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DESIGN AND FABRICATION OF THERMAL CONDUCTIVITY APPARATUS FOR CASHEW NUT

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ABSTRACT

Experiments were conducted for determination of various physical properties of Vengurla-4 variety of cashew nut. The diameter or size and sphericity of cashew nut were found to be 21.92 mm and 0.68 respectively. The average gravimetric properties such as bulk density were found to be 533 kg/m^3, true density were 663.3 kg/m^3 and porosity were 19.6%. Angle of repose for cashew nut were found as $30.5^{0.}$

Thermal conductivity of cashew nut were determined at different moisture contents of 8.7%, 13.6%, 19% and 25%(d.b). Thermal conductivity at 8.7% were found to be 0.109 W/m^0k, at 13.6% were 0.125 W/m^0k, at 19% is 0.142 W/m^0k and at 25% is 0.155 W/m^0k. Thus thermal conductivity of cashew nut were found to be increase with increase of moisture content.

INTRODUCTION

The thermal properties depend mainly on the physical characteristics of food such as temperature, size, shape, state (frozen or unfrozen), compositional parameters, (moisture content, fat content, protein, and ash) and fiber orientation. As these properties vary widely with temperature and composition, it is essential to report the measured properties in concerned with these parameters. Thermal data are more often reported, either as a function of moisture content or fat content.

The presence of all the required nutrients in the cashew nut makes them suitable for large-scale utilization in the manufacture of various food products, e.g. baby foods, snack foods, dietary foods, etc. During processing, the nut and kernel undergoes a number of unit operations such as drying, roasting, cutting, peeling, drying etc. Knowledge of thermodynamic properties of agricultural materials constitutes an important and essential engineering reference in the design of machines, structures, processes and controls. This is useful in analyzing and determining the efficiency of a machine or an operation, in developing new consumer products of plant or animal origins, and in evaluating and retaining the quality of the final product.

Such basic information should be of value not only to engineers but also to the food scientists, manufacturers and other scientists who may exploit these properties and find new uses (Mohsenin, 1980). Hence, this study to determine the thermal properties, viz., specific heat, thermal conductivity and thermal diffusivity of the cashew nut and kernel with reference to moisture dependence, has been made.

Methods for measuring thermal conductivity can be classified into two broad categories: steady- and transient-state heat transfer methods (Mohsenin, 1980). The tests using steady-state methods often require a long time to complete and moisture migration may introduce significant measurement errors (Mohsenin, 1980; Kazarian & Hall, 1965; Dutta et al., 1988). The latter methods are more suitable for biological materials that are generally heterogeneous and often contain high moisture content. The line source method is the most widely used transient-state method. This method uses either a bare wire or a thermal conductivity probe as a heating source, and estimates the thermal conductivity.

MATERIALS AND METHODS

About 3 to 4 kg (depends on moisture content) sample of cashew nut of vengurla-4 variety were taken for testing of each replication. Then its moisture content was determined as thermal conductivity is affected by moisture content. This quantity of sample is required for each replication. Three replications were taken at each moisture content. Such replications at four different moisture content of 8.7%, 13.6%, 19% and 25%(d.b) were taken and effect of moisture content on thermal conductivity were determined.

Properties of Cashew nut:

Spatial dimension

Three dimensions viz. length, breadth and thickness of the seed were, measured by using digital vernier. Dimensions were calculated by noting the dimension of ten randomly selected seeds of local variety. From these dimensions, flatness ratio, elongation ratio and surface area were calculated.

Flatness ratio was calculated by taking the ratio of length to breadth. Elongation ratio was calculated by taking the ratio of breadth to the thickness. Surface area was calculated by taking the ratio of breadth to the thickness. Surface area of seed was calculated by considering the shape of grain as spherical. Geometric mean diameter was taken as the diameter of the cashew nut.

Longest dimension called length 'L' second longest dimension perpendicular to L called breadth ' B' and third longest dimension perpendicular to both is called thickness ' T ' of an object.

