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DEVELOPMENT OF A LOW-COST SOLAR KILN FOR LUMBER DRYING IN THE HUMID TROPICS

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Abstract:

A 25m^3 capacity low-cost solar lumber drying kiln was to designed, constructed and evaluated in Ibadan, Oyo State, Nigeria. The walls of the kiln were made of 110mm thick burnt clay brick. For roof construction, 7mm corrugated zinc roofing sheets constituted 57.8%, while 3mm thick acrylic sheets constituted 42.2% of total roof area. The roof was tilted to face the south at an angle of 20^0 which made it approximately perpendicular to the mean position of the sun at noon. A re-chargeable battery-powered propeller fan was installed on the northern wall of the kiln for air circulation while five 120 x 310mm vents were created 500mm above the ground level on the opposite (north and south) walls of the kiln. Dry and wet bulb thermometers were installed to monitor daily variations in indoor/outdoor temperature and relative humidity at 12.00 hours and 16.00 hours respectively. The total cost of construction was about US $850. Eight samples of 25 x 300 x 3600mm Gmelina arborea lumber were used for kiln evaluation. Another set was air-dried under shed. Daily temperature and relative humidity in the shed were also taken. Progressive moisture losses in the kiln- and air-dried lumber samples were monitored over a period of five weeks. The minimum and maximum dry bulb temperatures recorded within the kiln were 32^{0}C and 45^{0}C respectively, indicating that it is a low temperature kiln. The minimum and maximum relative humidity inside the kiln were 31% and 80% respectively, confirming that it could be used to dry green wood. Drying experiments showed an average moisture loss of 0.1kg/week in the kiln compared to 0.05kg/week for air-drying under a shed, suggesting that the kiln could season Gmelina arborea at twice a faster rate than air drying.

Key Words: *Tropical hardwoods, Solar kiln, Lumber drying.*

INTRODUCTION

Living trees and freshly felled logs contain a large amount of water, sometimes constituting over 50% of the weight of some tropical timbers. It can vary from as high as over 200 to as low as 40% of the oven-dry weight of some species (Table 1). Most of this water must be removed before useful solid wood products can be made. Besides, wood is hygroscopic, i.e., it tends to either gain or lose moisture in a bid to blend with the climatic conditions of the environment in which it is placed. The gain and/or loss of moisture result in swelling and shrinkage respectively, particularly if the wood has not been properly dried and leads to the appearance of aesthetic and market value reducing deformations such as warpage, cupping, bowing, et c in the poorly dried wood products. Proper drying under controlled conditions prior to use is, therefore, of great importance in timber utilisation. It enhances wood strength and stiffness. If carried out promptly after felling of trees, it protects wood against primary decay, fungal stain and attack by certain kinds of insects. Organisms, which cause decay and stain, generally cannot thrive in timber with a moisture content below 20% (Lucas 1983, Deacon 2005).

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Table 1

Typical Green Moisture Contents of Selected Tropical Timbers Grown in Nigeria

Species	Green Moisture Content (%)
Ricinodendron heudelotii	160
Ceiba Pentandra	140
Terminalia superba	85
Alstonia boonei	80
Khaya grandifoliola	70
Triplochiton scleroxylon	65
Nauclea diderrichii	65
Gossweilerodendron balsamiferum	55
Cylicodiscus gabunensis	55
Brachystegia spp.	50
Lophira alata	50

Source: Olorunnisola (2018)

The most common method of timber drying in Nigeria, is air-drying, also known as seasoning, whereby timber is exposed to the atmosphere, usually in a yard, without the use of any artificial heat source as shown in Fig. 1 (Lucas and Olorunnisola 2002, Olorunnisola and Omoniyi 2016, Olorunnisola 2023). If it is not in contact with a moist body and is protected from rain, timber dries very slowly if the weather is inclement, more quickly if the sun is shining, and quite rapidly if there are strong winds. It eventually assumes a moisture content that is in equilibrium with the surrounding air. In general, the degree of drying that is necessary depends on the use to which the timber is to be put. In case of woodwork for use in buildings as panelling, doors, furniture etc., the wood material should be dried to about 12 to 16% moisture content, depending on the dryness of the locality. Carpentry timbers generally should be dried to below 20% moisture content unless they are employed for rough carpentry purposes in exposed positions where further drying can occur *in situ* (Adefisan and Ajala 2016, Olorunnisola 2019).

Air-drying is simple, energy conserving and reduces harmful atmospheric emission as there is no need to burn any fuel to dry the wood. However, the drying rates of tropical timbers differ from species to species (Table 2) and the ambient humidity in most localities prevents the timber from reaching the moisture content necessary for the dimensional stability, especially for interior use. Besides, air-drying is associated with a lot of challenges particularly in the humid tropics such as the uncontrollable rate of drying (determined by the prevailing weather conditions-temperature, relative humidity, rainfall and wind speed which vary considerably), efficiency of drying, and evenness of drying. Furthermore, any direct exposure to excessive high temperature during sun drying can cause case hardening, where a hard shell develops on the outside of products, trapping moisture inside (Owoyemi *et al*. 2015, Adefisan and Ajala 2016, Olorunnisola 2023). In general, open-air drying does not fulfil the international quality standards and therefore wood dried by this process may not be readily acceptable in the international market.

Fig. 1.
Air-drying of lumber in a sawmill.

