Investigation INTO Some Physical Properties of Chestnut Grown in Nigeria

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Abstract

In order to design and fabricate equipment for harvesting, processing and transportation, separating and packing for chestnut, some physical properties of chestnut were determined. Fifty dried samples of the nut were selected and used for the measurement. In this paper, the physical properties such as length, width, thickness, geometric mean diameter, arithmetic mean diameter, mass, true volume, apparent volume, true density, bulk density, porosity, sphericity, aspect ratio, were determined for chestnut grown in Nigeria. Microsoft Excel spread sheet package was used to analyse the data obtained. The results showed that the length, width, thickness, arithmetic mean diameter, geometric mean diameter, of chestnut were 19.11, 14.82, 16.00, 1513.83, 16.48 mm respectively. The sphericity, aspect ratio, mass, true volume, apparent volume, true density, bulky density, porosity and moisture content were 87.0%, 84.5%, 1.86 g, 0.412 cm^3, 19.03 cm^3, 0.84 g/cm^3, 0.47 g/cm^3, 44.0 % and 14.1%$_{(wb)}$ respectively.

KEYWORDS: Physical properties, chestnut, Rheological properties, engineering properties, sphericity

1.0 Introduction

A good knowledge of engineering properties of agricultural materials is necessary in order to design efficient agricultural system and machines. The basic engineering properties exhibited by agricultural materials include: Mechanical, Physical, Thermal, Optical, Electrical, Chemical, Rheological, Electromagnetic properties. These basic engineering properties are widely applicable in storage, packaging, handling, transportation, and processing of agricultural materials (Lewis, 1987 and Barbosa-Cánovas et al., 2005).

Data concerning physical properties are important in the design of a specific machine or analysis of the behaviour of the product under various post harvest operations. Generally, grading of fruits is done based on characteristics like, size, shape, mass, color, soundness, maturity etc. The information on size of the fruits is essential for uniformity and packing in standard containers.

Properties such as bulk density, true density and porosity are useful in storage, transport and separation systems (Singh et al., 2004a).

Chestnut is one of the most important forest species in Southern Europe. Besides, the intrinsic interest in the ecological aspect, this crop has been widely cultivated for the production of timber and fruit. It has been an important food source for the rural areas of mountain forest and hills, as the chestnut were used mainly for the production of flour (Bournous et al., 2000).

Chestnuts have been a valuable resource for the survival of the population living in many areas of Asia, South Europe, North Africa and of most countries bordering the Mediterranean Sea. The nuts of *Castanea sativa* in Europe and of *C.mollissima* and *C. crenata* in Asia were not only daily bread but could store for the whole year if well dried. The trees can also serve as fuel wood, building timber and wood products for many crafts. At present, both European and Oriental chestnuts are no longer a source for subsistence but continue to play an important role in many agro forestry systems in food, timber and landscape strategies for the new millennium (FAO, 1990). The seeds of Indian Horse-chestnut tree have edible uses. They have been used as food during the times of famine by various tribes of North and North-Eastern India. The seeds can be ground into powder and used as gruel (Mumtaz et al., 2010). The crushed seeds if fed to cattle are reported to improve the quality and quantity of milk. There are reports that the seeds are also given to horses to cure colic disorder (Anonymous, 1985). The chestnut oil is used to cure rheumatism and also applied to wounds. Nine most important plants have been reported by Sharma (1991) for treating rheumatic pains in Jammu and Kashmir and among them *Aesculus indica* tree (Indian Horse-chestnut) finds the prominent place with respect to medicinal value of its seed oil. Chestnut is not quite popular in Nigeria. The products of those grow as ornament plants at homes often waste away.

Chestnuts are formed in pods (Fig. 1), which splits naturally after maturity to discharge the nuts (Fig.2). The seed nut is further processed by removing its outer cover mostly using manual methods. The manual shelling takes long time and tedious. In oder to design a system for carry out this processing effectively; there is need to determine obtaining the basic engineering properties of the nut. There is paucity of information on the engineering properties of chestnuts. Their properties therefore need to be investigated and utilized in the design of various post-harvest systems that can handle this crop. This research was conceptualized to generate this data.

