A study of some hydro-thermal properties of sandbox (*Hura crepitans*) seed

Idowu, D.O.* and Abegunrin, T.P.

(*Department of Agricultural Engineering, Ladoke Akintola University of Technology, Ogbomoso, Oyo State, Nigeria*)

Abstract: Thermal properties of crops are very important in the design of drying, processing and storage equipment. The availability of thermal properties data on *Hura creptans* seed will assist in machine design; equipment manufacturing and the seed processor were heat treatment is required.

The specific heat, thermal conductivity and thermal diffusivity of *Hura creptans* seed were determined as a function of moisture content, which varies from 6% to 20% (d.b). The results of the experiment on the moisture content related to thermal properties were analyzed using regression analysis.

The specific heat capacity of the seed was found to be in the range 0.0681J/Kg ^{o}C to 0.2949J/Kg ^{o}C with temperature range from 40^{o}C to 80^{o}C, while the thermal conductivity was found to be between 0.0062 W/mK to 0.1323 W/mK. The thermal diffusivity was found to be between 1.62 m^2/s to 16.74 m^2/s in the same range of moisture content. The results show that thermal properties of the seed are moisture dependent. A linear relationship was established between the moisture content and the thermal properties investigated in the range of moisture studied. The analysis showed that moisture content was significant on all properties studied.

The results of this experiment could be useful in the seed processing and storage when heat treatment is involved.

Keywords: thermal properties, heat capacity, specific heat, thermal diffusivity, moisture content.

Citation: Idowu, D.O., and T.P. Abegunrin. 2014. A study of some hydro-thermal properties of sandbox (*Hura crepitans*) seed. Agric Eng Int: CIGR Journal. 16(4): 255−260.

1 Introduction

Sandbox tree (*Hura crepitans*) is an evergreen ornamental tree that belongs to the spurge family (Euphorbiaceae), which grows in the tropical regions of the world (Feldkamp and Susan, 2006). The fruits produced are pumpkin shaped (Plate 1) which are usually green when fresh and brown when dry. In some places, the leaves are used for medicinal purposes but the seed (Plate 2) has not been fully exploited, as there is dearth of information on the properties, traditional handling methods and utilization of the seeds. However, it has been reported that the seed contain oil and some essential vitamins (Idowu *et al.*, 2012). The result of proximate analysis showed that the oil from the seed is very rich in crude protein (25.16 ±0.22%), crude oil (51.43±0.22%), and energy content (2,621.891± 6.357kJ/100g) (Fowomola and Akindahunsi, 2007). The oil may be useful in industries of even food, feed, paints and cosmetics. The acceptability of any oil seed as an industrial raw material depends on the quality of the seed and availability of the processing technology.

For some years now there has been widespread interest in the engineering properties of agriculture product. The information on the engineering properties is required by food researchers for the purpose of quality

Received date: 2014-01-22 **Accepted date:** 2014-11-10

*** Corresponding author: Idowu, D.O.**, Department of Agricultural Engineering, Ladoke Akintola University of Technology, Ogbomoso, Oyo State, Nigeria.
Email: idowu.david@yahoo.com

assessment and evaluation, process design, operation and control of food plant and equipment design etc. (Idowu and Adejumobi, 2009; Idowu *et al*., 2012). The effect of moisture content on physical properties of *Hura creptans* seed has been reported in literature by Idowu *et al*. 2012. However, the thermal property of the seed, which is an important engineering property during mechanical oil expression, has not been reported. The understanding of thermal property of agricultural product and their responses to heat treatment is necessary not only because they affect the physical treatment received during processing, but also because they are the commonest indicators of other properties and qualities. Thermal property such as thermal conductivity, thermal diffusivity, and specific heat of seed are germane to engineering design calculations involving efficient design of processes of heat transfer. The thermal property data are used as a guide for optimum design of heat transfer equipment such as dehydrating, sterilizing and oil expeller machine.

Plate 1: Fresh and dry *Hura crepitans* seedpods

Plate 2: *Hura crepitans* seeds

In agricultural materials, temperature and moisture content greatly influence the specific heat and thermal conductivity due to the relatively high specific heat and thermal conductivity of water. The effect of moisture content on thermal properties of some crops has been reported by some researchers (Singh and Gowaani 2000; Aviara and Haque, 2001; Anyakoha, 2007; Nouri Jangi *et al*., 2011), but that of *Hura creptan*s is yet to be reported. For *Hura crepitans* to be accepted as an industrial raw material, the knowledge of its moisture content related to thermal properties is essential in predicting seed temperature and drying rate which is useful information during the design of processing and storage equipment and also during oil extraction from the seed. The aim of this work is therefore to determine the effect of moisture content on specific heat, thermal diffusivity and thermal conductivity of the seed.

