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Modelling of the Thermophysical Properties of Ground Dika Kernel (*Irvingia wombolu* Vermoesen) as Affected by Temperature and Moisture Content

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors designed the study. Author BMF carried out the experiment, performed the statistical analysis, managed the literature searches and wrote the first draft of the manuscript. Author KAT managed the analyses of the study, read and approved the final manuscript.

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ABSTRACT

The specific heat capacity and thermal conductivity of the ground dika (*Irvingia wombolu* Vermoesen) kernel were measured using the thermal probe method. Bulk density was determined using the graduated cylinder and the value obtained was used to calculate thermal diffusivity. The effects of temperature (Room temperature – 90℃) and moisture content (5.17 – 20% wet basis) on the thermo physical properties of the ground and hydrated dika kernel were studied. Linear, quadratic and cubic regressions were modelled at each temperature as a function of the corresponding moisture contents, and the best model was selected based on the coefficient of determination (R^2) values. The results of the specific heat capacity ranged between 0.951 and 3.089 kJ/kg℃, thermal conductivity (4.36 and 31.87 W/m ℃*10^5), bulk density (0.492 and 0.680 g/cm^3) and the thermal diffusivity values between 6.313 and 43.065 m^2/s*10^5. All the values are within literature range. The result of the investigation revealed that thermo physical properties were

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moisture content and temperature dependent, and quadratic equation fitted all the models than linear equation for all the properties investigated. The data obtained from the study can be used in the process design of the ground kernel or the soup on a commercial scale.

Keywords: Temperature; moisture content; thermophysical properties; ground dika kernel; regression models.

1. INTRODUCTION

The information of the thermal properties of food materials is vital in equipment design [1], the rate of heat transfer must be known for efficient equipment and process design to prevent overheating or under heating during processing. Under heating will cause problems such as unsafe food production while overheating will waste energy in addition to depleting the nutritional value of the food. Processes such as cooling, cooking, pasteurisation, dehydration and freezing involve heat transfer [2] and the design of such processes require a detailed knowledge of the thermal properties of the materials involved. The primary thermal properties of foods are thermal conductivity, specific heat, and thermal diffusivity. Specific heat gives information of the amount of heat needed to raise the temperature of unit mass by unit degree at a given temperature [3]. The thermal conductivity of a food material is important in order to forecast or control heat flux and processing time. The value of thermal diffusivity of a given food can be calculated from the known values of the thermal conductivity, density, and specific heat capacity. The most significant parameters that affect thermal properties of food are bulk density, temperature and moisture content [4]. These properties determine the ease with which heat can flow into or out of a food material.

The method of mixtures has been reported to be the most common method for determining the specific heat of food and agricultural materials [5-7]. Several techniques have been used to determine the thermal conductivity of biological materials, the accuracy of the results varied with each method. Use of a line probe technique causes a minimum disturbance to the material being measured and is effective for determining the thermal conductivity of materials at low or high moisture content [6]. [8] have reported that the thermal probe measurement was found to give accurate, consistent and reliable experimental results of thermal conductivity in a given range.

Irvingia trees are a valuable source of income for West and Central African farmers. The kernels form an important part of their diet, providing lipids, protein and minerals [9]. The dried kernel is widely accepted by the consumers, and it serves as a thickener for soups and stews. The kernel is growing interest in the food service sector due to the nutritional, functional and rheological characteristics [10-13]. Thermal properties of some selected Nigerian soups have been studied and reported [14-16]. The values obtained showed that the soups can hold or dissipate heat a little during canning and freezing and concluded that the chemical compositions and water fractions greatly influenced the thermal properties of soups [15]. Oladimeji [17] reported some thermal properties and regression models of *Irvingia gabonensis* “ogbono’ soup; such parameters were stated to serve as a basis for future research in the canning of Nigerian soup [15]. The models are useful for process automation operations and equipment design. An assessment of related literature revealed that such data on *Irvingia wombolu* kernel is lacking, hence this study investigated the influence of moisture content and temperature on the thermal properties of the ground kernel and also the regression models of these properties.