Fig.1: Chestnut pod

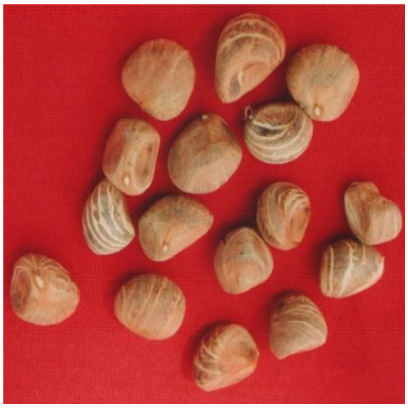

Fig.2: Seed nuts of chestnut

2.0 Materials and Methods

Chestnuts were procured from Ondo State Ministry of Agriculture Akure, Ondo state Nigeria. Fifty (50) dried samples were randomly drawn from harvested chestnuts. These samples were used in the measurement.

2.1 Physical Properties Determination

The following physical properties were determined:

Size and Shape

Fifty (50) dried samples of chestnut were randomly selected and put in a cellophane sachet. The sachets were numbered 1 to 50 to avoid repetition during the measurement. For each of the nut, the major (*a*), intermediate (*b*), and minor (*c*) diameters were measured using a digital vernier caliper having a resolution of 0.01 mm. The averages of a, b and c with their standard deviations were calculated. The geometrical mean diameter (D_g) and arithmetic means diameter (D_a) were calculated using equation (1) and (2) respectively after Mohsenin (1970), Singh (2004) and (Razavi and BahramParvar , 2007) as:

$$D_g = (abc)^{1/3} \quad \ldots \ldots (1)$$

$$D_a = \frac{(abc)}{3} \quad \ldots \ldots (2)$$

Sphericity (S)

The criterion used to describe the shape of chestnut samples was sphericity which was determined according the relationship given by Mohsenin (1978):

$$S = \frac{(abc)^{1/3}}{a} \quad \ldots \ldots (3)$$

Aspect Ratio (A_R)

The aspect ratio was obtained using following relationship as used by Razavi and BahramParvar (2007):

$$A_R = \frac{b}{a} x\, 100 \quad \text{...} (4)$$

Volume and Mass

True volume was determined by the liquid displacement method (Mohsenin, 1978). The true volume (V_t) calculated by the following equation:

$$V_t = \frac{m_a - m_w}{\rho_w} \quad \text{...} (5)$$

Where, m_w is mass of sample in water; m_a, mass of sample in air andρ_w, density of water.

Apparent volume (Va) was calculated theoretically by the following equation used for volume of ellipsoid materials (Razavi and BahramParvar , 2007):

$$V_a = \frac{4\pi}{3} abc \quad \text{...} (6)$$

Mass (m_a) of 50 individual chestnuts was measured with an electronic digital balance model DT-502A, Osaw Industrial Products Private Limited, India having an accuracy of 0.01 g. The average value and standard deviation were calculated.

Bulk Density and True Density

Bulk density of chestnut was determined using a cylindrical container (266-mm diameter and 300-mm height) and balance (ASAE Standards, 2001). The fruits were filled in to a container above its top edge. Nuts having one-half its portions projected above the top edge of the container were removed. Mass of the chestnuts filled in container was measured using electronic balance while bulk density (ρ_b) of chestnut was calculated using the equation given by, (Mohsenin 1980):

$$\rho_b = \frac{m_b}{V_b} \quad \text{...} (7)$$

where, m_b = mass of the chestnut in bulk (g) and V_b = volume of the chestnut in bulk (cm^3)

True density: the true density of chestnut obtained by the following relationship:

$$\rho_t = \frac{m_a}{V_t} \text{...} (8)$$

Where, ρ_t = true density ($g/cm^{3)}$; m = mass of individual fruit (g) and $V_{t\,=}$ true volume of (cm^3).

Porosity

Representative values of bulk and true densities were taken as the average of five replications. Porosity *(e)* was calculated from the average values of bulk and true densities using following relationship (Thompson and Issac, 1967).

$$e = \frac{\rho_t - \rho_b}{\rho_t} X\ 100\% \quad \ldots\ldots (9)$$

Where, ρ_t and ρ_b are true and bulk density respectively in (g/cm^3).