Size or equivalent diameter

Size or equivalent diameter is the geometric mean of the three dimensions viz. length, breadth and thickness. The size was calculated by using following relationship.

$$D = \sqrt[3]{LBT}$$

Where

L = Length
B = Breadth
T = Thickness

Sphericity

Assuming that the volume of the solid is equal to that triaxial ellipsoid with intercept L, B, T and that the diameter of the circumscribed sphere if the longest intercept (L) of the ellipsoid (Mohsenin, 1950), the degree of sphericity was determined as follows,

$$\text{Sphericity} = \frac{\sqrt[3]{LBT}}{L}$$

Where, L =Length
B = Breadth
T = Thickness

$$\text{Sphericity} = \frac{\text{geometric mean diameter}}{\text{Mean diameter}}$$

Flatness ratio

It is the ratio of length of sample to breadth of sample.

$$\text{Flatness ratio} = \frac{\text{length of sample}}{\text{Breadth of sample}}$$

Elongation ratio

It is the ratio of breadth of sample to thickness of sample.

$$\text{Elongation ratio} = \frac{\text{breadth of sample}}{\text{Thickness of sample}}$$

Bulk density

It was determined by filling a specific mass of sample in known volume of cup. The sample was weigh, which required filling the cup. The density of any material may be expressed as below,

$$\text{Bulk density} = \frac{\text{weight of material}}{\text{Volume of material}}$$

True density

It was determined by pouring a specific mass of sample in known volume of toluene. Increase in level of toluene was observed and from that volume was determined.

$$\text{True density} = \frac{\text{weight of material}}{\text{Volume of material}}$$

True density was calculated from he known values of bulk density and porosity, using the following standard relationship,(mohsenin,1980)

$$\rho_t = \frac{\rho_b}{1 - P_t}$$

Where

P_t = porosity in fraction

ρ_t = True density and

ρ_b = Bulk density

Porosity

Porosity is also known as packing factor, it was determined from bulk density and true density of grains may be expressed by following expression (Mohsenin, 1970)

$$\text{Porosity} = \frac{\text{True density - Bulk density}}{\text{True density}}$$

Angle of Repose

Angle of repose was determined using a set-up. It involves the measurement of the height of the grain heaped over a circular disc of known diameter (V. V. Sreenarayanan, 1988).

Initial moisture content

The initial moisture content of sample was determined in gravity air oven at 110^0 C for 16-20 hours till constant weight was obtained. From above procedure final moisture content was obtained.

$$M_{(d.b)} = \frac{W_1 - W_2}{W_2}$$

$$M_{(w.b)} = \frac{W_1 - W_2}{W_1}$$

Where,

W1= weight of wet sample, gm

W2= weight of dry sample, gm

EXPERIMENTAL PROCEDURE

The line heat source method is used for measurement of thermal conductivity of cashew kernel. The sample holder is cylindrical in shape with 15cm diameter and 30cm height. For thermal conductivity determination sample holder is fully loaded with case nut sample. As stated earlier, two thermocouples are fixed at center of cylinder for measuring temperature of sample at center of cylinder and near the surface of cylinder. These thermocouples are fixed with cylinder. Constantan heater wire with 0.035 Ω per cm resistance passes vertically through sample holder. After loading, cylinder was closed from both ends with insulating material to avoid heat loss. Power is given to circuit and thus heating wire is energized at constant voltage and current. Heating wire continuously transfer the heat to the sample and heat is transferred through sample due to surface contact i.e. due to conduction. Digital temperature indicator records the three different temperatures with the help of selector switch. Simultaneously time was recorded till constant temperature is obtained. Thermal conductivity of cashew sample was hence calculated. Four replicates were taken at different moisture content of 8.7%, 13.6%, 19%and 25% and data was recorded for thermal conductivity calculations. Sufficient time was given for getting 10 ºC differences in temperature of sample. It normally ranges from 15-20 min between replicates and 2-3 hours for each moisture content measurement.

