Determination of selected physical properties of *Brachystegia eurycoma* seeds

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Abstract: The research looked at some selected physical properties of *Brachystegia eurycoma*, such as axial dimension, roundness, sphericity, surface area, bulk density, solid density, porosity, and volume which are essential in the design and construction of the processing and handling equipments of *Brachystegia eurycoma*. All the above physical properties measured showed some deviations from the average values which is typical of agricultural biomaterials. Solid density showed the highest deviation of 4.04 g/mm^3 while the volume showed the least deviation of 0.01 mm^3 when compared to those of other physical properties. The angle of repose increased with the increase in the moisture content with a coefficient of determination of 0.98.

Keywords: physical properties; angle of repose; solid density; *Brachystegia eurycoma*

Brachystegia eurycoma (Figures 1 and 2) is an economically very valuable tree crop mostly grown in the tropical rain forest of West Africa. Its uses range from food to medicine. In West Africa, the edible seed is used in soup making as a thickener and is common among the rural dwellers. According to researchers, it helps in maintaining heat within the body when consumed, in other words, it is a good source of nutrient and helps in the control of the body temperature (Onimawo & Egbekun 1998). It is recommended rather for adults than infants, due to its low fiber content. The seeds help in softening bulky stools and have been associated with the protection against colon and rectal cancer; their proximate composition shows that they are a good source of nutrient supplement. Due to their absorption capacity, they are useful as functional agents in fabricated foods such as bakery products and meat formulations. The nutritional value of *Brachystegia eurycoma* (Achi) has been studied by analysing collected sample of this soup thickener for its concentration of carbohydrates, proteins, fat and oil, moisture, ash, and fiber. The result of the analysis showed that its percentage amount of moisture resembles those of other thickeners such as *Draceama fragrance*, *Irvina garbonesis*, *Cucubita pepo* (punkin seed), *Citrulus vulgaris* (melon seed). Chemical analysis showed that the crude protein content of raw seeds ranges from 12.2% to 23.2%, while the fat content varied from 4.9% to 12.0%. The level of phytic acid in the raw seeds (192.4–215 mg/100 g) was found to be lower than that found in some commonly consumed seeds in Nigeria (Oke 1967).

In West Africa and Nigeria in particular, this important seed is subjected to local processing method which includes roasting, boiling, dehulling/shelling, soaking, and size reduction, which is labour intensive, with a low output. The aspect which is of interest to the engineer (food processor) is the physical properties, mechanical properties, electrical properties, and thermal properties. This gives the engineer guidelines for the designing of agricultural machine that will be suitable for the processing of the bio material. Most important among then is the physical property which is the first consideration in the design of the handling and sorting equipment; therefore, the objective of this research is justified.

MATERIAL AND METHODS

Samples sized 20 seeds each were used in the experiments. The samples were thoroughly mixed and stored in a container at room temperature (25°C) to allow a uniform distribution of moisture (Nderika & Oyeleke 2006). The size and principal axes of the seeds (minor, intermediate and major) were determined using a digital caliper of precision

0.01 mm, model Greprufte Sichrhelt (GS) made by Chirist, Germany. The weights of the seeds were also determined using a digital scale of maximum weight of 400 g and approximate error of 0.01 g, model scout Pro SPU 405, made in China. The moisture content was determined using a drying oven of model uniscope SM9023, made in Surgifriend Medicals, England. The angle of repose was determined using a T-square (diamond brand, made in China) and a stainless steel ruler made in Germany. Other materials used were aluminum foil, thermometer, calibrated beaker, and electric boiling ring of 1 000 W and 220 V.

Moisture content

In order to obtain different levels of the moisture content, the samples were conditioned by soaking in water at different time limits. The weights of the samples were taken individually and recorded, then an empty can was weighed, and the can and the samples were also weighed. The seeds were oven dried at a temperature of 105°C for 24 h, according to ASAE Standard S358.2 (1983).

