

Evaluation of Wooden Silo during Storage of Maize (*Zea mays*) in Humid Tropical Climate

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ABSTRACT

The aim of this study was to evaluate the performance of wooden silo for long-term (wet and dry seasons) storage of maize (*Zea mays*) under tropical climate. A one tonne capacity, 1.4m diameter and 1.1m height hexagonal wooden silo was constructed and erected in Minna. The silo was of Iroko (*Melicia excelsa*) ribs and exterior grade (redwood) plywood stress-skin panel as sheathing material. It had double-layered wall panels with a small air gap in-between the layers, for adequate heat insulation. A loading door and discharge chute were located on the wall panels and a triangular loading door on the top panels. The silo floor rested on wooden pile foundation. Grain and ambient temperature measurements and silo evaluation were done for 9 months. The ambient temperatures during the dry season were 4°C - 7°C higher than during the wet season. The minimum and maximum ambient temperatures were 20.9°C (31st day of storage, wet season) and 38°C (189th day of storage, dry season) respectively. There were no incidences of moisture condensation within the silo. The structure possessed adequate structural integrity except for slight incidences, colour change, delaminating and peelings of sheathing materials.

Keywords: Silo, Wooden, Tropics, Climate, Temperature Variations, Performance, Maize

1. INTRODUCTION

Farmers all over the world lose much of their grains due to influence/activities of insects, rats, birds, micro – organisms and the interplay of some environmental conditions that could promote the activities of these agents of deterioration. In Nigeria, these losses are up to 50% in storage with farmers storing their farm produce in rhumbus, local cribs, bags, pots, calabashes, baskets and earthen pots (Igbeka, 1992). Oyebanji, (1996) reported that on-farm and post-harvest losses alone account for about 25 – 40% of the total crop yield in the country. To arrest the increasing losses, an efficient storage structure or building that will minimize losses and maintain quality of food grains is necessary.

Everyday, one out of five people in the developing world cannot get enough food to meet his or her daily calorific need. It is the responsibility of all nations to ensure access by all people at all times to safe and adequate nutritious food value needed to maintain a healthy and active life. Also, the commonly used metallic silos are susceptible to moisture migration and thus unsuitable for the long-term storage of grain under the humid climatic conditions (FAO, 1995). Alabadan and Oyewo, (2005) reported that wooden silo performed better than metal silo in the tropics.

The objective of the study was to evaluate wooden silo used for storage of Maize in Minna, tropical Nigeria.

2. MATERIALS AND METHODS

2.1 Design of the Wooden Silo

Factors considered in the design of the silo include the objectives of the storage, the environment wherein the silo will be placed, the duration of storage, the type of grain (grains), the quantity of produce to be store, silo type, the desired shape of silo and its capacity, expected loads on silo; the dead loads and live loads, materials of construction, cost of materials and labour and ease of operation and maintenance of the silo (Alabadan, 2002).

2.2 Description of the Silo

The wooden silo is hexagonal in shape having internal dimensions of 1.1m in height and 1.4m in diameter (Photo 1). Plywood of exterior grade was used. The plywood is 3 plies (9 mm) thick, 1440 mm by 2880 mm in area and bonded together using Phenol – formaldehyde resin adhesive. The plywood was used for the walls, roof and floor while a 2 by 2-solid Iroko (*Melicia excelsa*) timber was used for the frames. The silo has three openings; a triangular shaped one at the top for loading, and two rectangular shaped ones at the sides that serve as door and discharge chute. The door was used for loading until the lower door level is reached with stored grains while the remaining was loaded through the roof opening with the door and discharge chute closed. The discharge chute is used for unloading. All the openings are normally kept closed so that the bin is practically airtight.

The silo is one-third capacity filled with shelled corn of 300 Kg weight at initial moisture content of 13.8 % wet basis. The silo is raised 0.5m above the ground level with the timber columns. The columns were erected in six dug earth holes filled with a 1: 2: 4 concrete mix to the ground level. All the surfaces of the bin were under almost similar ambient conditions.

2.3 Evaluation of the Silo Structure

Colour change, moisture condensation, delaminating at the joints, delaminating and peeling of sheathing materials (plywood), wood deterioration, sinking and overturning of structure, foundation settlement and deflection of floor of the structure were observed daily and photographs taken.

Light blue colour paint was chosen for the silo at installation because it has a low absorptivity for short wavelengths of in-coming solar radiation and a high emissivity for the long wavelengths of infrared radiation leaving the grain bin. The effect of different paints on the temperature variation from the ambient to the stored grain was not considered in this study.

