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Effects of Moisture Contents on the Physical, Thermal and Isothermal Drying Properties of Granular Cassava Particles

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Abstract: The effects of moisture contents on the physical, thermal and drying properties of granular cassava particles were determined experimentally. These properties are physical properties such as loose particle density, porosity, voidage fraction and particle size distributions, thermal properties such as specific heat capacity and thermal conductivity and drying properties such as moisture ratio, drying rate versus free moisture and diffusion coefficients with moisture contents. The methods used for the experiments include gravimetric analysis, sieve analysis, calorimetric and oven drying. The empirical equations developed for loose particle density, porosity, voidage fraction, specific heat capacity, thermal conductivity are found to be linear functions of the percentage moisture contents. All these properties are found to increase with the percentages moisture contents, except the specific heat capacity which decreases with increase in the percent moisture content. The diffusion coefficients obtained from the isothermal drying curves are expressed empirically as a function of drying temperatures and are found to be non linear.

Key words: Cassava, properties, drying, isothermal, moisture content

INTRODUCTION

Granular cassava particles (gari) are one of the by-products of cassava and it is one of the major stable foods in Nigeria and in some West African countries. Cassava, Manihot esculenta Crantz, is a common perennial woody shrub with an edible root, which grows in tropical and subtropical areas of the world. It is also called yuca, manioc and mandioca. Cassava has the ability to grow in a low nutrient soil, where cereal and other crops do not grow well. It has the ability to tolerate drought. Cassava roots take between 12-36 months to mature depending on the variety. This permits the harvest, processing and marketing to be done at a suitable and favourable time. Cassava is no longer cultivated as a subsistence crop in Nigeria as before, but now as a commercial crop. According to FAO, as reported by a newspaper, the ANCHOR of November 23, 2001, 172 million tonnes of cassava were produced worldwide in year 2000. Africa accounted for 54%, Asia 28% and Latin America and Caribbean for 18% of the total world production. In 1999, Nigeria produced 33 million tonnes, making her the world largest producer.

The primary defect of cassava is that it contains cyanogenic glycosides (linamarin and lotaustralin) liable to produce hydrocyanic acid (Nartey, 1981). Parts of the cyanides are removed in the production process of cassava particles. Usually after cassava tubers are harvested and grated, they are compressed under a mechanical press to de-water the surface and unbounded water from the particulates. The product is left to ferment for about 3-5 days. Fermentation and drying are 2 major ways of removing the cyanides so as to make the production good for consumption. It has been shown that sun drying can eliminate large proportion of the hydrocyanic acid (Cooke and Maduagwu, 1978; Gomez *et al*., 1984a). Monroy Rivera *et al*. (1991) have found that drying by heated air is more efficient for the elimination of total cyanides from cassava chips locally. The technique of fluidization has been used to successfully dry various particles, ranging from chemical to agricultural products (Kunni and Levenspiel, 1991; Strumillo and Kudra, 1986; Reay, 1986). This technique is found to be suitable for drying cassava particulates in its production process from cassava.

To design a fluidized bed dryer and to simulate the drying process in the bed, the properties of the cassava particles to be dried constitute part of design parameters and necessary data required for numerical simulation. These properties are physical properties such as loose particle density, porosity and voidage fraction, particle size distribution; thermal properties such as specific heat capacity and thermal conductivity and drying properties such as particle temperature rise and phases of drying,

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moisture ratio, drying rate and diffusion coefficients. These properties and the effect of moisture contents on them are yet unknown in literature. The effects of moisture contents on these properties are now experimentally investigated and empirically evaluated for each of these properties.

MATERIALS AND METHODS

Specimen preparation: To obtain cassava particles (gari) from cassava, 36 major production processes subsequent to drying/roasting must be done. They are grating of cassava tubers, packing the particulates in sacks to press out the unbounded water and for fermentation and sieving of fermented product to get rid of coarse and rough particles.

