Temperature Variations within Wooden and Metal Grain Silos in the Tropics during Storage of Maize (*Zea Mays*)

B. A. ALABADAN, O. A. OYEWO

Department of Agricultural Engineering, Federal University of Technology, Minna, Nigeria
topealabadan@yahoo.co.uk

Abstract

The study was carried out on the comparative analysis of temperature variation within wooden and metal grain silos under a typical tropical weather condition in Nigeria. Temperature variations within and outside the silos were monitored for 130days (July to November) during storage of maize. Results showed that the grain temperature at the centre of the silos ranged between 24.0-32.7°C and 23.8-35.0°C for wooden and metal silos respectively. Also, at the silo walls, grain temperatures ranged between 24.5-35.8°C and 24.0-34.7°C respectively. The standard error of estimate between the results of the silos at the centres and walls were 1.65°C and 1.16°C respectively. The temperatures at the top of the metal silo (grain surface) were 1.9°C and 4.1°C higher than those of the wooden silo and ambient respectively. It can be concluded that wooden silo is more effective at temperature control than metal silo under the tropical conditions.

Keywords

Tropics, Temperature, Silo, Wooden, Metal

Introduction

A stored-grain bulk is a man-made ecological system in which deterioration of the stored product results from interactions among physical, chemical and biological factors. Temperature is a key factor in the regulation of pest populations in the stored grain (Chang *et al.*, 1993). In the absence of metabolic heat release by heavy infestations of insects, weather influences are the major cause of temperature changes in bulk storage. Sensible heat is transferred through the bulk by conduction and, where temperature gradients occur, by convection. Seasonal temperature changes in stored grain bulks have been measured and modelled (Basunia *et al.*, 1996 and Lucas and Alabadan, 2002).

In Nigeria, bulk storage of grains are done in 25,000 metric tonnes imported metal silos located in every state and the Federal Capital Territory. These silos of temperate region origin, although purchased, installed and stocked at very high cost, are associated with moisture condensation, hot spots development and caking (Talabi, 1996). Up to date, very few data is available on temperature changes in grain bulks stored under tropical conditions. These few data concentrated on comparative tests of temperature variation within silos of different materials using empty silos (Sinha, 1973 and Lucas and Mijinyawa, 1996). The objective of this work is to carry out a comparative analysis of temperature variation within silos made of metal and wood (plywood) during storage of maize (*Zea mays*) under tropical conditions.

Materials and Methods

Two hexagonal silos made entirely of wood (Plywood) and metal were constructed and used for the study. The hexagonal shape shown in Plate 1 is preferred to either a rectangular or a square type because of the improved load distribution at the corners (Bokhoven, 1983). Also, according to Jayas, *et al.*, (1994) the shape of the silos (circular, rectangular and square) had little influence on the temperatures attained within a silo. Due to land tenure and the subsistence nature of agriculture in Nigeria, the annual grain output for a medium farmer is between one and five tonnes (Igbeka, 1983). Hence, a capacity of one tonne (1000Kg) of shelled corn is considered adequate for this study. The height and diameter of the silos of capacity 1000kg were 1.1m and 1.4m respectively. Each was filled with 300kg of maize (*Zea mays*) at 11.5% moisture content (wet basis). The maize, identified as TZESRW

variety according to AERLS, (1987) was obtained from the Minna Market. The cleaned and sound maize grains were stored in the silos erected in Minna, Nigeria between July and November, a period of 130 days.

Plate 1. The Constructed Silo

The temperatures within and outside (ambient) the silos were measured. Temperatures were measured within the silos at the geometric centre of the bulk and at the wall (grain/wall interphase). All temperature measurements were recorded at 7:00am (Morning), 1:00pm (Afternoon) and 6:00pm (Evening) with the average daily measurements plotted.

Results and Discussion

The Environment Study

The study area is Minna, Nigeria. It lies in the middle-belt zone of the country with latitude 09° 39'N and longitude 06° 28'E (FAAN, 1999).

Minna has a mean annual rainfall of between 1,300mm. The peak of the rainy season is in September when the highest mean monthly rainfall of 300mm is recorded. The mean on-set date of the rains is between the 17th and 22nd April and the length of the rainy season (L.R.S) is about 190 - 200days. The cessation dates of the rainy season are between 17th and 22nd October for a delayed cessation. The mean monthly temperature is highest in March at about 36°C and lowest in August at 25°C.