2 Material and Methods

2.1 Material collection

Hura creptans seed were collected from Agricultural and Environmental Engineering Department of University of Ibadan, Ibadan, Oyo State, Nigeria. The seeds were removed from the fruit pod manually, since no mechanical depoder is yet known for the fruit. The seeds were cleaned and stored prior to use in the experiments.

2.2 Moisture content determination

The moisture content of the *Hura crepitans* seed was determined by using oven drying method as adopted by Idowu *et a*l. 2012 for the seed. A weighed sample of the seed was kept in an oven at a temperature of 105°C for six hours (Idowu *et al*., 2012). The sample was weighed again at the end of the period to determine its final weight. This experiment was replicated five times and the average weight was recorded.

2.3 Moisture conditioning of the seed

The wetting techniques adopted by Shepherd and Bhardwaj (1986); Carman (1996); Deshpande *et al.* (1993); and Aydin (2007) were used to vary the moisture content of the seed. Samples of seed at desired moisture levels were prepared by adding calculated amounts of distilled water and sealing in separate polyethylene bags. Lower moisture content was achieved by oven drying to desired moisture. The samples were kept at low temperature (5 ^{o}C) in a refrigerator to equilibrate the samples and to avoid the growth of micro-organisms. Before starting a test, the required quantity of the sample was taken out of the refrigerator and allowed to warm up to room temperature. The final moisture content of the seed was then determined by oven drying method.

2.4 Determination of bulk density

The bulk density of Hura crepitans was measured by filling an empty cylindrical container of 1000 ml with the seed at a height of about 15 cm, striking the top of the level ten times and then weighing the content, the bulk weight was then recorded. This was done five times. Using the equation below, the bulk density (ρb) was then calculated for each of the replications.

$$\rho_b = \frac{M_b}{V_b} \qquad (2)$$

2.5 Measurement of thermal properties

The thermal properties of *Hura crepitans* in relation to moisture content were determined, since processing of this crop is done at different moisture content. The thermal properties investigated in this experiment included specific heat, thermal conductivity and thermal diffusivity. They were determined at four moisture levels (4.0, 8, 12.0 and 20.0% d.b).

2.5.1 Determination of specific heat capacity of *Hura creptans* seed

The specific heat capacity of *Hura crepitans* seed was determined using the method of mixture which is a common technique reported in literature for measuring the specific heat of agricultural and food materials (Singh and Gowaani, 2000; Aviara and Haque, 2001; Anyakoha, 2007; Nouri Jangi *et al*., 2011). The seed of a known mass, temperature and moisture content was dropped into the calorimeter of a known mass, containing a known quantity of distilled water at a known temperature and mass. The mixture was stirred continuously using a glass rod stirrer: at equilibrium the final temperature of the mixture was taken using a digital thermometer that was also used in monitoring the temperature of the mixture. Therefore, the specific heat of kernel was calculated using the following heat balance equation.

$$C_s = \frac{C_c M_c (Q_2 - Q_1) + M_W C_W (Q_2 - Q_1)}{M_s (Q_2 - Q_1)} \qquad (3)$$

Where;

Cs, Cc and Cw = Specific heat of kernel, calorimeter and water (J/kgK)

Mc, Ms and Mw = Masses of calorimeter, sample and water (Kg)

Q_1 = Initial temperature of water and Q_2 = Final temperature of sample.

2.5.2 Thermal conductivity determination

The thermal conductivity was determined using transient method as described by Hooper and Lepper (1950) and modified by Mohsenin (1980). This method was used by Alagusundaram, *et al*. (1991) and Ali and Mohamed (1995). The equation bellow is the solution of the transient heat conduction in the radial direction of the temperature rise at a point on the line heat source between times t_1 and t_2. The slope of the graph of temperature against time was used to determine thermal conductivity using the equation below.

$$k = \frac{Q}{4\Pi(T2-T1)} \ln\frac{t2-t0}{t1-t0} \qquad (4)$$

Where,

K = Thermal conductivity of the sample (W/mK)

Q = line source heat strength, W/m

T_1 = temperature at time t_1, K

T_2 = temperature at time t_2, K

T_0 = time correction factor

The time correction factor t_0 was calculated as the time at which a plot of dT/dt versus time cuts the time axis (dT/dt = 0).