Determination of physical properties of cassava particles

Percentage moisture content: Experimental determination of the properties of cassava particles as functions of percentage moisture contents was carried out with samples prepared as follows. Total 900 g of wet cassava particulates (obtained as given in section 2.1) were measured and put in 15 trays. Each tray has 60 g of the sample. The trays were labeled 1-15. The first tray was not put in the oven. It represented the wet sample of cassava particulates at the beginning. The others were put in the oven while the oven was maintained at constant temperatures say, 120°C with heating times varying from 3-42 min. The trays were retrieved from the oven at a time interval of 3 min and accurately weighed using a (0-1 kg) electronic beam balance with sensitivity 0.5 g. The last tray was allowed to be completely dried. The mass of this sample represented the mass of dried sample and was used to calculate the percentage moisture content on dry basis. All the other cassava samples in trays 1-14 were at different moisture content levels. The percentage moisture contents (mc) of the other samples on dry basis were calculated using (Adeyemi and Adeyemi, 2002) the expression of Eq. (1):

$$mc = \frac{m_i - m_d}{md} \times 100\ \% \qquad (1)$$

Where,

m_i = Mass of cassava particles at various moisture contents.

m_d = Mass of dried cassava particles.

Loose specific gravity: The samples of cassava particles were put in 15 trays and oven dried to different time intervals, so that each tray contained samples of cassava particles at different percent of moisture content. The percent moisture content of the first tray, which represented wet sample of cassava particles is at 122.22% moisture content was analyzed first for loose density determination. The specific gravity was first determined by weighing a measuring cylinder empty and by filling accurately the cylinder loosely with the samples to measure volumes ranging from 10-100 cm^3. Various volumes of cassava particles were carefully measured with the measuring cylinder, the mass of each volume was determined using a sensitive digital balance, of maximum capacity 0-1 kg range with a sensitivity of 0.5 g. By subtracting the mass of the empty cylinder from the various mass measurements of cylinder with various volume samples, the masses of 10-100 cm^3 of cassava particle samples were obtained. The mass of equivalent volumes of water were determined also by measuring the cylinder with water using same digital balance. The graph of masses of cassava particles at a given percent moisture content for various volumes versus the masses of water at equivalent volumes ranges of 10-100 cm^3 was plotted with the slope of the straight line obtained as the loose particle specific gravity of the cassava particles at the given percent moisture content. The above procedures were repeated for cassava particles samples at other percent moisture content (i.e., samples in trays 2-15). An empirical relation was found to relate the specific gravity of cassava particles to the percent moisture contents.

Porosity of cassava particles (gari) as function of moisture content: A steel cylinder of height 100 mm on a steel base was completely filled with a sample of cassava particles. A steel plunger was used to compress the cassava sample inside the cylinder using a mechanical press, until the sample was rigidly solidified. The length of void i.e. the depression of sample after compression was measured with the aid of vernier caliper. The porosity (n) was determined (Atkinson, 1993) using Eq. (2):

$$\text{Porosity, } n = \frac{hV}{hT} \times 100\% \qquad (2)$$

Where,

h_v = Height of void = h_T-h_s

h_T = Height of the cylinder

h_s = Height of the compressed solid

The whole procedures were repeated for all the samples at various moisture contents.

Particle size distributions determination: Dried samples of cassava particles (gari) of weight 300 g were placed on the top of sieves arranged with aperture openings ranging from 4.75-0.075 mm. These sieves were arranged adjacent to each other from the largest aperture to the smallest aperture. The whole set of sieves were agitated for about 10 min by a vibrating machine. The particles retained on each sieve were collected and weighed accurately. This experiment was repeated 4 times. These average values of the weight of cassava particles samples retained on each sieve were taken and recorded. The percent weight of the cassava particle sample on each sieve was divided by the size of the aperture opening i.e. X_I/d_{Pi} where X_I is the percentweight retained and d_{Pi} is the size of the aperture opening. The mean particle diameter d_p of the cassava particles sample was estimated (Geldart, 1986) using the Eq. (3):

$$dp = \frac{100}{\sum X_I/d_{Pi}} \tag{3}$$

Determination of thermal properties cassava particles

Specific heat capacity of cassava particles: A known mass of water put inside a copper calorimeter was heated with an immersed electric heating coil. The calorimeter was insulated with fibre glass before it was placed inside a wood casing, so that the base of the calorimeter made direct contact with known mass of sample of cassava particles contained inside the wood casing enclosure. A constant applied current measured with an ammeter was maintained throughout the heating, while the rise in temperature of the heated water was measured with a laboratory mercury thermometer. The temperature of cassava particles started to increase, as the temperature of water increased with time. Using a K-type thermocouple buried inside the cassava particles, the temperatures of the particles with time were continuously measured and recorded. The specific heat capacities of the cassava particles at various known percent water content were determined from Eq. (4) obtained from energy balance equation of this system.