Temperature Variations Outside and Within the Silos

The temperature pattern within and around the silos is shown in Fig. 1. The temperature within the metal silo was generally higher than those within the wooden silo and the ambient.

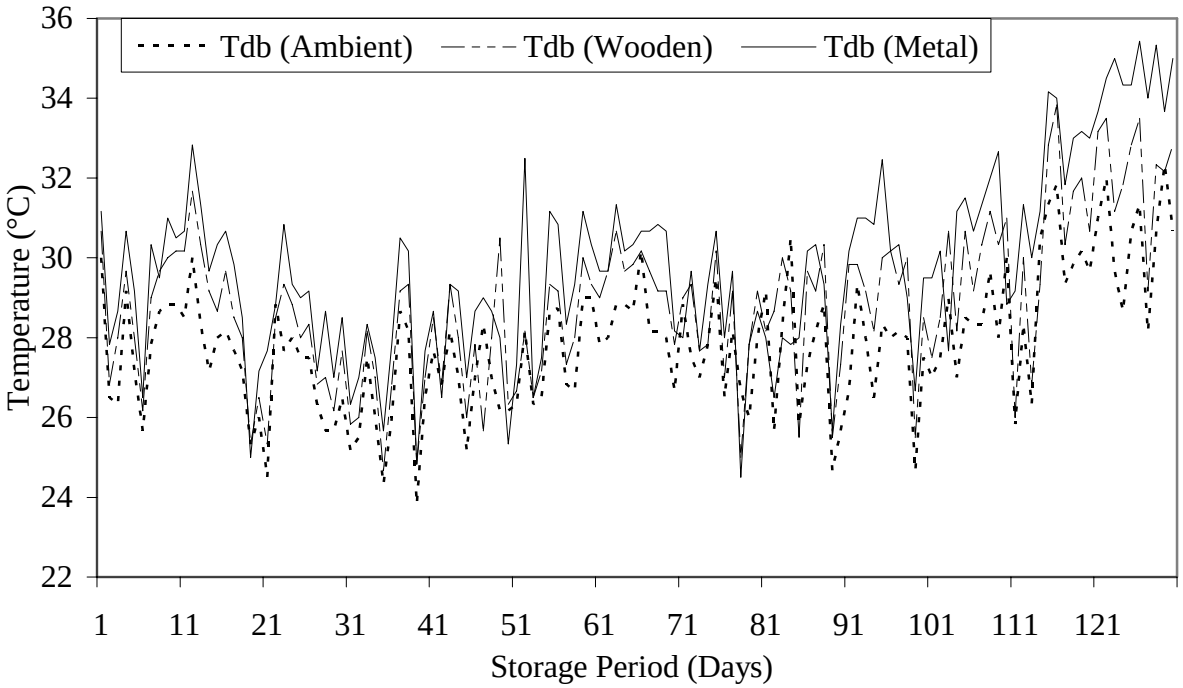

Fig. 1. Dry-bulb Temperatures of the Ambient and within Wooden and Metal Silos

The minimum temperatures recorded for the ambient, wooden and metal bins were 23.8°C (39 day), 24.7°C (35 day) and 24.5°C (78 day) respectively. The maximum temperatures for ambient, wooden and metal were 32.3°C (129 day), 33.8°C (116 day) and 35.4°C (126 day) respectively. These resulted into fluctuations of 8.5°C, 9.1°C and 10.9°C for the ambient, wooden and metal silos respectively. At 126 day of storage when the metal silo recorded the maximum temperature, its value was 1.9°C and 4.1°C higher than wooden silo and ambient respectively due to high temperatures prevalent during the dry season of November. Also, at maximum ambient temperature, the metal silo value was higher by 1.4°C.

It was observed that temperatures were lower at the beginning of the study than towards the end of the storage due to the change from rainy to dry seasons. The implication of these generally high temperatures in the metal silo is that grain stored in such silo may not remain in good condition throughout the year.

