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Abstract. Inert atmosphere silo (IAS) has been advocated by Nigerian Stored Products Research Institute (NSPRI) as a sustainable alternative to the use of conventional silos and synthetic chemicals for grains storage in tropical climates. A battery of two units of 250 tonnes IAS installed at the commercial farm of Landmark University Omu-Aran by NSPRI was evaluated for maize storage. Quality parameters such as proximate compositions and microbial loads were determined and their respective results subjected to T-Test statistical analysis. The results of the analysis showed a slight increase in moisture content from 10.57 % to 10.66 % (db) after 6 months of storage. During the storage period, insect infestation was completely suppressed and quality of the grain was maintained, as there was no significant difference at ($P \le 0.05$) in the proximate compositions of the initial and final samples. There was significant difference ($P \le 0.05$) in bacteria loads and fungi counts of the initial and final samples. Reduction in microbial loads was experienced and the values obtained were within acceptable limits (10^4 Cfu/g) recommended for cereals. The germinability of the maize was maintained at 96 % after 6 months; thus indicating effectiveness of the technology for commercial storage of maize seed.

1. Introduction

Globally, food losses are high however, over 40 % of the food losses are experience in postharvest and processing activities in developing countries whereas, over 40 % of food losses in industrialized nations are experience at retail and consumer stages [1]. One of the major challenges militating against agricultural sector in Nigeria is inappropriate and inadequate postharvest facilities [2]. The consequential effect of the losses on the nation's economy was estimated at US$320 Million. This is because of poor harvesting techniques and use of inappropriate storage facilities for grains, root crops, tubers and fruits. It the provision of appropriate and adequate storage facilities that can guarantee all season availability of safe food products; however, this has been a great challenge in third world countries [3]. The agricultural value chain has identified safe storage of agricultural products as a curial

postharvest stage in supply of food to ensure surplus during off-season [4]. Other benefits of food storage are; provision of a balanced diet for man and livestock, addressing of demand and supply dichotomy and preparation for emergencies that can result from drought, insurgency and calamity. In addition, effective storage keeps produce quality and extends its shelf life, thereby encouraging increase in production, processing and consumption of varieties of product [5].

One of the major means by which food security can be achieved is through efficient preservation and storage of agricultural produce [6], Maize is one of the major grain crops in Nigeria and West Africa providing food for human and animals feed. The crop is susceptible to severe postharvest attack by *Sitohilus zeamais*, which is one of the identified destructive storage pests for maize. It causes severe losses in the maize during storage if not adequately taken care. The use of chemicals such as phosphine is widely practise in Nigeria as means of controlling insects attack in stored maize. The chemical residue however constitutes a danger to human and animal health. Natural ways of protecting grains against infestation during storage is the use of materials gotten from plant, which has given appreciable results [7]. However, the limitation of its industrial application has rendered it unpopular for grain storage.

Utilization of inert atmosphere silo for grain storage in the Tropics is known for its technical benefits over conventional silos, which are not airtight in operation. Research efforts have revealed the superiority of grains preserved under nitrogen atmosphere compared to grains stored in conventional silo with phostoxin fumigants. The storage technology has demonstrated its potential in addressing the challenge of moisture migration and condensation associated with conventional silos [8, 9, 10]. It was the aforementioned advantages of the storage system that convinced and encouraged Landmark University Omu-Aran, an agricultural focused University in Nigeria to adopt it for its commercial farm. This study was aimed at evaluating the suitability of the silo for commercial utilization in grains storage.

2. Materials and method

2.1. Description of the silo
The technology is an airtight storage facility with provisions for modification of its environmental conditions to suit control of insect infestation in stored grains. It is a patented storage technology of NSPRI. The installed capacity at Landmark University is 500 tonnes (2 units of 250 tonnes) (figure 1). Its major components are bin, plinth, gallery, gas supply network, monitoring devices and handling equipment. The bin is a cylindrical metal structure with conical top coated with food grade paint. It has three outlets for loading, discharging and accessibility. It has an overall height and diameter of 10 m and 8 m respectively. The plinth is a reinforced concrete basement that provides supports for the bin and the gallery. The ladder and walkway constitute the gallery for easy access of the silo. The gas supply system of the silo is responsible for supply of nitrogen to the bin through the following components: gas cylinder, gas line, gas control valve, gas regulators and purging container. The gas line is supported with gas line tray and vertical support. The main storage conditions monitoring devices are pressure gauge and temperature probes. The handling accessories of the silo include grain bunker, grain sampling probe, loading and unloading auger conveyors.