$$Ivt = m_w C_{pw} \Delta T_w + m_c C_{pc} \Delta T_c + m_g C_{pg} \Delta t_g \tag{4}$$

Where,

I = Current.
v = Voltage.
t = Time.
m = Mass.
C = Specific heat capacity.
T = Temperature and the subscripts.
g = Gaari.
w = Water.
c = Calorimeter.
p = constant pressure.

Thermal conductivities of cassava particles: The thermal conductivities of cassava particles with percent moisture contents during drying were determined, using Lees' Disc Apparatus method of measuring thermal conductivity of poor conductor.

The experiment was set up for Lees' method of measuring of thermal conductivity of a poor conductor is shown in Fig. 1. The experimental set up consisted of a steam flask connected to a steam chest, S. The base of the steam chest was placed over a poor conducting disc B, which in turn was placed on top of a suspended brass disc C. The suspension was done with 2 strings in a place away from draught. A little glycerine was used to ensure a good thermal contact. Two thermometers were inserted into the 2 holes, one on disc A and the other on disc C. As the steam flow through S, the 2 thermometers were read at every minute, until they indicated that a steady state has been reached. The steam chest S was removed, while disc C was heated with a low bunsen flame until its temperature was about 10°C above the previous steady temperature reached. The bunsen burner was removed and the disc C, containing gari particles of known mass m was allowed to cool. The cooling rate of disc C was recorded at every minute until its temperature fell to about 20°C below the initial steady temperature. The cooling rate curve i.e. cooling rate versus time curve was plotted. The slope of the tangent (g) to the curve at the temperature corresponding to the steady value was measured. The whole procedures were repeated, using gari particles at various known percent moisture contents. The thermal conductivity K_g of gari at a given moisture content is given as (Oladebeye and Oladebeye, 2006):

$$k_g = \frac{4mcgX}{\pi d_2 \, (T_1 - T_2)} \tag{5}$$

Where,

m = Mass of brass disc C.
c = Specific heat capacity of brass disc C.
d = Internal diameter of disc B.
X = Thickness of disc B.
T_1 and T_2 = Temperatures of the 2 faces of disc B.

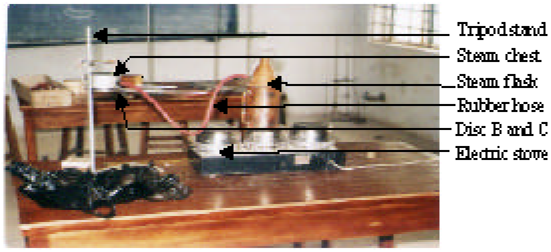

Fig. 1: Experimental Set up of lees disc apparatus for determination of K-value

Temperature T_1 for cassava particles increases stepwise as the percent moisture content decreases. While temperature T_2 decreases gradually as the percent moisture content decreases. The slopes of the cooling rate curves with time of disc C, containing cassava particles at various percent moisture contents were calculated. The average slope of cooling rate of disc C was found to b-0.0311°C sec^{-1}. The mass m of disc C by weighing is 1.015 kg. From engineering Tables, the specific heat capacity C_p (Yildiz and Ozisik, 1988) of brass is 380 J kg^{-1}K. The internal diameter d of disc B is 0.068 m and its thickness X is 0.00322 m.

Isothermal oven drying of cassava particles

Moisture content and free moisture content determination: Total 60 g of wet cassava particles each was measured and spread uniformly in a steel trays of 15 cm square in dimension. Each steel tray was initially weighed, numbered and arranged in an electric oven set at a drying temperature of 60°C. After initial 5 min of heating, a steel tray was removed and measured by a digital electronic beam balance to determine the current mass m_i, of the cassava particles after drying operation. After 10 min intervals of heating the current new masses of the cassava particles in other steel trays were accurately measured and recorded.