2. MATERIALS AND METHODS

2.1 Sample Collection and Preparation

Irvingia wombolu kernels were obtained from Agbeonu-Obey farm, near Ile-Ife. The variety was confirmed at the Herbarium, Department of Botany, Obafemi Awolowo University, Ile-Ife. The kernel was removed from the fruit, skinned, cleaned and sorted to remove unwanted materials. The dika kernels were sundried and milled (Plate 1) using a laboratory mill (Perten, 3303, Sweden).

Plate 1. *Irvingia wombolu* (a) kernel (b) ground powder

The ground dika kernel at its initial moisture content (5.17%), was conditioned to different moisture contents ranging from 5.17 to 20% (wet basis) by water addition. The conditioned samples were obtained by spraying pre-determined mass of distilled water to the ground sample using Equation 1. The samples were sealed in airtight plastic bags and kept in a refrigerator at 5 ℃ for 5 days to ensure uniform moisture distribution.

$$M_w = \frac{M_s\left(M_f - M_i\right)}{100 - M_f} \tag{1}$$

Where:

M_w is the mass of distilled water to be added to the sample (g);
M_s is the initial mass of the sample (g);
M_f is the final (desired) moisture content of the sample (%w.b); and
M_i is the initial moisture content of the sample (% w.b)

Each sample was taken out, allowed to equilibrate at ambient temperature and moulded using a circular disc shape moulding device while maintaining a uniform compression. Variations in the temperature of the sample were achieved by placing the sample in the already set oven (Surgifriend Medicals, SM9023, England). The sample was allowed to reach the set temperature by measuring the temperature using the thermocouple probe (Center, 301, Taiwan). The samples were later analysed using the thermal conductivity apparatus (as shown in Plate 2 - sourced from the Department of Agricultural and Environmental Engineering, University of Ibadan, Nigeria) for specific heat capacity and thermal conductivity between ambient temperature and 90 ℃.

2.2 Specific heat Capacity Determination

The circular disc-shaped sample of about 45 mm diameter was used. A thermocouple was connected with two sensors to both sides, positioned firmly on the samples and connected to the digital temperature indicator. The complete set up was placed gently in a thermal insulated evacuated cylindrical chamber. The specific heat capacity of each sample was determined by calculating heat supplied, change in temperature and mass of the samples using Equation 2. The specific heat capacity of each sample was obtained from the average of three replicate values.

$$C_p = \frac{Q}{\Delta T . m} \tag{2}$$

Where:

C_p is the specific heat capacity (kJ/kg℃)
Q is the heat supplied through the element (kJ);
ΔT is the change in temperature (T_f – T_i) ℃; and
M is the mass of the sample (kg).

2.3 Thermal Conductivity Determination

The circular disc-shaped sample of about 45 mm diameter and 10 mm thick was prepared for the test. The thermal conductivity of each sample was determined according to the methods of [18,19]. The thermal conductivity experimental set-up (Plate 2) consists of heating element