2.5.3 Thermal diffusivity determination

The thermal diffusivity of the selected samples was calculated using the experimental data of thermal conductivity, specific heat capacity and bulk densities of the sample.

$$\alpha = \frac{K}{\rho_b C_p} \qquad (5)$$

Where,

α = Thermal diffusivity (m^2/s)

K = Thermal conductivity (W/mK)

ρ_b = Bulk density (g/cm^3)

C_p = Specific heat capacity (J/kgK)

3 Results and discussion

3.1 Effect of moisture content on bulk density of sandbox (*Hura crepitans*) seed

The bulk densities of the sample decreased linearly with increase in moisture content from 0.05 to 0.0268 g/cm^3 as the moisture increase from 4.0% to 20% d.b. Gowda *et al.* (1990) and Visranathan *et al.* (1996) reported similar decrease with moisture content increase for linseed and neem nut. The variation in bulk densities of sandbox kernel with moisture content is as shown in Figure 1.

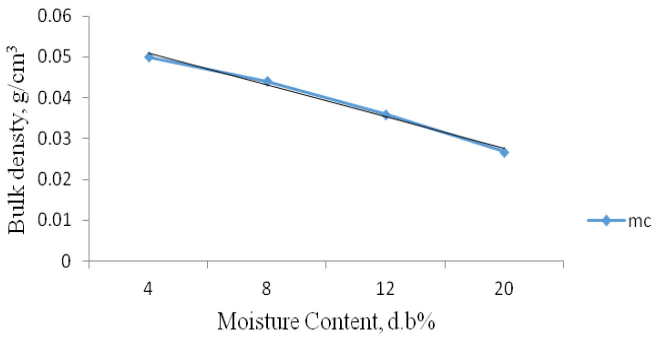

Figure 1: Effect of moisture content on bulk density

The variation of the bulk densities with moisture content was fitted mathematically using the regression equation bellow.

$$\rho_b = -0.0078 M_c + 0.0586 \qquad (R^2 = 0.990) \qquad (6)$$

3.2 Effect of moisture content on specific heat capacity

The variations in specific heat capacity of sandbox seed with moisture content and temperature are presented in Figure 2 and Figure 3. The specific heat capacity of sandbox seed was found to increase from 0.0681 J/kgK to 0.2949 J/kgK when the temperature is in the range of 40°C to 80 °C and moisture content in the range of 4% to 20% (w.b) respectively.

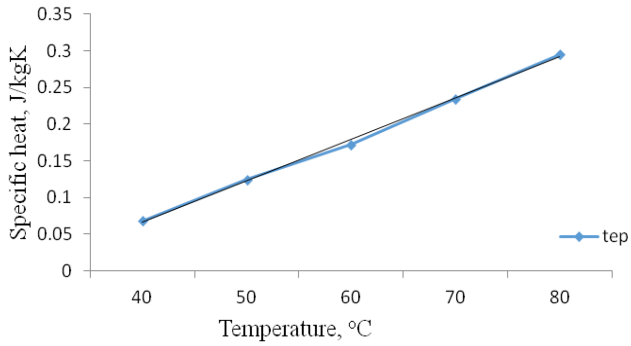

Figure 2: Effect of temperature on the thermal codunctivity of *Hura creptans*

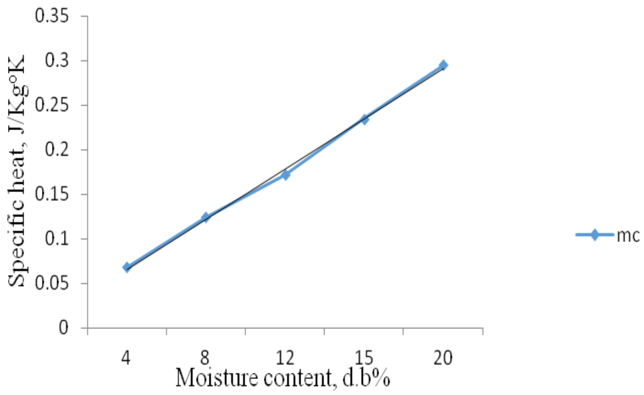

Figure 3: Effect of moisture content onthe specific heat capacity of *Hura crepitans*