A similar steel tray, containing 60 g of wet cassava particles with K-type thermocouple inserted inside the cassava particles was used to monitor the temperature rise during the drying process. The K-type thermocouple was connected through a cold junction box container, containing melting ice maintained at 0°C to a sensitive multimeter to determine the temperature rise with drying time.

From the experimental current masses of the drying cassava particles, the percent moisture content of each steel tray specimen on dry basis was determined, using Eq. (6) given as:

$$m_c(\%) = \frac{m_i - m_d}{m_d} \times 100 \qquad (6)$$

Where,

m_i = Mass of cassava particles at various moisture values.

m_d = Mass of dried cassava particles.

The whole procedures were repeated to determine the percent moisture content at various isothermal drying temperatures ranging from 60-160°C at an incremental temperature of 20°C.

From these values, the moisture content that is removable at a given temperature and humidity known as free moisture content as obtained (Adeyemi and Adeyemi, 2002) using Eq. (7):

$$M_{FM} = M_T - M_{EM} \qquad (7)$$

Where,

M_{FM} = Free moisture content.

M_T = percent moisture content at time t.

M_{EM} = Equilibrium moisture content at the prevailing conditions of drying.

Moisture ratio and diffusion model: The ratio of free moisture at any time, t, to the initial free moisture content of the material at time zero is known as the moisture ratios (Mr). This ratio is calculated from Eq. (8) by (Adeyemi and Adeyemi, 2002):

$$Mr = \frac{M_{c_i} - M_{c_{ie}}}{M_{c_0} - M_{c_{ie}}} \qquad (8)$$

Where,

Mc_i = Percent moisture content of any sample i at any time.

Mc_{ie} = Percent equilibrium moisture content at the prevailing drying temperature.

Mc_0 = Initial percent moisture content of sample I.

A diffusion model Eq. (9) given by Singh *et al.* (1986) which was used by Adeyemi and Adeyemi (2002) to fit into the experimental data is given as:

$$M = B_0\, e^{-K_0 t} \qquad (9)$$

Taking the logarithm of Eq. (9) we have

$$\text{In}\, M = \text{In}\, B_0 - K_0 t \qquad (10)$$

The values of the intercept (B_0), the gradient (K_0) are obtained from the moisture ratios versus times by regression analysis with their correlations coefficients are determined.

Dying rate and diffusion coefficient determinations: The drying rate R according to (Geankoplis, 1993) is proportional to the slope of the free moisture content versus drying time. This is given by Eq. (11):

$$R = -\frac{Ls}{A}\frac{dX}{dt} \qquad (11)$$

where,

R = The drying rate in kg H_2O/min. m^2.

X = Percent Free moisture content.

L_s = Is the final mass of dried cassava particles.

A = Is the surface area of the material used for drying in m^2.

The slope of the tangents drawn to the curve of percent free moistures contents versus t ime can be measured to give the values of dX/dt at any given drying time t.

The diffusion coefficient is estimated from the drying rate curve at various drying temperature. Beyond the critical free moisture content point, the rate of drying is not constant but decreases when drying proceeds. The movement of water in the period of drying occurs by diffusion. The unsteady-state diffusion Eq. (12) describes quantitatively the moisture distribution curve.

$$\frac{\partial X}{\partial t} = D_L \frac{\partial^2 X}{\partial x^2} \qquad (12)$$

Where,

D_L = Liquid diffusion coeffcient $m^2 s^{-1}$.

x = Thickness of the sample if drying only from the top face.

X^2 = ½ the thickness of the sample if drying occurs from the top and the bottom parallel faces.

Solving this equation analytically, we have:

$$\text{In}\ \frac{\pi^2 X}{8X_c} = -\frac{D_L \pi^2 t}{4x_1^2} \qquad (13)$$

Plotting the log of unaccomplished moisture ratio X/Xc against time, we obtained a straight line. From the slope of this line, the diffusion coefficient can be estimated from Eq. (14):

$$\text{slope} = -\frac{\pi^2 D_L}{4x_1^2} \qquad (14)$$

RESULTS AND DISCUSSION

Physical Properties of Cassava Particles (GAARI)

Specific gravity: The specific gravity is plotted against various percentage moisture contents on dry basis as shown in Fig. 2. It is a straight line graph with positive slope i.e the specific gravity increases with increase of percentages water contents.

