Determination of physical and aerodynamic characteristics of African olive (*Canarium Schweinfurthii)* nut

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Abstract: This study investigated the physical and aerodynamic properties of African olive (*Canarium schweinfurthii)* nuts. The nut mass frequency was identified and three fractions of the nut namely, I (unit mass <2.30 g), II (2.30 g ≤ unit mass ≥ 3.00 g) and III (unit mass >3.00 g) were defined to determine their properties. Generally, it was observed that the physical and aerodynamic characteristics of the nut were significantly influenced (p<0.05) by the unit mass. Comparison of means revealed that the mean values of the nut physical and aerodynamic properties were significantly different between the nut fractions at p<0.05 except for the true density which ranged from 1.20 to 1.22 g cm^{-3}. The static angle of repose appeared higher than the dynamic angle of repose for all the nut fractions. The coefficient of static friction of the nut fractions I, II, and III on different material surfaces was highest on plywood (ranged from 0.61 to 0.66) and lowest on Formica® (ranged from 0.37 to 0.44). High positive correlation was recorded for the terminal velocity (R^2 = 0.94) and Reynolds number (R^2 = 0.95) in relation to unit mass of the nut. The results of this study are important in the design of handling, and processing systems for *Canarium schweinfurthii* nuts.

Keywords: *Canarium schweinfurthii* nut, physical properties, aerodynamics properties, models

Citation: Obi, O. F., N. C. Ijere, and M. E. Okechukwu. 2018. Determination of physical and aerodynamic characteristics of African olive (*Canarium Schweinfurthii*) nut. Agricultural Engineering International: CIGR Journal, 20(3): 172–179.

1 Introduction

Canarium schweinfurthii commonly referred to as African olive is a tall forest tree found throughout African tropical rain forest. The tree grows flowers in clusters at the end of the twigs, and the flowers are small and dark green in colour. The tree produces its fruits in the rainy season usually between the months of April and September. The tree fruit is similar in appearance to olives, green in colour, becoming red-purple when fully mature (Georges et al., 1992). It contains a single multi-angular shaped nut with small projections at the edges. The slightly greenish outer pulp of the fruit may be eaten raw or softened in warm water to improve its palatability. It is sometimes prepared into vegetable-butter and eaten as a substitute for Shea-butter (Kochar, 1981). The pulp contains several fatty acids including oleic (36%), linoleic (28%), palmitic (26%) and stearic (7%) (Georges et al., 1992; Agu et al., 2008). The fruit is best stored under cold storage; preventing microbial growth and moisture loss that may result in shrinkage of the fruit surface thus reducing its aesthetic value. Although many studies have been carried out on the fleshy part of the tree fruit, little is known about the multi-angular shaped *Canarium schweinfurthii* nut. Bassey et al. (2015) reported the potential of the nut as a heavy metal absorbent. Locally, the nut has been used as a source of feed supplement for livestock when dried and ground into fine particles. In addition to that, local women have also used it as a source of fuel for heating purposes.

In the determination, evaluation and optimization of biomaterials such as seeds, nuts, fruits, etc. as a useful end-product, determination of their properties is a requirement (Penci et al., 2013; Babic et al., 2013; Kareem et al., 2013). Such properties include the physical, mechanical, chemical, sensory and aerodynamic

Received date: 2017-11-26 **Accepted date:** 2018-08-19

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properties. These properties affect the cleaning, grading, drying, packaging, storage, aeration, and discharge of the material. Several studies have been published on different properties of biomaterials such as coconut (Chantaro et al., 2016), durian and lai (Belgis et al., 2016), wild mustard (Shahbazi, 2013), and Makhobeli, triticale and wheat seeds (Shahbazi et al., 2014), and cocoa beans (Abhay et al., 2016). However, there is no published information on the physical and aerodynamic properties of *Canarium schweinfurthii* nuts.