Moisture Content

The moisture contents were determined directly using the Indosaw Intelligent Digital Moisture Testing Machine, Model S 2004. The machine measures moisture content in percentage within a range of 3.5 to 40%.

2.1 Data analyses

All the physical properties were measured at least in five replications, unless stated otherwise. Maximum, minimum, mean, standard deviation, regression equations and coefficient of determination were obtained using Microsoft Excel Spreadsheet (2007).

3. 0 Results and Discussion

A summary of the results obtained for physical properties of kiwifruit is shown in Table 1. As it can be seen, the average length, width and thickness were found to be 19.11, 14.82 and 16.00 mm, respectively. These values were lower than those reported by Mehmet et al. (2009) as 21.79, 23.93 and 14.55 mm respectively for wild chestnut (*Castanea sativa* Mill.) fruit grown in Turkey. Alonge and Adegbulugbe (2005) obtained major, minor and intermediate diameters of 12.47, 7.21 and 7.78 mm for shelled groundnut seeds. The importance of these dimensions in determining aperture size of machines, particularly in separation of materials have been discussed by (Mohsenin, 1978). Also, it may be useful in estimating the number of nut to be engaged at a time and the spacing of slicing discs. The major axis has been found to be indicating the natural rest position of the material and hence in the application of compressive force to induce mechanical rupture. Also, this dimension will be useful in applying shearing force during slicing (Owolarafe and Shotonde, 2004).

The sphericity and aspect ratio of chestnut were found to be 0.87 and 84.5%, respectively. The sphericity was almost the same as that of wild chestnut obtained by Mehmet et al. (2009) as 0.89. The high sphericity value is inductive of the tendency of the shape towards a sphere. The value of chestnut sphericity was higher than the results reported for gumbo (77.80%) by (Akar and Aydin, 2005), shelled groundnut (69.61%) by (Alonge and Adegbulugbe, 2005) orko (64.00%) by (Owolarafe and Shotonde, 2004) and myrtle (58.32%) by (Aydin and Ozcan, 2007), sweet cherry (85.27%) and cactus pear (83.10%) by (Haciseferrogullari et al., 2005; Vursavus, et al, 2006 and Kabas, et al, 2006). On the other hand, it was lower than the sphericity of wild medlar (0.90%). Taken along with the high aspect ratio of 84.5% (which relates the nut width to length), it may be deduced that chestnut will rather roll than slide on their flat surfaces. However, the aspect ratio value being close to the sphericity value may also mean that the chestnut will undergo a combination of rolling and sliding action on their flat surfaces.

Fig. 3 shows the relationship between geometric and arithmetic mean diameters of chestnut. As this figure indicates, the average diameters calculated by the arithmetic mean and the geometric mean formulas (equations 1 and 2) were similar. Therefore, either the arithmetic mean or the geometric mean method can be used to calculate the equivalent diameter of chestnut. The regression relationship between geometric mean diameter and arithmetic mean diameter was obtained as follow:

$$D_g = 273.91 D_a - 3000.5 \qquad (R^2 = 0.994)$$

The geometric mean diameter of chestnut (16.48 mm) was a little lower than the reported value for wild chestnut (19.62 mm) (Mehmet et al., 2009).

The average values of true volume, apparent volume, true density, bulk density and porosity of chestnut were 0.142 cm^3, 19.03 cm^3, 0.84 g/cm^3, 0.47 g/cm^3 and 44%, respectively (Table 1). The average error of apparent volume to true volume of chestnut was obtained as 134. This result shows that the apparent volume will be more applicable in designing the processing equipments. From the true density value, there is a tendency for chestnut to be partially submerged in water. These properties may be useful in the separation and transportation of the nut by hydrodynamic means.

The bulk density, true density and porosity of wild chestnut reported 0.59 g/cm^3, 1.136 g/m^3 and 49.19%, respectively (Mehmet et al., 2009). Also, bulk density, true density and porosity of cactus pear fruit reported by (Kabas et al., 2006) as 0.64 g/m^3, 1.224 g/m^3 and 46.9%, respectively and Alonge and Adegbulugbe (2005) reported the mean bulk density, kernel density, porosity to be 0.60 g/cm^3, 0.46, 1.11 g/cm^3, 0.36 cm^3 and 24.5 degrees respectively for shelled seeds; were higher than data obtained for the chestnuts as 0.47 g/cm^3, 0.84 g/cm^3 and 44%.