Table 2

Drying Rates of Selected Nigerian Timber Species

Botanical Name	**Drying Rate*** **R, FR, RS, S, VS**
Mitragyna ciliata	R
Terminalia superba	R
Lovoa trichiloides	FR
Afrormosia elata	RS
Gossweilerodendron balsamiferum	FR
Albizia spp.	VS
Alstonia boonei	R
Anogeissus leiocarpus	VS
Antiaris africana	FR
Afzelia africana	VS
Distemonanthus benthamianus	R
Berlinia spp.	RS
Celtis spp.	FR
Lophira alata	VS
Entandrophragma angolense	FR
Milicia excelsa	FR
Khaya senegalensis	FR
Khaya ivorensis	FR
Mansonia altissima	FR
Triplochiton scleroxylon	FR
Nauclea diderrichii	FR
Brachystegia spp.	S
Cylicodiscus gabunensis	S

Legend: R - Rapid, FR - Fairly rapid, RS - Rather slow, S - Slow, VS - Very slow (Source: NCP (2005))

Kilns are closed chambers in which air temperature, relative humidity and airflow can be controlled to dry stacked timber to target moisture content with minimal drying defects. In the process, heat is introduced either directly using solar energy, natural gas and/or electricity or indirectly through steam-heated heat exchangers. The process is faster but may be very expensive to install, operate and often requires skilled operators. Solar kilns provide a means of overcoming some of these limitations. Solar kilns can be broadly divided into two categories: passive (greenhouse) solar kilns and active solar kilns with external collectors. Passive solar kilns are cheaper to construct and maintain than active solar kilns. They offer several advantages to those desiring an inexpensive means of drying small quantities of lumber (Troxell 2004).

In both air- and kiln- drying moisture is removed by evaporation from the surface of the wood material. The rate of evaporation is partly controlled and therefore depends largely on the prevailing weather conditions. In the dry season in Nigeria (November to March) drying may be rapid, and in the rainy season (April to October) it may be very slow. It is possible to dry timber down to about 12% in the dry season in the South and still further in the North, but 18% is a more usual figure in the rainy season in the South (Olorunnisola 2018). The objective of this study was to design and evaluate a low-cost passive solar kiln for lumber drying in Ibadan, Nigeria.

MATERIALS AND METHODS

Kiln Construction Site Selection

Ibadan, the study site, is located on latitude 7°26'23'' to 7°27'00''N and longitude 3°53'31'' to 3°55'15''E. A solar kiln must be sited in the sunniest possible location, ideally facing south to maximize the amount of sunlight available. Hence locations near trees and buildings which could cast shadows and reduce kiln efficiency were avoided.

Kiln Design and Construction Materials

The size of a kiln is largely determined by the volume of lumber to be dried. The kiln was designed to accommodate 25m^3 of lumber. It has a width is 3m and a length of 5.1m. Positioning of a solar kiln depends on the latitude of the location. However, one difficulty is choosing the optimum roof angle is that the optimal of solar collection changes with the season since the angle of the sun changes. To overcome this difficulty and achieve optimum solar collection, the latitude plus 10^0 to 20^0 is usually recommended (Bond 2014). The latitude of the kiln location in the University of Ibadan, Nigeria, is 7^0. Hence, the kiln was designed to have a roof slanting at an angle of 20^0 to make it approximately perpendicular to the mean position of the sun at noon. Thus, the heights of the kiln at the front (north end) and the rear (south end) were 2.6m and 1.5m respectively. A solar battery-powered propeller fan was selected because of its forward rotating airflow which enhances air flow and circulation within the kiln.

Strip foundation (150mm thick) was used for the kiln. The ground was excavated to the required level (450mm wide and at least 210mm deep). Burnt red bricks of 210mm (depth) x 245mm (length) x 110mm (thickness) were selected and used kiln wall construction. The bricks were selected because of their great heat retention capacity. Cement mortar mixed in the cement: sand ratio of 1:8 was poured on the excavated floor after which bricks were laid up the plinth level. The earth was then re-filled around the wall. The mortal was also used joining the bricks together to prevent heat loss and for plastering the interior of the kiln. Concrete slab was used as the floor of the kiln.

Wood drying kilns are designed to operate within specific range of temperatures. Low temperature kilns typically operate in a range of 21^{0}C to 49^{0}C, while conventional-temperature kilns operate in the range of 43^{0}C to 82^{0}C (Wengert and Oliveira 2008). The kiln was designed to operate as a low temperature kiln for light and medium density tropical hardwoods (e.g., *Gmelina arborea* Roxb., with a density of 400 – 510kg/m^3 at 12% moisture content) some of which are knotty (e.g., *Mansonia altissima*) and have a reputation for warping (e.g., *Entandrophragma candollei*). Their shrinkage and hence distortion increase as the drying temperature is raised. The kiln temperature should be kept relatively low to minimize warping and to avoid loosening of knots. A few species such as *Mitragyna stipulosa* may collapse and/or honeycomb if dried at high temperatures. Many species tend to darken appreciably during drying (e.g., *Tectona grandis*), while for some very resinous species (e.g., *Gossweilerodendron balsamiferon*) drying at temperatures above 50^{0}C may cause exudation of resin on the wood surfaces (Pratt 1974, Lucas 1983, Lucas and Olorunnisola 2002, Desalegn *et al.* 2020). To achieve the low temperature regime, 1.85m x 0.72m x 0.7mm corrugated zinc roofing sheets (Fig. 2) alone were tested, in a preliminary experiment as the roof covering for the kiln. Corrugated zinc roofing sheets are popularly used in low-cost residential buildings in Nigeria because of their affordability. (Olorunnisola 2019, Oyebanjo *et al.* 2022). For example, a sheet of roofing sheet cost an equivalent of US $2.37 in Nigeria during the study period. However, since zinc is a good conductor of heat with a thermal conductivity of 112.2 W/m-K, the use of zinc roofs without ceilings results in strong heat transfer to the interior environment, which is an advantage in lumber kiln construction. The daily average dry bulb temperature within the kiln ranged from 32.3^{0}C to 38.5^{0}C, the average being 35.1^{0}C compared to an outdoor temperature range of 26.2^{0}C to 30.5^{0}C and an average of 28.2^{0}C, giving an average difference of 6.9^{0}C. The corresponding average indoor and outdoor relative humidities were 56.6% and 61.6%, giving a difference of 5%. There was an evidence of considerable heat loss by conduction.