The objective of this study was to investigate the physical and aerodynamic properties of *Canarium schweinfurthii* nut. The properties considered were nut size, arithmetic and geometric diameter, sphericity, unit volume, unit mass, one thousand nut mass, bulk and true density, porosity, surface area, specific surface area, aspect ratio, angle of repose, static friction angle, coefficient of static friction, terminal velocity, projected area, drag coefficient, and Reynolds number. The selection of a method for the determination of the properties was based on simplicity, accuracy of results and wide acceptability in relevant literature.

2 Materials and Methods

2.1 Material preparation

About 17 kg of *Canarium schweinfurthii* fruits were obtained from a local farmers' market, in Enugu state, South-east Nigeria. The fruits were manually cleaned and soaked in warm water (70^{o}C) for about 1 to 2 hours (Georges et al., 1992) to remove the outer pulp after which the nuts were dried in open air. The mean moisture content in wet basis (% w.b.) of the nuts after drying was determined to be 7.48%±0.33% w.b using oven dry method set at a temperature of 103°C±2°C until a constant weight was reached (Kashaninejad et al., 2005).

2.2 Experimental design

About 6 kg of *Canarium schweinfurthii* nuts were randomly selected from a bulk of about 11 kg nuts. The 6 kg sample consisted of 2,410 *Canarium schweinfurthii* nuts, which were weighted individually with an experimental balance (SHIMADZU BZ 32 OH, Japan) having an accuracy of ±0.001 g. The nut mass frequency distribution was drawn in the form of a histogram and three fractions of the nut were defined according their unit mass *m* (Figure 1).

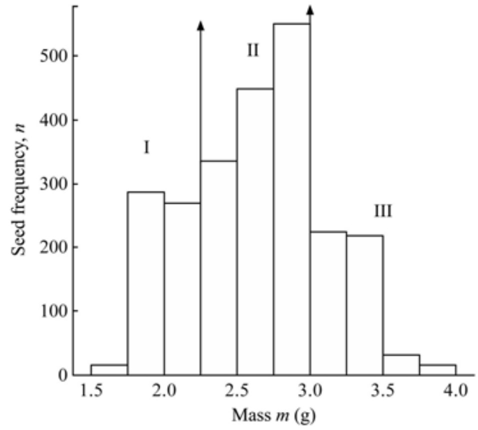

Figure 1 *Canarium schweinfurthii* nuts mass frequency (n=2410) for three fraction, sizes: (I) m<2.30 g, (II) 2.30 g ≤m≤3.00 g, and (III) m>3.00 g

The first fraction, I was all nuts with unit mass less than 2.30 g, the second fraction, II were all nuts with unit mass greater than or equal to 2.30 g, and less than or equal to 3.00 g, and the third fraction, III were all nuts with unit mass greater than 3.00 g (Figure 2).

(a) Fraction I (m<2.30 g) (b) Fraction II (2.30 g ≤m≤ 3.00 g)

(c) Fraction III (m> 3.00 g)

Figure 2 *Canarium schweinfurthii* nut fractions

2.3 Determination of the physical properties

The size of the *Canarium schweinfurthii* nut fractions was determined being an important variable in biomaterial processing (Suthar and Das, 1996). The physical dimensions of the nuts were determined by randomly picking 100 *Canarium schweinfurthii* nuts from each of the fractions and measuring the nut length *a*, width b, and thickness c, using a SKOLE digital vernier calliper with an accuracy of 0.001 mm. The ratio of the nut dimensions was determined and the relationships existing among them established. Geometric mean diameter D_g, mm, arithmetic mean diameter D_a, mm, and the degree of sphericity $Ø$ of the nut fractions were calculated using the equations in Mohsenin (1986) and Jain and Ball (1997). The unit volume V_u (cm^3) of the nuts was determined based on the assumption that *Canarium schweinfurthii* nuts were similar to a scalene ellipsoid where $a > b > c$. The formula was derived from the scalene ellipsoid volume as follows (Mohsenin, 1980):

