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Effect of Moisture Contents on Physical Properties of African Breadfruit (*Treculia Africana*)

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Abstract: *Some selected physical properties of African breadfruit (Treculia africana), were determined as a function of moisture content. This research focused on eight physical properties such as weight, linear dimensions, sphericity, angle of repose, aspect ratio, volume, porosity and density of African breadfruit seeds at four different moisture levels: 15.82%, 20.25%, 24.45%, and 28.01% wet basis (w.b). As moisture content rises from 15.82 – 28.01%, the major diameter, intermediate diameter, and minor diameter range from 10.98 – 11.02mm, 6.78 – 6.89mm, and 5.69 – 5.73mm respectively. Arithmetic mean diameter, geometric mean diameter, and equivalent diameter ranged from 7.82 – 7.88mm, 7.51 – 7.58mm, and 2.99 – 3.02mm respectively. Sphericity and aspect ratio increase from 68.00 – 68.80% and 61.74 – 62.62% respectively. It was discovered that the selected physical properties of the seeds increased with increase in moisture content.*

Keywords: Geometric property, Gravimetric property, Moisture content and Sphericity.

Introduction

African breadfruit *(Treculia Africana)*, is a member of the mulberry family found in the tropical areas of Africa (Ojimelukwe and Ugwuona, 2021). Its common name is derived from its big fruit and edible seeds, which can be cooked and consumed as a starch in the same way as actual breadfruit. According to Shafiee, Modares, Mainace, and Heldargili (2019), the seeds are an inexpensive and extremely nutritious source of vitamins, minerals, proteins, carbs, and fat. The seeds are processed into flour, which has a strong potential for use in pastries, and used to thicken soups, make bread, fruit cakes, snacks, and cookies (Aneke, Udorah, and Oshagbemi, 2021). The seeds can also be used as a flavoring in alcoholic beverages and processed to produce edible oil (Aniegboka, Okunola, and Adekanye, 2024).
(Falaye, *et al*., 2019 and Baiyeri, *et al*., 2016) made a non-alcoholic beverage from the species' seeds that was found to be acceptable when consumed without milk and sugar. This gave the species a clear advantage over beverages made from cocoa, given the scarcity and high cost of milk and sugar in rural areas of developing nations.
Both conventional and contemporary medicine employ a variety of Treculia parts and products. The bark is used to cure rheumatism, cough, and neck swelling, while the roots are utilized as a malaria tonic and worm expeller for kids (Okafor, 2015). Additionally, it is utilized to treat gastrointestinal issues, rashes, and mouth-yaw. Rashes are treated using a liquid extract made from cooked leaves. Additionally, fire burns are treated with the sap from the trunk (Ugwoke, *et al*., 2013). It is declared as one of the forest tree species that is of enormous benefit to both rural and urban dwellers. *Treculia Africana* is widely distributed in tropical Africa within the approximate latitudinal range of 15° N to 20° S

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(Onyekwelu and Bernd, 2019). The natural habitat of this plant includes West Africa, Central Africa, East Africa, some tropical parts of North Africa as well as some parts of South Africa(Oyetayo and Oyetayo, 2020). However, this plant has been found to also exist outside its natural habitat range. For example, the species is reported to exist in Sudan and Tunisia where it has been introduced as an exotic species. The survival of this plant in these two countries shows that it can survive within and outside its natural habitat (Onyekwelu and Bernd, 2019).

Treculia africana is a large and giant tree that is capable of attaining a maximum height of 50 m. Although, the mean total height of a mature tree varies between 20 and 30 m. The leaves of this plant are large, having a length of between 15 and 20 cm (maximum of about 50 cm) and breadth of between 7 and 15 cm (maximum of about 20 cm) (Onyekwelu and Bernd, 2019). The heavy, large fruit of this plant is not traditionally harvested but allowed to ripen and drop on its own (Ojimelukwe and Ugwuona, 2021). The tree produces fruits between February and March in Nigeria while it fruits around December in Ghana. However, when the climatic conditions are favorable, collection of fruits is possible throughout the year (Onyekwelu and Bernd, 2019).

