THERMAL PROPERTIES OF OIL AND RAFFIA PALM FIBRES

LOUIS E. AKPABIO, SAMUEL D. EKPE, SUNDAY E. ETUK and KUFREABASI E. ESSIEN

ABSTRACT

Thermal conductivities, specific heat capacities and bulk densities were determined for some fibre samples from oil and raffia palms. Thermal diffusivities and absorptivities were evaluated for each sample. Results show that the thermal conductivity values for the different samples are within he range of the thermal conductivities of construction and heat insulating material which is between $0.023 - 2.9$ $Wm^{-1}K^{-1}$. Raffia palm frond fibre has the greatest thermal diffusivity of 3.4×10^{-8} m^2s^{-1} while oil palm frond fibre has the least diffusivity of 1.9×10^{-8} m^2s^{-1}.

A model was developed for the prediction of temperature variation with thickness of the samples. Prediction from the model show that raffia palm frond fibre will make the best choice over the other fibres for use in making insulation fibre boards. The various fibre samples could also be used for lateral and bottom insulation in the making of simple solar oven/cooler.

INTRODUCTION

Extensive theoretical and experimental studies of the thermal properties of porous materials (such as building materials and soils) have been made and many models based on different assumptions, have been developed in order to effectively predict the thermal conductivities of these systems (Mahrer, 1982; Monteith, 1990; Pratt, 1969; Ekpe et. Al, 1996 and Bouguerra et al, 1997). Porous materials are used for thermal insulation and heat exchanges. A knowledge of their thermal properties is essential to analyze the heat transfer through such materials. For example, the thermal conductivity of a sand mould must be known in order to accurately determine the solidification time and rate of casting.

The oil and raffia palms are heavily fibrous. From ancient time inhabitants of the tropical rain forest (where these palms flourish) had perfected the art of making roofing mate from the foliage of raffia palm. These mats combined with the laterite walls produce a passively cooled building design. These designs as concluded by some researchers (Ekpe et al 1994), cuts down cost in the use of mechanical and electrical devices in cooling buildings.

The essence of this work is to determine if fibres from oil and raffia palms can be used as thermal insulators. This could be achieved by determining the specific heat capacity, thermal conductivity, density and hence thermal diffusivity and absorptivity for every sample collected. From the absorptivity values, a temperature-thickness variation model shall be developed for every sample and consequently used as criterion for selecting purposes. Table 1 shows the classification of oil and raffia palms used for this research work.

Table 1 Classification of Oil and Raffia Palms

	Oil Palm	Raffia Palms
Botanical name	*Elaeis guineensis*	*Raphia hookeri*
Average height	$(8 - 20)$m	$(7 - 15)$m
Type of wood	Soft and pored	Soft and pored

THEORETICAL BACKGROUND AND CALCULATION

The three main processes of heat propagation in materials are: thermal conduction through the solid phase, radiation and convection through porous materials.

LOUISE E. AKPABIO, Department of Physics, University of Uyo, Uyo, Nigeria
SAMUEL D. EKPE, Department of Physics, University of Uyo, Uyo, Nigeria
KUFREABASI E. ESSIEN, Department of Physics, University of Uyo, Uyo, Nigeria

Convection can be neglected for small pore sizes while radiation transport is Strongly dependent on temperature and becomes significant at high temperatures. The temperature of a porous material at any depth depends on the net amount of heat absorbed by the material (a factor of thermal conductivity), the heat energy required to bring about a given change in temperature of the material (thermal capacity) and the energy required for changes such as evaporation which occurs constantly at the surface. Temperature variations with thickness in solid materials determine whether or not the material can be used as a heat sink or source.

