

SOME STRUCTURAL AND GEOMETRICAL PROPERTIES OF *CHRYSOBALANUS ATACORENSIS* RELEVANT TO ITS PROCESSING

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Abstract

Chrysobalanus atacorensis is a popular spice in South-South Nigeria. It has medicinal potentials too. Some structural and geometrical properties of its seed which are necessary in designing systems appropriate for its handling and processing were studied using standard techniques such as the micrometer screw gauge; water displacement; correlation; and inclined plane. Results obtained revealed mean values \pm S.D. (standard deviation) of the properties studied as follows: bulk volume of $315.879 \pm 0.017\text{cm}^3$; solid volume of $161.0 \pm 0.652\text{cm}^3$; bulk density of $0.585 \pm 0.010\text{g/cm}^3$; solid density of $1.1532 \pm 0.385\text{g/cm}^3$; specific gravity of 1.1532 ± 0.385 ; major diameter of $1.483 \pm 0.885\text{cm}$; intermediate diameter of $1.395 \pm 1.224\text{cm}$; minor diameter of $1.338 \pm 0.909\text{cm}$; sphericity of $0.947 \pm 0.152\text{cm}$; roundness of $0.941 \pm 0.084\text{cm}$; porosity of $44.35 \pm 0.390\%$; estimated surface area of $142.546 \pm 0.823\text{cm}^2$. Its coefficients of sliding friction were 0.483 ± 0.01 on aluminium; 0.525 ± 0.01 on plywood; and 0.471 ± 0.01 on galvanized metal surfaces respectively. The samples' angles of repose of $25.80 \pm 0.05^\circ$; $25.20 \pm 0.03^\circ$; $27.70 \pm 0.05^\circ$ on the various surfaces evaluated suggested that its handling equipments should not be steeply designed in order to avoid line congestions.

Keywords: *Chrysobalanus atacorensis*, medicinal potentials, physical properties, processing, spice, techniques.

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1. INTRODUCTION

Food processing is the application of the principles and facts of science to transform raw food materials of plant and animal origin into consumables (Monteiro and Levy, 2010; Barbosa-Canovas *et al*, 2006; Heldman and Hartel, 1997). Thus, food processing encompasses the handling, preservation, storage and utilization of food materials (Barbosa-Canova *et al*, 2006). Consequently, the knowledge of the structural and geometrical (i.e. physical) as well as mechanical properties of food materials becomes key and strategic for their effective transformation. These properties constitute an important and essential data in the design of food process and control systems (Oje *et al*, 1999; Oje, 1993; Mohsenin, 1978). This valuable and basic information is important and useful not only to engineers but to those who may exploit these properties to find new uses for agricultural materials (Olaoye, 2000). The physical properties of various food materials have been studied

(Alonge, 2008; Altuntas and Yildiz, 2007; Alcali *et al*, 2006; Alonge and Adegbulugbe, 2005; Ogunjimi *et al*, 2002; Oje *et al*, 2001; Alonge and Adigun, 1999; Gupta and Das, 1997). *Chrysobalanus atacorensis* belongs to the Chrysobalanaceae family (Watson and Dallwitz, 1992) contrary to claims by Bassey *et al*, (2011) that it is of the Rosaceae family. It is a small evergreen tree with thick and bushy foliage (Fig. 1). Its leaves are oblong elliptic, acuminate and cuneate at base, its flowers are hermaphroditic, actinomorphic and arranged in cymes while its fruit is pubescent when young (Bassey *et al*, 2011) and forms a soft dark hull enclosing the seed when dry.

Its seed is a hard nut, somewhat spherical in shape and longitudinally ribbed round its entire body (Fig. 2) and has a harsh, onion-like aroma and unique flavour. The dried seeds are processed into powder and used as meat tenderizer, and spice in pepper-soup and other local delicacies (Bassey *et al*, 2011). *Chrysobalanus atacorensis* also possesses some medicinal potential which had been

reported (Stolton and Dudley, 2009; Gustafson *et al*, 1999). It is popular in Akwa Ibom State, South-South Nigeria where it is known by the vernacular name *eyim eto* (Basset *et al*, 2011) which is literally translated as *onion tree*.



