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Determination of some Physical properties of African Star Apple seeds (*Chrysophyllum albidum*)

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Abstract
The objective of this work was to determine some physical properties of African Star Apple (Agbalumo) with a view to highlight information necessary for the design and processing of similar seeds. A total of 100 seeds of same variety were randomly selected and physical properties such as Major Diameter, Intermediate Diameter, Minor Diameter, Unit Mass and Unit Volume were measured at 35.62% moisture content (dry base). The following results were obtained: the averageMajor Diameter, Intermediate Diameter, Minor Diameter, Unit Mass and Unit Volume of 22.57±0.11mm, 14.24±0.08 mm, 8.44±0.04mm, 0.91±0.01g and 1.99±0.03 (mm^3) respectively. The calculated physical properties such as Bulk density, True Density, Arithmetic Mean Diameter (AMD), Geometric Mean Diameter (GMD), Surface area, Sphericity and Porosity were 0.47±0.00g.cm^{-3},9.58±0.59 g.cm^{-3}, 15.08±0.05mm, 13.94±0.05mm^3, 611.03±4.26 mm^2, 0.16±0.00 and 75.67±3.92% respectively.With less variability and high stability of these physical properties in African Star Apple seeds, suitable technologies or machines for processing of this very important crop and other similar seeds can be developed with ease with a very high optimum efficiency thereby adding great value to it.

Key words: *Physical properties, Africa star apple, handling.*

Introduction

The African star apple *(Chrysophyllum albidum) also known as* Agbalumo in Yoruba, Udara in Igbo is a native of many tropical African countries. It is primarily a forest tree species and its natural occurrences have been reported in diverse eco-zones in Nigeria, Uganda, Niger Republic, Cameroon, and Cote d'Ivoire *(Ewansihaet al., 2011).* The tree grows as a wild plant and belongs to the family of *Sapotaceae* which has up to 800 species and make up almost half of the others *(Ehiagbonare et al., 2008).* It features prominently in the compound agroforestry system for fruit, food, cash income and other auxiliary uses *(Kang, 1992).*

African Star Apple (*Chrysophyllum albidum*) is one fruit of great economic value in tropical Africa due to its diverse industrial, medicinal and the use of fruit pulp for food. However, the use of the seeds remains traditional and underutilized. The seeds are usually discarded or threaded as anklets for dancing in southern part of Nigeria or to play out door games after which they are thrown away probably due to lack of information on the potential of the seeds, and lack of facilities to process it.

According to Bada (1997), the plant has become a crop of commercial value in Nigeria. Studies reported that the seeds have oil potential for domestic and industrial uses. Thus, it is possible to add value to the seeds by extracting oil from it. In this way, waste is converted to wealth. The knowledge of some physical properties such as unit mass, length, width, thickness, geometric mean diameter, surface area, unit volume, true density, bulk density, porosity, sphericity and other essential engineering data is important in the design of machines, storage structure and processes.

Many researchers have reported physical and mechanical properties of various types of seeds. These include locust bean seeds [*Ogunjimi et al., 2002*], quinoa seeds [*Vilche et al., 2003*], *parkia speciosa seeds [Abdullah et al., 2011],*amaranth seeds [*Abalone, et al. 2004*], caper seeds [*Dursun and Dursun, 2005*], sweet corn seeds [*Bulent Coskun et al., 2006*], cucurbit seeds [*Milani et al., 2007*], jatropha seeds [*Garnayak et al., 2008*], roselle seeds [*Sánchez-Mendoza et al., 2008*], chia seeds [*Ixtaina et al., 2008*], fennel seeds [*Ahmadi and Mollazade, 2009*], arigo seeds [*Davies, 2010*] and nutmeg seeds [*Abdullah et al., 2010*].

The value of this basic information is not only important to engineers but also to food scientist, processors and other scientists who may want to exploit these properties and find new uses *(Işik and Ünal, 2007).*The aim of this work was to determine some physical properties of African star apple seeds which could be useful in facilitating the design of machines to handle, process and store the seeds.

Materials and Methods

Ripe African star apple fruits were sourced from Ganmo market, Ifelodun Local Government Area, Kwara State. The seeds were extracted and method of random sample selection was used in picking out 100 seeds at 35.62% moisture content for this work, each seed was labelled using numerical tags. For each sample, the Major (L), Intermediate (W), and Minor diameters (T) of the seed were measured with Digital Vernier Calliper of±0.01 mm accuracy. The Volume (V) mm^3 for the seeds was determined using water displacement method as described by Dutta *et al*. (1988).

