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Note

Thermal properties of roselle seeds

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A b s t r a c t. The thermal properties of roselle seeds were determined as a function of moisture content. The initial moisture content of seeds was determined using the ASAE standard. Tests were carried out on the seeds at five moisture content from 8.8 to 19% (d.b.). The specific heat capacity was determined by the mixture method, thermal conductivity by steady state heat of vapourization method whereas the thermal diffusivity empirically. The thermal properties were: specific heat capacity – 4.04-5.63 kJ kg^{-1} K^{-1}, thermal conductivity – 1.22-1.56 W m^{-1} K^{-1} and thermal diffusivity – 4.274 to 4.877 10^{-4} m^2 s^{-1}. These values indicated the ability of the material to retain heat which enhances oil recovery.

K e y w o r d s: roselle seed, moisture content, thermal properties

INTRODUCTION

Roselle (*Hibiscus sabdariffa* L.) is a plant that originated either from West Africa or India. Roselle could be used for various food products such as the beverage known as *Zobo* produced from the calyces of the plant. This is usually served to entertain guests during festivities or ceremonies and can also serve as an income generation activity, (Adejumo, 1999; Olawepo *et al*., 1998). It was reported that people from the Plateau region of Nigeria prepare seed cake known as *iyu* which could be served as food to the people, (Blench, 1997). The oil obtained from the seeds is normally used for various cooking purposes, (Schippers, 2000).

Oje and Ugbor (1991) observed that lighter seeds had higher specific heat capacity values than heavier seeds indicating a decreasing linear trend of this parameter with increasing moisture content. Jha and Prasad (1993) reported that the values of the specific heat capacity and thermal conductivity for gorgon nut showed an increasing linear trend while a reverse trend was observed for the thermal diffusivity. Hsu *et al*. (1991) observed that there was an increase in the values of the specific heat and thermal conductivity while thermal diffusivity had decreasing values as the moisture content of pistachios increased. Bozikova (2007) stated that the thermal conductivity, thermal diffusivity and specific heat decreased as the moisture content increased due to biochemical composition of the crop. Omobuwajo *et. al*. (2000) and Sandoz-Medoza *et al*. (2008) had investigated some physical properties of roselle seeds.

The aim of this work was to obtained thermal properties of roselle seeds in the design of machines for its processing.

MATERIALS AND METHODS

Roselle seeds were obtained from the Department of Agricultural Engineering Teaching and Research farm of the Federal Polytechnic, Bida, Nigeria. The initial moisture content of the seeds was determined using the ASAE standard S 352.2 involving the use of oven drying method (ASAE, 1998). Tests were carried out on samples of roselle seeds at five moisture content in the ranges of 8.8 to 19% (d.b.). Samples at the desired moisture content in the above ranges were prepared by conditioning them using the method that was reported by Ezeike (1986). The bulk density was determined by pouring the seeds into a container of 500 ml from a height of 15cm and the excess seeds were removed by a strike-off stick. Next the seeds were weighed with a digital weighing balance, Model MT 2000 (Gibertini Electronical, Italy) having a sensitivity of 0.01 g and divided by the volume of the container.

The specific heat capacity of roselle seed was determined by the method of mixture reported by Hsu *et al.* (1991), Mohsenin (1980), and Tabil (2002). A sample containing a mass of 80 g at the ambient temperature of 28°C, and known moisture content was poured into a calorimeter containing

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water at a temperature of 80°C. The temperature of the grain was measured at 10 min intervals until a constant reading was obtained which marks the equilibrium temperature of the mixture. The equilibrium temperature for the mixture of water and the seed was recorded and the enthalpy change of the seed calculated from the heat exchange between water, calorimeter and the roselle seed using:

$$C_{ps} = \frac{C_{pw}(M_w + E)(T_{oc} - T_{em})}{M_s(T_{os} - T_{em})}, \quad (1)$$

where: C_{ps} – specific heat of sample (kJ kg^{-1}K^{-1}), C_{pw} – specific heat of water (kJ kg^{-1} K^{-1}), M_w – mass of water (kg), M_s – mass of sample (kg), E – water equivalent of the system (kg), T_{oc} – initial temperature of calorimeter (°C), T_{os} – initial temperature of sample (°C), T_{em} – equilibrium temperature for the mixture (°C).