The fruit heads of *Treculia Africana* house the plenty and edible seeds. The seeds are light brown in colour and spherical in shape. A mature African breadfruit seed, which is essentially ellipsoidal in shape (Nwigbo, *et al*., 2008), or roughly oval and spherical in shape (Omobuwajo, *et al*., 1999), is made up of an outer covering, the hull and the inner edible endosperm. The seeds have a short shelf life. They can only be stored under low temperature and low moisture content condition. Therefore, the best storage medium is a refrigerator. Other storage media (such as deep freezer, room, e.t.c) have been found to result either in very low germination or lack of germination. Moreover, seeds should not be dried under room temperature or ambient sunny conditions as this caused damage to the embryonic units of the seeds, thus hindering germination (Onyekwelu and Bernd, 2019). However, pre-treatment of the seeds by 15 % NaCl has been found to reduce spoilage by 95 % (Ojimelukwe and Ugwuona, 2021).

Materials and Methods

Sample Collection

African breadfruit seeds were purchased from Oja - Odan and selected portion (plate 1.) was processed experimentally for the research in the Department of Science Laboratory Technology, The Federal Polytechnic, Ilaro, Ogun State. Stones and other extraneous materials were handpicked and the seeds were kept safely in an air-tight container.

Plate 1. A*frican Breadfruit* seeds

Methods

Moisture Content

The moisture content of both wet and dry basis with there respective physical properties were considered using the method described by (Alonge, 2016). The initial weight (W_1) for each sample was measured and recorded before drying. The collected samples were transferred into the oven for 24 hours at 105˚C intervals, removed, and packed in a desiccator, to prevent moisture absorption. After cooling, change in moisture contents was obtained (Tables 1. and 3.), by weighing the selected samples again (W_2). The measured values were recorded till final results were reached. Thus, moisture values were determined using the mathematical expression below:

$$Moisture\ content\ (wet\ or\ dry\ basis) = \frac{\text{initial weight}\,(W_1) - \text{final weight}\,(W_2)}{initial\ weight\,(W_1)} \quad (1)$$

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Physical Properties

Weight

Each of the African bread fruit seed was weighed on electronic weighing balance and the weight of each seed was also recorded for the total of 50 seeds. The formula below was used in calculating the average weight of the seed:

$$Wavg = \frac{\Sigma\,(W_1 + W_2 + \ldots\ldots\ldots\ldots Wn)g}{n} \quad (2)$$

W_{avg} ---------------- Average weight of the seeds

$W_1, W_2 \ldots\ldots W_n$ ----------------- Initial weight to final weight respectively

n ----------------- Total numbers of weight

Linear Dimensions (Major, Minor and Intermediate Diameters)

The dimensions on the three perpendicular axes (major, minor and intermediate) were measured and recorded (Table 3.) using a Vernier caliper with an accuracy of 0.01mm.

Sphericity

The closeness to the sphere of the seed was determined by the equation below:

Mathematically, sphericity, $y = (\frac{abc}{a})^{1/3}$ (3)

where a = major diameter of *Treculia* seed (mm),

b = intermediate diameter of *Treculia* seed (mm) and

c = minor diameter of *Treculia* seed (mm)

Mean Diameters (Geometric & Arithmetic)

The mean diameters of African breadfruit seeds were determined by the equation below:

Determination of the geometric mean diameter (GMD):

$$GMD = (abc)^{1/3} \quad (4)$$

The arithmetic mean diameter (AMD) was obtained from:

$$AMD = \frac{(a+b+c)}{3} \quad (5)$$

Surface Area

The surface area of the seed was determined by selecting recommended seed from the fifty samples and tracing the outline of each seed with a sharp pencil on graph paper. The area of each trace was estimated and averaged.

