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Effect of Thickness on the Thermal Conductivities of Three Different Bulk Wood Products of Celtis Family

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Abstract
The study investigated the effect of thickness on the thermal properties of three different bulk wood products of celtis family: celtis zenkeri, celtis philipensis and celtis mildreadii. using the modified double Lee's disc apparatus incorporated with automatic data logger. The thermal conductivity of the samples obtained increase as the thickness increases. The result shows that celtis phillipensis records the highest thermal conductivity values of 0.3968Wm^{-1}K^{-1}. The values of the thermal conductivity and thickness obtained for the samples fall within the range of (0.3337 – 0.3968) Wm^{-1}K^{-1} and (6.79 – 6.88) mm respectively. This range fall within the thermal conductivity values of common insulator material used in solar collector. The particle sizes for the specific wood samples exhibit low thermal conductivity could be comparable with materials used as industrial insulators. Hence, the selected wood materials could be useful for applications in industrial insulating devices, if properly harnessed into particle sizes.
***Key words**: Thermal conductivity, wood materials, solar devices and automatic data logger.*

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I. Introduction

Wood is a fibrous material that cannot be overemphasized due to its usefulness in our environment. In fact, wood is a raw material used for wood-based panels, pulp and paper. Wood is still an important fuel in most of the world. Moreover, wood is available in various colours and grain sizes. It is strong in relation to its weight, its insulating to heat and electricity. People have come to understand that it has so many uses and is essential for human life (Adekoya *et al.*, 2018). A lot of researched have been carried out on the thermal properties of bulk and particle sizes of some selected wood products for solar device applications (Oluyamo and Bello,2014; Oluyamo and Adekoya, 2015; Oluyamo *et al.*, 2017a).

Thermal insulating material is an essential factor found very useful in energy storage system to minimize heat losses from the system. The selection of thermal insulating material to be consider base on the following properties such as thermal conductivity, thermal resistivity and specific heat capacity. Thermal conductivity is the amount of energy conducted through a material of unit area, and unit thickness in unit time when the difference in temperature between the faces causing heat flow is unit temperature difference. This suggest that the thermal conductivity is an essential attribute when discussed energy conserving building products. This is due to the fact that wood has exceptional heat insulation properties (Oluyamo *et al*., 2012; korkut *et al*., 2013). Materials of high thermal conductivity are widely used in heat sink applications, whereas materials of low thermal conductivity are used as thermal insulation (Oluyamo and Adekoya, 2015).

Thermal conductivity of the wood (a property of material) can be affected by the structure of the material, sizes, moisture content, density, presence of defect, temperature, pressure, thickness and other factors (Ayugi *et a*l., 2011; Oluyamo *et al*., 2017b). Wood samples with low thermal conductivity (high insulating properties) could be used as thermal insulator compared with the major insulating material correctly being used for insulators include; fibres, glass, polyurethanes, polystyrene and insulating cement. The uses of these materials have been limited because they are expensive.

Furthermore, there are many local materials available for consideration as thermal insulators includes: sawdust, charcoal dust, sugarcane and fibres (Ayugi *et al.*, 2011). However, little or no knowledge on the effect of thickness on the thermal properties have been established. The thickness played an essential part when considering the thermal properties of wooden products. Therefore, this study focuses on the effect of thickness on the thermal properties of three different bulk wood products of celtis family.

II. Sample Preparation and Experimental Procedure

The materials that were used in the study include three different wood products of *celtis family: celtis zenkeri, celtis philipensis and celtis mildreadii*. Samples found in the rainforest region, south western of Nigeria. The wood samples were collected from different saw-mill in Akure South Local Government Area of Ondo State, South Western Nigeria. These wood samples were taken to wood workshop to cut into circular disc's shape at the Department of Forestry and Wood Technology, Federal University of Technology Akure, (FUTA). The thermal conductivity of the samples was determined using the modified double Lee's disc apparatus incorporated with automatic data logger.