Roundness

The trace projected out of each seed was used to estimate its roundness. This was done by drawing a circle circumscribing the traced projection boundary and the area of the circle was estimated. The trace of the seed was done on graph paper, the area was estimated by counting the squares, and the total number of squares was multiplied by the area of each of the square to get the total area of the projections. In the end, the roundness was determined using the relationship:

$$\text{Roundness} = \frac{AP}{AC} \quad (1)$$

where:
AP – largest projected area of the seed in rest position
AC – area of smallest circumscribing circle (Mohsenin 1970)

Sphericity

The sphericity was determined, given that the volume of the seed is equal to the volume of the triaxial ellipsoid with intercepts, *a*, *b*, *c* which represent the major, minor and intermediate diameters, respectively, which can also be referred to as the length, width, and thickness. The degree of sphericity can be expressed using the relationship:

$$\text{Sphericity} = \sqrt[s]{\frac{bc}{a^2}} \quad (2)$$

where:
a – longest intercept
b – longest intercept normal to a
c – longest intercept normal to a and b

Surface area

A paper foil was used to determine the surface area of the seed, 20 seeds each having been selected at random. The seeds were carefully wrapped in foil paper, and then the boundary of the seeds as seen on the foil paper was cut and placed on graph paper and traced with pencil. The surface area of the seed was then determined by counting the number of square boxes the traced boundary covered on the graph and multiplying by the area of the box.

Volume

The volume of the seed was determined using Archimedes's principle as was described by Nelkon (2005). Twenty samples of the seeds each were weighed and immersed in a measuring cylinder containing a known volume of water. From the level of the water was subtracted the initial level, the difference between the new level of water in the measuring cylinder and the initial volume of water is the volume of the seed which is now recorded.

Bulk density

Density of the seed was also determined using Archimedes's principle as described by Nelkon (2005) as follows:

$$\text{Density} = \frac{\text{mass}}{\text{volume}} \quad (3)$$

The weights of 20 seeds sample were taken using a weighing scale and recorded, the volume as already determined using Archimedes' principle was also recorded and the density was obtained from Eq. (3).

Solid density

Solid density determination was carried out using a specific gravity bottle. This was carried out by first weighing the empty density bottle, followed by filling the bottle with a sample of seeds and then weighing again. The bottle was then filled up with water and weighed, and finally the bottle was weighed containing water only. The solid density of the material was determined using the following equation as described by Okeke and Anyakoha (1987).

$$\text{Solid density} = \frac{M_2 - M_1}{(M_4 - M_1) - (M_3 - M_2)} \quad (4)$$

where:

M_1 – weight of the empty density bottle (g)
M_2 – weight of the empty density bottle with a seed sample (20 seeds)
M_3 – weight of the density bottle filled with water and seeds (g)
M_4 – weight of the density bottle containing water only (g)

Bulk porosity

Bulk porosity was determined using the density (bulk and solid) parameters as described by Mohsenin 1970.

$$\text{Porosity} = \left(1 - \frac{\text{bulk density}}{\text{solid density}}\right) \times 100 \quad (5)$$

Angle of repose on stainless steel

This was carried out using a T-square and a stainless steel meter rule. The seeds were placed on the stainless steel meter rule which is placed on the T-square; the meter rule was allowed to lie slanting on the T-square which was held at an angle of 90°. Then the meter rule was tilted until the seed began to slide (flow) freely, the angle the ruler makes with the T-square at the time of free flow was taken as the angle of repose of the seeds on the stainless steel. This procedure was repeated five times for seeds at different moisture contents to ascertain the mean angle of repose of the seeds.

Specific gravity

The specific gravity of the seed is determined by using water displacement method given by the relationship:

$$\text{S.g.} = \left(\frac{\text{weight in air}}{\text{weight of the water displaced}}\right) \times \text{s.g. of water} \quad (6)$$

The seeds were weighed and then poured into a measuring cylinder with a known volume of water, the level of the displaced water and the difference is recorded. The ratio of the weight of the object in air to the weight of displaced water was multiplied by the specific gravity of water.