Fig. 1: The tree of *Chrysobalanus atcorensis*.

However, it appears that, besides a well-documented history and taxonomy, not much general research has been done about *Chrysobalanus atcorensis* at specie level.



Fig. 2: The seeds of *Chrysobalanus atcorensis*.

The objective of this study, therefore, is to elucidate some physical properties of

Chrysobalanus atcorensis which are relevant to its processing.

2. MATERIALS AND METHODS

A. Materials

Chrysobalanus atcorensis seeds used in this study were purchased from Itam market in Uyo, Akwa Ibom State of Nigeria. The seeds were identified and authenticated by the Department of Botany and Ecological Studies of the University of Uyo, Nigeria. The seeds were cleaned and sorted by hand. A sample size of hundred seeds was randomly drawn from the bulk, with minimal bias. Each seed was assigned a number and the sample divided into ten groups of ten seeds each. Mean values of properties were applied in the appropriate equations. This study was carried out in the Food Engineering Laboratory of the University of Uyo, Akwa Ibom State, Nigeria.

B. Mass

An electronic balance (about 0.01% sensitivity) was used to take the average mass of sample and indeed every other weighing carried out in this study.

C. Volume (bulk solid volumes)

The height which the sample occupied in a 100cm³ beaker and the internal diameter of the beaker was first determined using a veineer calliper. Then the bulk volume was calculated from equation 1.

$$V_b = \pi(d_i / 2)^2 h \quad (1)$$

where: d_i = internal diameter of beaker.

h = height occupied by sample in the beaker.

Similarly, the solid volume (V_s) of the sample was determined by the water displacement method (Oje and Ugbor, 1991; Shepherd and Bhardwaj, 1986; Mohsenin, 1984).

D. Density (bulk and solid densities)

The bulk and solid densities (ρ_b and ρ_s) were calculated by dividing sample weight by either V_b or V_s .

E. Specific gravity

The specific gravity (relative density) of sample was determined from equation 2 by dividing its solid density by density of water at 4⁰C, which was read off a density vs. temperature table from Weast (1972).

$$S.G.s = \rho_s / \rho_w \quad (2)$$

where: ρ_s = solid density of sample.
 ρ_w = density of water at 4⁰C.

F. Porosity

The porosity (P_f) was calculated based on the relationship for porosity by Mohsenin (1978), Shepherd and Bhardwaj (1986), according to equation 3:

$$P_f = (1 - [\rho_b / \rho_s]) \times 100 \quad (3)$$

where: ρ_b = bulk density of the seeds.
 ρ_s = solid density of the seeds.

G. Estimated surface area

The surface area (A_s) of the sample was estimated using equation 4.

$$A_s = (36\pi)^{1/3} V^{2/3} \quad (4)$$

where: V = solid volume of sample.

H. Shape (sphericity and roundness)

The shape properties were determined as follows:

a. Sphericity

The method of Mohsenin (1978) was applied and the sphericity determined from equation 5.

$$\text{Sphericity} = (xyz)^{1/3} / x \text{ or } (yz / x^2)^{1/3} \quad (5)$$

where: x = major diameter.
y = minor diameter.
z = intermediate diameter.

b. Roundness

The roundness of the seeds was determined by the method of Alonge (2008) using equation 6.

$$\text{Roundness} = r/R \quad (6)$$

where: r = intermediate radius.
R = major radius.

I. Size

Measurements of principal dimensions of the three mutually perpendicular axes namely major, intermediate and minor diameters of the sample (hundred seeds) were made with a micrometer screw gauge. Precautions such as the use of a magnifying glass to take readings in order to reduce parallax; and ensuring that the gauge does not press too hard on the seed before readings were taken, were strictly and meticulously observed.

J. Angles of repose

The angles of repose were determined with respect to three structural material surfaces namely: plywood, galvanized metal and aluminium using an inclined plane apparatus (Make: Cussons Technology, Manchester, England; Serial number: P5464/157). Each group was placed on the inclined surface and the height (by implication the inclination angle) was gradually raised until the seeds started to slide (Fig. 3).