$$Vu = \frac{4}{3}\pi(a \cdot b \cdot c) / 1000 \tag{1}$$

To obtain the 1000 nut mass, 250 *Canarium schweinfurthii* nuts were randomly selected from each of the nut fractions, weighed using a precision electronic balance (SHIMADZU BZ 32 OH, Japan) reading to an accuracy of 0.001 g and then multiplied by 4 to obtain the 1000 equivalent (Aghkhani et al., 2012). The bulk density ρ_b, was calculated as the ratio of weight of the nuts in a cylinder to the volume of the cylinder (Sharma et al., 2011). In calculating the true or solid density, the unit mass of each nut sample was determined using an electronic balance reading to an accuracy of 0.001 g and the particle volume V_u (cm^3) determined using the toluene displacement method (Zare et al., 2013). The true density was defined as the ratio of mass of the sample to its true volume. The porosity (ε) which indicates the number of pores in the bulk material was determined in relation to the bulk density (ρ_b) and the true density (ρ_t) (Garnayak et al., 2008).

Approximate surface area, S (mm^2) of the nuts was determined by approximating its shape by prolate ellipsoids (Mohsenin, 1980; Sirisomboon et al., 2007; Karaj and Müller, 2010):

$$S = 2\pi\left(\frac{b}{2}\right)^2 + 2\pi \cdot \frac{a \cdot b}{4d} \cdot \sin^{-1} d \tag{2}$$

where

$$d = \left[1 - \left(\frac{b}{a}\right)^2\right]^{1/2} \tag{3}$$

The specific surface area, S_s (cm^2 cm^{-3}) of the nuts was calculated as follows (Karaj and Müller, 2010):

$$S_s = \frac{s \cdot \rho_b}{m} \tag{4}$$

where, m is the mass in g of one unit of the nut. The aspect ratio (R_a) was calculated as follows (Tabatabaeefar, 2003):

$$R_a = \frac{b}{a} \cdot 100 \tag{5}$$

2.4 Determination of the frictional properties

The angle of repose indicates the cohesion among individual units of a material; the higher the cohesion, the higher the angle of repose (Karaj and Müller, 2010). The angle of repose for the *Canarium schweinfurthii* nut fractions was determined on four different structural materials namely, Formica®, rubber, Aluminium, and plywood, using two methods: (i) the filling method, to determine the static angle of repose and (ii) the emptying method, to determine the dynamic angle of repose.

For the filling method, the methodology described by Milani et al. (2007) was used while for the emptying method, a bottomless cylinder (12 cm diameter, 8 cm height) was used. The cylinder was placed over a material surface and *Canarium schweinfurthii* nuts were filled in. The cylinder was raised slowly allowing the sample to flow down and form a natural slope (Garnayak et al., 2008). The dynamic angle of repose was calculated from the height and diameter of the pile as:

$$\theta_d = \tan^{-1}\left(\frac{2h}{D}\right) \tag{6}$$

where, θ_d is the dynamic angle of repose (^{o}); h is the height of the pile (cm) and D is the diameter of the pile (cm).

The static coefficient of friction (μ_s) of the nut fractions was determined on four different structural surfaces namely, Formica®, rubber, Aluminium, and plywood using the inclined plane method described in Dutta et al. (1988). The static friction angle (α) was read from a graduated scale and the tangent of this angle was recorded as the static coefficient of friction on that surface.

$$\mu_s = \tan\alpha \tag{7}$$

2.5 Determination of the aerodynamic properties

The terminal velocity of *Canarium schweinfurthii* nut fractions was determined using equipment that consists of a vertical cylindrical wind tunnel made of Plexiglas, connected to a 1 hp motor-powered centrifugal fan to supply air flow into the wind tunnel. A wire screen was positioned in the top section of the vertical wind tunnel to prevent the nut from falling down to the bottom. The air flow rate of the fan was controlled at the bottom section of the wind tunnel using an adjustable diaphragm. A perforation was made on the Plexiglas just above the wire screen where a hot-wire probe of a digital anemometer (TPI 565C1) was inserted to measure the terminal velocity of the nuts.