To minimize heat loss by conduction through the corrugated zinc roofing sheets and therefore enhance heat retention inside the kiln, the roof covering was re-designed and re-constructed as a combination of zinc roofing sheets and 3mm thick acrylic sheets (Fig. 3). Transparent acrylic sheet is a lightweight thermoplastic with a thermal conductivity of 0.19 W/m-K. (Eshwar Pawar 2016). Compared to a glass panel, acrylic sheet reduces heat transfer and can withstand several years of exposure to weather elements and corrosive atmosphere without losing their transparency, glossiness or shape. They also will not darken or deteriorate from exposure to sunlight. They are, however, more expensive than corrugated zinc roofing sheets. A single 1.2m x 2.4m x 3mm acrylic sheet cost an equivalent of US $40 in Nigeria during the study period. Hence, two acrylic sheets were procured from the local market in Ibadan and installed in partial replacement of zinc roofing sheet. The area of coverage of the acrylic sheets was 36m² representing 57.8% of total roof area. *Terminalia ivorensis* species, selected because of its durability and strength properties, was used for the construction of the roof rafter and purlins. Joints were created using ordinary nails of different sizes- 100mm (4 inches) and 63.5mm (2.5 inches).The 100mm nails were used to fasten the rafter to the 50mm x100mm wall plates, selected based on structural design calculations, while the 63.5mm nails were used to fasten twelve 1200mm long purlins to the rafters.

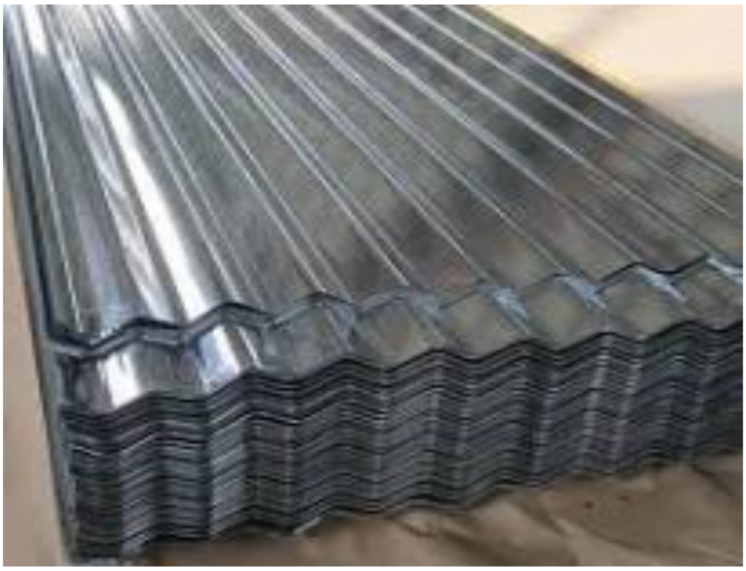

Fig. 2.
Corrugated zinc roofing sheets.

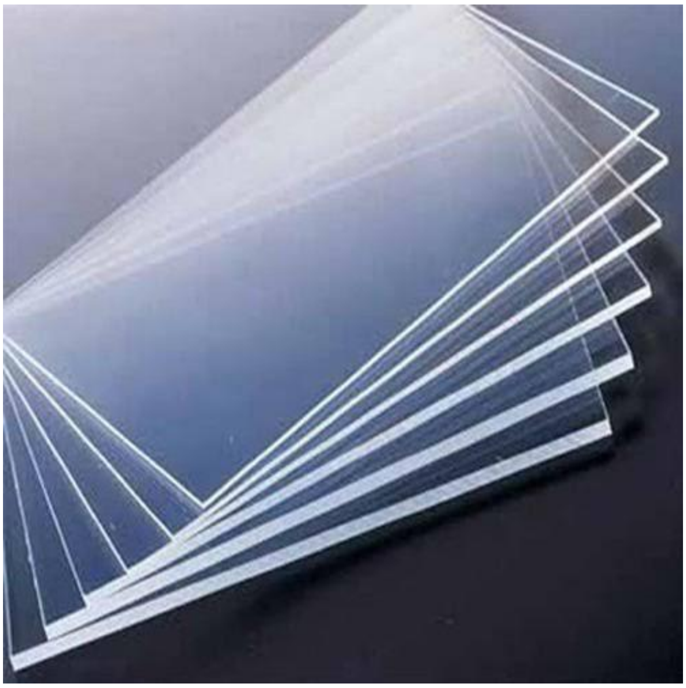

Fig. 3.
Transparent Acrylic sheets.

The zinc roofing sheets and acrylic sheets were then placed on the purlins and made to overlap each other. The plastered floor and interior walls of the kiln were then painted with matt black paint to improve the kiln efficiency. The 3.2m x 1.8m door frame was fabricated from dry 50mm x 50mm *Milicea excelsa* lumber. Black polythene-covered plywood was then nailed to the frame on both sides to form the door. Different views of the completed solar kiln are shown in Fig. 4-7. The total cost of construction was about US $850.

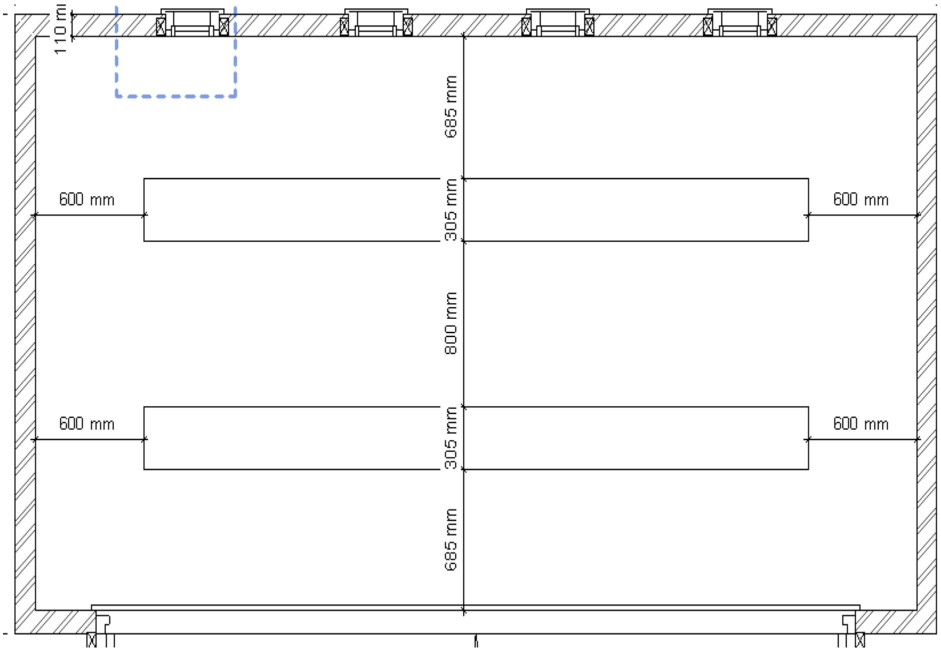

Fig. 4.
Floor plan of the solar kiln.