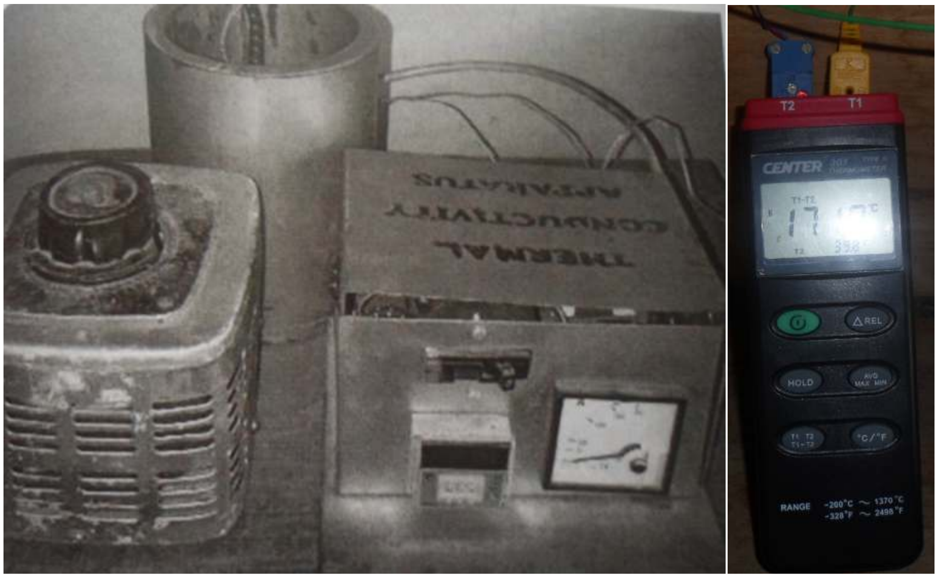

Plate 2. Thermal conductivity apparatus and thermocouple with K probes

connected to a conductivity device. A thermocouple meter with 2 type K probes was connected and placed on both sides of each sample. The setup was placed in the thermal lagged evacuated cylinder chamber to prevent heat loss of the sample. The heat supplied was maintained constantly until steady state was reached and the temperature at the thermocouple was noted using the digital temperature indicator. The thermal conductivity was later calculated (equation 3) using the measured temperature, heat supplied and the area of the circular disc shaped sample according to Fourier's law of one-dimensional heat conduction:

$$Q = \frac{kA\Delta T}{\Delta x} \tag{3}$$

Where:

K is the thermal conductivity of the sample (W/m ℃).
A is the surface area of the sample ((m^2));
ΔT is the change in temperature ($T_f - T_i$)℃;
Δx is the thickness of the circular disc sample (m); and
Q is the heat dissipated through the element (W)

2.4 Bulk Density

Bulk density was determined according to the method of [20]. A 10 ml graduated cylinder, previously tared, was gently filled with each sample. The bottom of the cylinder was gently tapped on the laboratory bench several times until there was no further diminution of the sample level after filling to the 10 ml mark. The bulk density calculated according to Equation 4 and expressed as weight of sample per unit volume of sample (g/cm^3).

$$Bulk\ density\ (\frac{\mathrm{g}}{\mathrm{cm3}}) = \frac{weight\ of\ sample\ (g)}{volume\ of\ sample\ after\ tapping\ (cm^3)} \tag{4}$$

2.5 Thermal Diffusivity Determination

The thermal diffusivity of the sample was calculated from the combination of the result from three thermal properties according to equation 5:

$$\alpha = \frac{k}{\rho C_p} \tag{5}$$

Where:

α is the thermal diffusivity (m^2/s)
C_p is the specific heat capacity
K is the thermal conductivity
ρ is the density of the sample

2.6 Statistical Analysis

To ensure reproducibility, the experiments were carried out in replicates. The data obtained were analysed using [21] and the means were separated with Scheffe Multiple Comparison Test at a significant level of 0.05.

3. RESULTS AND DISCUSSION

3.1 Specific Heat Capacity

The specific heat capacity values of the samples are presented in Table 1a. The values obtained ranged between 0.951 and 3.089 kJ/kg ℃. The highest specific heat capacity value was obtained at 90 ℃ for the sample having a moisture content of 20%. The values obtained in this study (0.951 - 3.089 kJ/kg ℃) are similar to the range of values (1.39 - 3.42 kJkg^{-1}℃$^{-1}$) reported for ground melon samples [16]; and also within the range (2.667 to 4.427 kJ/kg ℃) reported for *I. gabonensis* kernel [7]. Differences in the result may be due to the different range of varying moisture content (6.56 - 48.64%).