4.0 Conclusion

The central focus of this paper is to investigate the physical properties of chestnut that we be needful to design appropriate equipment for processing and handling. The underlying intention is to provide useful data for engineers. This study endeavoured to determine the relevant physical properties of the chestnut namely mass, size, sphericity, aspect ratio, arithmetic and geometric mean diameters, true and bulk densities, porosity. The regression relationship between arithmetic and geometric mean diameters were obtained. This information will facilitate the design of the machines involved.

Table 1: The results of measurement

Property	Symbol	Unit	Replication	Mean Value	Standard Deviation	Min	Max
Length	a	mm	50	19.11	±2.00	12.95	24.00
Width	b	mm	50	14.82	±1.81	11.20	20.20
Thickness	c	mm	50	16.00	±1.82	11.90	19.90
Geometric mean diameter	D_g	mm	50	16.48	±1.15	13.98	18.81
Arithmetic mean diameter	D_a	mm	50	1513.82	±316.81	911.61	2216.84
Sphericity	S	%	50	87.0	±0.07	0.74	1.08
Aspect Ratio	A_R	%	50	84.5	±12.89	65.40	132.05
Mass	m	g	50	1.86	±0.41	0.70	2.70
True Volume	V_t	cm^3	50	0.142	± 1.05	0.00	4.00
Apparent Volume	V_a	cm^3	50	19.03	±3.98	11.46	27.86
True Density	ρ_t	g/cm^3	50	0.84	±0.67	0.00	2.30
Bulk Density	ρ_b	g/cm^3	10	0.47	±0.08	0.40	0.82
Porosity	e	%	10	44.0	±2.30	38.00	46.20
Moisture content	mc_{wb}	%	5	14.10	0.20	12.20	15.50

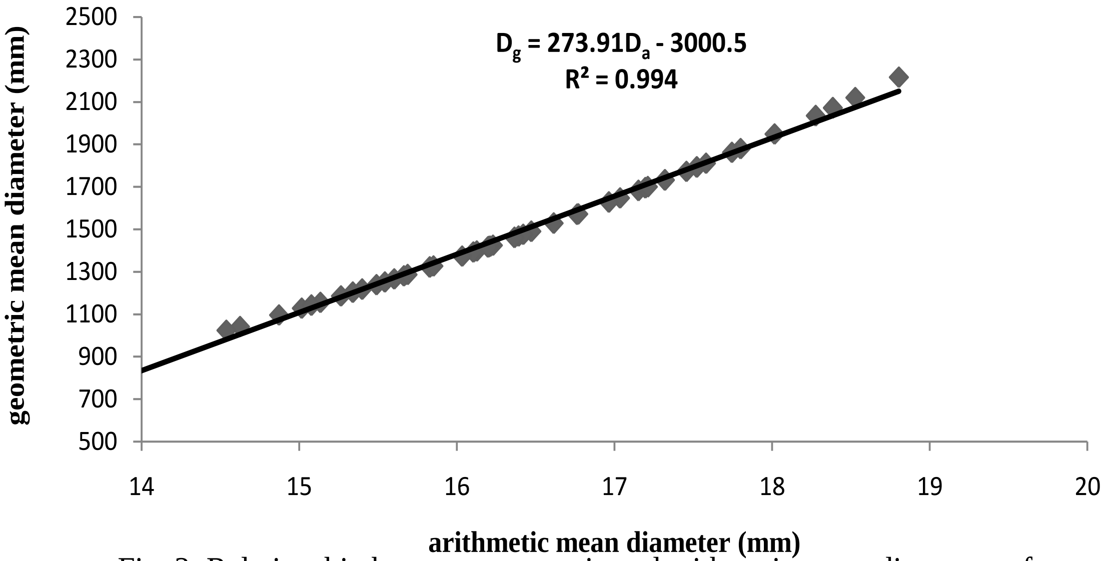

Fig. 3: Relationship between geometric and arithmetic mean diameters of chestnut

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