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Thermo-physical properties of selected cassava root varieties (NR8082, IMS30572, NR021201 and Nawibibo)

U.N.Onwuka*, C.U.Chigbu

Department of Agricultural Engineering, Michael Okpara University of Agriculture, Umudike, P.M.B.7267, Umuahia, Abia State, (NIGERIA)

E-mail : nellyami2001@yahoo.com; unonwuka@yahoo.com

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ABSTRACT

A line heat source apparatus was fabricated, calibrated and used to measure the heat transfer through a 50.8mm diameter for four (4) cassava root varieties namely NR8082, IMS30572, NRO21201 and Nwaibibo at 5 min, intervals. The temperature readings obtained through Omega HH 147 RS 232 Data logger 4-way thermocouple were used to calculate the thermal properties (thermal conductivity, K; thermal diffusivity, α; specific heat, C; and density ρ, for two moisture levels ranged from 50% -69% wet basis. The result showed that thermal conductivity ranged from 0.23 to 0.37$Wm^{-1}K^{-1}$, thermal diffusivity and specific heat varies from (3.01 to 3.8) × $10^{-7}m2s^{-1}$ and 1.518 to 3.283Kj/Kg°K respectively, while the density ranged between 417 to 466 Kgm^3 This result confirmed that thermo-physical properties are dependent on moisture content, and significantly between varieties NR8082 and IMS30572 at P<0.05, but no difference was observed between IMS30572, NR021201 and Nwaibibo (P>0.05).

KEYWORDS

Thermo physical-properties;
Cassava-root;
Variety;
Moisture;
Application of study.

INTRODUCTION

Cassava is the fourth most important energy staple in the tropics and the sixth global source of calories in human diet apart from maize, rice and wheat[7] and Nigeria presently ranks as the number one producer in the world[8]. Cassava is utilized as food for human when processed into *starch*, *gari*, *fufu lafun* and *abacha*, while some sweet variety (low cyanide) are eaten raw, boiled or roasted as snacks. It is also needed in other industries such as the textile, in glucose production, in biotechnology, for laundry starch and for ethanol production.

The presidential initiative on cassava estimates that by 2007, a sizable part of the produce would be exported[10], with a flourishing local demand also in place[13]. With these intended boost of cassava production, standardization of quality for export becomes pertinent[18] One of the quality attributes of agricultural product is the thermo-physical properties such as thermal conductivity, thermal diffusivity, specific heat capacity and density are required to evaluate, design, control and model heat transfer processes such as refrigeration, freezing, drying, during various food processing operation[2].

Ashrea[1] reported that a committee was set up during 1949-1978 to determine the thermal data for various

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food stuffs but cassava was not among the determined foodstuffs probably the root crop was not important to the western world as it is to the Africans and Nigeria in particular. International Institute for Tropical agriculture (IITA) and Standard Organization of Nigeria (SON) in 2005 published standards for cassava products and guideline for export, unfortunately nothing was mentioned on thermo-physical properties (TPP).

Most of the thermo-physical properties of food stuffs used today are derived or estimated on the basis of similar foreign foods. This is wrong because most foodstuff vary chemically with location, hence as recorded by Comini and Barina[4] TPP will also vary. Thus any empirical model of TPP developed for each specific food material should give a more accurate prediction.

Thermo-physical properties are therefore important in view of the search for process optimization between the different aspect of quality, under and over processing, and aim of minimal energy consumption as well as an instrument for evaluation of alternative processes[19,26]. In view of the on- going, this work determines the TPP of 4 cassava varieties on two moisture levels. This will help us establish data on TPP of these varieties and monitor the effect of moisture in them. These data will help food engineers and others to design effective processing method for these commodities.

Review of thermal properties measurement

Thermal conductivity, K, thermal diffusivity, α heat transport properties. In order to measure them, the sample must be subjected to heat flow of known pattern[17]. The Fourier's equation describes the temperature field generated by this heat flow according to the equation,

$$\frac{d}{dt}\left[\frac{kdT}{dt}\right] = \frac{\rho CdT}{dt} \quad (1)$$

By this implication, the measurement of thermal conductivity (K) can be by either steady state or transient method. On the other hand thermal diffusivity (α) can only be determined directly by transient method as reported by Nesvadba[17]. The temperature dependence of the K and α are often neglected because of the increased difficulty in solving the equation according to Mellor[15].

