# Studies on Some Physical Properties of Dikanut Seeds

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**Abstract**
The physical properties of dikanut seeds sold in Nigerian markets were determined. The dried seeds were evaluated for the principal dimensions, weight, volume, true density, bulk density, and porosity, angle of repose, static coefficient of friction and specific heat capacity. The average three principal dimensions were 2.375, 1.592 and 0.778cm. The seeds had an average weight of 1.904g, volume of 2.38cm$^3$, density of 0.832g/cm$^3$, bulk density of 0.475g/cm$^3$, porosity of 43%, and surface area of 3.468cm$^2$. Angle of repose and coefficient of friction varied quadratically with moisture content. The specific heat capacity of dikanuts was measured at four moisture contents and eight temperatures. The specific heat of dikanut varied from 1.9333J/g˚C to 6.075J/g˚C for moisture contents between 3% and 30% and those that were used to model multiple simple regression equations expressing specific heat as a function of moisture content.
**Key words**: Dikanut, seed, dimension, specific heat capacity

## 1. Introduction

Dikanut is the seed obtained from the fleshy fruit of Irvingia Gabonesis and is locally known as 'apon' in Yoruba land (Adeboye and Bello, 1998). The freshly harvested seeds are dried and sold openly in most Nigerian markets. The dried seeds are comminuted and used in the formulation of recipe for 'ogbono' soup in the southern part of Nigeria (Oguntona et al., 1999). Though dikanut is readily available in the market, its demand is always high. This has however, resulted to high selling price of dikanut (Anegbeh et al., 1996). As a result of high nutritional and economic value of dikanut (Ejiofor, 1994) coupled with a bid to bring about reduction in the market price, there are efforts to increase its production through intensive cultivation (Adeboye, 1997).

Since the physical properties of dikanut seed are the prerequisites for the design of equipment for handling, dehulling and other processes, it is essential to determine these properties. The objective of this study was to determine some of the physical properties of dikanut seed at safe storage moisture content, namely: sphericity dimensions, volume, surface area, true and bulk density, porosity, static coefficient of friction against different materials, angle of repose, specific heat capacity.

## 2. Materials and methods

A batch of 25kg of dikanut was obtained from several sources and thoroughly mixed together. All the samples were mixtures of different varieties. Manual sorting was done to remove the broken ones; the seeds were screened and air-blown to free them from any adhering particles. The batch was sun-dried to equilibrate the moisture content. The seeds were packed in double-layered low-density polyethylene bags and stored at 4˚C for 7days before starting the experiment. For each test, the required quantity of seed was taken out and allowed to warm up for about 2hours.

About 10g of the samples was placed in a hot air oven at 100˚C for 36 hours (Oje and Ugbor, 1991) and then cooled by placing in a desiccator, weighed and the moisture content of the seed calculated.

### *2.1 Seed Dimensions*

One hundred seeds were randomly selected from 25kg sample. Measurements were made of the seed dimension on three mutually perpendicular axes, namely: major, intermediate and minor diameters. These dimensions were measured with a micrometer (reading up to 0.01mm)

 

*2.2 Mass, Volume, Surface Area and Sphericity*

To determine the sphericity, each seed was placed in its natural resting position on a sheet of graph paper. A sharp thin pencil was used to carefully trace the edges of the seed. The projected area and the diameters of various circles inscribing and circumscribing the projected area were measured.

*Sphericity = di/dc ………………………….. (1)*

Where $d_i$ = diameter of largest inscribing circle
$d_c$ = diameter of smallest circumscribing circle

The surface area of the seed was determined by first coating the surface on a light sensitive paper. The edges on the paper were then traced on the graph paper. The surface was measured by counting the number of squares with the traced marks (Oje and Ugbor, 1991)

The volume was determined by the water displacement method as described by Dutta et al, 1988. 20 seeds were dropped into a can filled with water and the quantity of water displaced was weighed.

*2.3 True and Bulk Density and Porosity*

The volume of water displaced per seed was thus calculated and hence the density of the seed. 250 seed sample was filled into a volumetric flask, tapped five times to allow the seeds settle well in the flask. After initial settling, the vessel was further filled with more seeds and tapped three times again. A sharp edge flat was used to remove excess seeds to level the surface at the top of the vessel. The volume of the vessel had previously been determined and recorded. The seeds were weighed and the bulk density calculated (Jain and Bal, 1997). Porosity is the percentage of volume of voids in the test sample at a given moisture content. It was calculated as ratio of the difference in the seed and bulk densities to seed density, determined by the expression:

Porosity % = (1 – [bulk density/true density]) x 100…….. (2)