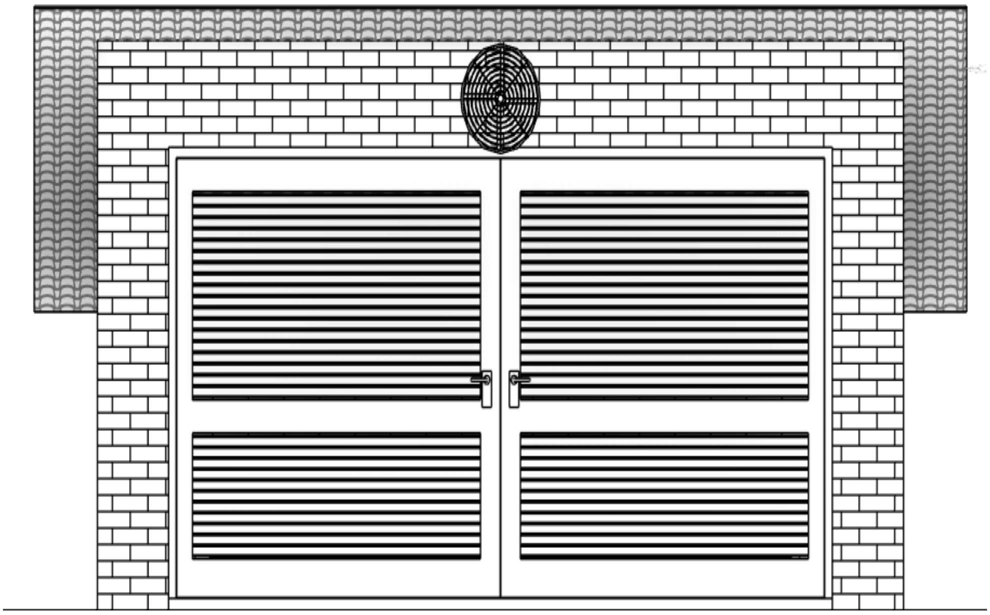

Fig. 5.
Loading end (rear view) of the solar kiln.

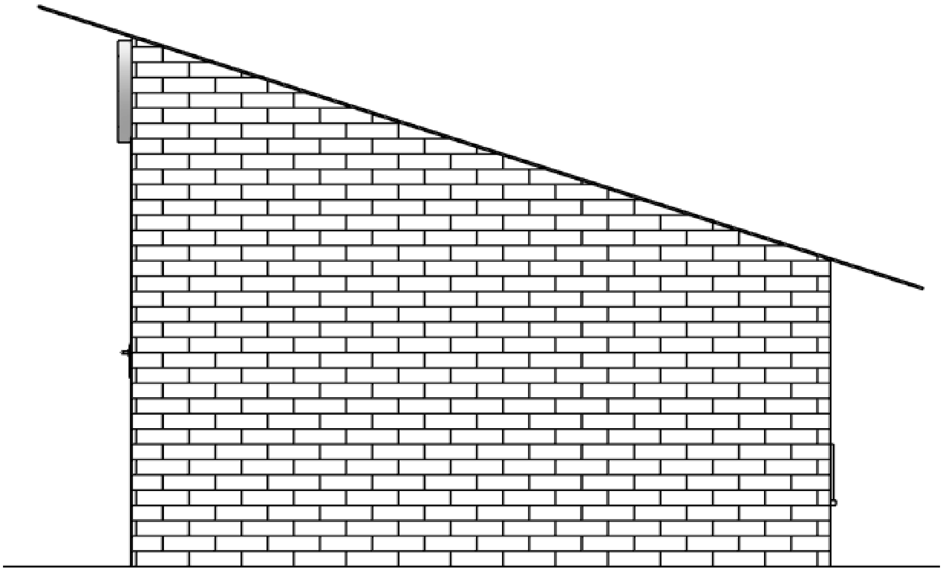

Fig. 6.
Side View of the solar kiln.