The regression equation relating to the specific heat to moisture content is as presented in Equation 6.

$$C_p = 0.0564Mc + 0.0097 \qquad (R^2 = 0.998) \qquad (6)$$

This result follows the same trend as reported by some researcher (Singh and Goswami, 2000 for cumin seed; Aviara and Haque, 2001 for shear nut kernel and Aremu and Falade, 2010 for Doum Palm Fruit). The linear relationship between the specific heat capacity (C_p) of sandbox with the moisture content (Mc) and temperature (T) is in agreement with findings of some previous researchers. Shrivastava and Datta (1999) investigation revealed that the specific heat capacity of mushrooms increased linearly from 1.7158 to 3.9498 J/kgK with increase in temperature and moisture content in the range of 40 ^{0}C-80 ^{0}C and 10.24-89.68 % w.b, respectively.

3.3 Thermal conductivity

The thermal conductivity of sandbox kernel (*Hura crepitans*) varied from a minimum of 0.0062W/mK to 0.1323 W/mK depending upon the moisture content (Figure 4) within the experimental range of the variable. An increasing trend in the thermal conductivity of sandbox kernel (*Hura crepitans*) was observed with the increase in both moisture content and temperature. Similar trend was observed in the investigations of Oluka and Bardey (2000) in which the thermal conductivity of pigeon pea flour paste varied from 0.566 to 0.800 W/mK

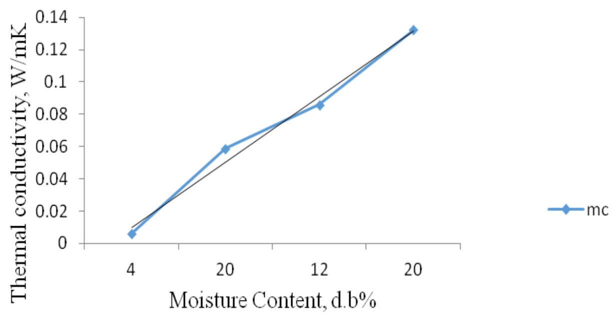

Figure 4: Effect of moisture content on thermal conductivity of *Hura crepitans*

The regression analysis was applied on thermal conductivity data and the resulting regression equation is as presented in Equation 7.

C_h= 0.0406Mc - 0.0305 (R^2= 0.9869) (7)

The regression analysis showed that there is a linear relationship between thermal conductivity and moisture content of the sandbox kernel (*Hura crepitans*) and that the thermal conductivity was dependent on moisture content.

3.4 Thermal diffusivity

The change of thermal diffusivity of sandbox seed (*Hura crepitans*) with moisture content, is as presented in Figure 5; shown that the thermal diffusivity of the sandbox kernel (*Hura crepitans*) increased linearly from 1.62 to 16.74 m^2/s for sandbox seed *(Hura crepitans*) with increase in moisture content. Similar trend was reported for the thermal diffusivity of shear nut kernel by Aviara and Haque |(2001); Taiwo *et al*. (1995) and Yang *et al*. (2002) for borage seed.

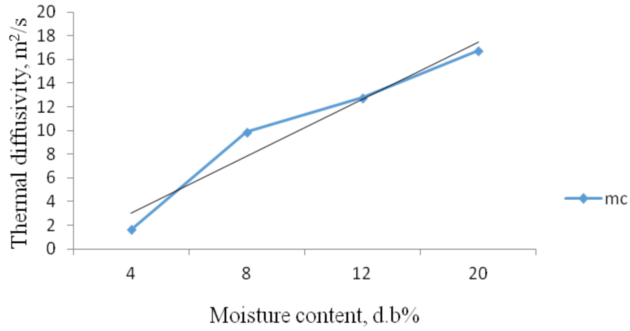

Figure 5: Effect of moisture content on thermal diffusivity of *Hura crepitans*

The relationship existing between thermal diffusivity of sandbox kernel (*Hura crepitans)* with moisture content can be expressed mathematically using the following regression equation.