*2.4 Dynamic Angle of Repose*

A plywood box 200 x 200 x 200m, having a removable front panel was used. The box was filled with the sample, and then the front panel was quickly removed, allowing the seeds to flow and assume a natural slope. The angle of repose (A) was calculated from the measurement of the depth (H) of free surface of the sample at the center (D) of the heap (Joshi, et al., 1991) using the following expression:

$A = \tan^{-1}(2H/D)$………………………… (3)

*2.5 Static coefficient of friction*

The static coefficient of friction for the seeds was determined against three structural materials, namely: plywood with the seeds parallel to the direction of motion, plywood with the seeds perpendicular to the direction of motion and galvanized iron sheet. A topless and bottomless galvanized iron box of 120mm x 80mm x 32mm was filled with the seeds and placed on an adjustable titling surface. The structural surface, with the box on it, was raised gradually with a screw-driver device until the box started to slide down and the angle of tilt was read from a graduated scale (Oje and Ugbor, 1991).

*2.6 Specific Heat Capacity*

An adiabatic drop calorimeter was used to determine the specific heat capacity by the method of mixtures (Fraser, et al, 1978). When the temperature of the water (150ml) and cylinder had equilibrated to the required temperature (20$^o$C, 30$^o$C, 40$^o$C, 50$^o$C, 60$^o$C), a 10g sample was placed in the cylinder then covered with the calorimeter lid. Dikanut seeds at various moisture contents were used for the specific heat determination. The final temperature at equilibrium was noted. Specific heat, $C_s$, was calculated by the expression:

$$Cs = Cw\,\frac{Cw}{Ms}\left(+\frac{Twi-Tt)}{(Tsi-Tt)}\right.$$

Where Cs = the specific heat capacity of the seed
$C_w$ = specific heat of water
$M_s$ = mass of seeds

 

$M_w$ = mass of water
$T_{wi}$ = Initial water temperature
$T_{si}$ = Initial temperature of seeds
$T_t$ = final temperature of mixture

## 3. Results and discussion

A summary of the results for all the parameters measured is shown in Table 1. The major diameter is in the range 15.4mm-31.9mm with a mean diameter of 23.75mm. More than 60% of these dimensions lie between 22mm and 26mm. About 50% of the seeds have their intermediate diameters in between 14mm and 16mm with a mean diameter of 15.92mm. 55% of the seeds have their minor diameters in between 7.4mm and 8.4mm with a mean diameter of 7.76mm. Generally the seeds with the largest principal dimension usually have high intermediate and minor diameters. However, these dimensions are smaller than what Oje and Ugbor (1991) observed for the three-axis dimensions of oil bean seed. The variation could be attributed to different in moisture content of dikanut and oil bean seeds. Since moisture content leads to significant ($p<0.05$) increase in the geometric means dimension of seeds.

### *3.1 Mass, Volume, Surface Area and Sphericity*

At the moisture content of 4%, the 1000seed weight gave a mean value of 1.904kg with a standard deviation of 0.246kg. This seed is greater when compared with pumpkin seed weight (0.173 at a moisture content of 7.5%) and Gram seed weight (0.173 at a moisture content of 17.3%) as reported by Joshi et al (1993(and Dutta et al (1988) respectively. The average seed volume was 2.38cm3 (Table 1). About 75% of the seed volume lies between 2.0cm3 and 2.5cm3. If the volume of the seed is calculated by assuming it to be an equivalent sphere whose diameter is the arithmetic mean of the three principal dimensions of the seed, then the volume is predicted to be higher by 30% but is reduced by 35% if geometric mean is used for the computation of the seed volume. The seed volume is higher than that of pearl millet but lower than that of oil bean seed (Jain and Bal, 1997; Oje and Ugbor, 1991).

The surface area of the seed averaged 3.468cm$^2$. More than 50% of the seeds have their surface area between 3cm2 and 4cm2. The surface area of dikanut was smaller than that of oil bean seed (40cm2) and greater than that of pearl millet (0.125cm2). Surface area is a relevant tool in determining the shape of the seed.
The sphericity of the seed was found to be 0.652. More than 90% of the seeds have sphericity less than 0.76. This explains the difficulty in getting the seeds to roll when placed on a particular orientation.

### *3.2 Density and Porosity*

More than 90% of the seeds have true densities between 0.6g.cm-3 and 1.0g.cm-3. Since the major component of the seeds is lipid (about 70%) (Okolo 1994). This physical characteristic is exploitable in separating the seeds from other denser unwanted materials. The bulk density gave a mean value of 0.475g.cm-3. The percentage porosity of the seeds was 43%. This was found to show the same variation as pearl millet (45%-49%)(Jain and Bal, 1997).