Most researchers have used the method of mixtures to experimentally determine the specific heat of biological products[16,28]. This method involves placing the material in heated water calorimeter and monitoring the temperature of until the equilibrium is reached.

Specific heat of materials is calculated from the energy balance equation between the material and the water according to the report of Onwuka[22]. This method assumes that moisture uptake by the material will be negligible during the process of heat transfer. This method of mixtures (a steady state method) is not effective for cassava roots because moisture level is important in the experiment hence the increase or decrease will alter the findings. In this study specific heat was calculated from measured values of thermal diffusivity as given by the relationship:

$$C = \frac{K}{\rho \cdot \alpha} \quad (2)$$

where C- specific heat (j.kg^{-1}K^{-1}), K-thermal conductivity (w.m^{-1}K^{-1}), ñ-density of the material (Kgm^{-3}), α-thermal diffusivity(m^{2}s^{-1}).

Eq. (2) was used by Suter et al.[27] and Moysey et al.[20] to determine the specific heat of peanut parts (Pod, hull and kernel) and rapeseed, respectively.

The line heat source technique is mostly used for TPP of granular materials. This method is a transient method with the advantage over the steady state for short duration of experiment[25] which is considered in this work.

The line heat source method involves applying a steady heat flux to the specimen and measuring the temperature rise at some point in the specimen resulting from the applied heat. When heat is applied by a small diameter wire as heat source imbedded in an infinite homogenous cylinder (cassava root), temperature will develop according to the equation below;

$$dT = \alpha\left[\frac{\partial 2T}{\partial r^2} + \frac{1}{r} + \frac{\partial T}{\partial r}\right] \quad (3)$$

where, T-temperature (°K), r-radial distance from heat source (m), t-time (s), Considering the equation proposed by Carslaw and Jaegar[3].

$$T = \frac{Q}{4\pi K}\left[\ln\frac{4\alpha t}{ro^2} - Ec\right] \quad (4)$$

$$\text{But } Q = \frac{KA[T_1 - T_2]}{x} = I^2RT \quad (5)$$

$$\text{Then } K = \frac{I^2Rd(\ln t)}{4\pi JldT} \quad (6)$$

where; T-temperature (°K), Q-Constant heat flux per unit length of wire (W.m^{-1}), r_o-distance from measuring point to heat source (m), A-Cross sectional area of root (m^2), I-current passing through the line heat source in time interval (A), α-thermal diffusivity, (m^2s^{-1}), x-thickness of the root(m), L-length of the wire (m), J-Joule equivalent of heat flux, $\pi = 3.143$, Ec-Euler's constant =0.57722.

MATERIALS AND METHOD

Four cassava root varieties namely NR 8082,TMS 30572,NR02/201 and *Nwaibibo* or local variety were purchased from National Root Crop Research Institute Umudike, Nigeria, while the PVC pipe, fiber insulator, heater wire and ammeter where obtained from Enugu, Nigeria. The cassava root was measured geometrically after selecting two moisture levels for each variety.

Figure 1 shows the schematic diagram of the apparatus used for the experiment. A 76.2mm diameter and 152.4mm long PVC pipe was used as the sample container. The sample holder was insulated at the sides and ends with 25.4mm of fiber insulator. A heater wire was stretched along the axis of the cylinder containing the cassava root. A constant power of 40w was supplied to the heater wire via A.C supply using a constant current of 0.2A as measured by the ammeter and variable with a variable resistor. The maximum variation in power supply for all the experimental combination was ±10w.

Temperature measurements were made with 0.25mm diameter Teflon coated constantan thermocouple (Omega HH147, RS232 Data logger).One probe was attached mid way along the heater, two other probes were inserted into the sample container from the sides such that the end of the probe was at a distance of 12.7mm form the heater wire as used by Fasinina and Solhansanj (1995).