Thermometers were inserted at three points in the storage bin. They were set at depth 0.2 m and radii 0.0 m (centre), 0.35 m (middle), and 0.7 m (wall) of the silo to measure the grain temperatures. One thermometer was hung at the top above the grain surface to measure the temperature of the air space above the grain surface.



Photo 1: Installed Hexagonal Wooden Silo

A psychrometer was used measured both the dry-bulb and wet-bulb ambient temperature of the silo. Measurements were taken three times daily at 900hours, 1200hours and 1500hours to ensure a complete representation of each day.

Measurements of rainfall, wind and solar radiation were not measured locally. However, the data available in the Minna Airport Meteorological Office were used for the work.

Seed grading was carried out during the period of storage according to NIS 253 (SON, 1989). The grains were graded into sound, infested, immature, broken and foreign materials. These were then expressed in percentages. The stored grains were mixed regularly to ensure good storability eliminate build-up of temperatures, hot spots, caking and mould formation.

3. RESULTS AND DISCUSSION

3.1 Colour

The colour of the silo structure has some influence on the radiant heat exchange between the silo and the environment. Yaciuk, *et al.*, (1975) reported that white paint has considerable better radiation properties. They noted that high emissivity at long wave-lengths is more important than a low absorptivity at short wave-lengths arising from the fact that the black-rubber bin simulated temperatures were close to those for bin painted white. Due to the effects of weather, the light blue colour paint of the silo at installation could not be maintained. However, it lasted from February 1998 to June 2000 (28 months) and repainting was done in July 2000.

3.2 Grading of the Stored Maize

Table 1 contained the result of the grading for 6 months of storage. At the beginning of storage in July, the test grain is about 61.50% whole and sound, 12.58% infested and 1% impurities. The result of the grading for July might be due to the fact that the stored grain was a year old before it was bought for the experiment.

For six months of storage in the wooden silo, these levels were maintained throughout with little variations. The stored maize in this study is within the permissible limits and thus can be classified as grade No 2 according to Nigeria-Grain Grading Standards (Maize) NIS 253-1989 Maximum Limits (SON, 1989). This is an indication that the wooden silo is able to maintain the quality of the stored grain.

Table 1: Grading of the Stored Maize

	July	Aug.	Sept.	Oct.	Nov.	Dec.
Whole sound (%)	61.50	38.09	46.03	66.43	41.32	72.72
Whole sound (coloured) (%)	07.30	29.36	07.47	36.31	14.35	05.40
Whole sound (immature) (%)	14.11	19.30	13.39	20.10	08.08	09.33
Broken (%)	03.43	01.09	02.54	08.66	02.53	01.93
Infested (%)	12.58	11.63	12.11	18.25	11.32	09.89
Impurities (%)	01.08	00.78	00.86	06.29	00.25	00.37

3.3 The Silo Joints

The six wall panels were jointed together with nails and the remaining crevices filled with car body filler to ensure an airtight silo system. The joints were constantly observed for any sign of failure such as nail pulling or opening of the inter-panel spaces. No sign of any failure was observed from installation until around February 1999, which is after 12 months of installations when small openings were noticed at roof panels as shown in Photo 2. These were filled with body filler as shown in Photo 2. This may be attributed to the effect of weather and the nails that are losing their gripping powers due to the alternating wetting and drying of the wood product. No warping was observed.



Photo 2: Delaminating of Joints

3.4 Delaminating and Peeling of Sheathing Materials

After the wet season of 1998 in October, the silo was exposed to a dry season from November 1998 to April 1999. Photos 3 and 4 showed stages of delaminating and peeling developments. Initially, it was the joints that were delaminating but due to continued exposure to weather over a period of time, the sheathing material for the silo roof began to peel. Photo 4 shows severe peeling of the painting materials and a thin ply layer of the plywood. The peeling is more pronounced where four roof panel members met and also at other parts of the roof. However, there were no traces of peelings on the wall panels. Continued peelings reduce the plies of the plywood and hence constitute a weak part of the material and structure. The peeled parts would allow free entrance to water, insects and other deteriorating agents. Provision of shade over the storage structure would help to reduce or eliminate the problem.

3.5 Foundation Settlement

Since installation in February 1998 to date, regular observation showed that none of the piles was found to have sunk which indicates the absence of any consolidation movement in the silo foundation. The lengths of the six piles remained the same as at installation while the concrete foundation provides for grip and stability remained intact. The silo is a shallow type, therefore overturning was not considered.