Temperature Variation at the Centre of the Silos

The temperature of the grain bulk at the centre of the wooden and metal silos is presented in Fig. 2. The temperature within the metal silo is generally higher than those within the wooden silo with up to 4°C. The minimum and maximum temperatures within the metal silo are 23.8°C (39 day) and 35°C (122 day) while that of the wooden silo are 24°C (47 day) and 31°C (126 day). The standard error of estimate between the results of metal and wooden is 1.65°C.

Temperature Variation at the Wall of the Silos

The temperature at the walls of the wooden silo is generally higher that those made of metal with up to 3.2°C as shown in Fig. 3. At 129 days when the maximum ambient temperature was 32.3°C, the corresponding wooden and metal temperatures were 36.0°C and 33.0°C respectively. The trend could be attributed to fact that wood has a low thermal conductivity than metal; consequently heat is retained at the wooden wall more than the metal wall that would lead to the accumulation of heat. Metal materials allow easy in-and out-flow of heat than wood. This made it possible for wooden silo to be able to maintain uniform temperatures through the storage period.

The standard error of estimate between the results of metal and wooden is 1.16°C. The minimum and maximum temperatures within the metal silo are 24°C (78 day) and 34.7°C (122 day) while that of the wooden silo are 24.5°C (35 day) and 35.8°C (122 day).