The temperature history of the thermocouple was recorded on a computer via Omega data logger and the test was conducted on 50.8mm diameter cassava root for both fresh and dried samples.

Data obtained were used to determine the thermal conductivity K according to eq. (6), specific heat and thermal diffusivity as in eq. (2), while density was determined as the ratio of weight of cassava root to the volume. The moisture content was determined by the method described by Pearson[23]. Data obtained was subjected to analysis of variance as described by Iwe[11].

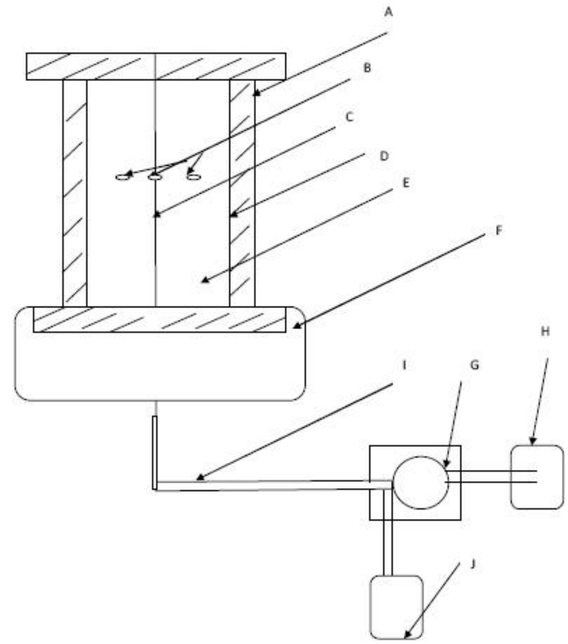

Figure 1 : Schematic of the TPP apparatus. Key: A-PVC pipe, B-Thermocouple wire, C-Heat source wire, D-Lagging material, E-Root tubers, F-Plastic stand, G-Voltage regulator, H-AC-source, I-Conductor

RESULT AND DISCUSSION

Thermal conductivity

The values of the mean thermal conductivities of the 4 cassava root varieties for the dried and the fresh samples are shown in TABLE 1.

The average K for fresh and dried samples ranged from 0.23 to 0.37 Wm-1ok^{-1} and Sample NR8082 showed the highest K, where as the least was obtained from *Nwaibibo*. There was significant difference between the dried and the fresh for all varieties indicating that moisture affects thermal conductivities of materials proportionally. Significant difference also exists between the K for varieties NR8082 and IMS30572 but not in others. Generally the thermal conductivities are low and foods with low thermal conductivity are poor conductors of heat, so according to Ohlsson[21], heat transfers through such foods are very low. Thermal conductivity is a measure of a material's ability to transmit heat. Levenspiel (1973), suggested that it is the proportionality factor in heat conduction equation. Subsequently, NR8082 variety has the ability to transmit heat faster than all other varieties for fresh and under dried conditions. Rahman[24] found that the thermal conductivity of water surpasses all basic food components, therefore

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TABLE 1 : Mean thermal conductivities(wm-^{1o}C K^{-1}) for dried and fresh cassava root varieties

Samples	Moisture content, %		Thermal conductivity (wm-^{1o}C K^{-1})	
	Fresh	Dried	Fresh	Dried
NR8082	56	69	0.37b	0.26a
TM530572	54	67	0.35bb	0.25ab
NR021201	52	66	0.33bb	0.24ab
Nwaibibo	50	65	0.32bb	0.23ab

a, b-means with the same subscript are not significantly different (P>0.05)

TABLE 2 : Mean thermal diffusivities for dried and fresh cassava root varieties (α×10-7m^{2}s-^{1})

Samples	Moisture content,%		Thermal diffusity (α×10-7m^{2}s-^{1})	
	Dried	Fresh	Dried	Fresh
NR8082	56	69	3.16a	3.80b
TMS30572	54	67	3.13ab	3.6bb
NR02/201	52	66	3.10ab	3.50bb
Nwaibibo	50	65	3.01ab	3.40bb

a,b means with the same subscript is significantly not different(P>0.05) across row and along column