Volume

The volume of the samples was carefully obtained by the xylene displacement method. Xylene was mixed with the seeds for a period of (2 to 4) seconds. The difference between the weight (W_2) of the (xylene + beaker + seed) and weight (W_1) of (xylene + beaker) was also taken as the weight of the displaced seed. This was divided by the weight density of xylene and the volume of the seed derived.

Mathematically,

$$\text{Volume, } V(cm^3) = \frac{W_2 - W_1 = W_d}{P_w} \quad (7)$$

Density (Bulk and True)

The true density, ρ_t was determined by dividing the seed weight (measured directly from the electronic weighing balance) by the seed volume.

$$True\ density = \frac{Seed\ weight\,(g)}{Seed\ volume\ (cm^3)} \quad (8)$$

The bulk density was obtained by filling an empty cylindrical container of pre-determined volume and weight. The seed was poured continuously from a constant height and the excess on the top of the container was removed by sliding a wooden stick along the top edge of the container.

After the excess had been removed completely, the bulk weight of the seed in the container was measured. This was replicated ten times and the bulk density was computed as the ratio of the bulk weight of the seed to the volume of the container.

$$\rho_b = \frac{W_s - W_c}{V} \quad (9)$$

Where W_s = Weight of container + seed,

W_c = Weight of container,

V = Volume of cylindrical container ($V = \Pi r^2 h$)

where r = radius of cylinder (cm)

h = vertical height of cylinder (cm)

Porosity

The porosity (packing factor) of the seed was determined using the equation below:

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$$P_f = 1 - \left(\frac{\rho_b}{\rho_t}\right) X\ 100\% \quad (10)$$

ρ_t = the density of the seed (g/cm^3)

ρ_b = bulk density of the seed (g/cm^3)

Results

The results of the physical properties of *TreculiaAfricana* seeds are presented in Table 1. Table 2. explained the Axial dimensions of some grouped seeds as a function of moisture content. Thus, the effect of moisture contents on some selected physical properties is presented in Table 3. and Table 4. respectively.

Table 1. Physical properties of African breadfruit seeds.

PROPERTY	MEAN VALUE
Seed gravimetric composition (g)	
Average seed mass	0.13±0.03
Endosperm	0.11±0.02
Hull	0.02±0.03
Axial dimensions (mm)	
Major	9.47±1.19
Intermediate	5.49±0.45
Minor	4.69±0.48
Density characteristics (g/cm^3)	
True density	0.92±0.002
Bulk density	0.61±0.002
Volume (cm^3)	3.22±0.015
Porosity (%)	33.67±0.577
Angle of repose (°)	30.1±0.05
Moisture content variation (%)	15.82 – 28.01

PROPERTY	MEAN VALUE
	Seed gravimetric composition (g)
Average seed mass	0.13±0.03
Endosperm	0.11±0.02
Hull	0.02±0.03

Table 2. Other physical properties of African breadfruit seeds determined.

Physical Properties	Mean Values
Sphericity (%)	66
Aspect ratio (%)	58
Arithmetic mean diameter	6.55
(mm)	2.49
Equivalent diameter (mm)	41.07±0.01
Projected area (mm^2)	6.25
Geometric mean diameter (mm)	122.73±0.01
Surface area (mm^2)	

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Table 3. Axial dimensions as a function of varying moisture content.

	Moisture Content (%)	Major Diameter (mm)	Intermediate Diameter (mm)	Minor Diameter (mm)
A	15.82	10.98	6.78	5.69
B	20.25	11.00	6.79	5.70
C	24.45	11.01	6.80	5.72
D	28.01	11.02	6.89	5.73

Table 4. Some selected physical properties increases with increase in moisture content.