To measure the terminal velocity for each of the nut fractions, the nut was placed on the wire screen within the cylindrical wind tunnel. The air flow from the centrifugal fan was then increased until the nut was suspended in the air stream within the wind tunnel. At the point when the rotational movement of the nut was lowest, the air velocity was measured (Shahbazi et al., 2014) using the digital anemometer measuring to an accuracy of 0.1 m s^{-1}. The probe of the hot-wire anemometer was inserted into the air stream through the perforation on the wind tunnel to measure the air velocity near the location of the suspended nut.

For an object in a free fall, the object will attain a constant terminal velocity (V_t) at which the net gravitational accelerating force (F_g) will equal the resisting upward drag force (F_r) (Mohsenin, 1986). To derive a general expression for the terminal velocity, the gravitational force (F_g) is set equal to the resisting drag force (F_r) and the velocity V, equalled to the terminal velocity V_t. The expression for the terminal velocity will be as follows:

$$V_t = \sqrt{\frac{2mg(\rho_s - \rho_a)}{\rho_s \rho_a A_p C_d}} \tag{8}$$

The drag coefficient C_d can be derived as follows:

$$C_d = \frac{2mg(\rho_s - \rho_a)}{\rho_s \rho_a A_p V_t^2} \tag{9}$$

And the projected area, A_p

$$A_p = \frac{\pi}{4} LW \tag{10}$$

where, A_p is the projected area of the nut (m^2); C_d is the drag coefficient (dimensionless); g is acceleration due to gravity (9.81 m s^{-2}); L is the nut length (m), m is the mass of nut (kg); V_t is terminal velocity (m s^{-1}); W is the nut width (m); ρ_a is the density of air (1.206 kg m^{-3} at room temperature); ρ_s is the density of the nut (kg m^{-3}).

Reynolds number is an important aerodynamic attribute that represents the ratio of inertial effects (i.e., the product of the particle's velocity and length scale) to viscous effects (i.e., viscosity of the medium/fluid in which the particle is moving—in this case, air) (Grega et al., 2013). The Reynolds number (Re) was calculated using the terminal velocity of each nut sample from the following relationship (Mohsenin, 1986):

$$Re = \frac{\rho_a V_t D_g}{\mu} \tag{11}$$

where, D_g is the geometric mean diameter of the nut (m); μ is air viscosity (1.816×10^{-5} Ns m^2 at room temperature).

2.6 Statistical analysis

The data obtained from the study were analysed using GenStat analytical software. The data were subjected to analysis of variance at 5% probability to ascertain any significant difference among the means. Comparison of means was carried out using Duncan multiple range test, and relationship between the properties investigated and the nut fractions were developed using regression models.

3 Results and Discussion

3.1 Basic geometric properties

The result of the basic geometric properties of *Canarium schweinfurthii* nut fractions investigated which include the major dimensions, dimension ratios, arithmetic and geometric diameters, unit volume and mass are presented in Table 1. The length (a) of the nut fraction I (unit mass <2.30 g) was observed to be longer than that of fractions II (2.30 g ≤ unit mass ≤3.00 g) and III (unit mass >3.00 g).

However, for other major dimensions, the mean values observed increased from nut fraction I up to fraction III as the unit mass increased. Most of the basic geometric properties revealed a linear relationship with the nut fractions, that is, as the mass of the nuts increased, the mean values of the properties also increased. However, a/b and a/c ratios showed an inverse relationship with the nut fractions.