TABLE 3 : Mean specific heat capacities for cassava varieties (Kjkg-^{1o}k)

Samples	Moisture content,%		Specific heat, (Kjkg-^{1o}k)	
	Dried	Fresh	Dried	Fresh
NR8082	56	69	1.83oa	3.283b
TMS30572	54	67	1.731ab	2.972bb
NR02/201	52	66	1.642ab	2.439bb
Nwaibibo	50	65	1.518ab	2.429bb

a,b means with the same subscript is significantly not different(P>0.05) across row and along column

TABLE 4 : Mean densities for dried and fresh cassava root varieties(kgm-^{3})

Samples	Moisture content, %		Densities (kgm^{-3})	
	Dried	Fresh	Dried	Fresh
NR8082	56	69	456b	466a
TMS30572	54	67	432ab	453bb
NR02/201	52	66	424ab	452bb
Nwaibibo	50	65	417ab	449bb

a,b means with the same subscript is significantly not different(P>0.05) across row and along column

more moisture -high K.

Thermal diffusivity

TABLE 2 shows the mean thermal diffusivity for the cassava root varieties. This is the property that quantifies a materials ability to conduct heat relative to its ability to store heat. It is the ratio of K to the specific heat[13]. The average thermal diffusivity range between 3.01 to 3.8x10^{-7} m^{2}s$^{-1,}$NR8082 had the highest while *Nwaibibo* the least. The result shows a significant difference between the α for dried and fresh samples, and also between NR8082 and TMS30572.Substances with high thermal diffusivity rapidly adjust their temperatures to that of their surroundings, because they conduct heat quickly in comparison to their volumetric heat capacity. Food materials are on the low side and the data could be used to predict cooling and freezing times of agricultural products.

Specific heat capacity

The various average specific heat capacities for cassava varieties at two moisture levels are shown in TABLE 3. The average values of specific capacity of cassava root for fresh and dried samples were 1.518 to 3.283 KjKg-^{1}K-^{1}. The sample NR8082 maintained the highest, while *Nwaibibo* the least. When comparing the fresh and the dried, specific heat also increased with moisture content. this implies that more heat will be required to increase the temperature of sample NR8082 than *Nwaibibo* and also more heat will be required to increase the temperature of the fresh than the dried irrespective of variety. Laider and Keith[14], have reported that more heat is required to increase the temperature of water than that of lipids. This conforms to this result when the dried samples could be likened to lipids with lower moisture content. Fraudorf[9] have reported that specific heat depends on moisture and temperature of the material The result obtained from variation compilation by Lewis[12] on Irish potato at moisture of 77.8 and 10.9 % were similar to that obtained here on NR8082 but for moisture of 69 and 56 % respectively. This therefore means that adaptation of the TPP of the much considered products with similar nutritional component or energy levels is not right since variations are likely occurrences.

Density

The mean densities for dried and fresh cassava root variation are shown in TABLE 4. The result persisted to the earlier trend that more moisture, higher density. The highest density was found in NR8082 at 466kg/m^3 and the least in *Nwaibibo* with 417 kg/m^3 dried. The fresh samples were significantly different in density from dried samples, while per variety difference existed between Nwaibibo and others ($p<0.05$).

Density has been defined as mass per unit volume of a material[5,22]. It is a property that affects convective heat transport and could be employed in cooling or freezing material considering the equation which defines thermal diffusivity of materials. So the knowledge of density of cassava root varieties is necessary.

This paper has therefore produced a data bank for the TPP of cassava root varieties selected. Thermal conductivity (K), thermal diffusivity(α) specific heat (C) and density (ρ) are the major TPP required to evaluate, design control and model heat transfer processes such as refrigeration, freezing, drying during variation food processing operation as reported by Becker and Frcke[2]. In this work modeling was not considered with just two moisture point but forms a bench mark for TPP of the selected root varieties. More research work are expected for more moisture levels and various cassava products, this will help to predict functionality and easy handling of the root and products.

REFERENCES

[1] Ashrae; 'A Hand Book of Fundamentals of American Society', Heat Refrig.Air Cond.Engineers, New York, 27-29 **(1997)**.