An empirical expression for specific gravity (SG) as a function of percentage moisture content (w), as obtained from the experimental data using curve fitting, is given by Eq. (15) as:

$$SG = 0.4793 + 0.001379\,w \qquad (15)$$

where, coefficient of regression r is 0.9932.

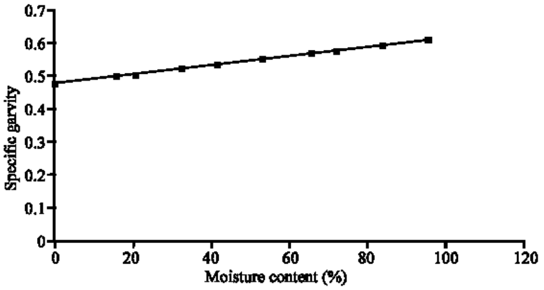

Fig. 2: Specific gravity of cassava particulate versus percentage moisture content

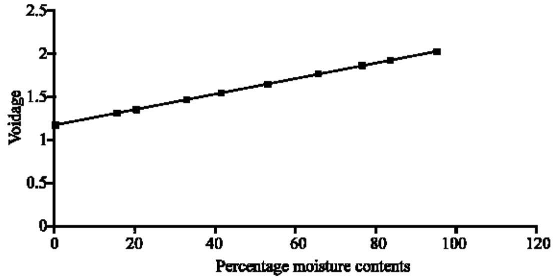

Fig. 3a: Voidage of cassava particles versus % moisture content

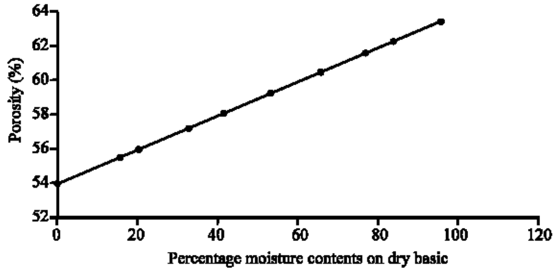

Fig. 3b: Porosity of cassava particles versus % moisture content

Voidage and porosity: The graphs of voidage and percent porosity are straight lines as shown in Fig. 3a and 3b. The voidage and percent porosity are found to increase with increase in percent moisture content.

The empirical relation for the porosity of cassava particles bed as a function of percentage moisture content obtained by curve fitting to experimental data is given by

$$n\% = 53.9 + 0.009\,w \qquad (16)$$

where, the coefficient of correlation r is 0.9409 (from Microsoft excel package)

The voidage fraction is given as:

$$e = 1.17 + 0.001\,w \tag{17}$$

where, the coefficient of correlation r = 0.9629.

Particle size distributions: The size distribution curves of the particles are shown in Fig. 4. Using Eq. (3), the mean particle diameter was calculated as 455.25 μm. The particle median size is $d_{pm} = d_{50\%}$.

From Fig. 4, $d_{pm} = d_{50\%} = 0.8239$ mm; $d_{84\%} = 1.542$ mm, $d_{16\%} = 0.4202$ mm.

Following Geldart (1986) the particle spread is given as:

$$\sigma = \frac{d_{84\%} - d_{16\%}}{2} = 0.5609 \text{ mm} \tag{18}$$

The relative spread is defined as $\sigma/d_{pm} = 0.6808$.

This result categorizes cassava particles among particles with very wide particle distributions that can be easily fluidized.

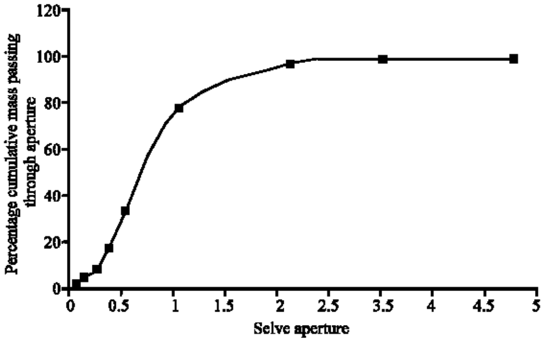

Fig. 4: Size distribution of cassava particles

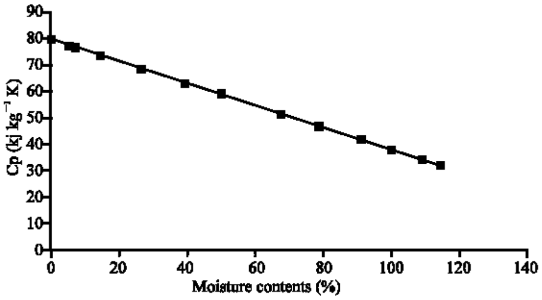

Fig. 5: Specific heat capacity of cassava particulate as a function of %moisture Content