Table 1 Properties of *Canarium schweinfurthii* nut fractions

Properties	Nut Fraction		
	I	II	III
Basic geometric			
Length *a* (mm)	30.28±1.30^a	29.14±1.29^b	29.45±1.04^b
Width *b* (mm)	11.78±0.42^a	13.18±0.49^b	14.74±0.66^c
Thickness c (mm)	11.10±0.42^a	12.59±0.53^b	13.75±0.58^c
a/b ratio	2.57±0.14^a	2.21±0.14^b	2.00±0.13^c
a/c ratio	2.73±0.12^a	2.32±0.17^b	2.15±0.13^c
Arithmetic diameter D_a (mm)	17.73±0.54^a	18.31±0.47^b	19.31±0.44^c
Geometric diameter D_g (mm)	15.82±0.42^a	16.90±0.44^b	18.13±0.49^c
Sphericity Ø (%)	52.28±1.48^a	58.08±2.38^b	61.63±2.57^c
Unit volume V_u (cm^3)	16.61±1.31^a	20.27±1.58^b	25.02±2.00^c
Unit mass *m* (g)	2.03±0.01^a	2.72±0.01^b	3.22±0.01^c
Complex geometric			
Thousand nut mass (g)	1977.33±6.48^a	2833.82±5.86^b	3284.03±5.83^c
Bulk density ρ_b (g cm^{-3})	0.68±0.01^a	0.73±0.02^b	0.75±0.01^c
True density ρ_t (g cm^{-3})	1.22±0.00^a	1.20±0.02^a	1.21±0.00^a
Porosity ε (%)	44.40±0.37^a	39.16±1.05^b	37.54±0.72^c
Surface area *S* (cm^2)	410.52±24.20^a	429.54±23.06^b	475.46±21.78^c
Specific surface area S_s (cm^2 cm^{-3})	136.99±8.08^a	115.74±6.21^b	111.36±5.11^c
Aspect ratio R_a (%)	38.98±2.16^a	45.31±2.66^b	50.14±3.30^c
Aerodynamic			
Terminal velocity V_t (m s^{-1})	9.68±0.05^a	10.5±0.00^b	10.93±0.05^c
Projected area A_p (mm^2)	280.32±15.84^a	301.63±15.24^b	340.84±16.11^c
Drag coefficient C_d	1.25±0.01^a	1.33±0.00^b	1.28±0.00^c
Reynolds number *Re*	10164.48±8.29^a	11787.32±9.85^b	13158.52±23.78^c

Note: Fractions size was: (I) m<2.30 g, (II) 2.30 g≤m≤3.00 g, and (III) m>3.00 g; *m* is unit mass. Means (±standard deviation) in the same row with different letters are significantly different at p<0.05.

Analysis of variance (ANOVA) carried out revealed significant differences at 5% probability (p<0.05) among all the mean values of the basic geometric properties of the nut except for the length where there was no significant difference (p>0.05) between the nut fractions II and III (Table 1). Karaj and Müller (2010) reported that the unit mass, major dimensions, arithmetic and geometric diameter, and volume of *Jatropha curcas* L. seeds and kernels were significantly different at p<0.01 for different mass fractions (I) $m < 0.35$, (II) $0.35 \le m < 0.52$, (III) $0.52 \le m < 0.69$, and (IV) $m > 0.69$ g. The basic geometric properties did not show strong correlation to unit mass of the nut. These properties could be an important consideration in the development of nut sizing and grading equipment and in their flow through an orifice (Aviara et al., 2013).

The following general expressions can be used to describe the relationship among the major dimensions of *Canarium schweinfurthii* nut fractions:

$$a_{\mathrm{I}}=2.57b_{\mathrm{I}}=2.73c_{\mathrm{I}} \quad (12)$$

$$a_{\mathrm{II}}=2.21b_{\mathrm{II}}=2.31c_{\mathrm{II}} \quad (13)$$

$$a_{\mathrm{III}}=2.00b_{\mathrm{III}}=2.14c_{\mathrm{III}} \quad (14)$$

where, *a*, *b* and *c* are the length, width and thickness of the nut; the subscripts I, II and III represent the nut fractions. The above parameters would be an important consideration in the separation of the nut fractions from undesirable materials (Aviara et al., 2013).