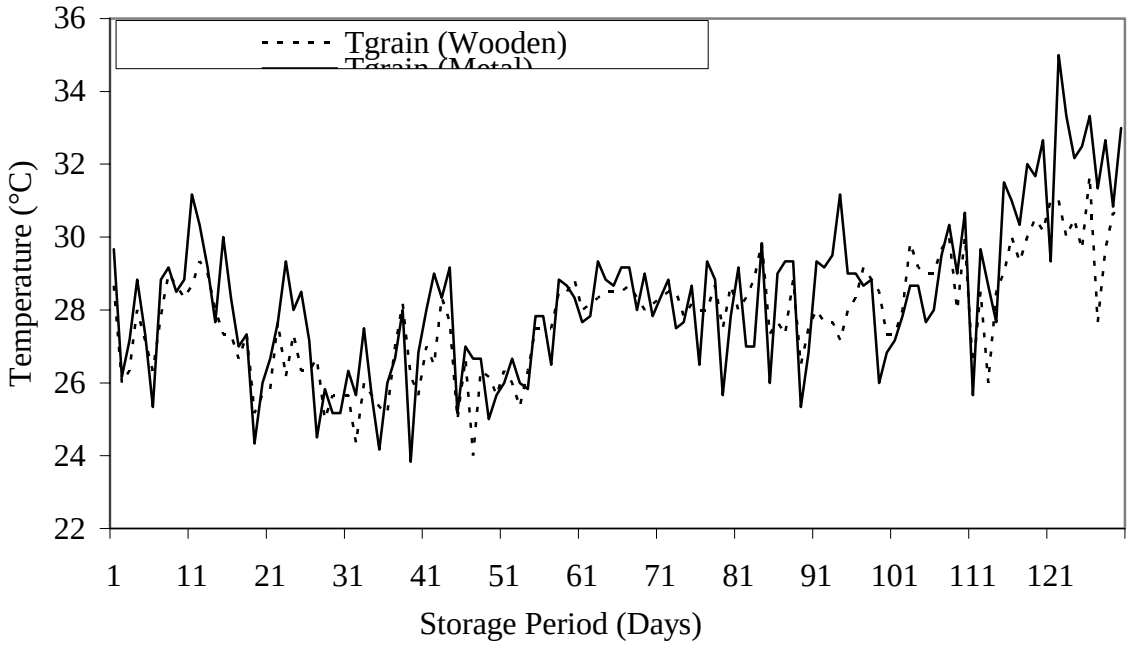

Fig. 2. Temperatures of Grain Bulk at the Centre of the Wooden and Metal Silos

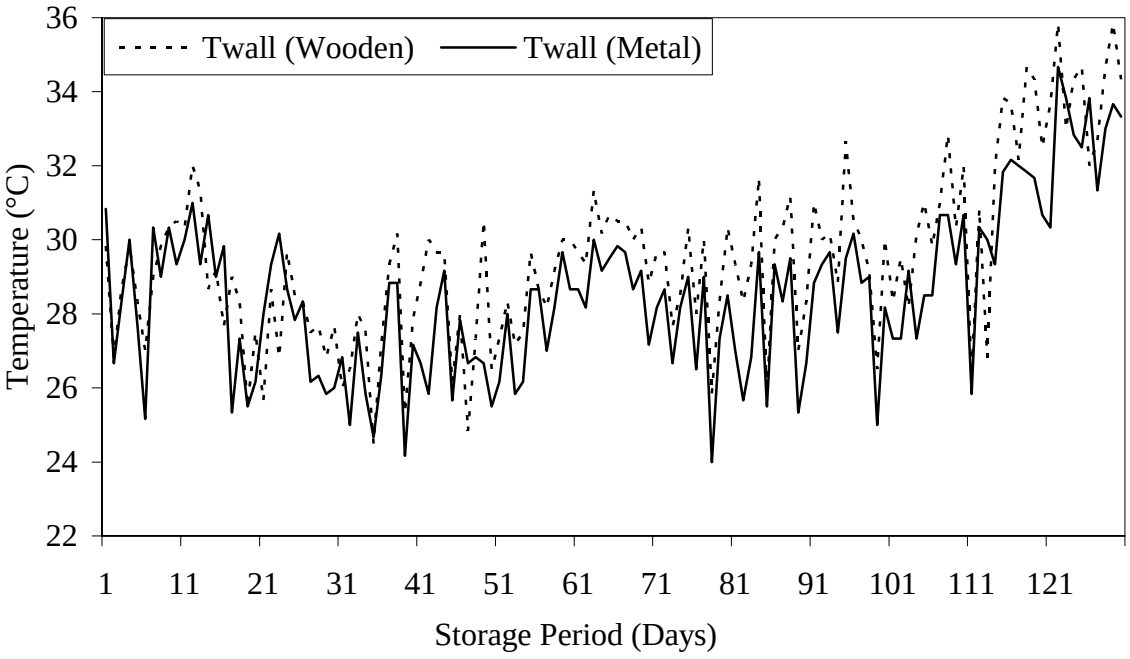

Fig. 3. Temperatures at Wall of the Wooden and Metal Silos

Relative Humidity Within and Outside the Silos

The pattern of variations of relative humidity is depicted in Fig. 4. The relative humidity (RH) is generally highest in ambient and lowest in metal silo except at days 74 and 94 where wooden was higher than ambient.

The lowest recorded was 59% for metal at 130 day of storage with the corresponding ambient and wooden values of 65.3% and 62.7% respectively during the dry season of November. The highest relative humidity was recorded at 94 day of storage with 96.7% for ambient, 98.7% for wooden and 86% for metal during the peak period of the wet season. The standard error of estimate between the results of metal and wooden is 4.70%.