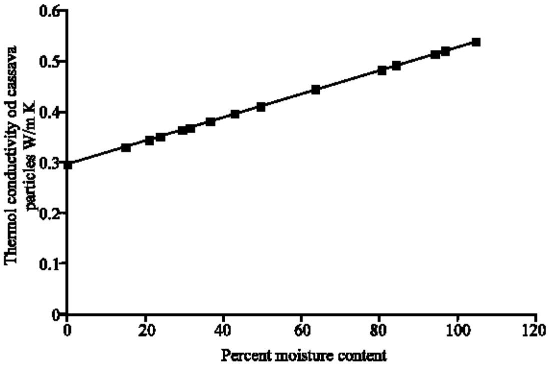

Fig. 6: Thermal conductivity of cassava particles at different percent moisture content

THERMAL PROPERTIES

Specific heat capacity: The variation of specific heat capacity, C_{pg} versus percent moisture content is shown in Fig. 5. The graph is a straight line with negative slope. The value of specific heat capacity decreases as the percent moisture content increases.

The empirical relation between specific heat capacity C_{pg} and percent moisture content is given by

$$C_{pg} = 44.377 - 0.141w \tag{19}$$

where the correlation coefficient, r is -0.89279.

Thermal conductivity: The thermal conductivity is a linear function of percent moisture content as shown in Fig. 6. The slope is positive, showing that the thermal conductivity increases with increase in percent moisture content of the sample.

The empirical relation of Eq. (20) was obtained through curve fitting to experimental data as:

$$K = K = 0.298 + 0.00234\,w \tag{20}$$

where, the coefficients of regression, r is 0.9722.

Isothermal drying properties of cassava particles

Moisture ratio and particle temperature rise with time: Figure 7a shows a typical particle temperature rise and the moisture ratio versus drying time for an isothermal heating temperature of 120°C. The 36 distinct phases of drying processes are clearly seen on the typical heating temperature of 120°C shown and the corresponding moisture ratio with drying times. Similar 36 distinct drying phases are also identified in the other heating temperatures with the drying time. The initial increase in temperature at the start of heating is called the warm-up phase. This is followed closely by the constant rate drying period. This is the portion that is approximately horizontal along the temperature-time curve in Fig. 7a. The final phase, which corresponds to the second rise in temperature-time curve, is the falling rate drying period.

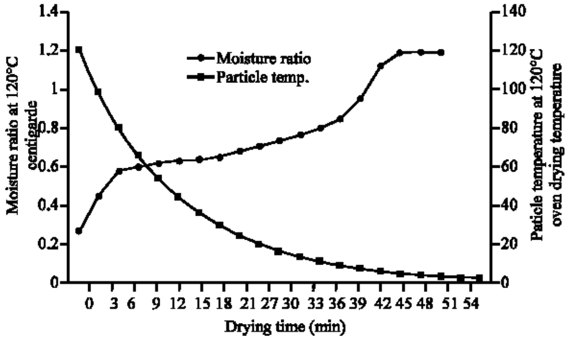

Fig. 7a: Typical moisture ratio and particle temperature rise versus drying time at 120°C

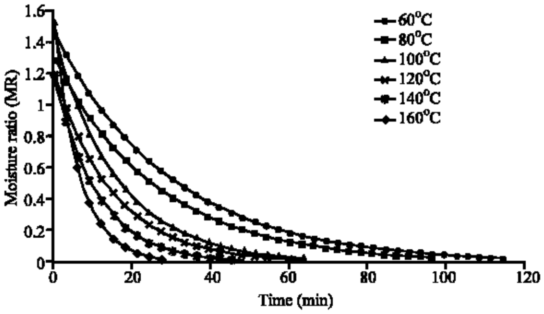

Fig. 7b: Moisture ratio of cassava particles versus time at various isothermal drying temperatures