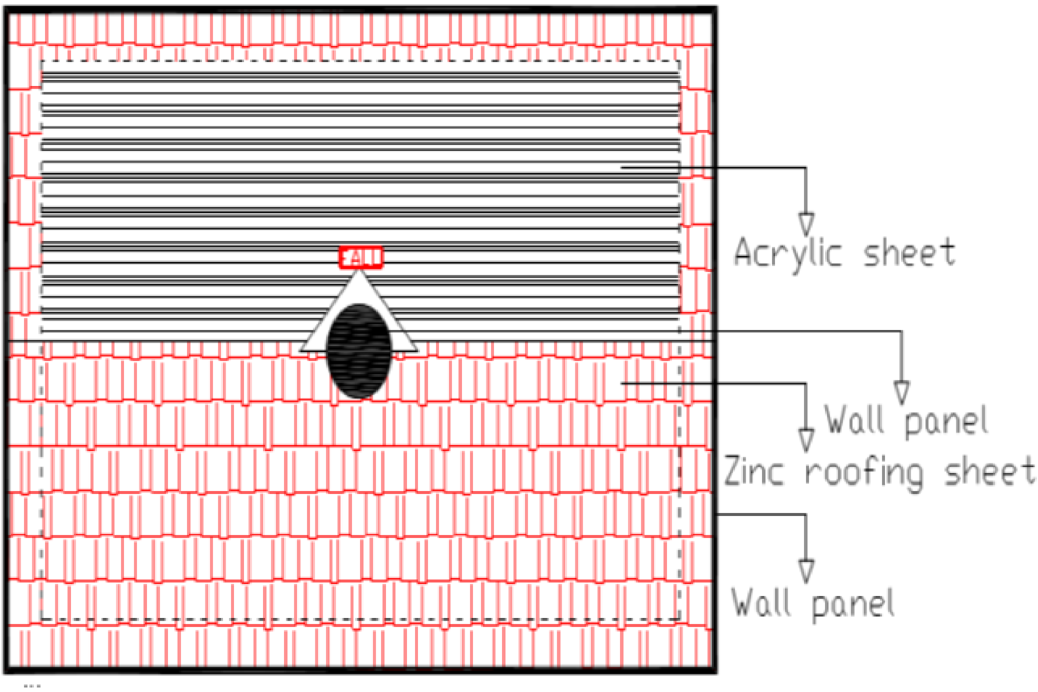

Fig. 7.
Roof Plan of the solar kiln.

Kiln Evaluation

The no-load performance test on the final version of the kiln with a combined zinc-acrylic roofing sheets were carried out over a period of 41 days, i.e., September 27 to December 3. The changes in temperature and relative humidity in solar kiln were monitored and compared with the ambient condition right outside the kiln and an airdrying shed located about 30m away from the kiln. A thermo-hygrometer with facilities for reading the temperatures and relative humidities within and outside the kiln was used to compare the indoor and outdoor conditions. A wet and dry bulb thermometer was placed in the drying shed to monitor the temperature and relative humidity. Data were collected two times a day: 12:00pm (12:00 hours) and 4:00pm (16:00 hours). For a preliminary loading test, eight samples each *Gmelina Arborea* planks (25 x 300 x 3600mm) were placed inside the kiln and another set placed in the drying shed for a period of five weeks. Each plank was labelled for proper identification. The daily loss in moisture in both kiln- and air-dried samples were monitored and recorded.

RESULTS AND DISCUSSION

Patterns of Variation in Temperature Within and Outside the Kiln

The pattern of variation in temperature within and outside the kiln at 12 noon and 4pm are shown in Fig. 8 and 9. The minimum temperature recorded within the kiln was 32^{0}C, while the maximum was 45^{0}C, a difference of 13^{0}C. The temperature range compares favourably with the range of 31°C to 48°C reported by Owoyemi *et al.* (2015) for a solar kiln operated in Akure, Nigeria, located on the longitude of 005.14796°E and latitude of 07.29311°N. The average temperature within the kiln at 12 noon was 36^{0}C, compared to an average of 39^{0}C at 4pm. The average temperature outside the kiln at 12 noon was 35^{0}C, compared to an average of 36^{0}C at 4pm. The minimum temperature recorded outside the kiln was 32^{0}C, while the maximum was 40^{0}C, a difference of 8^{0}C. Evidently, the temperature regime within the kiln was generally higher the regime outside the kiln. Also, the highest temperature regime was observed at 4pm. The temperature increased gradually from morning till afternoon because of the high sun intensity during the afternoon and the low radiation in the morning.

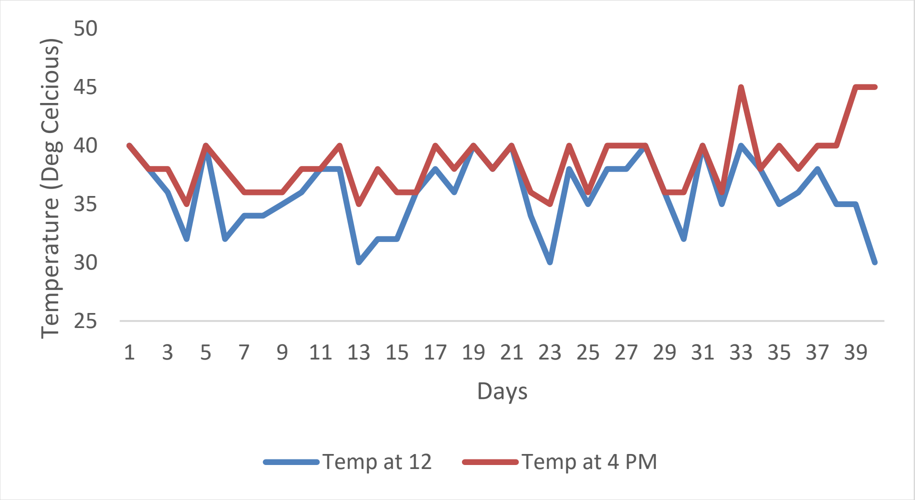

Fig. 8.
Temperature variation inside the solar kiln at 12 noon and 4pm.

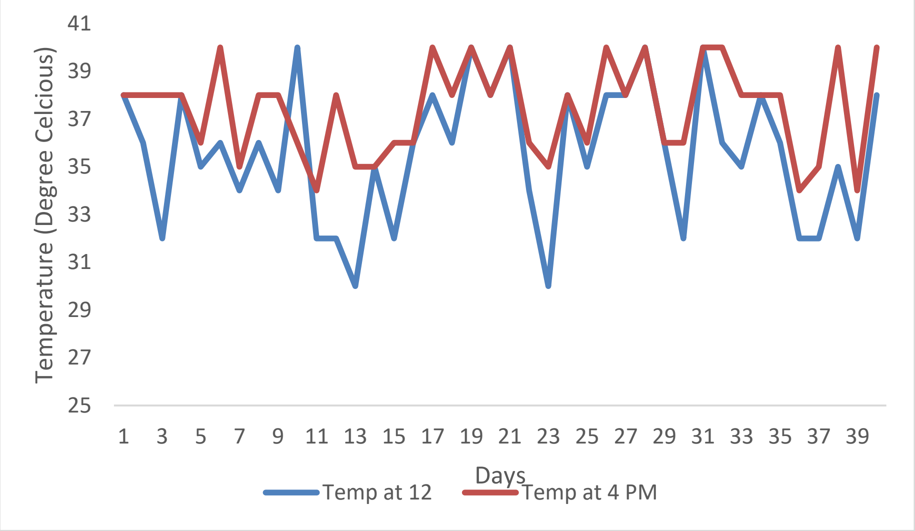

Fig. 9.
Temperature variation outside the solar kiln at 12 noon and 4pm.