3.2 Complex geometric properties

The mean values obtained for the complex geometric properties of *Canarium schweinfurthii* nut fractions which include the 1000 nuts mass, bulk and true density, porosity, surface area, specific surface area and aspect ratio are presented in Table 1. The mean values determined for the 1000 nut mass, bulk density, surface area and aspect ratio all increased as the nut fraction increased from I to III. This shows a linear relationship with *Canarium schweinfurthii* nut mass. The increase in the bulk density of the nuts as the unit mass increased could be attributed to the fact that the increase in the mass of the bulk was higher than the corresponding increase in volume. Bulk density is useful in the analysis of thermal processes, estimation of pressures on storage structures and material handling equipment design. Trend in the means of the surface area of the nut fractions were similar to that reported by Karaj and Müller (2010) for *Jatropha curcas* L. The porosity and the specific surface area revealed an inverse relationship with the nut fractions; increasing the nut fractions from I to III reduced the mean values determined for porosity and specific surface area of the nut from 44.40% to 37.54% and from 136.99 to 111.36 cm^2 cm^{-3} respectively. Porosity is useful in the design of storage equipment and in the estimation air flow resistance during drying (Mohsenin, 1986; Aviara et al., 2013).

ANOVA carried out on the complex geometric properties investigated showed significant differences (p<0.05) among the mean values determined for each of the properties except for the true density where no significant difference (p>0.05) was observed among the nut fractions (Table 1). Similar to the basic geometric properties, the complex geometric properties did not show strong correlation to the unit mass.

3.3 Frictional properties

Frictional properties are useful in the design of deep bins, hoppers, discharge bins and material handling equipment (Aviara et al., 2013). The angle of repose determined on four structural surfaces using the filling (static angle of repose) and emptying (dynamic angle of repose) methods is shown in Figure 3. The static angle of repose appeared higher than the dynamic angle of repose on all the structural materials for all the nut fractions. Furthermore, the angle of repose, both static and dynamic appeared to increase as the nut fraction increased from I to III except on plywood where the angle of repose recorded were similar as the unit mass of the nut fractions increased (Figure 3d).