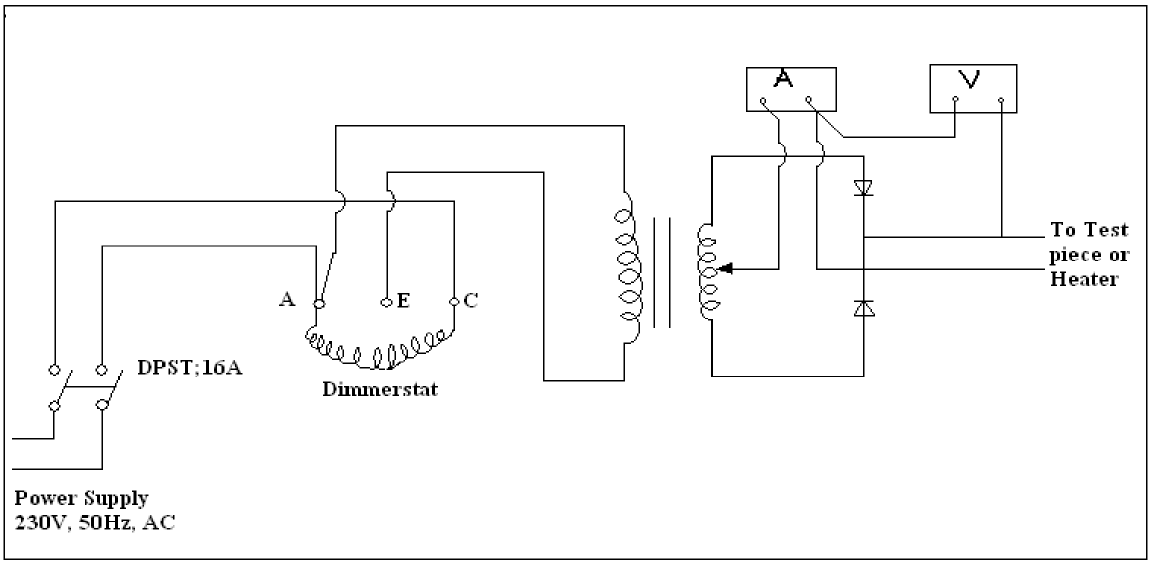

Fig. 1 Circuit diagram of thermal conductivity apparatus

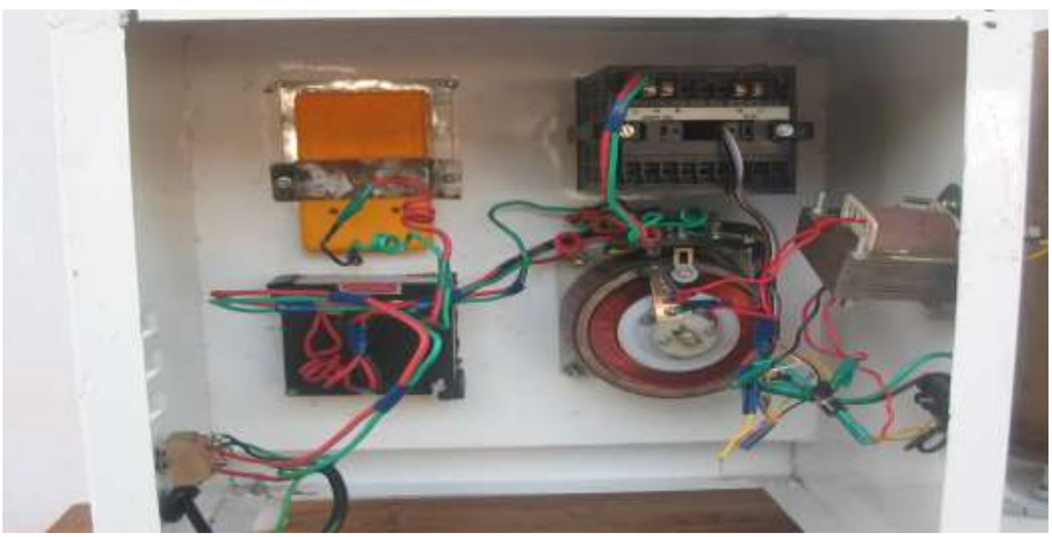

Fig. 2 Circuit of thermal conductivity apparatus

Following equation was used for calculating thermal conductivity

$$k = \frac{q \ln(\theta_2 - \theta_1)}{4\pi (t_2 - t1)}$$

where,

k=thermal conductivity

q=heat input and

t_1 and t_2 are the temperatures of heating element at times θ_1 and θ_2 respectively.

RESULT AND DISCUSSIONS

Physical Properties

The spatial dimension of the seed such as length, breadth and thickness of cashew nut were measured and from that equivalent diameter, sphericity, flatness ratio, elongation ratio, surface area were evaluated. The average values of physical properties of cashew nut at moisture content of 8.7%(d.b) are given in Table 4.1.

Table 1 Average values for physical properties of cashew nut.

Particular	Length, mm	Breadth, mm	Thickness, mm	Equivalent Diameter	sphericity	Flatness Ratio	Elongation Ratio
	L	B	T	$LBT^{1/3}$	$LBT^{1/3}/L$	L/B	B/T
Cashew nut	32.36	22.70	14.34	21.92	0.68	1.42	1.58

Gravimetric Properties

Bulk density

The bulk densities of Vengurla-4 variety of cashew nut at 8.7% (d.b) moisture content were recorded. The average bulk density of cashew nut is 533 kg/m^3. Three replications were taken and bulk densities were obtained as 530kg/m^3; 520 kg/m^3 and 526.6 kg/m^3.

True density

The true densities of Vengurla-4 variety of cashew nut at 8.7%(d.b) moisture content were recorded. The average bulk density of cashew nut is 663.3 kg/m^3. Three replications were taken and true densities were obtained as 690 kg/m^3; 680 kg/m^{3}and 620 kg/m^3.

Porosity

Porosity of Vengurla-4 variety was calculated from the values of bulk density and true density at 8.7%(d.b) moisture content. Porosity of cashew nut at above moisture content is 19.6%.

Angle of repose

Angle of repose of Vengurla-4 variety of cashew nut is measured and found as 30.5^0.