	Moisture Content (%)	Sphericity (%)	Aspect Ratio (%)	Arithmetic Mean Diameter (mm)	Geometric Mean Diameter (mm)	Equivalent Diameter (mm)	Projected Area (mm^2)	Surface Area (mm^2)
A	15.82	68.00	61.74	7.82	7.51	2.99	58.80	177.21
B	20.25	68.40	61.77	7.83	7.53	2.99	59.05	177.92
C	24.45	68.47	62.00	7.84	7.54	3.00	59.32	178.51
D	28.01	68.80	62.62	7.88	7.58	3.02	59.67	180.45

Discussion

Information on the gravimetric composition, axial dimensions, and density characteristics, of the seed, are presented in Table 4.1. The mean major, intermediate,and minor axial dimensions of the seed were found to be 9.47mm, 5.49mm, and 4.69mm respectively. The values obtained are almost following the ones previouslyreported in the literature. Chijioke, *et al*., (2016) derived 9.068mm, 6.422mm, and 5.350mm for the major, intermediate and minor dimensions respectively when they workedonsome selected physical properties of parboiled *TreculiaAfricana* seeds. A slight difference in the values could be a resultof the treatment (parboiling) the seeds were subjected to. Omobuwajo, Akande and Sanni, (1999) also studiedsome selected physical, mechanical, and aerodynamicproperties of African breadfruits and obtained 11.91, 5.69and 4.64mm for the same physical properties listed above. Only the major dimension showed a significant difference but the intermediate and minor dimensions are following the data presented in Table 1.

The axial dimensions of the seeds are vital for some reasons. A knowledge of these dimensions will be useful in determining the aperture sizes in the design of grain handling pieces of machinery. Moreover, the major axis being indicative of the natural rest position of theseedwill be useful in the application of compressive forcetoinduce mechanical rupture of the hull (Omobuwajo, Akande and Sanni 1999).

Sphericity is an expression of the shape of a solid relative to that of a sphere of the same volume while aspect ratio relates the width to the length of the seed and is indicative of a tendency towards an oblong shape (Omobuwajo, Akande and Sanni 1999). The observed sphericity and aspect ratio of 66% and 58% reported in Table 2. are inthe range of those obtained by Omobuwajo, Akande, and Sanni (1999) who reported 60.61% and 51.35% for sphericity and aspect ratio respectively. This sphericityof *Treculia Africana* seeds was found to be significantly higher than that of *Afzelia Africana* seeds reported byOc and Uc (2018) which was in the range of 0.572-0.602% but the difference in the aspect ratio was not much (50.39-50.43%). The value obtained for sphericity is almostunder that of sesame seeds obtained to be 62.84% by Arafa (2007). Sphericity and aspect ratio are properties that are important in the design of hoppers and dehulling equipment.

The gravimetric composition of the African breadfruit seed shows that the average seed mass was 0.13g. this was accounted for by 0.11g of endospermand 0.02g of a hull. This was quite different fromthe average *Treculia* seeds mass reported to be 0.193g by Omobuwajo, Akande, and Sanni, (1999). The average mass of sesame seeds as reported by Arafa, (2007) was 0.01g which is significantly lower than that of African breadfruit seeds. The true density of the African breadfruit seed was found to be 0.92 g/cm^3 (920 kg/m^3) while the bulk density was 0.61 g/cm^3 (610 kg/m^3). This was similar to that of Omobuwajo, Akande, and Sanni, (1999) who obtained 979 kg/m^3 as true density and 614 kg/m^3 as bulk density. These values were higher than that of coriander seeds reported by Balasubramanian, Singh, and Kumar, (2012) who obtained values in the range of 291.89-288.66 kg/m^3 for bulk density and 806.76-797.75 kg/m^3 for true density. The gravimetric and density characteristics of the seeds are quite useful in estimating product yield and throughput.