Patterns of Variation in Relative Humidity Within and Outside the Kiln

The relative humidity (RH) data collected inside and outside at different times of the day are presented in Fig. 10 - 11. The minimum RH inside the kiln was 31% while the maximum was 80%. This result compares favourably with a minimum of 33% and maximum of 78% RH was reported by Owoyemi *et al.* (2015) for a solar kiln operated in Akure, Nigeria. In contrast, the minimum RH outside the kiln was 54% while the maximum was 94%. Expectedly, the RH inside the kiln was generally lower than the values obtained outside the kiln. The average RH within the kiln at 12 noon was 66%, compared to an average of 52% at 4pm. The average RH outside the kiln at 12 noon was 78%, compared to an average of 75% at 4pm. The highest indoor and outdoor RH values were recorded during the rainy season months of September/October, while lowest RH values were recorded during the dry months of November/December in the study location, i.e., Ibadan, Nigeria. The RH for kiln drying lumber is typically between 70–80% when the wood is green. The upper end of the RH, i.e., 80%, is suitable for very refractory timbers such as *Lophira alata* which are inclined to splitting and checking and for which the humidity should be kept high until drying is well advanced.

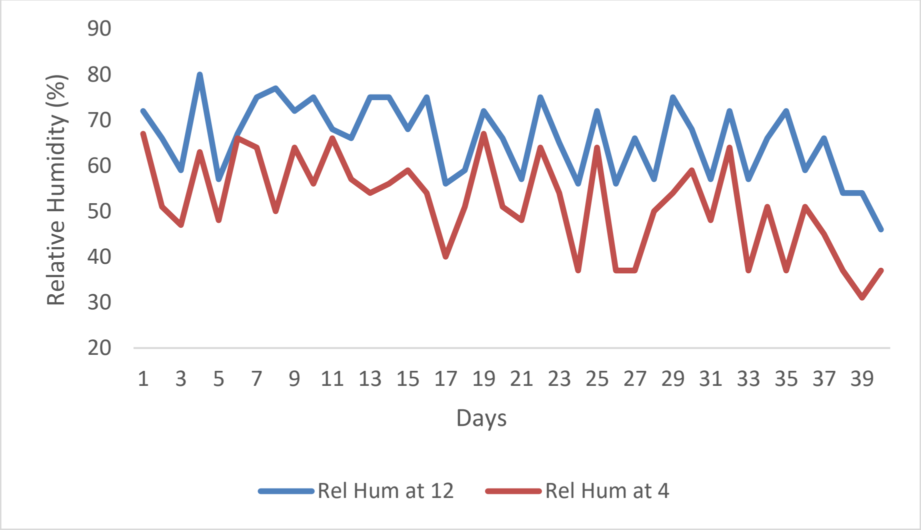

Fig. 10.
Relative humidity variation inside the solar kiln at 12 noon and 4 pm.

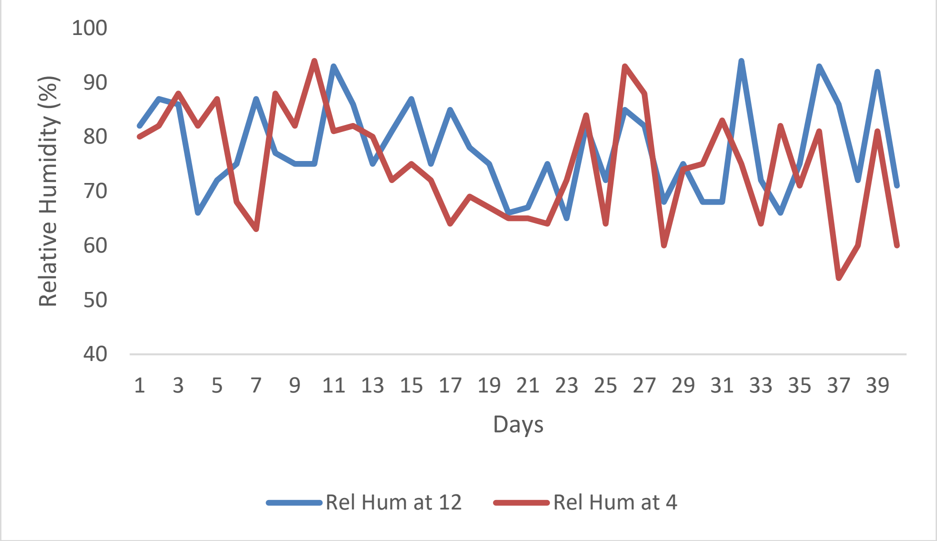

Fig. 11.
Relative humidity outside the solar kiln at 12 noon and 4pm.

Comparison of Temperature Variation within the Solar Kiln and the Drying Shed

The minimum and maximum temperature in the drying shed were 30^{0}C and 37^{0}C respectively (Fig. 12), compared to the corresponding temperatures of 32^{0}C and 45^{0}C within the solar kiln. The average temperature within the kiln at 12 and 4pm was the same, i.e., 33^{0}C. The difference in the maximum temperature of the solar kiln and the air-drying shed showed that solar kiln had a better heat retention capacity compared to air drying shed as also observed by Ogunsanwo and Amoo-Onidundu (2011) and Owoyemi *et al*. (2015). However, both the air-drying shed and the solar kiln attained their highest temperatures at about the same time of the day, i.e., the air-drying shed attained its maximum temperature of 37^{0}C at about 2pm, while the solar kiln also attained its maximum temperature of 45^{0}C at about 2pm. A similar trend was reported by Owoyemi *et al.* (2015).