T_{hd} = 4.828Mc - 1.82 (R^2= 0.9464) (7)

4 Conclusions

Following conclusions could be drawn from the studies

1) The results from these experiment shows that the specific heat capacity, thermal conductivity and the thermal diffusivity of *Hura creptans* are all moisture dependent.
2) The specific heat capacity of sandbox kernel increased with both moisture content and temperature between 0.0681 to 0.2949 J/kgK with a linear relationship.
3) The thermal conductivity of the sandbox kernel (*Hura crepitans*) increased with increase in moisture content between 0.0062 to 0.1323 W/mK.
4) The thermal diffusivity increased with increase in moisture content from 1.62 to 16.74 m^2/s.

References

Alagusundaram, K., D. S. Jayas, W. E. Muir, and N. D. White. 1991. Thermal conductivity of bulk barley, lentils, and peas. *Transaction of the American society of Agricultural Engineers,* 34(4): 1784-1788.

Ali, H., and H.T. Mohamed. 1995. Bulk thermal conductivity of Barley. *Res. Bulleting*., pg 5-17

Aremu, A. K., and O. K. Fadele. 2010. Moisture dependent thermal properties of doum palm fruit. *Journal of Emerging Trends in Engineering And Applied Sciences (JETEAS),* 1(2): 199-204.

Ayadin, C. 2007. Some engineering properties of pearnut and kernel. *Journal of Food Engineering,* 79: 810-816

Anyakoya, T. 2007. *Heat transfer through materials.* Africana first publisher Onistha. 630-680. Third edition.

Aviara, N.A., and M. A. Haque. 2001. Moisture dependence of Thermal properties of shea nut kernel. *Journal Food Engineering*, 47: 109-113.

Carman, K. 1996. Some physical properties of lentil seeds. *Journal of Agricultural Engineer Research*, 63:87-92.

Dehspande, S. D., S. Bal, and T. P. Ojiha. 1993. Physical properties of soybean. *Journal of Agricultural Engineering Research*, 56: 89-98.

Encyclopedia Britannica online: The history of sandbox tree (Plant) Fowomola, M. A., and A. A. Akindahunsi. 2007. Nutritional quality of sandbox tree (hura crepitans linn). *Journal of Medicinal Food*, 10(1): 159-164.

Feldkamp, L. A., and F. Susan. 2006. Hura crepitans Wikipedia the free encyclopedia. Wikipedia.org/ wiki/ Hura crepitans.(accessed ??)

Hooper, F. C., and F. R. Lepper. 1950. Transient heat-flow apparatus for determination of thermal conductivities. *Transactions of ASHVE,* 56: 309-322.

Idowu, D. O., and M. A. Adejumobi. 2009. Effect of processing variables on angle of repose and coefficient of friction of dried fermented cassava granues. *Journal of Engineering and Technology, Lautech, Ogbomoso*, 5(1): 53-57.

Idowu, D. O., T. P. Abegunrin, F. A. Ola, A. A. Adediran, and J. A. Olaniran. 2012. Measurement of some engineering properties of sandbox seeds (*Hura crepitans*). *Agriculture and Biology Journal of North America*, 3(8): 318-325.

Mohsenin, N.N. 1980. *Thermal properties of Foods and Agricultural Materials.* Pp 83-121, Gordon and Breach, New York.

Nouri Jangi, A. S. A. Mortazavil, M. Tavakoli, H. Ghanbari, A. Tavakolipour, and G. H. Haghayegh. 2011. Comparison of mechanical and thermal properties between two varieties of barley grain. *Australian journal of Agric. Engr*, 2(5): 132-139

Oluka, S. I., and I. A. Bardey. 2000. Thermal properties of pigeon pea. *Journal of Agricultural Engineering and Technology,* 8: 37-43.

Shepherd, H., and R. K. Bhardwaj. 1986. Thermal properties of pigeon pea. *Cereal foods World,* 31: 466-470

Shrivastava, M., and A. K. Datta. 1999. Determination of specific heat and thermal conductivity of mushrooms (pleurotus forida). *Journal Food Engineering*, 39: 255-260.

Singh, K. K., and T. K. Goswami. 2000. Thermal properties of cumin seed. *Journal Food Engineering,* 45: 181-187.

Taiwo, K. A., C. T. Akanbi, and O. O. Ajibola. 1995. Thermal properties of ground and Hydrated cowpea. *Journal of Food Engineering. Elsevier science Direct*, 29: 249-256.

Yang, W., S. Sokhansanj, J. Tang, and P. winter. 2002. Determination of thermal conductivity, specific heat and thermal diffusivity of borage seeds. *Journal of Biosystem Engineering,* 82(2): 169-176.