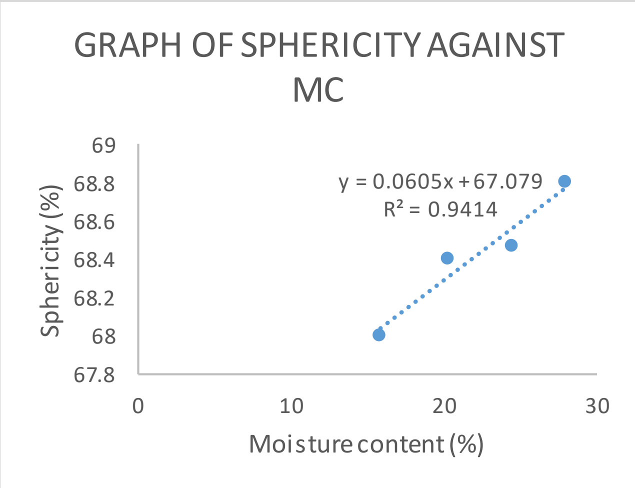

Fig. 1. Graph of Sphericity against Moisture Content (MC).

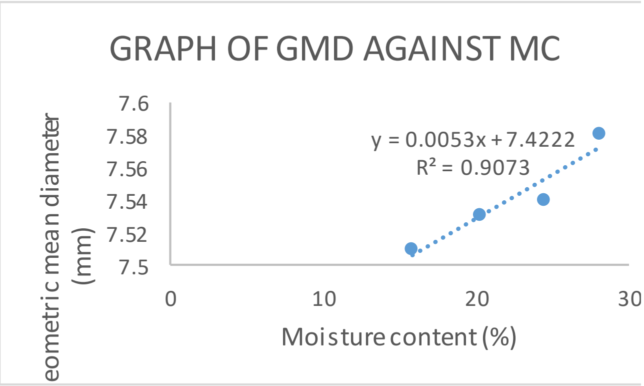

Fig. 2. Graph of Geometric Mean Diameter (GMD) against Moisture Content (MC)

The axial dimensions of *Treculia Africana* seeds increased with an increase in moisture content as presented in Table 3. due to the absorption of moisture, which resulted in swelling of capillaries, stretching of longitudinal ridges on the breadfruit seed surface, and, finally, expansion in medium and minor axes. Similar trends were shown by Balasubramanian, Singh, and Kumar, (2012) for coriander seeds and by Koocheki, *et al*., (2007) for watermelon seeds.

Geometric mean diameter and sphericity (Table 4.) of breadfruit seeds increased linearly from 7.51 to 7.58 mm and 68 to 68.80 % respectively as the moisture content increased and the R^2 values were 0.907 (Fig 1.) and 0.941 (Fig 2.) respectively. This increase was also observed in coriander seeds by Balasubramanian, Singh, and Kumar, (2012) when the moisture content was increased, although the sphericity of coriander seeds ranged from 82.2 to 91.1 % which was significantly higher than that of breadfruit seeds reported. The surface area increased linearly from 177.21 to 180.45 mm^2 with an increase in moisture content from 15.82 to 28.01 %. The same increase with an increase in moisture content was found in a projected area which increased from 58.80 to 59.67 mm^2. A similar trend was also reported (Balasubramanian et al., 2012; Koocheki, *et al*., 2007). An increase in moisture content increased the selected physical properties.

Conclusion and Future Works

The advancement of any food processing technique is a direct function of available data on the physical properties relative to moisture content. This study has shown that an increase in moisture content of *Treculia Africana* seeds increased all the physical properties considered. The physical properties studied: length (major diameter), width (intermediate diameter), thickness (minor diameter), arithmetic mean diameter, geometric mean diameter, sphericity, aspect ratio, surface area, and the projected area will provide useful and fundamental information in agriculture machine design for innovative advancement in post-harvest technology and engineering.

Despite the under-utilization of the African breadfruit despite its traditionally announced food and medicinal advantages, there is a need for the availability of knowledge on the physical properties of the African breadfruit seed. A lack of knowledge of good storage techniques and standard processing procedures has necessitated this research. Therefore, it is recommended that the physical properties of the seeds be determined which could also be useful in the design and development of machines for handling and processing the seeds for future purposes.

Certain farm products need to be re-sized, reshaped, or given special treatment when their physical properties are taken into consideration as this is important to elongate their shelf-life and also attain good storage and preservation, thereby countering the problem of food insecurity.

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