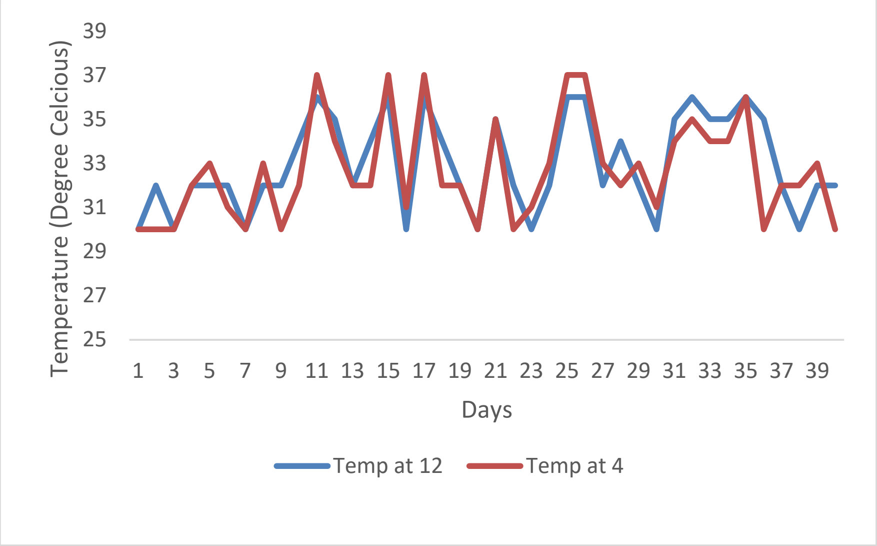

Fig. 12.
Temperature variation within the drying shed at 12 noon and 4pm.

Comparison of Relative Humidity within the Solar Kiln and the Drying Shed

The minimum RH obtain in the drying shed was 54% while the maximum was 94% (Fig. 13). This is in contrast to the minimum of 31% and maximum of 80% RH obtained in the solar kiln. The average RH values recorded within the shed at 12 noon and 4 pm were 89% and 78% respectively. Expectedly, the RH values were generally higher in the mornings than the afternoons. Also, the variations in RH values obtained were representative of the seasonal weather conditions during the test duration. The lower range of RH in the solar kiln compared to the drying shed, falls within acceptable limits for lumber kilns and confirmed its superiority for lumber drying.

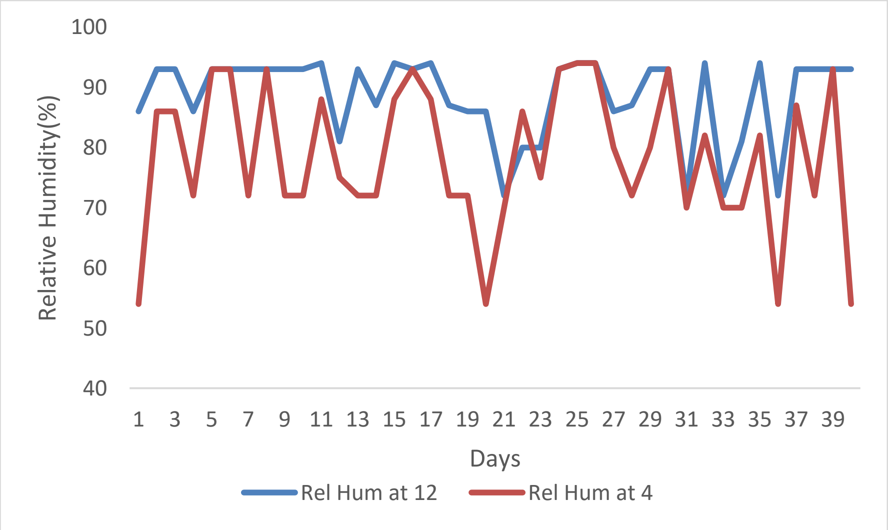

Fig. 13.
Relative humidity variation within the drying shed at 12 noon and 4pm.

Patterns of Moisture Loss in the Kiln- and Air-Dried *Gmelina arborea* Lumber

Gmelina arborea is extensively planted in large plantations across Africa in countries such as Burkina Faso, Cameroon, Cote d'Ivoire, Ghana, Malawi, Mali, and Nigeria, with an estimated plantation area of 13,000ha (Arora and Tamirakar 2017, Desalegn *et al.* 2020). The patterns of moisture loss in the kiln- and air-dried *Gmelina arborea* lumber are shown in Figure 14. The initial average weight of the samples kiln-dried which was 1.53kg dropped to 1.0kg after five weeks, indicating an average moisture loss of 0.53kg, representing an approximate weight loss of 0.1Kg/week. In contrast, the initial average weight of the samples subjected to air-drying which was 1.1kg dropped to 0.81Kg after five weeks of drying, indicating an average moisture loss of 0.25Kg, an approximate weight loss of 0.05kg/week. As expected, the samples placed in the kiln dried at a faster rate than those air-dried. The drying rate of the wood samples placed in the solar kiln was approximately twice those placed in the drying shed confirming that the drying rate of a wood species depends to a large extent on the drying method used.