The specific heat capacity increased linearly with temperature for the conditioned and unconditioned samples (Table 1a). This linear response to temperature is similar to literature values [22] on most moist foods. The specific heat capacity decreased with increase in moisture content up to 10%, but further increase in the moisture content increased the specific heat capacity. This trend is similar to those reported for rapeseed [23], but contrary to the report of [7] where it was stated that specific heat capacity decreased linearly with increase in moisture content (6.56 - 48.64%). A model describing the relationship between the moisture content and specific heat capacity at varying temperatures was established from the data. A quadratic equation fitted the models than a linear equation (Table 1b). Earlier studies also confirmed multiple quadratic regression equations predicting specific heat as a function of moisture content and temperature [6,17]. Table 1c showed the details of the regression equation modelled at each temperature predicting the specific heat capacity as a function of the corresponding moisture contents, including the coefficient of determination (R^2). All the equations expressed in Table 1c have an R^2 value close to 1. The best R^2 value was observed at room temperature (0.999).

Table 1a. Specific heat capacity (*kJ/kg℃) of Dika Kernel

Moisture content (%)	Temperature (℃)			
	RT	**50**	**70**	**90**
5.17	1.199±0.08 $_{ab}$	1.221±0.02 $_{b}$	1.493±0.07$_{b}$	2.798±0.04$_{a}$
10	0.951±0.01 $_{b}$	1.043±0.01 $_{b}$	1.099±0.03$_{c}$	1.406±0.12$_{b}$
15	1.034±0.10 $_{ab}$	1.299±0.12 $_{b}$	1.457±0.10$_{b}$	1.610±0.19$_{b}$
20	1.488±0.11$_{a}$	1.881±0.02 $_{a}$	1.891±0.01$_{a}$	3.089±0.10$_{a}$

**RT- Room Temperature; *Mean of three replicates and moisture content was on dry basis*
Means in the same column with different letters are significantly different $(P \leq 0.05)$ *± standard deviation*

Table 1b. Regression analysis of the relationships between specific heat capacity and moisture content of the sample

Temperature (℃)	Regression equation	Regression constants (a,b,c,d)	Coefficient of determination (R^2)
RT	$y=a+bx$	0.924,0.019	0.275
50		0.791,0.045	0.641
70		1.088,0.032	0.391
90		1.940,0.023	0.029
RT	$y=a+bx_1+cx_2$	1.842,-0.161,0.007	0.999
50		1.778,-0.149,0.008	0.998
70		2.163,-0.180,0.008	0.924
90		5.703,-0.718,0.029	0.996
RT	$y=a+bx_1+cx_2+dx_3$	1.795,-0.147,0.006,3E-05	1
50		2.002,-0.219,0.014,-2E-04	1
70		3.456,-0.583,0.044,9E-04	1
90		6.435,-0.946,0.049,-5E-04	1

Table 1c. Models describing the relationship between specific heat capacity (C_p) and moisture content of the sample at varying temperatures

Temperature (℃)	Coefficient of determination (R^2)	Quadratic regression equation
RT	0.9998	$C_p = 0.0072M^2 - 0.1612M + 1.8419$
50	0.9982	$C_p = 0.0077M^2 - 0.1488M + 1.778$
70	0.9239	$C_p = 0.0084M^2 - 0.1800M + 2.1630$
90	0.9964	$C_p = 0.0294M^2 - 0.1718M + 5.7025$

3.2 Thermal Conductivity

The results of the thermal conductivity (Table 2a) obtained represents the ability of the food to transmit heat. The values were very low ranging between 4.36 and 31.87 W/m ℃ $*10^5$. By Fourier's Law, heat flow is positive in the direction opposite the temperature gradient, since the energy transferred from high to low. The low values may be as a result of the presence of pores in the samples, as this influenced the thermal conductivity of dried porous foods [23,24]. The result showed that a linear relationship exists between thermal conductivities of the samples and relatively high moisture content. This is expected because as the samples were conditioned to higher moisture, the thermal conductivity values tended to move closer to that of water [24]. The values have also increased with increase in temperature. Thermal conductivity was greatest at the highest moisture content of 20% at 90 ℃ . This may be because thermal energy intake by the samples was low at room temperature, but as the temperature increased, thermal energy also increased as a result of a large amount of moisture present in the samples cellular structure [16].