Figure 1. A battery of two units of 250 tonnes inert atmosphere silo installed at the commercial farm of Landmark University in Omu-Aran

2.2. Maize loading and storage
A mixture of white and yellow maize was supplied by the University for the storage exercise. A unit of the bin was used to store the maize. The moisture content of the maize was determined to be 10.57% (db) at the point of loading into the silo. The storage duration was 6 months (March to September 2018). The maize was cleaned with a mechanical grain cleaner before loading into the silo as shown in figure 2. Silo loading was carried out mechanically with the use of auger conveyor and grain bunker (figure 3). After loading, the silo was sealed up and nitrogen gas was applied through purging. The gas was applied at a pressure rate of 5 bars from three valves for 2 hours. This was done to modify the micro climate of the storage system. The purging exercise was repeated after 3 months of storage. However, it only lasted for 1 hour unlike the initial purging. After six months of storage, the maize grain was discharged via a mechanical auger conveyor provided for unloading of the silo.

Figure 2. Cleaning of the maize grain for loading.

Figure 3. Cleaned maize loading using auger.

2.3. Determination of moisture content
Laboratory oven drying method was used to determine the moisture content. 2 g of ground maize sample was weighed in a clean, dried moisture dish and recorded as W_1. The weighed dish with sample was allowed to dry in an oven at 103.5 °C for 4 hours until a constant weight was obtained. After cooling for 30 minutes in a desiccator, it was weighed as W_2 according to [11]. The % moisture content was calculated on dry basis (db).

2.4. Proximate analysis
Samples were obtained from bulk grain at the top, middle and bottom of the bin using a sampling probe provided for the purpose. The samples were placed in sealed container and immediately transported to laboratory for analysis. The proximate compositions; carbohydrate, moisture, crude protein, crude fibre, fat and ash were determined in accordance with the methods of the Association of the Official Analytical Chemists (AOAC) [11].

2.5. Insect count and germinability
Insect mortality of the insect was determined by counting live and dead insects as well as species found in the samples. Germinability test was conducted on the samples. From each sample, 100 seeds were randomly selected for the germination test. Twenty (20) seeds were arranged on a moistened cotton wool in each of the five (5) 9-cm disposable petri dishes and placed on laboratory bench. The

arrangement was moistened with 10 ml of water. The numbers of seeds germination was calculated using the equation adopted by Adedire and Akinkurolere [12] (Equation 1).

$$\% \text{ Germination} = \frac{\text{Number of germinated seeds}}{\text{Total number planted seeds}} \text{ x } 100 \qquad (1)$$

2.6. Microbial analysis
The analysis was carried out in accordance with the manuals of Food Quality Control of the Food and Agriculture Organization (1997). The maize samples were first reduced to smaller particle size using a dry-mix laboratory blender at 7000 rpm and thereafter, were serially diluted to yield five dilutions. 10 g reduced grains was dissolute in 90 ml sterile distilled water to present 10-1 dilution, subsequent (1 ml) aliquot into (9 ml) diluents gave other dilutions. Nutrient Agar (Lab M Limited, Lancashire) was used for the enumeration of bacterial species; MacConkey agar (BIOMARK Laboratories, India) and Potato Dextrose Agar (Sisco Research Lab. Pvt. Ltd., India) were utilized for total coliform and fungi enumerations respectively. Few drops of streptomycin were incorporated into the PDA in order to prevent Bacteria growth. The culture media were prepared according to the manufacturer's specifications and sterilized in the autoclave at 121 ˚C for 15 minutes.

Microbial species were enumerated using pour plate inoculation techniques; inoculums (1 ml) from desired dilution tubes were dispensed into sterile Petri dishes using sterile micropipette and respective (20 - 25 ml) sterile molten medium for target microorganisms were dispensed. Inoculated plates were incubated in an incubator at 35 ± 2 ˚C for 24 hours. Microbial loads were expressed in colony forming unit per gram (Cfu/g) of each sample. Experimental setups were in triplicate.

2.7. Statistical analysis
The obtained data were subjected to statistical analysis using T-Test for significance difference among treatments mean at ($P \leq 0.05$) using SPSS software package version 15.0.0 (IBM Statistics).