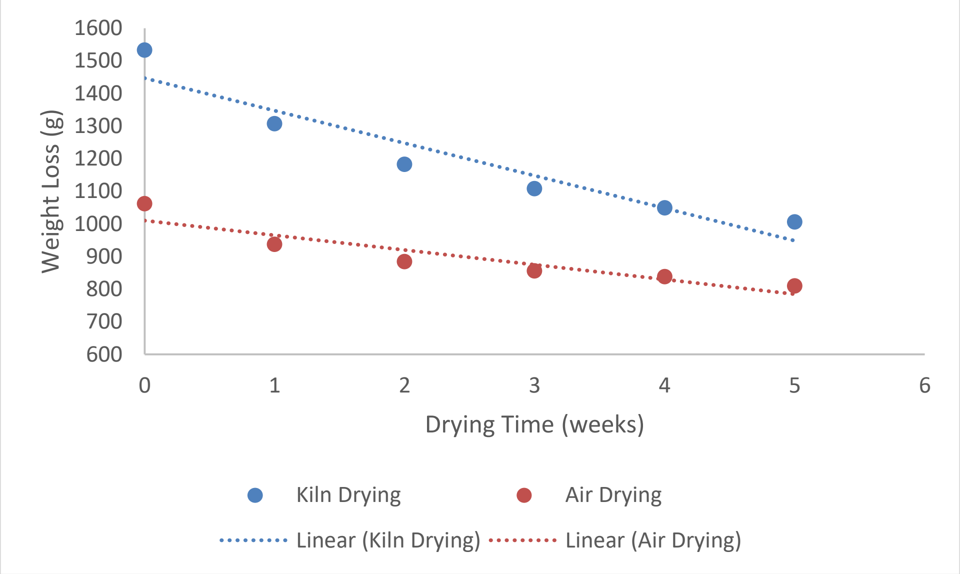

Fig. 14.
Patterns of Moisture Loss in the Kiln- and Air-Dried Gmelina arborea.

CONCLUSION

A 25m^3 capacity low-temperature passive solar kiln for drying tropical hardwoods was designed and constructed. Burnt clay bricks were used for the walls, while a combination of relatively low-cost corrugated zinc roofing sheets and transparent acrylic sheet was used for the roofing. The performance of the solar kiln, when compared with air drying under a shed, showed that the kiln seasoned *Gmelina arborea* lumber about twice faster than natural air drying. It was concluded that burnt clay bricks, corrugated zinc roofing sheets and acrylic sheets are suitable materials for low-cost solar kiln construction in Nigeria and other tropical African countries.

REFERENCES

Adefisan OO, Ajala OO (2016) Emerging Trends in Wood Seasoning and Preservation. In: Renewable Natural Resources Engineering: Essays in Honour of Canon Prof. E. Babajide Lucas. Published by Zenith BookHouse Publishers, Ibadan pp. 181-198.

Arora C, Tamirakar V (2017) Gmelina arborea: Chemical Constituents, Pharmacological Activities and Applications. International Journal of Phytomedicine 9(4):528-542.

Bond B (2014) Design and Operation of a Solar-Heated Dry Kiln. Virginia Cooperative Extension Publication No. 420-030.

Deacon J (2005) Wood Decay and Wood-Rotting Fungi. University of Edinburgh.

Desalegn G, Kaba G, Tesfaye A, Amanuel S (2020) Seasoning Technologies of Gmelina arborea Roxb. Lumber Species Grown at Bonga, SNNP, Ethiopia. World News of Natural Science 29(3):269-281.

Lucas EB (1983) Factors Preventing Wider Commercialization of Nigerian Trees. Forest Products Journal, 33(5):64-68.

Lucas EB, Olorunnisola AO (2002) Wood Processing and Utilization in Nigeria: The Present Situation and Future Prospects in: Ajav, E.A., Raji, A.O., and Ewemoje, T.A. (eds.) Agricultural Engineering in Nigeria: 30 Years of University of Ibadan Experience, Published by the Department of Agricultural Engineering, University of Ibadan, Nigeria. Pp. 98-109.

NCP (2005) Nigerian Code of Practice (NCP) for Structural Timber Design. A Publication of the Standards Organisation of Nigeria.

Ogunsanwo OY, Amoo-Onidundu ON (2011) Selected Drying Characteristics of Plantation Grown Gmelina arborea Under an Experimental Solar Drying Kiln. Journal of Agriculture and Social Research. 11(2):128-138.

Olorunnisola AO, Omoniyi TE (2016) Wood Conversion and Processing in Nigeria: A Status Report, in Olorunnisola, A.O. (ed.), Renewable Natural Resources Engineering: Essays in Honour of Canon Prof. E. Babajide Lucas, Published by Zenith BookHouse Publishers, Ibadan pp. 101-121.

Olorunnisola AO (2018) Design of Structural Elements with Tropical Hardwoods, Springer Publishers, New York, ISBN 978-3-319-65342-6.

Olorunnisola AO (2019) Development of Sustainable Building Materials from Agro-Industrial Wastes in Nigeria, *in Sayed Hemeda (ed.)* Sustainable Construction and Building Materials_Published online and in hard copy by INTECHOPEN. DOI: 10.5772/intechopen.78713, ISBN: 978-1-78985-750-4, Print ISBN: 978-1-78985-749-8, https://www.intechopen.com/books/sustainable-construction-and-building-materials, pp. 55-74.

Olorunnisola AO (2023) The Past, Present and Future Outlook of the Wood Industry in Nigeria in Guanben Du (ed.) Wood Industry - Past, Present and Future Outlook Published online and in hard copy by INTECHOPEN. DOI: 10.5772/intechopen.105794. ISBN: "Wood Industry - Past, Present and Future Outlook," 978-1-80356-450-0. https://www.intechopen.com/chapters/82612.

Owoyemi JM, Oyebamiji WO, Aladejana JT (2015) Drying Characteristics of Three Selected Nigerian Indigenous Wood Species Using Solar Kiln Dryer and Air Drying Shed. American Journal of Science and Technology 2(4):176-182.http://www.aascit.org/journal/ajst

Oyebanjo OO, Oyebanjo OA, Ogunlana YO (2022) Comparison of the Thermal Properties of some Selected Ceiling Materials for Cost Effectiveness in Nigeria. Journal of Science and Information Technology 17(1): 27-35.

Pratt GH (1974) Timber Drying Manual. Building Research Establishment Report, Department of the Environment, London. 120 pp. https://www.google.com.ng.

Troxell HE (2004) Application of solar energy for drying timber in Central Rocky Mountains Region. Proceedings of the Workshop on Practical Application of Solar Energy to Wood Processing, Virginia Tech. and State University, Virginia, U.S.A.

Wengert EM, Oliveira LC (2008) Solar heated lumber dry kiln designs: A discussion and compilation of existing solar heated lumber dry kiln designs. Blacksburg, VA: Department of Forest Products, Virginia Polytechnic Institute and State University.