### *3.3 Frictional Properties*

The static coefficient of friction for the seeds was determined with respect to plywood and Iron varied between 0.445 and 0.549. Maximum coefficient of friction was obtained for the plywood with the seeds perpendicular to the direction of the slide and minimum against the galvanized iron. The static coefficient of needed to be recast friction for dikanut is higher than those of oil-bean (Oje and Ugbor, 1991) and pearl millet (Jain and Bal, 1997). It was found that the static coefficient of friction for dikanut increased with moisture content on all the three structured surfaces. The variation in values could be attributed to the various surfaces used. These values are needed in the design of agricultural machine hoppers and other conveying equipment. It determined how a pack of grain or seed will flow in these systems. The angle of repose of dikanut varied between 27.6 to 32.5$^o$. It was observed that the angle of repose increased with increase in moisture content. This could be due to their sphericity of the samples. The frictional properties were analyzed and five equations, viz; quadratic, linear, power, logarithmic, and exponential, were tested for the best fit of the data. Among these, the quadratic form of the equation was found to be the best with the correlation coefficient more than 0.98. The equations are given through equations 5 – 8.

Coefficient of friction on plywood with seeds parallel
$F_c = 0.4855 + 6x10^{-4}M + 4x10^{-6}M^2$………………………………….. (5)
Coefficient of friction on plywood with seeds perpendicular
$F_c = 0.5218 + 7x10^{-4}M – 3x10\text{-}6M^2$………………………………… (6)
Coefficient of friction on galvanized iron sheet
$F_c = 0.4774 + 2x10^{-6}M^2$………………………………………………… (7)
Where $f_c$ is the coefficient of friction
Angle of repose (a)
$a=26+0.3662M – 4x10^{-4}M^2$…………………………………………… (8)

*3.4 Specific Heat Capacity*
The specific heat capacity of the seed was determined for four moisture contents and five different temperatures. The specific heat capacity ranges from 1.933J/g˚C for moisture contents between 3% and 30%. (Oje and Ugbor (1991) reported a similar high range of specific heat for oil bean seed (2.14J˚C to 5.32J/g˚C). The specific heat capacity of the seed did not follow a particular trend. It increased with an increase in temperature up to 15$^o$c, then decreased up to 25˚C, then increased up to 40˚C and finally decreased with further temperature increases at all moisture levels considered in this study. This behavioral trend may be connected with the plethora of fatty acids constituents present in dikanut seed (Okore and Udeata, 1997) with a variable melting and yield point values.

The temperature at which the highest specific heat value was obtained varied for different moisture contents but lied in-between 35˚C and 40˚C. While Muir and Viravanichai (1971) generated multiple quadratic regression equations to describe the effects of temperature and moisture content on specific heat, Fraser et al (1978) generated multiple linear regression equations to describe the effect of moisture content at various temperatures. The multiple simple regression equations modeled for each temperature predicting specific heat as a function of the corresponding moisture contents of dikanut seeds between 3% and 30% moisture content. The correlation coefficient ranges from 0.55 to 0.98. At 40˚C the large increase in the slope of the regression equation, compared with the other temperature range, is probably due to the effect of the heat of fusion of the fatty acid components that liquefy within this temperature range.

## 4. Conclusion
The average length, width and thickness of market grade halves dikanut seed was 2.375, 1.592 and 0.778cm respectively. The average seed volume was 2.38cm$^3$ and average seed weight was 1.904g. Average surface area was 3.468cm$^2$. Average seed density was 0.833g/cm3 and the bulk density was found to be 0.475g/cm$^3$. Porosity and sphericity were 43% and 0.652 respectively. Angle of repose and coefficient of friction of dikanut varied quadratically with moisture content. Specific heat capacity of the seed was modeled by multiple simple regression equations expressed as a function of moisture content of the seed.

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**Table 1: Some Physical Properties of Dikanut Seeds**

| **Physical property** | **No of observation** | **Mean Value** | **Min. value** | **Max. value** | **Standard deviation** |
|---|---|---|---|---|---|
| Length (cm) | 100 | 2.375 | 1.54 | 3.190 | 0.239 |
| Width (cm) | 100 | 1.592 | 1.09 | 2.10 | 0.173 |
| Thickness (cm) | 100 | 0.778 | 0.56 | 0.98 | 0.088 |
| Surface area ($cm^2$) | 100 | 3.468 | 2.25 | 5.625 | 0.775 |
| Sphericity (g) | 100 | 0.652 | 0.379 | 0.833 | 0.083 |
| Weight (g) | 20 | 1.904 | 1.194 | 2.424 | 0.246 |
| Volume ($cm^3$) | 20 | 2.38 | 1.80 | 4.00 | 0.644 |
| Density ($g/cm^3$) | 10 | 0.833 | 0.578 | 1.034 | 0.136 |