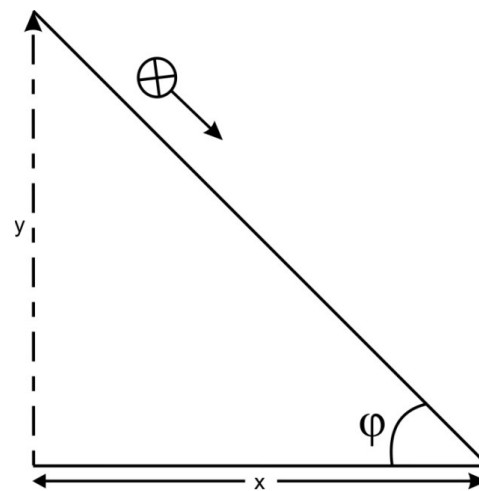


Fig. 3: Determination of the coefficient of friction by the inclined plane technique.

y = height of inclination;
x = base of inclination;
φ = angle of inclination or repose.

The angle of inclination or repose at this instance was recorded. These determinations were made in triplicates.

K. Coefficient of sliding friction

The tangent of the angle of inclination is the measure of coefficient of friction (Mohsenin,

1978; Chakraverty, 1988). Thus, the coefficient of sliding friction of the sample on the three surfaces evaluated was related to the angles of repose according to equation 7:

$$\mu_s = \tan \varphi \quad (7)$$

where: μ_s = sliding co-efficient of friction.
 φ = angle of repose.

L. Experimental design

The study was conducted in a nested classification design (NCD) with the fifteen properties measured/observed (treatments) nested within ten groups (blocks of ten seeds each according to size) of the sample to obtain group or block means from which the sample means were derived. Each measurement was replicated three times to give four hundred and fifty treatment units.

M. Statistical analysis

The mean values and standard deviations (S.D.) of the properties measured were calculated using the method of Ubom (2004).

3. RESULTS AND DISCUSSION

The results of the physical properties of the *Chrysobalanus atacorensis* sample investigated are displayed on Table 1.

A. Mass

The mean mass of the sample (hundred seeds) used in this study was 184.51 ± 0.012 g.

B. Volumes

The sample had a mean bulk volume of 315.874 ± 0.017 cm³ and a mean solid volume of 161.0 ± 0.652 cm³, respectively. Volume change and porosity are important parameters in estimating diffusion coefficients for shrinking systems (Barbosa-Canovas *et al*, 2006).

C. Densities

The bulk density of the sample was 0.585 ± 0.010 g/cm³ while its solid density was 1.1532

± 0.385 g/cm³. Density of food materials is useful in mathematical conversion of their mass to volume as well as determining the strength and other characteristics of their package.

D. Specific gravity

The mean specific gravity of the sample was 1.1532 ± 0.385 . The specific gravity (relative density) is the ratio of the mass (or density) of a product to the mass (or density) of equal volume of water at 4⁰ C. During processing, the factor of specific gravity provides the basis for relating or comparing the mass, weight or volume of a food material with that of another food material or substance.

E. Size

The values for the three principal and mutually perpendicular dimensions which determined the size of the seed were: major diameter, 1.483 ± 0.885 cm; intermediate diameter, 1.395 ± 1.224 cm; and minor diameter, 1.338 ± 0.909 cm. Size factor is used to grade food materials as well as affects its flow pattern during processing.

F. Shape factors

The shape factors of the sample were: sphericity (0.947 ± 0.152 cm) and roundness (0.941 ± 0.084 cm) respectively. Structural and geometrical properties such as roundness and sphericity are used to characterize the shape of a food material. They also determine the level of void spaces of such food material in processing. Whereas roundness measures the sharpness of corners of a solid (Barbosa-Canovas *et al.*, 2006), sphericity, on the other hand, defines the ratio of the surface of a sphere which has the same volume as that of the solid (Oje *et al*, 2001), that is, how the shape of the solid deviates from a sphere (Barbosa-Canovas *et al*, 2006). Sphericity and shape factors are also needed in heat and mass transfer calculations (Barbosa-Canovas *et al*, 2006) during processing operations.