3. Results and Discussion

3.1. Moisture content
A slight increase in moisture content from 10.6 % to 10.7 %(db) was noticed after 6 months of storage. The increased was analysed to be significantly different at $P \leq 0.05$ (Table1). The increase was still within the acceptable limit of moisture content of maize of 12 % recommended by [1].

3.2. Proximate analysis
The results of the proximate showed no significant difference in the carbohydrate, ash, fat, crude protein and fibre contents of the initial and final samples of the maize (table 1). The observation can be attributed to the inaction of insects' activities, decline in mould infestation and reduction in water activity. This corroborated the reports of several researchers on inert atmosphere storage that during the storage period, insect infestation was completely suppressed and grain quality maintained throughout the period [8\; [10]; [13] ;[5].

Table 1. Moisture content and proximate composition analysis.

Conditions	Moisture Content (db) (%)	Ash (%)	Fat (%)	Crude Fibre (%)	Crude Protein (%)	Carbohydrate (%)
Initial	10.6 ± 0.05*	1.8 ± 0.19	7.0 ± 0.08	2.3 ± 0.09	9.8 ±0.24	69.6 ± 0.33
Final	10.7 ± 0.39*	1.7 ± 0.12	4.4 ± 0.14	2.3 ± 0.22	9.5 ± 0.06	72.4 ± 0.26

Note: Mean ± S.E. within a column followed by "*" differ significantly.

3.3. Insect count and germinability

There were no live insects in the samples collected. However, dead adult insect of *Sitophilus zeamais* was found in all the sampled grains and one *Tribolium castaneum* from one of the samples taken at the bottom of the silo. First Filial (F_1) emergence was only recorded from the initial sample taken at the point of loading the silo, whereas, there was none from the samples taken thereafter from the silo (table 2). The microclimate created in the silo did not support live as reported in previous studies on inert atmosphere silo [13; [5]. Germinability test result indicated that seed viability was maintained throughout the six months storage period and there was no significant difference in the samples taken bi-monthly when compared with the result of initial test carried out. This justifies the report of [14] on modified atmosphere storage of seeds with respect to functional characteristics, germinability and viability of seeds. This suggests that inert atmosphere silo can be used for commercial storage of seeds.

Table 2. Insect count and germinability test results.

Samples	Sample location	Numbers of live insect	Numbers dead	Insect type	F1 Emergence	Germinability(%)
	Top	0	1	*Sitohilus zeamais*	0	98
	Middle	0	2	*Sitohilus zeamais*	0	97
	Bottom	0	0	-	0	98
	Top	0	2	*Sitohilus zeamais*	0	97.5
	Middle	0	4	*Sitohilus zeamais*	0	98
	Bottom	0	3	*Sitohilus zeamais, Tribolium castaneum*	0	98
	Top	0	3	*Sitohilus zeamais*	0	98
	Middle	0	1	*Sitohilus zeamais*	0	95
	Bottom	0	0	*Sitohilus zeamais*	0	96

3.4. Microbial analysis

The microbial loads of the initial maize grain were within the acceptable limits set by the International Commission on Microbiological Specifications for Foods. The technology was able to record a decline in microbial loads present in samples at the end of the storage. A significant difference at $P \leq 0.05$ was recorded in the bacteria loads and fungi counts of the initial and final samples (table 3).

Table 3. Microbial analysis of the initial and final maize samples.

Conditions	Bacteria Loads (Cfu/g)	Fungi Counts (Cfu/g)	Total Coliform Counts (Cfu/g)
Initial	$1.9 \times 10^3 \pm 2.1 \times 10^2*$	$2.6 \times 10^3 \pm 1.4 \times 10^1**$	$9.6 \times 10^1 \pm 0.9 \times 10^1$
Final	$1.8 \times 10^2 \pm 1.4 \times 10^1*$	$1.8 \times 10^2 \pm 1.5 \times 10^1**$	$1.7 \times 10^1 \pm 0.9 \times 10^1$

Note: Mean ± S.E. within a column followed by "*" and "**" differ significantly.

4. Conclusion
The study carried out on the 250 tonnes inert atmosphere silo for maize storage has proved that the technology is commercially viable for storage of grains. The silo is an efficient technology in stored product insects infestation prevention and control as well as maintenance of moisture content and microbial loads during storage. The silo can also be utilised for commercial seed storage with grains viability maintained for 6 months.

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