The trends observed in this study are similar to earlier reports for rapeseed, borage seeds, shea kernel, cocoa beans and ground melon [23,25-26,16]. The values obtained (4.36 and 31.87 W/m ℃$*10^5$) in this study are lower than those values (0.33 - 0.56 $\mathrm{Wm^{-1}{}^{\circ}C^{-1}}$) reported for ground melon [16] and *I. gabonensis* (0.335 – 0.578 W/m ℃) [7]. Differences in the values may be because of the fat content, moisture content range, particle size and the thickness of the samples. Thermal conductivity gives the amount of heat that will be conducted per unit time through a unit thickness of the material [24]. Thermal conductivity may, therefore, be influenced by the surface area of the material.

A Linear relationship between thermal conductivity and moisture content gave a poor R^2 value (not close to 1) (Table 2b). The data were therefore fitted into quadratic equations which gave better equations (Table 2c). The equations presented in Table 2c can predict the thermal conductivity of dika kernel at different moisture levels within the experimental values. The best fit was observed at 50 ℃ (0.986). This value is lower than that R^2 value reported for shea kernel (0.974) and cocoa beans (1.000) as temperature increased from 35 to 55 ℃ [26], but higher than that R^2 value (0.816) reported for *I. gabonensis* seed at 50 ℃ [17].

3.3 Bulk Density

The effect of moisture content on the density of the samples at various temperatures is presented in Table 3a. The density values for all the temperatures studied ranged between 0.492 and 0.680 g/cm^3. The values obtained in this study are similar to those reported (0.5.5 – 0.625 g/cm^3) for cashew nut and kernel [27] but higher than those reported (0.453-0.472 g/cm^3) for borage seeds [25]. Differences may be due to the moisture content range (1.2 – 30.3% w.b) and the type of oilseed explored.

Table 2a. Thermal conductivity (W/m ℃ $*10^5$) of Dika Kernel

Moisture content (%)	Temperature, (℃)			
	RT	50	70	90
5.17	$4.362 \pm 0.15_a$	$4.402 \pm 0.35_b$	$5.145 \pm 1.38_b$	$6.256 \pm 0.16_c$
10	$4.530 \pm 1.64_a$	$4.611 \pm 0.07_b$	$5.711 \pm 0.03_b$	$14.348 \pm 0.76_b$
15	$4.609 \pm 0.03_a$	$5.282 \pm 0.16_b$	$7.204 \pm 0.01_b$	$15.506 \pm 0.35_b$
20	$7.218 \pm 0.02_a$	$7.928 \pm 0.06_a$	$20.017 \pm 0.02_a$	$31.872 \pm 0.18_a$

**RT- Room Temperature; *Mean of three replicates and moisture content was on dry basis*
Means in the same column with different letters are significantly different $(P \leq 0.05)$ *± standard deviation*

Table 2b. Regression analysis of the relationships between thermal conductivity and moisture content of the sample

Temperature (℃)	Regression equation	Regression constants (a,b,c,d)	Coefficient of determination (R^2)
RT	y=a+bx	2.979,0.175	0.676
50		2.696,0.228	0.803
70		-2.209,0.935	0.718
90		-2.789,1.577	0.881
RT	$y=a+bx_1+cx_2$	6.164,-0.451,0.025	0.939
50		5.855,-0.394,0.025	0.986
70		13.737,-2.203,0.125	0.965
90		7.876,-0.522,0.083	0.929
RT	$y=a+bx_1+cx_2+dx_3$	1.332,1.054,-0.109,0.004	1
50		3.078,0.472,-0.052,0.002	1
70		-5.373,3.751,-0.404,0.014	1
90		-33.586,12.397,-1.065,0.030	1

Table 2c. Models describing the relationship between thermal conductivity (k) and moisture content of the sample at varying temperatures

Sample	Temperature (℃)	Coefficient of determination (R^2)	Quadratic regression equation
Dika kernel	RT	0.9399	$k = 0.0249x^2 - 0.4513x + 6.1635$
	50	0.986	$k = 0.0247x^2 - 0.3938x + 5.8551$
	70	0.9649	$k = 0.1246x^2 - 2.2033x + 13.737$
	90	0.9288	$k = 0.0833x^2 - 0.5216x + 7.8757$