The seeds were weighed and coated with table glue and allowed to dry in order to prevent water absorption. The geometric mean diameter (D_g)*mm*^{3}, arithmetic mean diameter (D_a)*mm.* and surface area*(S) mm*^{2} of the seeds were, respectively calculated using the following equations*(Tarighi et al.,2011)*:

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

$$D_a = \left(\frac{L+W+T}{3}\right) \quad (2)$$

$$S = \pi (D_g)^2 \quad (3)$$

Where: D_g *= geometric mean diameter of seed (mm*^{3}*)*
D_a *= arithmetic mean diameter of seed (mm); S = surface area of seed (mm*^{2}*).*

The used criteria to describe the shape of the seed is the sphericity. Thus, the sphericity (□) was computed as *(Ghamari, 2012)*:

$$\phi = \frac{(L+W+T)^{1/3}}{L} \quad (4)$$

The mass (M) of individual seeds was measured by using a digital weighing scale with ±0.0001 gram accuracy. Seed volumes (mm^3) was measured by water displacement method. Each seed was weighed and placed in water. Mass of water displaced by the seed was recorded. Finally true density ($g.mm^{-3}$) was calculated by using the following equation *(Rafiee et al., 2007)*:

$$\rho_t = \frac{M}{M - M_w}\rho_w \quad (5)$$

Where, ρ_t *is the true density (g.mm*$^{-3}$*),* ρ_w *is the water density (1.05 g.mm*$^{-3}$ *at laboratory temperature); M and* M_w *are mass of seeds and water, respectively.*

Bulk density, ρ_b, is based on the volume occupied by known bulk sample. In order to measure the bulk density, the seeds without any compaction were poured into a calibrated container of known volume. The ratio of the mass and volume was expressed as bulk density *(Koocheki et al., 2007):*

$$\rho_b = \frac{M}{V} \quad (6)$$

Where, ρ_b *is the bulk density (g.mm*$^{-3}$*), M and V are mass of seeds and volume, respectively.*

The porosity (ϵ) was calculated from the measured values of bulk density and true density using the following relationship *(Mohsenin, 1980)*:

$$\epsilon = (1 - \rho_b/\rho_t) \times 100\% \quad (7)$$

Results and Discussion

Size and shape of seeds.

The summary of the statistics are as shown in table 1**,** an African star seed chosen at random will have its *major diameter* ranging between 20.13mm to 26.06mm with mean value of approximately 22.57±0.11mm. The *intermediate diameter* of African star apple ranges between 12.17mm to 15.58mm with mean value estimated at 14.24±0.08mm. While the *minor diameter* ranges from 7.23mm to 9.82mm with an estimated mean of 8.44±0.04mm.The mean values of major, intermediate and minor diameters of the African star apple seed is close to that of *Parkia speciosa* seeds, which was23.20 (±1.13), 17.27 (±0.99) and 9.87 (±0.82) mm respectively according to Abdullah et al, 2011.

The dimensions of *African star apple* seeds were higher than those for cucurbit seeds *[Milani et al., 2007]* and jatropha seeds *[Garnayak et al., 2008]* but lower than fennel seeds *[Ahmadi and Mollazade, 2009]*. Dimensions of the seed are of paramount importance in determining the aperture size of the machine to process the seed. Apart from that, the dimensions could be useful in determining the shape of the seed. These dimensions may also be useful in estimating the size of machine components like the hopper. Since the three semi-axes of the seed are unequal, the shape of *African star apple* seed is considered as scalene ellipsoid.

The geometric mean diameter, sphericity and unit mass and unit volume

The calculated *geometric mean diameter* ranges from 12.65 – 15.09mm^3 with a mean value of 13.94±0.05mm^3. The geometric mean diameter obtained can be used to determine the sphericity of the seeds theoretically.

The mean of *sphericity* of the seeds were 0.16±0.00.It skews to the right i.e positive value (0.03) while the kurtosis is of platykurtic distribution i.e negative value (-0.09).The sphericity was higher compared to fennel seeds *[Ahmadi and Mollazade, 2009]* but lower than amaranth *[Abalone, et al. 2004]* and caper seeds *[Dursun and Dursun, 2005]*. The low sphericity of the seeds indicates that the African star apple seeds are likely to slide on their flat surfaces rather than roll. This parameter is of utmost importance in designing of machine hopper to handle the seeds.