Table 1: Structural and geometrical properties of *Chrysobalanus atacorensis*

S/N	Property	Minimum value	Mean value	Maximum value	Standard deviation
1.	Mass (g)	184.501	184.510	184.530	±0.012
2.	Bulk volume (cm ³)	315.881	315.879	315.884	±0.017
3.	Solid volume (cm ³)	160.000	161.000	163.000	±0.652
4.	Bulk density (g/cm ³)	0.586	0.585	0.589	±0.010
5.	Solid density (g/cm ³)	1.1530	1.1532	1.1535	±0.385
6.	Specific gravity	1.1530	1.1532	1.1535	±0.385
7.	Major diameter (cm)	1.321	1.483	1.730	±0.885
8.	Minor diameter (cm)	1.161	1.338	1.625	±0.909
9.	Intermediate diameter (cm)	1.035	1.395	1.744	±1.224
10.	Sphericity (cm)	0.954	0.947	0.981	±0.152
11.	Roundness (cm)	0.848	0.941	1.008	±0.084
12.	Porosity (%)	42.400	44.350	43.840	±0.390
13.	Estimated surface area (cm ²)	142.238	142.546	143.054	±0.823
14.	Coefficient of sliding friction:				
	Aluminium surface	0.268	0.483	0.649	±0.01
	Plywood surface	0.384	0.525	0.577	±0.01
	Galvanized metal surface	0.384	0.471	0.625	±0.01
15.	Angle of repose (degrees):				
	Aluminium surface	15.00	25.80	33.00	±0.05
	Plywood surface	21.00	27.70	32.00	±0.05
	Galvanized metal surface	21.00	25.20	30.00	±0.03

G. Porosity

With a mean porosity value of $44.350 \pm 0.390\%$, the sample possesses an almost average drying capacity considering the available void spaces. Porosity indicates the volume fraction of air spaces present in a food structure such as a packed bed and is essential in drying operations during processing. Porosity is used to calculate effective diffusivity during mass transfer process (Barbosa-Canovas *et al*, 2006).

H. Estimated surface area

The mean estimated surface area of the sample was $142.546 \pm 0.823\text{cm}^2$. Surface area is important and useful in packaging operations.

Values for surface areas of food materials are needed in investigations related to evaporation rate in heat transfer calculations for heating or cooling (Barbosa-Canovas *et al*, 2006).

I. Angle of repose

The angles of repose of the sample on the various surfaces evaluated were $25.80 \pm 0.05^\circ$; $25.20 \pm 0.03^\circ$ and $27.70 \pm 0.05^\circ$ respectively. This presupposes that its handling equipments would not require steep angles for conveyance in order to avoid recurrent line congestion. The angle of repose of a sample is the angle made when the sample is allowed to flow to its natural slope (Oje *et al*, 2001). This factor with

other mass properties such as volume and density play important roles in defining the flow characteristics of bulk solids (Carson *et al.*, 1986) during conveyance in food processing operations.

J. Coefficients of sliding friction

From table 1, the coefficients of sliding friction of the seed on the three surfaces evaluated were low and did not vary widely. The implication of this was that it can be effectively conveyed on various surfaces with little or no problems. This property, [in synergy with the angle of repose], directly or indirectly affects the design of processing machines (Alcali *et al.*, 2006) such as hoppers and other unloading devices (Oje *et al.*, 2001).

4. CONCLUSION

Size, roundness, sphericity, volume, surface area, density, porosity, etc., are important structural and geometrical characteristics of food materials in handling and processing operations. The study of the various structural and geometrical characteristics (physical properties) of *Chrysobalanus atacorensis* revealed the following:

- i. That the principal dimensions and surface area of its seeds varied widely.
- ii. That their coefficients of friction were low, a fact which made them easily slide and roll on the surfaces evaluated.
- iii. That considering their low angles of repose on the surfaces evaluated, their handling equipments, such as hoppers and conveyors need not be designed to be steep in order to avoid line congestion.

As a matter of fact, the processing of some food and biomaterials had been impeded by lack of knowledge of their engineering (physical and mechanical) properties. This has often led to huge cost in post-harvest losses, as well as out-of-season scarcity of food materials, especially in developing countries, which is a potential threat to food security. Finally, research efforts should be furthered on *Chrysobalanus atacorensis* considering its nutritional roles and concomitant medicinal potentials.

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