The density of the samples decreased for dika kernel conditioned at 10% moisture content. This decrease may be due to the microscopic particles of the sample absorbing water, thereby increasing the volume of the samples, causing a decrease in the bulk density. However, further moisture content may have caused the microscopic particles to spread across the surface of the sample, thereby increasing the mass of the samples, resulting in higher densities. The increase in temperature to 50℃ caused an increase in the bulk density. This may be due to the gelatinization of the starch particle causing an increase in the mass of the sample. However, a further temperature increase caused a decrease in the bulk density. The density of a food material changes with temperature, with higher temperature causing a reduction in the density of the material [28].

From the results obtained, a poor relationship exists between the bulk density and moisture content using linear equation (Table 3b). Quadratic equation was developed to establish the relationship between moisture content and bulk density at all the temperatures studied (Table 3c). The best R^2 value (close to 1) was observed when the data were fitted into the quadratic equations. The equations obtained can be used to predict the bulk density of the samples at different moisture levels within the experimental values. The highest R^2 was obtained at 90 ℃ (0.9879). Density describes the relationship between the mass and the volume of a material. Calculation of the thermal diffusivity of the dika kernel at varying temperatures requires knowledge of the bulk density of the samples. The bulk density results were used to further calculate the thermal diffusivity of the samples.

Table 3a. Bulk density (g/cm^3) of Dika Kernel

Moisture content (%)	Temperature (℃)			
	RT	50	70	90
5.17	$0.550\pm0.00_a$	$0.678\pm0.00_a$	$0.667\pm0.01_a$	$0.657\pm0.01_a$
10	$0.492\pm0.01_c$	$0.581\pm0.00_b$	$0.474\pm0.00_b$	$0.475\pm0.00_b$
15	$0.531\pm0.00_b$	$0.578\pm0.00_b$	$0.500\pm0.01_b$	$0.500\pm0.00_b$
20	$0.538\pm0.00_{ab}$	$0.595\pm0.01_b$	$0.500\pm0.00_b$	$0.657\pm0.01_a$

**RT- Room Temperature; *Mean of three replicates and moisture content was on dry basis*
Means in the same column with different letters are significantly different $(P \leq 0.05)$ ± *standard deviation*

3.4 Thermal Diffusivity

Thermal diffusivity results are presented in Table 4a. The values ranged between 6.313 and 43.065 $m^2/s*10^5$. The thermal diffusivity increased with moisture content over the range of temperatures studied. This trend is similar to earlier reports for *I. gabonensis* [7] but does not agree with that of borage seeds [25]. Differences in the trend of the relationship between thermal diffusivity and moisture content with other earlier reports may depend on the combined effects of thermal conductivity, density and specific heat capacity of the samples.

Thermal diffusivity values obtained in this study were higher than those (0.09 - 0.13 $*10^{-5}$ m^2s^{-1}) reported for ground melon [16], *I. gabonensis* flour (5.52 – 9.53 $*10^{-6}$ m^2/s) [7] and for cashew kernel (2.369 – 2.588 $*10^{-7}$ m^2/s) reported by [27]. Differences in the results may be due to the differences in the food material, their forms (ground or whole), moisture content range and other parameters necessary for calculating the thermal diffusivity ($\rho, \alpha, k, and\ C_p$). From the data obtained (Table 4b), quadratic relationship was established between thermal diffusivity and moisture content (Table 4c). This is similar to the report of [7] that second order polynomial relationship exists between the thermal diffusivity and moisture content of *I. gabonensis*. A well fitted equation was observed at room temperature (0.9961) for dika kernel. The thermal properties studied were found to be moisture dependent. Values obtained for the thermal properties of the dika kernel can be used as parameters when designing and manufacturing packaging equipment, and processing of the product for safe storage and shelf life.