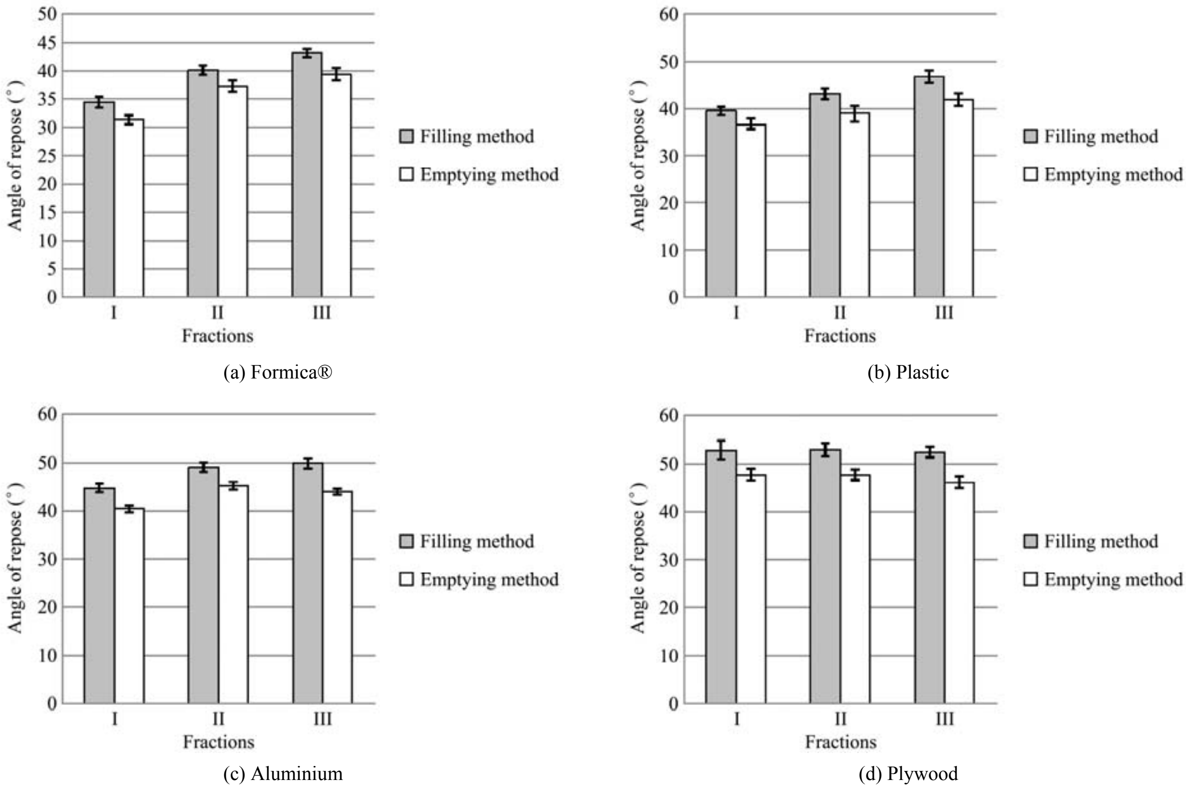

Figure 3 Angle of repose of *Canarium schweinfurthii* nut fractions on different structural materials: (a) Formica® (b) plastic (c) Aluminium (d) plywood; Fractions size: (I) m<2.30 g, (II) 2.30 g$\leq m \leq$3.00 g, and (III) m>3.00 g; m is unit mass

This suggests that cohesion forces between heavier nuts and the material surfaces are higher than that between lighter nuts and the material surfaces. The static angle of repose ranged from 34.48^{o} to 43.22^{o}, 39.53^{o} to 46.82^{o}, 44.78^{o} to 49.96^{o}, and 52.50^{o} to 52.80^{o} for the structural surfaces: Formica®, rubber, Aluminium, and plywood, respectively. While the dynamic angle of repose ranged from 31.34^{o} to 39.46^{o}, 36.62^{o} to 41.95^{o}, 40.45^{o} to 43.98^{o}, and 46.18^{o} to 47.77^{o} for the structural surfaces: Formica®, rubber, Aluminium, and plywood, respectively.

The static friction angle and the static coefficient of friction of *Canarium schweinfurthii* nuts on different structural materials namely, Formica®, rubber, Aluminium and plywood are shown in Figures 4 and 5. The static friction angle was lowest on Formica® followed by rubber, Aluminium and plywood; and the corresponding static coefficient of friction on the material surfaces followed the same order. The static friction angle ranged from 20.28^{o} to 23.55^{o}, 25.55^{o} to 27.60^{o}, 28.58^{o} to 29.55^{o}, and 31.48^{o} to 33.45^{o} on Formica®, rubber, Aluminium and plywood surfaces, respectively. The corresponding static coefficient of friction however ranged from 0.37 to 0.44, 0.48 to 0.52, 0.54 to 0.57, and 0.61 to 0.66 on Formica®, rubber, Aluminium and plywood surfaces, respectively. For all the nut fractions, the static friction angle and the coefficient were highest on plywood while the lowest mean values were observed on Formica®. This was due to the smooth surface of Formica® which allowed for easy movement of the nuts while the rough surface of plywood resulted in higher static friction angle and coefficient. Similar results were reported by Sirisomboon et al. (2007).

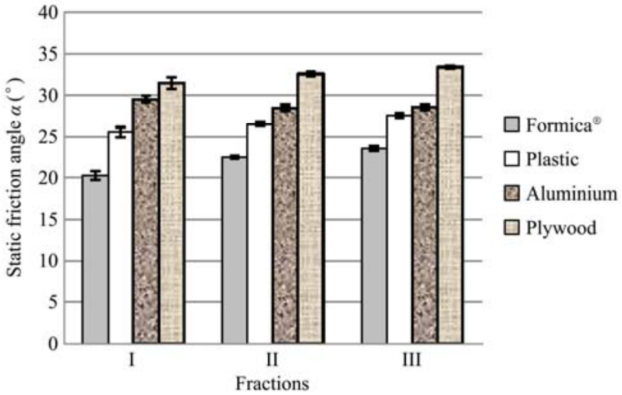

Figure 4 Static friction angle of *Canarium schweinfurthii* nuts on different structural materials. Fractions size: (I) m< 2.30 g, (II) 2.30 g≤m≤ 3.00 g, and (III) m>3.00 g; m is unit mass