Photo 3: Mild Peeling of Sheathing Material



Photo 4: Severe Peeling of Sheathing Material

3.6 Wood Deterioration

There were no noticeable sign of deterioration of the structure except for the loading chute door on the roof that was replaced. Due to much rainfall in 1998 and 1999 and the possible accumulation of moisture at the interface of the loading chute door and the roof panel body, the door decayed and was replaced. One reason that can also be adduced for this occurrence is the fact that the loading chute door on the roof was locked immediately after loading and remained locked throughout the storage period to prevent rainwater from getting into the silo. For long service life of the wooden silo, it should not be exposed to direct rainfall.

3.7 Deflection of the Silo Floor

With the loading and unloading of the silo, there was no critical deflection of the floor at the one-third loading and this is not expected to pose a threat even at full load. The observations of the floor support underneath did not indicate any damaging effect of loading on the floor. This shows the adequacy of the joints to resist the imposed load, the foundation and soil to provide adequate support. Deflection of the floor was not measured because of the manner the floor was designed and built and the small test grain used for the experiment.

3.8 Ambient and Silo Temperature Variations

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°C around the wet season of August to 38.9°C in the dry season of February and March giving a range of 10.4°C (FAAN, 1999). The corresponding average monthly rainfall is usually about 409 mm in August and none in February and March. Figure 1 shows the temperature variations within and outside the wooden silo.

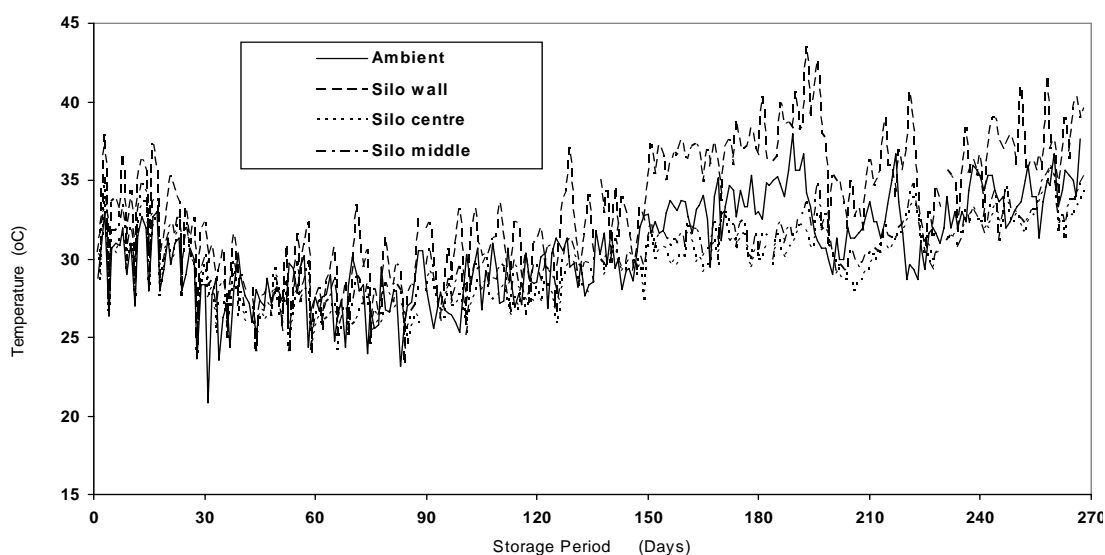


Fig. 1: Ambient and Measured Temperatures at the Geometric Centre, Middle and wall of the Wooden Silos.

The ambient temperatures were lower than the wall temperatures but higher than the middle and centre temperatures. Temperatures decreases from the wall to the centre. The wooden silo was able to keep down temperature fluctuations within the silo interiors and hence will

perform better in the tropics than steel (Alabadan and Oyewo, 2005). There were no incidences of moisture condensation within the silo even with the higher wall temperatures.

4. CONCLUSIONS

Based on the results of this study, the following conclusions are drawn:

The temperatures at various points within the bulk were generally lower than the ambient temperatures. This shows a great potential of the wood product in reducing the effect of the ambient temperatures.

The highest grain temperatures within the silo were 36⁰C while the highest ambient temperature was 38⁰C during the dry season. The lowest temperature within the silo was 24⁰C while the lowest ambient temperature was 20.9⁰C during the wet season.

The stored grain can be classified as grade No 2 grain based on the Standards Organization of Nigeria. The grade was maintained throughout the storage period.

The defects such as colour change, delaminating and peeling of sheathing materials noticed can be eliminate, minimized or reduced by insulating or covering the silo structure with a shade.

The silo structure maintained structural integrity after four years of erection except for mild peelings of sheathing materials, nail slip and colour change.

5. REFERENCES

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