Details of the procedure can be found in the literatures (Griffin and George, 2002; Oluyamo *et al*., 2012; Oluyamo *et al*., 2016). The thermal conductivity (k) of each sample of thickness (d) and radius (r) were estimated using equation 1 and 2

$$k = \frac{ed}{2\pi r^2}\left[a_S\left(\frac{T_A + T_B}{2}\right) + 2a_A T_A\right] \quad 1$$

where,
heat transfer coefficient e is given by:

$$e = \frac{IV}{\left[a_A T_A + a_S\left(\frac{T_A + T_B}{2}\right) + a_B T_B + a_C T_C\right]} \quad 2$$

and,

$$a_A = a_B = 2\pi r^2 + 2\pi r l_d$$

$$a_B = 2\pi r l_B$$

$$a_S = 2\pi r l_S$$

where l_d is the thickness of the discs, l_S is the thickness of the wood samples, while a_A, a_B, a_C and a_S are the exposed surface areas of discs A, B, C and the specimen respectively. T_A, T_B and T_C are the temperatures of the discs A, B and C above ambient (i.e. the thermal equilibrium temperature of the disc minus the ambient temperature). V is the potential difference across the heater and I is the current which flows through it. In order to fully analyse the thermal behaviour of the samples within the temperature range, a MATLAB programme was written to compute the thermal conductivities at given time interval.

III. Results and Discussion

The results of the analysis are illustrated in Figure 1-2. The variations of the thickness with thermal conductivity of three different bulk wood is given in Figure 1 while the graph of thermal resistivity against the thickness samples of *celtis* family is illustrated in Figure 2.

The thermal conductivities values obtained were ranged from 0.3331 $Wm^{-1}K^{-1}$ - 0.3372 $Wm^{-1}K^{-1}$ for *celtis zenkeri*, 0.3729 $Wm^{-1}K^{-1}$ - 0.3961 $Wm^{-1}K^{-1}$ for *celtis mildreadii and* 0.3901 $Wm^{-1}K^{-1}$- 0.3968 $Wm^{-1}K^{-1}$ for *celtis philipensis* in Table 1. All the samples have low thermal conductivity values. C*eltis philipensis* records the highest thermal conductivity of 0.3923 $Wm^{-1}K^{-1}$ with the thickness of 6.88mm while *celtis zenkeri* recorded lowest thermal conductivity of 0.3331 $Wm^{-1}K^{-1}$ with the thickness of 6. 81 mm. However, this variation could be due to the fact that *celtis philipensis* usually have it grains aligned more than others and interlocked (Kumaran *et al*., 2002).

As presented in Figures 1, thermal conductivity increases with increase in thickness of the wood samples. Thermal conductivity value obtained for all the wood samples fall within the range of thermal conductivity of material used as thermal insulator in solar cell device and applications. Also, the thermal resistivity of the samples decreases as the thickness increase as shown in Figure 2.

Table 1: Thermal conductivity (W/mK) and thermal resistivity (mK/W) values of three different wood samples with their thickness

Botanical Name	Thickness (mm)	Thermal conductivity (W/mK)	Thermal Resistivity (mK/W)
Celtis *zenkeri*	6.79	0.3331	3.0021
	6.81	0.3341	2.9931
	6.84	0.3347	2.9878
	6.86	0.3351	2.9842
	6.88	0.3372	2.9656
Celtis mildreadii	6.79	0.3729	2.6817
	6.81	0.3821	2.6171
	6.84	0.3843	2.6021
	6.86	0.3951	2.5310
	6.88	0.3961	2.5246
Celtis philippensis	6.79	0.3901	2.5634
	6.81	0.3923	2.5491
	6.84	0.3934	2.5419
	6.86	0.3934	2.5419
	6.88	0.3968	2.5202