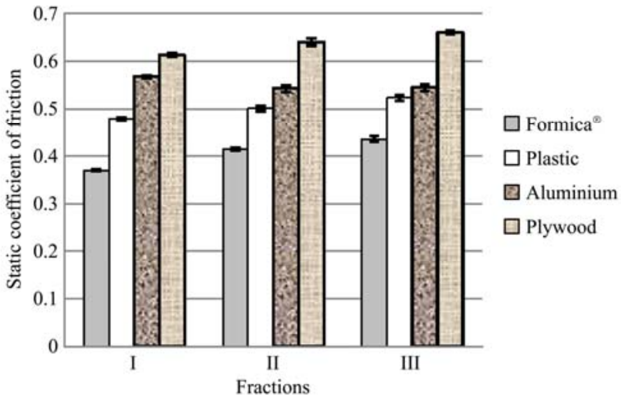

Figure 5 Static coefficient of friction of *Canarium schweinfurthii* nuts on different structural materials. Fractions size: (I) m< 2.30 g, (II) 2.30 g≤m≤3.00 g, and (III) m>3.00 g; m is unit mass

3.4 Aerodynamic properties

The mean values of the aerodynamic properties of *Canarium schweinfurthii* nut fractions are shown in Table 1. The terminal velocity, projected area and Reynolds number all increased from 9.68 to 10.93 m s^{-1}, 280.32 to 340.84 mm^2, and 101644.48 to 13158.52, respectively, as the unit mass of the nuts increased from nut fraction I to III. The terminal velocity presented in Table 1 shows the air velocity needed for separating a specific fraction of the nut from others.

From the ANOVA carried out on the aerodynamic properties, each of the properties were significantly influenced by the nut mass at p<0.05. High positive correlation coefficient, R^2 of 0.939 and 0.947 were observed for terminal velocity and Reynolds number, respectively, to mass and were expressed in the form of polynomial equations (15 and 16) at p<0.05. Karaj and Müller (2010) reported an exponential relationship between the terminal velocity of *Jatropha curcas* L. seeds to mass (R^2 = 0.989).

$$V_t = 24.52m + 7.81m^2 - 0.992m^3 \quad R^2 = 0.94 \qquad (15)$$

$$Re = 30618.0m + 10570.0m^2 - 1280m^3 \quad R^2 = 0.95 \qquad (16)$$

4 Conclusion

The physical and aerodynamic properties of three fractions of *Canarium* s*chweinfurthii* nuts (I: unit mass < 2.30 g, II: 2.30 g ≤ unit mass ≤3.00 g, and III: unit mass >3.00 g) classified based on their unit mass were investigated. The basic and the complex geometric properties of the nut were all significantly influenced (p<0.05) by the unit mass; the properties related linearly to the unit mass except for the dimension ratios, porosity and specific surface area which were inversely related to the unit mass. The dimension ratios length/width and length/thickness ranged from 2.00 to 2.57, and 2.15 to 2.73 respectively, for the nut fractions. The porosity and specific surface area range from 37.54% to 44.40%, and 111.36 to 136.99 cm^2 cm^{-3} respectively. The static angle of repose appeared higher than the dynamic angle of repose on different structural materials for all the nut fractions; and the angle of repose, both static and dynamic appeared to increase as the nut fractions increased. Generally, the aerodynamic properties of the nuts increased with increasing unit mass of the nut; the terminal velocity and the Reynolds number showed high correlation (R^2) of 0.94 and 0.95 respectively to unit mass. This study provides background information for the design and processing of *Canarium* s*chweinfurthii* nuts for value added products.

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