Thermal conductivity of cashew nut

Around 3.15kg of cashew sample for each replication were taken and thermal conductivity at different moisture content were calculated. At each moisture content three replications are taken and result obtained are as follows;

Table 2 Thermal conductivity of cashew nut

Sr. No.	Moisture content, % (d.b)	Thermal Conductivity, (k) W/m^{0}k	Avg. Thermal Conductivity, (k) W/m^{0}k

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1.	8.7	0.109	0.109
		0.108	
		0.109	
2.	13.6	0.123	0.125
		0.126	
		0.127	
3.	19	0.141	0.142
		0.139	
		0.146	
4.	25	0.155	0.155
		0.159	
		0.153	

DEVELOPMENT OF APPARATUS

The Thermal Conductivity apparatus using a probe for the measurement of thermal conductivity of a cashew nut was developed and fabricated based on the theory of the line heat source method. The sample holder of the apparatus was designed using the known physical properties of cashew nut. The designed dimensions of sample holder are 15cm inner thickness; 30cm height and 0.5mmthickness.considering time response factor smaller probes were used in design of apparatus. The probe lead wires were soldered to the insulated wires at ends. Constantan heater wire of 0.250mm diameter, 500mm length and made up of 0.035Ω per cm resistance used as line heat source. Accordingly range of ammeter (0-2A), voltmeter (0-20V) were chosen and used in the design and fabrication of apparatus. All the specified parts are assembled on single platform of 65cm×30cm×7cm.The overall dimensions of thermal conductivity apparatus are length 65cm, breadth 30cm and height 40cm. During fabrication all parts are connected according to circuit diagram and enclosed in apparatus with M.S sheet. Thermocouples are inserted in brass cylinder at its center to indicate two different temperatures. Heating wire is connected vertically across the cylinder passing through sample.