Table 3b. Regression analysis of the relationships between bulk density and moisture content of the sample

Temperature (℃)	Regression equation	Regression constants (a,b,c,d)	Coefficient of determination (R^2)
RT	$y=a+bx$	0.527,9E-05	0.001
50		0.671,-0.005	0.466
70		0.655,-0.009	0.469
90		0.564,0.001	0.002
RT	$y=a+bx_1+cx_2$	0.611,-0.017,0.001	0.548
50		0.822,-0.035,0.001	0.955
70		0.908,-0.059,0.002	0.866
90		1.009,-0.087,0.004	0.988
RT	$y=a+bx_1+cx_2+dx_3$	0.855,-0.093,0.007,-2E-04	1
50		0.967,-0.079,0.005,-1E-04	1
70		1.379,-0.206,0.015,-3E-04	1
90		1.165,-0.136,0.008,-1E-04	1

Table 3c. Models describing the relationship between bulk density (BD) and moisture content of the sample at varying temperatures

Temperature (℃)	Coefficient of determination (R^2)	Quadratic regression equation
RT	0.5479	$BD = 0.0007M^2 - 0.0165M + 0.611$
50	0.9547	$BD = 0.0012M^2 - 0.0346M + 0.8216$
70	0.8657	$BD = 0.002M^2 - 0.0595M + 0.9084$
90	0.9879	$BD = 0.0035M^2 - 0.0869M + 1.0088$

Table 4a. Thermal diffusivity (m^2/s $*10^5$) of Dika Kernel

Moisture content (%)	Temperature (℃)			
	RT	50	70	90
5.17	$6.313\pm1.16_a$	$6.640\pm0.49_c$	$6.760\pm0.06_b$	$7.800\pm0.01_d$
10	$7.283\pm0.19_a$	$7.647\pm0.17_c$	$9.891\pm1.52_b$	$10.858\pm0.06_c$
15	$8.390\pm0.10_a$	$26.598\pm0.09_b$	$11.001\pm0.00_b$	$19.356\pm0.00_b$
20	$9.016\pm0.16_a$	$43.065\pm0.01_a$	$21.238\pm0.18_a$	$27.839\pm0.05_a$

**RT- Room Temperature; *Mean of three replicates and moisture content was on dry basis*
Means in the same column with different letters are significantly different ($P \leq 0.05$) *± standard deviation*

Table 4b. Regression analysis of the relationships thermal diffusivity and moisture content of the sample

Temperature (℃)	Regression equation	Regression constants (a,b,c,d)	Coefficient of determination (R^2)
RT	y=a+bx	5.416,0.186	0.988
50		-11.592,2.598	0.915
70		0.913,0.902	0.844
90		-0.953,1.389	0.967
RT	$y=a+bx_1+cx_2$	4.919,0.284,-0.004	0.996
50		7.990,-1.257,0.153	0.977
70		10.120,-0.910,0.072	0.948
90		5.824,0.055,0.053	0.994
RT	$y=a+bx_1+cx_2+dx_3$	5.995,-0.052,0.026,-0.001	1
50		46.051,-13.115,1.207,-0.028	1
70		-10.646,5.559,-0.503,0.015	1
90		15.825,-3.061,0.329,-0.007	1

Table 4c. Models describing the relationship between thermal diffusivity (α) and moisture content of the sample at varying temperatures

Temperature (℃)	Coefficient of determination (R^2)	Quadratic regression equation
RT	0.9961	$\alpha = -0.0039M^2 + 0.284M + 4.9187$
50	0.9770	$\alpha = 0.0153M^2 - 1.2566M + 7.9903$
70	0.9476	$\alpha = 0.0719M^2 - 0.9103M + 10.120$
90	0.9941	$\alpha = 0.053M^2 + 0.0547M + 5.8241$

4. CONCLUSION

Thermophysical properties of the dika kernel powder were measured as a function of temperature and moisture content. From this study, it was concluded that these properties increased with increase in temperature and moisture content. Quadratic equations (second order polynomial) established the relationship between the properties studied and the moisture content better than linear equations. This study provided information on the thermophysical properties of dika kernel for the production of the kernel and its soup on a commercial scale.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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