Studies of Physical and Mechanical Properties of Velvet tamarind

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Abstract-An experiment was conducted to investigate physical and mechanical properties such as length, width and thickness, 1000 unit mass, bulk and true densities, sphericity, surface area, coefficient of static friction, angle of repose and rupture force of velvet tamarind seeds and fruits as well as establish a database for engineering properties of velvet tamarind seeds and fruits. Length, width and thickness of velvet tamarind fruits and seeds were 9.00 mm, 6.65 mm and 3.30 mm with coefficient of variation of 11.2, 7.5 and 6.1% respectively. The Sphericity, aspect area, surface area, volume and 1000 unit mass of velvet tamarind fruits were 93.4, 73.0%, 88.72 mm², 61.22 mm³ and 293.54 g respectively. The mean true and bulk densities, porosity, angle of repose were determined the velvet tamarind fruits and seeds were 779.43, 1090 and 410.87, and 687.82 kgm³, 47.29%, and 36˚, 30˚. Stainless steel had the lowest coefficient of static friction for velvet tamarind fruits and seeds. It is recommended to use stainless steel as construction material in the manufacture of process components to easy movement of products along its surface.

Keywords: Axial dimensions, engineering properties, coefficient of static friction, angle of repose, sphericity

1. INTRODUCTION

Velvet tamarind (Dialium guineense) is a tall, tropical, fruit-bearing tree. It is a member of Leguminosae family, and has small, typically grape-sized edible fruits with brown hard inedible shells. The fruit is oval in shape with brown hard inedible shells and length of about 3.8 cm long. The fruits hangs in bunches of more than a dozen on the tree. It has sweet edible pulp that can be soaked in water for the production of beverage or eaten raw. One of the major ingredients used in the production of Domoda (Ghanaian dish) is velvet tamarind leaves. In Nigeria velvet tamarind is referred to as Awin among the Yorubas, Icheku in Igbo and Tsamiyarkurm in Hausa[1 2]. The bark and leaves have medicinal properties and are used against several diseases. Ogungbenle[3] reported that pod of velvet tamarind contains seed and sweet sour juicy pulp which is can be used to flavor a variety of foods.

It has been reported that some women chewed the fruits to improve lactation and check genital infection in Nigeria [1]. According to the findings of Arogba et al.[4], the pulp is edible and sweet, low levels of ascorbic acid and tannins. The fruit has been ranked as one of good source of plant protein and minerals [1 2 4]. Some researchers reported velvet tamarindis used as chewing stick as an indigenous tooth brush among Nigerian populace [2 5]. Velvet tamarind leaves and stem bark have been reportedly used for the treatment of infections such as diarrhoea, severe cough, bronchitis, wound, stomach aches, malaria fever, jaundice, antiulcer and haemorrhoids [6]. It has been
confirmed scientifically that the plant leaves and stem bark are useful as analgesic and antibacterial properties [6, 7]. Gideon et al. [8] has been used for antioxidant and antimicrobial treatment.

The design and manufacturing of equipment for post-harvest processes of velvet tamarind fruit such as cleaning, grading, sorting, cleaning, handling, transportation, separation, drying, aeration, juice and oil extraction processes, packaging and storing requires information on its physical and mechanical properties [9]. The engineering characteristics have been investigated by some scientists for various biological materials for example soybean [10], caper fruit [11], wheat [12], gbafilo fruit and kernel and cowpea [13], moth gram [14], pistachio nut [15], bitter kola seeds and shell (Davies and Mohammed, 2013) [16], almond nut and kernel [17], arigo seeds [18], pistachio nut and its kernel [19] and orange [20] and garlic [21].

The knowledge of fruit volume, shape and density are imperative for the design of fluid velocities for transportation [22]. Porosity is significant in determine the resistance to air flow through bulk solids [23]. Information on frictional properties of fruits and seeds are important for design of handling and storage equipment [22]. Literature reviewed showed no detailed study on the engineering properties of velvet tamarind seeds has been investigated. The objective of the study was to investigate and establish a database for engineering properties of velvet tamarind seeds and fruits.