Temperature as a function of time and thickness can be estimated from an equation given by Ekpe et al. 1994 and Ekpe et al. 1996.

$$T(x, t) = T_m - A_s \exp(-\alpha x) \cos[\omega(t - t_o, -\alpha x/\omega)] \quad 1$$

Where
A_s = daily temperature amplitude at $x = 0^oC$:
t = time of the day in hours
t_o = time of minimum temperature at the surface hours
α = thermal absorptivityb (m^{-1})
ω = angular velocity day^{-1} (365 days cycle).
T_m is calculated from the hourly surface temperature average T_{hss} (^oC) as:

$$T_m = \sum_{n=1}^{24} (T_{hss}/24) \quad 2$$

Hence on a 24 – hour period, equation (1) becomes
$$T(x, t) = T_m - A_s \exp(-\alpha x) \cos[(2\pi/24)(t - t_o - 12\alpha x/\pi)] \quad 3$$

The measurement of thermal diffusivity, λ allows us to obtain the thermal conductivity, k, once the density, ρ and the specific heat, c_v of any material are known. We determine thermal diffusivity, λ by the relation (Silva et al 1998 and Suleiman, 1997).
$$\lambda = k/(\rho c_v) \quad 4$$

The thermal diffusivity (λ) is used in calculating the thermal absorptivity α from
$$\alpha = [\omega/2\lambda]^{1/2}$$
Inserting values of the respective absorptivity into equation (3) yields the temperature-thickness variation models at any given time of the day, t for each sample. For oil palm bunch fibre:
$$T(x, t) = T_m - A_s \exp(-25x) \cos[0.262(t-t_o-95.5 x)] \quad 6a$$

For oil palm frond fibre:
$$T(x, t) = T_m - A_s \exp(-30.9x) \cos[0.262(t-t_o- 118.0x)] \quad 6b$$

For raffia palm frond fibre:
$$T(x, t) = T_m - A_s \exp(-23.1x) \cos[0.262(t-t_o- 88.2x)] \quad 6c$$

For raffia (Woven):
$$T(x, t) = T_m - A_s \exp(-30.2x) \cos[0.262(t-t_o- 115.4x)] \quad 6d$$

For oil palm trunk fibre:
$$T(x, t) = T_m - A_s \exp(-25x) \cos[0.262(t-t_o- 95.5x)] \quad 6e$$

MATERIALS AND EXPERIMENTAL METHOD
Materials
Five samples of oil (*Elaeis guineensis*) and raffia palms were collected for this research work. The five samples were oil palm bunch fibre, oil palm frond fibre, raffia palm frond fibre, Raffia (woven) and oil palm trunk fibre. Each fibre sample was collected fresh from the respective plants. They were subsequently dried of moisture and shaped into cylindrical discs with thickness varying between 4.58mm and 10.03mm. Dry fibre samples were used to eliminate the problem of moisture redistribution under the influence of a temperature gradient when fresh fibre samples are used.

Experimental method
For each of he five fibre samples, the thermal conductivities were determined using the steady state method (modified Lee's disc apparatus) (Ekpe et al 1994). At steady state, the heat conducted across the fibre sample is equal to the rate at which it is emitted from the exposed surface.
The specific heat capacities were determined for each fibre sample using the cooling correction method, which takes into account heat, loses due to radiation.

Bulk densities were also measured for each fibre sample suing the weighing and displacement methods (Ekpe et al 1996). The thermal diffusivity and absorptivity were calculated for each sample using equations (4) and (5) respectively.

RESULTS AND DISCUSSION
Table 2 shows the experimental results for the thermal conductivity k. specific heat capacity C_v, density ρ, thermal diffusivity λ and thermal absorptivity α for the different fibre samples.

The highest thermal conductivity 0.1190 Wm^{-1}K was obtained for oil palm bunch fibre while c

Table 2: Thermal Properties of Oil and Raffia palm Fibre

Fibre Samples	K wm⁻¹K⁻¹	CV Jkg⁻¹K⁻¹ x 10³	ρ kgm⁻³ x 10³	λ m²s⁻¹ x 10⁻³	α m⁻¹
Oil-palm Bunch fibre	0.1190	4.50	0.90	2.90	25.00
Oil palm frond fibre	0.0586	8.20	0.38	1.90	30.90
Raffia palm Frond fibre	0.0737	5.07	0.42	3.40	23.10
Raffia (Woven)	0.0699	7.00	0.48	2.00	30.20
Oil-palm trunk fibre	0.0711	9.09	0.26	3.00	25.00

palm frond fibre had the least thermal conductivity of $0.586 \ Wm^{-1}K^{-1}$.