Testing of apparatus

The developed thermal conductivity apparatus was initially tested for determination of thermal conductivity of food grains whose thermal conductivity is known. The average value of thermal conductivity of paddy and wheat was found to be 0.10W/m^0k and 0.14 W/m^0k respectively, which closely match with the values of literature (0.106 W/m^0k for paddy and 0.15 W/m^0k for wheat).

Effect of moisture content on Thermal conductivity

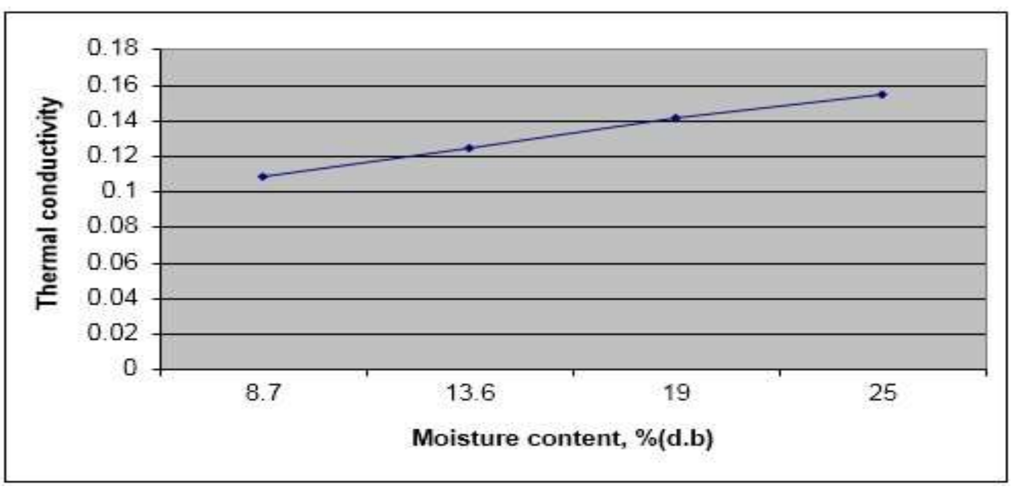

Fig. 3 Effect of moisture content on Thermal conductivity of cashew nut

Thermal conductivity of cashew nut were determined at different moisture contents of 8.7%, 13.6%, 19% and 25%(d.b). Thermal conductivity at 8.7% were found to be 0.109 W/m^{0}k, at 13.6% were 0.125 W/m^{0}k, at 19% is 0.142 W/m^{0}k and at 25% is 0.155 W/m^{0}k. Thus thermal conductivity of cashew nut were found to be increase with increase of moisture content.

DISCUSSION

Water is good conductor of heat and electricity. In thermal conductivity measurement we used both of these parameters i.e., heat and electricity. Electric current through constantan wire is given to cashew sample to increase its temperature. Heat transfer through sample occurs due to conduction. Therefore by increasing moisture of cashew nut sample its current carrying capacity also increases and thus it results in increase of thermal conductivity.

CONCLUSIONS

1. The average value of length, breadth, thickness of the cashew nut was found to be 32.36mm, 22.70mm, and 14.34 mm respectively. The average size and sphericity of cashew nut were found to be 21.92mm and 0.68 respectively at 8.7%(d.b) moisture content.
2. The bulk density, true density and porosity of cashew nut were found to be 533 kg/m^3, 663.3 kg/m^3 and 19.6% respectively. The dynamic angle of repose of cashew nut was found to be 30.5^{0}c at 8.7%(d.b) moisture content.
3. The thermal conductivity of cashew nut increases from 108W/m^{0}k to 0.155W/m^{0}k with increase in moisture content from 8.7% to 25% (d.b).

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