RESULTS AND DISCUSSIONS

Table 1 shows that there were deviations in all the measured parameters but the most significant deviation was found for solid density with the standard deviation of 4.04 g/mm^3 while the least significant was the volume with a standard deviation of 0.01 mm^3. The higher deviations in solid density can

Table 1. Variations in the physical properties of *Brachystegia eurycoma*

Parameters	No. of samples	Mean value	SD
Roundness	20	1.41	0.25
Major diameter (mm)	20	21.78	1.33
Minor diameter (mm)	20	17.58	1.01
Thickness (mm)	20	3.73	0.034
Sphericity	20	0.52	0.02
Surface area (cm^2)	20	6.66	1.36
Bulk density (g/mm^3)	20	1.22	–
Solid density (g/mm^3)	20	63.20	4.04
Porosity	20	80.90	1.21
Moisture contene (%) db	20	12.90	–
Volume (mm^3)	20	0.01	0.01
Angle of repose on stainless steel (°)	20	21.50	1.96

SD – standard deviation

Figure 1. *Brachystegia eurycoma* (undehulled)

Figure 2. *Brachystegia eurycoma* (dehulled)

be attributed to the variations in axial dimensions. For engineering design, the mean values might be appropriate. Figure 3 shows the relationship between the angle of repose and moisture content. The angles of repose increased with the moisture content. This is an important factor in hopper design for the seed processing. The relationship revealed a very high R^2 value of 0.988, which implies that R^2 value fits well with the moisture content data. However, since the physical properties of biomaterials are somehow inter related, the moisture content will also affect other physical properties of *Brachystegia eurycoma.* The best fit equation for the moisture content and angle of repose is given by:

$$\%mc = 0.723A - 2.714 \quad (7)$$

where:

A – angle of repose on stainless steel

CONCLUSION

The research looked at some selected physical properties of *Brachystegia eurycoma*, such as axial dimension, roundness, sphericity, surface area, bulk density, solid density, porosity and volume which are essential in the design and construction of the processing and handling equipments of *Brachy-stegia eurycoma.* All the above physical properties measured showed some deviations from the average values which is typical of agricultural biomaterials. Solid density showed the highest deviation of 4.04 g per mm^3 while the volume showed the least deviation of 0.01 mm^3 when compared to those of other physical properties. The angle of repose increased with the increase in the moisture content with a coefficient of determination of 0.988. For engineering design, the consideration of the above conclusions might be adequate.

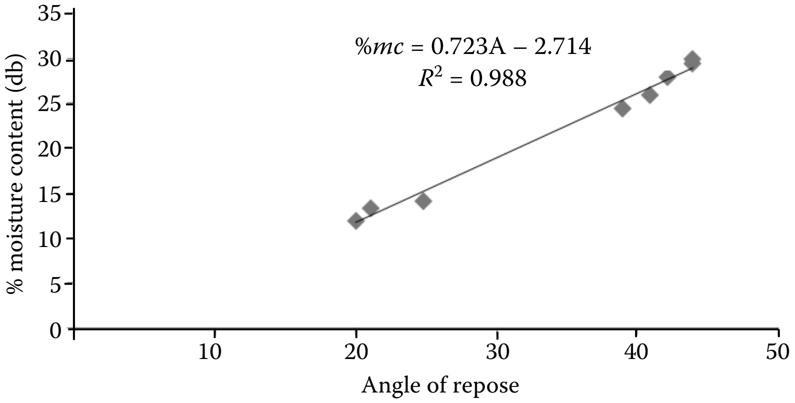

Figure 3. Effects of moisture content on the angle of response on stainless steel

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Abstrakt

Ndukwu M.C. (2009): **Stanovení vybraných fyzikálních vlastností semen stromu *Brachystegia eurycoma*.** Res. Agr. Eng., **55**: 165–169.

Ve výzkumu se sledovaly vybrané fyzikální vlastnosti semen stromu *Brachystegia eurycoma*, a to axiální rozměry, kulatost, sféričnost, plocha povrchu, hustota, porozita a objem, které jsou významné pro návrhy a konstrukci zpracovatelského zařízení. Naměřené fyzikální vlastnosti ukázaly ve všech případech odchylky od průměrných hodnot, jak je typické pro agrikulturní biomateriály. Největší odchylka byla nalezena u hustoty, a to 4,04 g/mm^3, nejmenší u objemu, 0,01 mm^3. Klidový úhel (úhel sesuvu) se zvyšoval s růstem obsahu vlhkosti při determinačním koeficientu 0,98.

Klíčová slova: fyzikální vlastnosti; klidový úhel (úhel sesuvu); hustota; *Brachystegia eurycoma*

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