The thermal conductivity was determined by steady-state heat of vaporization method. The sample was placed between two copper plates: one plate was in contact with water at the boiling point of 100°C and the other plate was in contact with ethanol of a lower boiling point of 78°C. The time to vaporize a unit volume (1 ml) of ethanol was recorded. The thickness of whole sample was maintained as the minor axial dimension of the seed at the moisture content in which the experiment was conducted. The thermal conductivity (k) was determined using Eq. (2):

$$k = \frac{QL}{\theta(t_A - t_B)A}, \quad (2)$$

where: k is the thermal conductivity (kJ s^{-1} m^{-1} K^{-1}), Q – heat of vaporization of the liquid at lower boiling point (kJ kg^{-1}), L – thickness of specimen (m), θ – time to vaporize a unit volume of ethanol (s), $t_{A-}\ t_B$ – difference in the boiling points of the two liquids (K), A – area of specimen (m^2).

The experiments were replicated three times at each moisture content, the average values of the thermal conductivity and specific heat.

The thermal diffusivity was determined from the values of the thermal conductivity, specific heat capacity and the bulk density of the roselle seed using the empirical equation given below:

$$\alpha = \frac{k}{\rho_b\, C_{ps}}, \quad (3)$$

where: α is the thermal diffusivity (m^2 s^{-1}), ρ_b is the bulk density of the seed (kg m^{-3}), C_{ps} is the specific heat capacity of the sample (kJ kg^{-1} K^{-1}).

The results were subjected to regression analysis and analysis of variance at 5% level of confidence.

RESULTS AND DISCUSSION

The thermal properties of roselle seeds are shown in Table 1. The specific heat capacity of roselle seed showed a linear decreasing trend in value with an increase in moisture content. The mean values decreased from 5.63 to 4.04 kJ kg^{-1} K^{-1} within the moisture range considered. A similar trend was reported for Borage seeds (Yang *et al*., 1998). These values are almost the same with those of oilbean seed and hydrated soybean hull but lower than those of prepared food (beef and pork roll) (Muzilla *et al*., 1991; Oje and Ugbor, 1991). This could be attributed to the fact that this property is always higher for lighter seeds but lower for heavier seeds, as was also reported for both fababeans and oilbean seeds (Fraser *et al*., 1978, Oje and Ugbor, 1991). There was a significant difference ($p< 0.05$) in the effect of moisture content on the specific heat capacity.

The regression equation showing the relationship between the specific heat capacity and moisture content of seed is shown in Eq. (4) with high value of coefficient of determination. This indicates a high effect of moisture content on the specific heat capacity of seed:

$$C_{ps} = 7.0227 - 0.1557M, \qquad R^2 = 0.99, \quad (4)$$

where: M is the moisture content.

Table 1. Thermal properties of roselle seeds

Property	Unit of measurement	Moisture content (% d.b.)				
		8.8	10.0	12.5	16.0	19.0
Specific heat capacity	kJ kg^{-1} K^{-1}	5.63 (±0.53)	5.49 (±0.43)	5.06 (±0.44)	4.57 (±0.35)	4.04 (±0.45)
Thermal conductivity	Wm^{-1} K^{-1}	1.56 (±0.22)	1.44 (±0.21)	1.37 (±0.23)	1.23 (±0.22)	1.22 (±0.23)
Thermal diffusivity	m^2 s^{-1}	4.274 10^{-4}	4.297 x 10^{-4}	4.335 10^{-4}	4.440 10^{-4}	4.477 10^{-4}

Values in parentheses are the standard deviations.