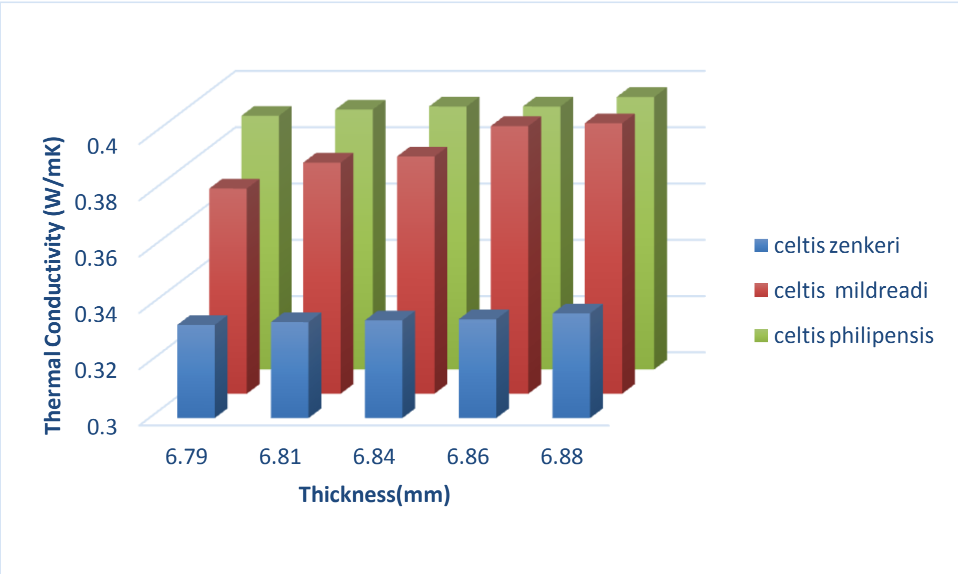

Figure 1: Thermal conductivity as a function of thickness for *celtis zenkeri, celtis philipensis* and *celtis mildreadi*

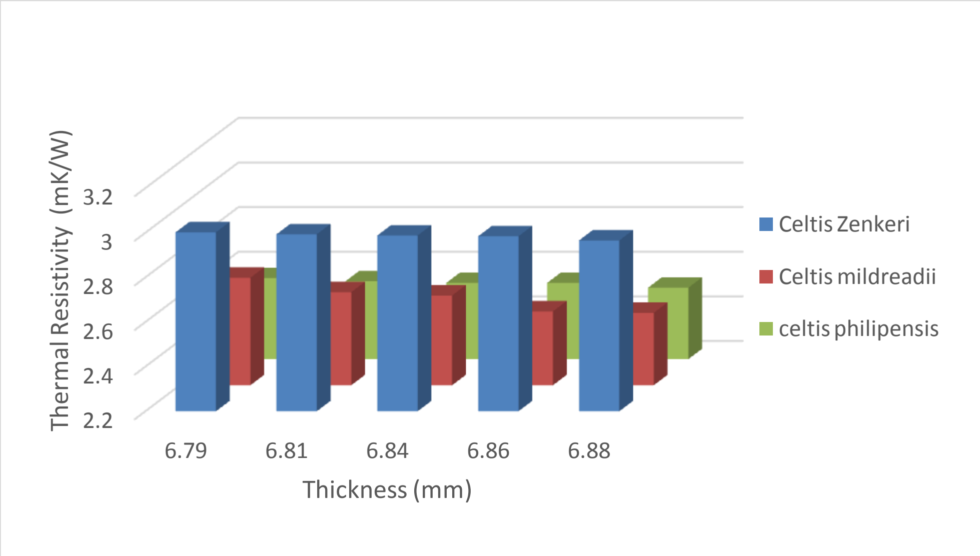

Figure 2: Thermal resistivity as a function of thickness for *celtis zenkeri*, *celtis philipensis* and *celtis mildreadi*

IV. Conclusion

It was established in this research that the thermal conductivity of celtis famlly, ranged between 0.3331 $Wm^{-1}K^{-1}$- 0.3968 $Wm^{-1}K^{-1}$. Among the three wood product of *celtis* family considered i.e *celtis philipensis*, *celtis mildreadi* and *celtis zenkeri.* The result revealed that *celtis philipensis* has highest thermal conductivity values of 0.3968 $Wm^{-1}K^{-1}$ which can serve as thermal insulators due to the low thermal conductivity in conformity with material values used as industrial insulator. Hence, the influence of thickness in wood utilization needs to be considered in various modes of applications in industries and domestic.

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