[2] B.R.Becker, B.A.Frick; Int.Comm.Heat Mass Transfer, **26(5)**, 627-636 **(1999)**.

[3] H.S.Carslaw, J.C.Jaegar; 'Conduction of Heat in Solid', Oxford University Press Oxford, **(1959)**.

[4] G.Comini, S.Barina; 'Thermal Properties of Food Stuff', Bull.IIR, Annexe, 163 **(1974)**.

[5] P.A.Conshohocken; 'Test Method for Density and Specific Gravity', (Relative Density of Plastic by Displacement), ASTM Standard D792-00, **8**, 101 **(2004)**.

[6] O.O.Fasina, S.Sokhansanj; Transactions of ASAE, **35(5)**, 1615-1619 **(1992)**.

[7] FAO, Food and Agricultural Organization, Production Year Book FAO STAT, Data Base http:// app Fao.org/c91-bin/nph-db.pl.(Consulted Feb,2008), **(1999)**.

[8] FAO, Food and Agricultural Organization, Production Year Book FAO STAT. Data Base http:// app3.1 Fao.org. (Consulted Feb,2008), **(2003)**.

[9] P.Fraudorf; American Journal of Physics, **71(11)**, 1142-1151 **(2003)**.

[10] IITA International Institute for Tropical Agriculture; 'The Cassava Industrial Revolution in Nigeria', The Potential for a New Industrial Crop IITA, Ibadan, Nigeria, **(2004)**.

[11] M.O.Iwe; 'Handbook of Sensory Methods and Analysis', Rojoint Communication Service Ltd., Enugu, Nigeria, 106 **(2002)**.

[12] N.J.Lewis; 'Physical Properties of Foods and Food Processing Systems', Ellis Horwood, New York, 412 **(1990)**.

[13] H.C.Knipscheer; Opportunities in the Industrial Market in Nigeria IITA, Ibadan, **(2003)**.

[14] I.Laider, J.Keith; 'The World of Physical Chemistry', Oxford University Press, ISBNO-19- 855919-4, **(1993)**.

[15] J.D.Mellor; Bull.IIR, **60**, 493-515 **(1980)**.

[16] N.N.Mohsenin; 'Thermal Properties of Food and Agricultural Materials', Gordon and Breach Publ., New York, **(1990)**.

[17] P.Newsvadba; J.Food Eng., **1(2)**, 93-113 **(1982)**.

[18] NRCRI, Annual Report 2005 National Root Crop Research Institute Umudike, Nigeria, **(2006)**.

[19] T.H.Ohlsson, S.Svensson; Proc.N.int.Congr.Fd. Sci.Technol., **4**, 380 **(1974)**.

[20] E.B.Moysey, J.T.Shaw, W.P.Lampman; Transaction of ASAE, **20(3)**, 461-477 **(1977)**.

[21] T.Ohlsson; 'The Measurement of Thermal Properties in Physical Properties of Foods', R.Jowit Ed.; Applied Science, London, **(1983)**.

[22] U.N.Onwuka; 'Basic Approach to Food Engineering', Logon Technologies In.Ltd., Lagos, Nigeria, 175 **(2005)**.

[23] D.Pearson; 'Chemical Analysis of Food,' 7th Ed., Church Hill Livingston, Edinburgh London, **(1976)**.

[24] S.Rahman; 'Thermal Conductivity of Foods', Food Properties Hand Book CRC, Press, 275-335 **(1995)**.

[25] G.A.Reidy, D.L.Rippen; Transactions of the ASAE, **14(2)**, 248-254 **(1971)**.

[26] J.Ronald; 'COST 90', Physical Properties of Foods, Applied Science Publishers, London, 229-245 **(1990)**.

[27] D.A.Suter, K.K.Aganwak, B.L.Clary; Transaction of the ASAE, **18(2)**, 370-375 **(1975)**.

[28] V.E.Sweat; 'Thermal Properties of Foods', In Engineering Properties of Foods, MA.Rao, S.S.H.Rizoi, Eds., 2nd Ed., Marcel Dekker, New York, USA, 126 **(1995)**.