best practices on the opening and closing of the Cocoon should be integral part of the practical training for the users of hermetic storage cocoon.

2. It is highly advised that the stored grain be cleaned to eliminate dust, cores and fines (foreign matters) and re- bagged in desired bags before stacking inside the cocoon for storage. However it should be noted that every polypropylene bags has its expiring dates. If it is expected to hold bagged grains inside the cocoon for more than two years, special/stronger bags with longer lifespan should be used.
3. For proper and efficient use of cocoon, various monitoring and control equipment such as: Oxygen sensors, meters, industrial blowers or hand blowers, leak detectors should be made easily available for farmers to buy.
4. It is recommended that the expiration dates of cocoons be written on them to avoid problems during storage. However, its life span largely depends on use and handling. If carefully handled could serve for many years. It is pertinent to note that continuous holding of grains concurrently for two years or more may weaken the base. When grains have been unloaded from cocoon, it becomes easy for rodents to eat it up the cocoon,

because of smell of grains in its body. A lot of work is therefore needed to protect the cocoon from rodents after use, for purpose of re-use. The cocoon must be washed immediately after unloading of grains. A cocoon that is perforated at several places by rodents is not completely useless, it could be patched and used along with fumigants in non-hermetic storage system , where it will serve as ordinary flexible silos. Its near air tight condition will help during fumigation.

5. It is recommended that cocoon manufacturers pads or reinforces the cocoon base (the portion that lies on the ground) using stronger materials that can withstand more stress, pressure, and bio-degeneration. This is because presently it is the weakest component and will get bad before other parts of the cocoon.
5. Hermetic storage cocoon deserves more publicity, as it is still largely unknown in developing countries, especially to peasant farmers who can procure one with the help of their farmer's co-operative societies.

4.4 Conclusion

There is no doubt that cocoon storage is one of the best forms of storage for both delicate and non-delicate dry food crop presently. Its ability to take care of the protracted issues in crop storage history, such as insect infestation, flocculating moisture content and mass retention of stored crops, presence of moulds such as aphlatoxins, and huge storage losses associated with available storage systems/structures, and still maintains the quality of stored crops, prescribes it as a way forward in crop storage in the tropics and developing countries, when it comes to middle and commercial level crop storage.

References

[1] Grains and Legumes Nutritional Council (GNLC). Retrieved from, www.glnc.org.au/grains/types-of-grains, 2010, Retrieved 16th August 2015.

[2] S. K. Vassal, Quality Protein Maize Story. *Food Nutrition Bulletin*, 21, 2000, 445 – 450. Retrieved fromhttp://www.best home remedies. Com/herbal medicine/grains & pulses. Retrieved on 12/12/2016.

[3] S. Akande, & G. O. Lamidi, Performance of Quality Protein Maize Varieties and Disease Reaction in the Derived-Savannah Agro-ecology of South-West Nigeria. *African Journal of Biotechnology*, 5(19), 2006, 1944-1758.

[4] Food and Agriculture Organization (FAO), Grain Storage in Sub Saharan Africa. Retrieved from, www. fao. Org/dorcrep/5125oeo, htm 2010. Retrieved on 20th July, 2015.

[5] B. A. Adejumo, & A. Raji, Technical Appraisal of Grain Storage System in Nigerian Sudan Savannah. Agricultural Engineering International. *The CIGR- E Journal*,11(9), 2007, 1-9.

[6] B. A. Alabadan, C. A. Okolo, & A. A. Adekola, Evaluation of Nutritional Characteristics of Corn Stored in Metallic Silos. *CIGR Journal*, 18 (3), 2016, 194-204.

[7] P. Villiers, Hermetic storage: A Viable option. *New Agriculture development bulletin 2008.* Retrieved from www.New-aginfo/en/developments/dev.Hem.php.Retrieved 11th August, 2015.

[8] Food and Agriculture Organization (FAO). Post Harvest Losses Discovering the Full Story: Overview of the Phenomenon of Losses during Postharvest System. F.A.O Rome. 2009, pp. 41-52.

[9] N. Jonfia – Essien, S. Navarro, & P. Villers, Hermetic storage : A Novel approach to the protection of Cocoa Beans. *African Crop Science Journal.* 18, (2), 2010, 59-68.

[10] P. Villiers, T. De Bruin, & S. Navarro, Development of Applications of hermetic storage Technology. *9th International Working Conference on Stored Product protection* Sao Paulo Brazil. 2006, 719 – 729.

[11] C.A. Okolo, O. Chukwu, B. A. Adejumo, S. A. Haruna, Hermetic storage Technology: The Way Forward in solving Numerous Cereal Grain Storage Challenges in Developing Countries. International Journal of Research and Technology (6) 7, 2017, 682-692.

[12] P. J. Anankware, A. O. Fatunbi, K. Afreh-Noumah, D. Obeng–Ofori, & A. F. Ansah, Efficacy of the multiple layer hermetic storage bags for bio-natural management of primary pests of stored maize. *Academic Journal of Entomology* 5 (1), 2012, 47-53. ISSW 1995 – 8994.

[13] S. Navarro, Modified Atmospheres for the control of stored products insects and mites: Insect Management for Food Storage and Processing, Second Edition. Heaps, J. W Ed. ACCC International ST. Paul Minnesota U.S.A , 2006, 105 – 146.

[14] P. Villiers, T. Navarro, & T. De Bruin, New applications of Hermetic storage for grain storage and Transport. *10th International Working Conference on Stored Product Protection (INCSPP)* Portugal 2010. Retrieved from http: /grain pro. Com/gpi/images/pdf/commodity/N. Retrieved 22nd October, 2015.

[15] Association of Official Analytical Chemist (AOAC), Official methods of Analysis 18 Edition, *Association of official Analytical Chemists, Gaithersburg, MD* 2006. Pp 215-275.

[16] G. I. Onwuka, Food Analysis and Instrumentation. Food and Science Technology Department, 2010, Michael University Umudike, Umuahia Nigeria.

[17] A. I. Durojaiye, Destructive and Non Destructive Measurement of some Proximate Composition of Cereal for Confectionery and Pasta Production. Unpublished, M. Eng Federal University of Technology Minna, Nigeria, 2012, 3-54.

[18] O. P. Gupta, K. Venkatesh, R. K. Gupta, & E. Sharma, Prolong Storage Impairs the Industrial Quality of Stored Grain, 2013. Retrieved from Agriculture Information Hub Http:// www.krishisewa.com/cms/articles pht/2.

[19] A. A. Osipitan, O. K. Olaifa, & O. A. Lawal, Evaluation of proximate Composition of maize grain infested by maize weevil. Sitophilus (*Zea Mays*). Mun. Ent zool,7,2012,439 450. Retrieved from www.munisentzool.org.

[20] O. Chukwu, & E. S. Ajishegiri, Effect of Moisture Sorption Cycle on some Physical Properties and Nutritional content of Agricultural Grains. *African journal of technology*, 9 (2), 2005, 121-125.

[21] P. Pushpama, & V. Vimala, Storage and The Quality of Grain: Village Level Studies, 2012. Retrieved From http://unu.edu/unpress/unupbooks/80478e/80478EOk.htm. Retrieved on 19/5/2017.

Okolo, C. A. “Cocoon Storage: A Better Alternative to the Use of Inorganic Insecticides/Pesticides in Middle Level and Large Scale Storage, in the Tropics.” International Journal of Engineering Science Invention(IJESI), vol. 6, no. 10, 2017, pp. 62–70.