Table 1: Diffusion Model Constants obtained from regression analysis

Diffusion constants	Drying temperature °C					
	60	80	100	120	140	160
K_0	0.034	0.038	0.062	0.067	0.091	0.153
B_0	1.471	1.3	1.443	1.212	1.184	1.52
Coefficient of correlation R	0.972776	0.966259	0.986832	0.990651	0.98937	0.971307

The falling rate drying period coincides approximately to the curved portion of the moisture ratio-time curve with varying falling rates of the moisture ratios.

Figure 7b shows the graph of moisture ratios versus drying times for cassava particles at various isothermal drying temperatures indicated. For any given moisture ratio, the higher the drying temperatures, the shorter the drying times to attain the given moisture ratio. For any given drying times, t within the constant rate drying period, the rate of falls in moisture ratio are found to increase at higher drying temperatures (Fig. 7b).

By using the diffusion model of Eq. (9) and regression curve fitting on the experimental moisture ratio-times data obtained, the values of constants B_0 and K_0 are computed for various isothermal drying temperatures (Table 1). The values of K_0 obtained at different drying temperatures indicated show increase in values with increase of drying temperatures.

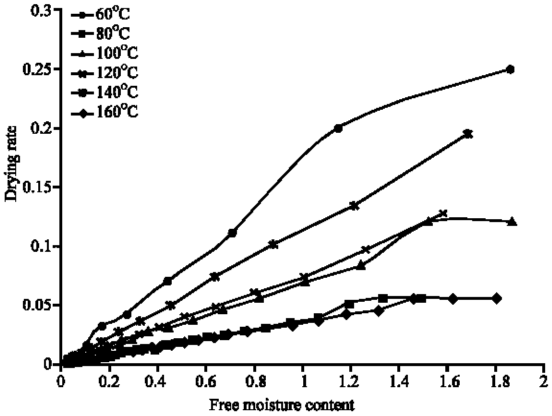

Fig. 8: Drying rate of cassava particles at various drying temperatures

Table 2: Critical free moisture content and drying rate at various drying temperatures

	Drying temperatures (°C)					
	60	80	100	120	140	160
Critical free moisture X_C	1.31	1.19	1.24	1.26	1.21	1.14
Drying rate Rc	0.045	0.051	0.0829	0.0967	0.134	0.2

Table 3: Diffusion coefficients at various drying temperature

	Drying temperatures (°C)					
	60	80	100	120	140	160
Slope	-0.03464	-0.03706	-0.06573	-0.07398	-0.10678	-0.15744
$D_L(m^2\ s^{-1})$	3.46E-06	3.71E-06	6.57E-06	7.39E-06	1.07E-05	1.57E-05
R	-1	-0.97584	-1	-1	-1	-1

Drying rate versus free moisture content: For various drying temperatures, the drying rates versus free moisture contents are shown in Fig. 8. The constant portion of the curve is the constant drying rate period. It is observed that at higher drying temperatures, this was absent. At a critical point where the translation from constant drying rate period to falling rate drying period, the curve falls approximately linearly to the origin. The critical free moisture content and the drying rate at various drying temperatures are shown in Table 2. It is observed that free moisture content averagely decreases with increasing drying temperature and the drying rate increases with drying temperature.

Diffusion coefficients determination: The slopes of the log of unaccomplished moisture ratios versus drying times for various drying temperature are shown in the Table 3. Using Eq. (14), the diffusion coefficient for each drying temperature is calculated and recorded as shown in Table 3. The diffusion coefficient obtained is a function of temperature as shown in Fig. 9. Empirically, D_L has a quadratic relationship with the drying temperature (Eq. 21):