As a means of testing our method and evaluating its accuracy, we have compared the values of our results with those found in some literature. Generally the thermal conductivities of construction and heat insulating materials lie between 0.023 and 2.9 $Wm^{-1}K^{-1}$ (Isachenko et al (1987), Twidell et al (1990). It is obvious that the results are within the given range.

From our experimental results (Table 2), it is shown that raffia frond fibre has the least thermal absorptivity, and would make a better materials than other fibre samples for the design of a passively cooled building.

On application of the mathematical model (equations (6a – 6e); the hourly variation of the temperature – thickness model of the different fibre samples used for this research work with the same thickness is presented in Figure 1, the result shows that raffia frond fibre which has the least thermal absorptivity also records the least temperature.

From Table 2, we have seen that oil and raffia palm can be used for lateral and bottom insulation in a solar oven/cooker. When we compare the values of our thermal conductivity with those given by Nandwani (1988) (Table 3).

Table 3: Various Materials used for lateral and bottom insulation in a solar oven (Nandwani 1988)

Material	Thickness (m)	Conductivity (Wm⁻¹K⁻¹)
Aluminium paper	0.001	0.0465
Plywood (Pine Fibre Board)	0.004	0.0519
Asbestos sheet	0.004	0.3190
Glass Wool	0.041	0.0372

CONCLUSION

From the results obtained in this research, oil and raffia palm fibres have thermal properties, which compare favourably with those of good thermal insulators. One obvious application of this work is in the solar oven/cooker where these materials can help to lower the heat losses.

However, the hourly variation of the temperature-thickness model for the same thickness of the different samples, the prediction shows that raffia palm frond fibre with the least thermal absorptivity value will record the least temperature. Hence, raffia palm frond fibre will make the best choice over the other fibres in the making of insulation fibre boards.
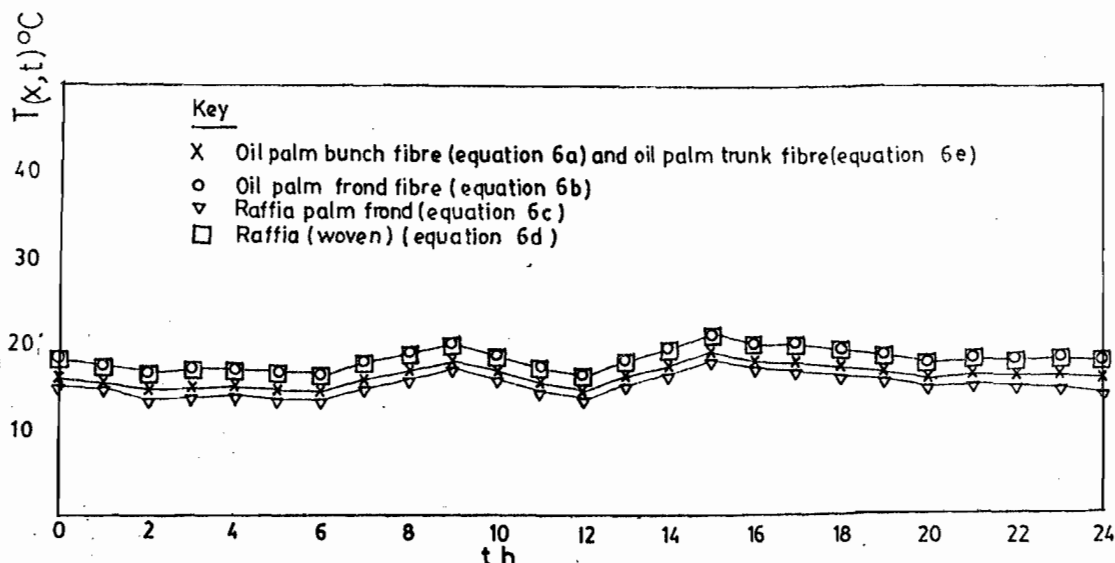

Fig.1: Hourly variations of temperature _ thickness

Finally, we hereby recommend our research findings to the construction industry for adoption and modification in the making of ceiling boards, which will further assist in the construction of low-cost housing.

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