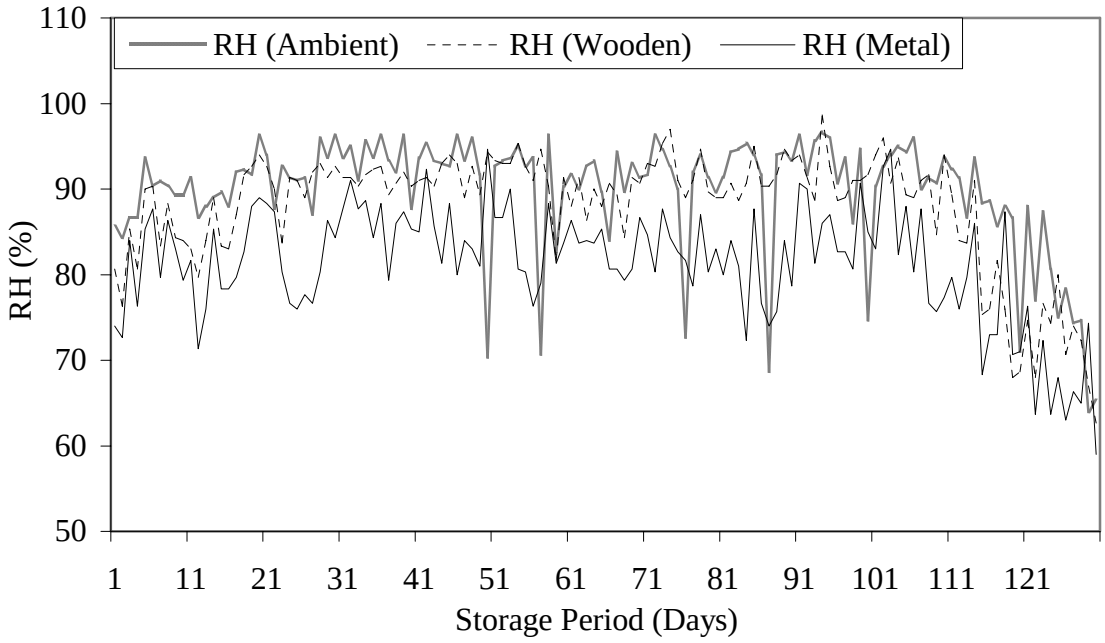

Fig. 4. Relative Humidity of the Ambient and within the Wooden and Metal Silos

Conclusions

Temperature variation within silo made from plywood was lower than temperature variations within metal silo. This will limit the activities of other deteriorating agents; reduce the development of hot spots and eliminate caking and moulding arising from moisture condensation.

Temperatures were higher at the end of the storage period than the beginning due to change in weather from wet to dry season. This implies that grain stored in the metal silo with generally high temperatures may not remain in good condition throughout the year. Temperatures decrease from the wall towards the centre of the bins.

References

AERLS (1987), Maize Production in the Northern States of Nigeria, *Extension Bulletin* No. 11. Agricultural Extension and Research Liaison Services, Ahmadu Bello University, Samaru-Zaria, Nigeria, 28 p., 1987.

Basunia M.A., Abe T., Bala B.K. (1996), *Application of Finite Element Method for the Simulation of Temperature Distribution During Storage of Rough Rice in Cylindrical Bin*, Agricultural Mechanization in Asia, Africa and Latin America (AMA), 1996, 27(2), p. 33-40.

Bohkoven W.H. (1983), *Grain Bin Loads and Pressures*, In: *Structures and Environment Handbook of the Midwest Plan Service*, 122, Davidson Hall, Iowa State University, Amess. Iowa, 1983.

Chang C.S., Converse H.H., Steele J.L. (1993), *Modelling of Temperature of Grain During Storage with Aeration*, Transactions of the ASAE, 1993, 36(2), p. 509-519.

FAAN (1999), *Meteorological Data of Minna, Nigeria,* Federal Airport Authority of Nigeria, Minna International Airport, 1999.

Igbeka J.C. (1983), *Evaluation of Grain Storage Techniques in Nigeria*, African Journal of Science and Technology, 1983, 2(2), p. 22-34,

Jayas D.S., Alagusundaram K., Shunmugam G., Muir W.E., White N.D.G. (1994), *Simulated Temperatures of Stored Grain Bulks*, Canadian Agricultural Engineering, 1994, 36(4), p. 239-245.

Lucas E.B., Alabadan B.A. (2002), *Simulation of Temperature Changes During Storage of Maize in Hexagonal Wooden Bin Due to Weather Variability*, Journal of Applied Science and Technology, 2002, 2(1), p. 16-32.

Lucas E.B., Mijinyawa Y. (1996), *Comparative Studies of Temperature Fluctuations within Wooden and Steel Silos Erected in Ibadan,* Proceedings of the 18th Annual Conference of the Nigerian Society of Agricultural Engineers, O.A.U., Ile-Ife., 1996, p. 299-302.

Sinha R.N. (1973), *Interrelations of Physical, Chemical and Biological Variables in the Deterioration of Stored Grains,* In: *Grain Storage: Part of a System,* Edited by Sinha R.N., and Muir W. E., AVI Publishing Company, New York, 1973, p. 15-48.

Talabi A.E. (1996), *Implementation of National Food Security Programme: Experience So Far*. Proceedings of the National Workshop on Strategic Grains Reserve Storage Programme: Nucleus for National Food Security, Organised by Strategic Grains Reserve Storage Division, Federal Ministry of Agriculture with Technochips System and Consult, Abuja, 1996, p. 67-73.