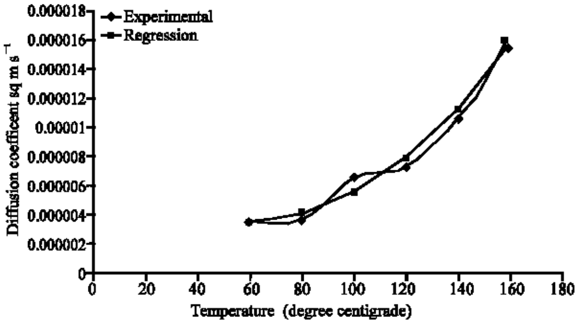

Fig. 9: Diffusivity coefficient ($m^2\ s^{-1}$) versus drying

$$D_L = 7.04E\text{-}06 - 1.25E\text{-}07\ T + 1.11E\text{-}09\ T^2\ m^2\ s^{-1} \quad (21)$$

with coefficient of regression r as tabulated temperatures

CONCLUSION

This work determines the properties of cassava particles experimentally. These properties are physical properties such as loose particle density, porosity and voidage fraction and particle size distribution, thermal properties such as specific heat capacity and thermal conductivity and drying properties such as moisture ratio, drying rate versus free moisture and diffusion coefficients with drying temperature. The loose particle density, porosity, voidage fraction, specific heat capacity, thermal conductivity are found to be linear functions of the percentages moisture contents. All these properties increase with the percentages of moisture contents, except the specific heat capacity which decreases with increase in the percent moisture content. These physical properties, thermal properties of isothermal drying are expressed empirically as a function of percent moisture contents of drying the granular cassava particles. These determined properties of cassava particles are valuable experimental data for the designing of fluidized bed dryer for frying of cassava particles in its production process and also for the simulating the process of the dryer.

REFERENCES

Adeyemi, S.O. and M.B. Adeyemi, 2002. Curing temperatures and hardener resin addition affecting drying and properties of particle board. Int. J. Materials Produc. Technol., 17 (7): 590-599.

Atkinson, J., 1993. An Introduction to the Mechanics of Soils and Foundations. McGraw Hill Book Company, pp: 51.

Geankoplis, C.J., 1993. Transport processes and unit operations, Prentice-Hall International. Inc., Chapter 9: 520-551.

Cooke, R.D. and E.N. Maduagwu, 1978. The effect of simple processing on the cyanide content of Cassava Chips. J. Food Technol., 13: 299-306.

Geldart, D., 1986. Single Particles, Fixed and Quiescent Beds. In: Gas Fluidization Technology. Wiley Interscience Publication, 15-33: 65-69.

Gomez, G., M. Valdiviesco, D. De La Cuesta and T.S. Salcedo. 1984a. Effect of Variety and Plant Age on the Cyanide Content of Whole-Root Cassava Chips and its Reduction by Sun Drying. Anim. Feed Sci. Technol., 11: 57-65.

Kunni, D. and O. Levenspiel, 1991. Fluidization Engineering, Butterworth-Heinemann. Stoneham, pp: 15-58.

Monroy-Rivera, J.A., A. Lebert, C. Marty, J Muchnic and J.J. Bimbenet, 1991. Simulation of Cyanoglu-cosidic Compounds Elimination in Cassava During Drying, in Drying '91 Ed. by Mujumdar A.S. and I. Filkova'. Elsevier Science Publishers, Amsterdam, pp: 463-470.

Nartey, F., 1981. Cyanogenesis in Tropical Peeds and Foodstuff. In: Cyanide in Biology by Wennesland, B., E.E. Coon, C.J. Knowles, J. Westley and F. Wissing (Eds.). Academic Press, London, pp: 115-132.

Oladebeye, D.H. and A.O. Oladebeye, 2006. Effect of Agricultural Waste on Thermal Conductivity of Natural Rubber Composite. Nig. J. Mechanical Eng., 4 (1): 54-63.

Reay, D., 1986. Fluid Bed Drying. In: Gas Fluidization Technology By Geldart, John, D. (Ed.). Wiley and Sons, pp: 259-284.

Singh, B.P.N., M. Narain and Srivastara, 1986. Thin-layer Drying of Paddy. In: Drying of solids, Recent International Developments, Wiley Eastern Ltd., New Delhi, pp: 109-113.

Strumillo, C. and T. Kudra, 1986. Drying. In: Principles, Applications and Design, Gordon and Breach Science Publishers, Switzerland, pp: 257-259.

Yildiz, B. and M.N. Ozisik, 1988. Elements of Heat Transfer, Mcgraw-Hill Inc. Singapore, pp: 58-100.