A decreasing linear trend was observed in the thermal conductivity of the seed as the moisture content increased, with the mean values varying from 1.56 to 1.22 $Wm^{-1} K^{-1}$. At higher moisture contents, the porosity of the samples increased and inter granular void spaces also increased; thereby making the individual seed to be loosely packed relative to each other thus, leading to low heat transmission within the seeds at these moisture content. This trend is similar to the results obtained for tortilla chips, maize and wheat (Moreira *et al*., 1995; Sitkei, 1986). On comparison with other seeds these values were found to be higher than those of tortilla chips and within the same range with those of gorgon nut (Jha and Prasad, 1993; Moreira *et al*., 1995). The relationship between moisture content and thermal conductivity of seed is shown below:

$$k = 1.794 - 0.0324M. \quad (5)$$

The mean values increased linearly from 4.274 to 4.477 $10^{-4} m^2 s^{-1}$ as moisture content increased. The increasing linear trend with respect to moisture increase may be attributed to its dependence on bulk density which also affects the porosity of the seed thereby making it possible for the seeds to transmit heat and have the ability to store it. The relationship between thermal diffusivity of seed and moisture content is shown below:

$$\alpha = 0.0209M + 4.0869. \quad (6)$$

This shows that the thermal diffusivity is moisture content dependent.

CONCLUSIONS

1. Thermal properties showed a very good correlation to moisture content.
2. Linear decrease relationship was observed for the specific heat capacity and thermal conductivity, while the thermal diffusivity had a linear increase trend to moisture content.
3. Thermal properties of the seed or its products have the ability of transmitting and retaining heat when subjected to heat treatment.

REFERENCES

Adejumo O.I., 1999. Development of a device for roselle (*Zobo*) calyces extraction. Proc. 21 An. Conf. Nigerian Inst. Agric. Eng., November 7-11, Bauchi, Nigeria.

ASAE, **1998**. S352.2 Moisture Measurement. ASAE Press, St. Joseph, MI, USA.

Blench R., 1997. Agriculture within the Cultural System of the Tarok People of East Central Nigeria. Overseas Develop. Inst. Press, London, UK.

Bozikova M., 2007. Thermal conductivity, thermal diffusivity and specific heat of potatoes. Proc. 3rd Int. Conf. Trends Agric. Eng., September 12-14, Praha, Czech Republic.

Fraser B.M., Verma S.S., and Muir W.E., 1978. Some physical properties of fababeans. J. Agric. Eng. Res., 22, 53-57.

Hsu H. M., Mannaperuma J.D., and Singh R.P., 1991. Physical and thermal properties of pistachios. J. Agric. Eng. Res., 49 4, 11-21.

Jha S.N. and Prasad S., 1993. Physical and thermal properties of gorgon nut. J. Food Process Eng., 16(3), 237-245.

Moreira R.G., Palau J., Sweat V.E., and Sun X., 1995. Thermal and physical properties of tortilla chips as a function of frying Time. J. Food Proces. Preserv., 19(3), 175-189.

Muzilla N., Helsel Z., Unklesbay K., and Unklesbay N., 1991. Thermal properties of hydrated soybean hulls. Crop Sci., 31, 1541-1544.

Oje K. and Ugbor E.C., 1991. Some physical properties of oilbean seeds. J. Agric. Eng. Res., 50, 305-313.

Olawepo O., Akoma O., and Nwangumah U., 1998. The phytochemistry and change in the quality attributes of preserved *Zobo* during ambient storage. Proc. 16th An. Conf. Agric. Eng., November 24-27, Ibadan, Nigeria.

Omobuwajo T.O., Sanni L.A., and Balami Y.A., 2000. Physical properties of roselle seeds. J. Food Eng., 45, 37-41.

Sánchez-Mendoza J., Domínguez A., Navarro-Galindo S., and López-Sandova J.A., 2008. Some physical properties of roselle (*Hibiscus Sabdariffa* L.) seeds as a function of moisture content. J. Food Eng., 87, 391-397.

Schippers R.R., 2000. African Indigenous Vegetables: An Overview of the Cultivated Species. CAB Press, Wallingford, UK.

Sitkei G., 1986. Mechanics of Agricultural Materials. Elsevier Press, Amsterdam, The Netherlands.

Yang W., Sokhansanj S., Tabil Jr., J., and Yannacopoulus S., 1998. Specific heat capacity measurement for borage seeds by differential scanning colorimetry. J. Food Proces. Preserv., 44(3), 23-32.