The *unit mass and unit volume* of African star apple seeds are of the mean 0.91±0.01g and 1.99±0.03mm^3 respectively **(*Table1*)**. The mass and surface area skewed to the right i.e positive skewedness (0.52 and 0.23 respectively) and the volume had a negative skewedness (-0.59).Mass, volume and surface area had leptokurtic distribution i.e. positive kurtosis (0.38, 2.04 and 0.30 respectively).With these values, grading, sorting and cleaning machines and sieves can be specifically made for African star apple seeds.

The bulk density, true density and porosity.

The *bulk and true densities* of African star apple seeds at 35.62% moisture content were 0.47 $g.mm^{-3}$ and 9.58 $g.mm^{-3}$respectively. The reported values of true density for quinoa *[Vilche et al., 2003]* and arigo *[Davies, 2010]* are very similar to *African star apple* seed. However, their bulk density was higher compared to *African star apple* seeds. The bigger size of *African star apple* seeds may have contributed to the lower value of the bulk density. The bulk density had the highest positive skewedness (1.60) and leptokurtic distribution (5.04) of the whole parameters examined (Table 1).

This information will be useful in aeration, drying and development of storage facilities for African star apple seeds. The true density of the seed is less than density of water (100 $g.mm^{-3}$), hence, water can be used to convey it or does the separation process from other heavier objects. True density skewed left i.e negative skewedness (-0.40) and a platykurtic distribution i.e negative kurtosis (-0.88). This parameter is very important in determining the storage capacity.

The average *porosity* of the *African star apple* seeds was 75.67±3.92%. This value was found to be close to sweet corn *[Bulent Coskun et al., 2006]* and fennel seeds *[Ahmadi and Mollazade, 2009]* but higher than locust bean *[Ogunjimi et al., 2002]* and chia seeds *[Ixtaina et al., 2008]*. The porosity of seed is important because it shows the resistance of the seeds to airflow during drying process.

Variability and Stability of African Star Apple seeds

Coefficient of Variation (CV) which is expressed as the ratio of standard deviation and mean was estimated for all the physical properties of the seed. This is to enable the investigator measure the variability of the data. Theoretically, when the value of coefficient of variation is higher, it means that the data has high variability and less stability and when the value of coefficient of variation is lower, it means the data has less variability and high stability.

The table shows very minimal coefficient of variation which indicates less variability and high stability for all the physical properties of African Star Apple (Agbalumo) seeds.

Table 1: Summary of results for the Physical Properties of African Star Apple seeds.

Parameter	Mean	Minimum	Maximum	STD	Kurtosis	Skewedness	CV
Major Diameter (L)mm	22.57±0.11	20.13	26.06	1.14	0.17	0.33	0.05
Intermediate Diameter (W) mm	14.24±0.08	12.17	15.58	0.77	-0.08	-0.65	0.05
Minor Diameter (T)mm	8.44±0.04	7.23	9.82	0.43	0.77	-0.11	0.05
AMD(L+W+T/3) (mm)	15.08±0.05	13.83	16.64	0.55	0.15	0.29	0.04
GMD(∛LWT) (mm^3)	13.94±0.05	12.65	15.09	0.49	0.32	0.12	0.03
Unit Mass(g)	0.91±0.01	0.70	1.30	0.11	0.38	0.52	0.12
Unit Volume (mm^3)	1.99±0.03	1.00	2.50	0.29	2.04	-0.59	0.15
Bulk Density($g.cm^{-3}$)	0.47±0.00	0.35	0.80	0.08	5.04	1.60	0.17
True Density($g.cm^{-3}$)	9.58±0.59	0.00	16.80	5.92	-0.88	-0.40	0.62
Surface area((mm^2)	611.03±4.26	502.79	715.75	42.59	0.30	0.23	0.07
Sphericity	0.16±0.00	0.14	0.17	0.00	-0.09	0.03	0.04
Porosity (%)	75.67±3.92	0.00	97.61	39.23	0.09	-1.44	0.52

Inferences

From the analysis of the data measured and calculated, fabricators and processors are provided with adequate information needed for:

(1) The design of equipment for the cracking of the seeds in the process of oil extraction from the cotyledons.
(2) The development of grading, sorting, cleaning and storage facilities specifically for the African star apple seeds and other similar seeds can be done.
It can also be inferred that,

(3) With less variability and high stability of these physical properties in African Star Apple seeds, suitable technology or machines for processing of this very important cash crop can be designed with ease and with a very high optimum efficiency, hence, increasing the production of bio-diesel.

Conclusion

From the inferences drawn, it was concluded that the development of machines and technologies for processing African star apple seeds and other similar seeds is possible in order to add value to the seeds.

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