II. MATERIALS AND METHODS

A. Sample Preparation and Moisture content Determination

The Velvet tamarind seeds (Dialium guineense) (Fig. 1) was cleaned manually to remove all foreign materials such dust, dirt, broken and immature ones. The sample was packed inside polythene bags and air sealed. The seeds were then put inside the freezer at -5°C to assume maintain expected moisture content. The moisture content of the Velvet tamarind seeds was determined by oven method as described by ASAE [24] were found to be 12.9% dry basis.

B. Geometric Properties

To determine mean of velvet tamarind seeds dimension, 100 seeds were randomly selected and their three linear dimensions namely, length ($L$), width ($W$) and thickness ($T$) were measured by means of digital Vernier Caliper with an accuracy of 0.01 mm. The mean length of velvet tamarind seed was determined using the three axial dimensions. The arithmetic mean diameter ($D_a$), geometric mean diameter ($D_g$), sphericity ($\Phi$), surface area $S$, aspect ratio $R_a$ of Velvet tamarind were calculated by using the following relationships [15, 22, 25, 26, 27].

$$D_a = \frac{L + W + T}{3} \quad (1)$$

$$D_g = (LWT)^{-\frac{1}{3}} \quad (2)$$

$$D_{sm} = \left(\frac{LW + WT + LT}{3}\right)^{0.5} \quad (3)$$

$$D_e = \frac{D_a + D_g + D_{sm}}{3} \quad (4)$$

$$\Phi = \frac{3\sqrt[3]{LWT}}{L} \quad (5)$$
\[ Ra = \frac{W}{L} 100(6) \]  
\[ As = \frac{nBL^2}{2L-B} \]  
\[ V = \frac{\pi d^2 L^2}{6(2L-3)} \]  
\[ B = (LW)^{0.5} \]  

The volume \( V \) of velvet tamarind seeds and fruits were evaluated by employing toluene displacement method [28]. The 1000 unit mass of velvet tamarind seeds and fruits determined using precision electronic balance to an accuracy of 0.01g. To evaluate the 1000 unit mass for fruits and nut, 50 randomly selected samples were weighed and multiplied by 20 to give the mass of 1000 fruit and nut. The experiment was replicated ten times. Packing coefficient (\( \lambda \)) was investigated according to Jannatizadek \textit{et al.} [29]. It is ratio of the volume of velvet tamarind seeds or fruits \( V \) packed to the total volume \( V_T \) and calculated by the following equation

\[ \lambda = \frac{V}{V_T} \]  

where: \( \lambda \) – packaging coefficient, \( V \) – volume of velvet tamarind seeds and fruits (mm\(^3\)).

The bulk density \( (\rho_b) \) of velvet tamarind seeds and fruits were evaluated using the technique adopted by Garledar \textit{et al.} [15].

\[ \rho_b = \frac{\text{Mass of bulk seeds}}{\text{Volume of bulk seeds}} \]  

The true density of velvet tamarind seeds and fruits was evaluated using the water displacement method [30]. Water displacement method was used for velvet tamarind seeds and fruits because of its low water absorption characteristic. The porosity of the bulk velvet tamarind seeds and fruits were evaluated from the values of the bulk density and true density based on the relationship given by Mohsenin [22].

\[ \varepsilon(\%) = \left(1 - \frac{\rho_b}{\rho_t}\right) 100 \]  

The static coefficient of friction was determined with respect to six structural materials namely: galvanized iron sheet, rubber sheet, plywood sheet, iron sheet and angle of repose in accordance with Daviesand EL-Okene [10]. The mean force required to initiate rupture in velvet tamarind seeds and fruits in the horizontal and vertical axes were measured using an Instron Testing Machine equipped with a 5 kg load cell at a compressive rate of 30 mm min\(^{-1}\).

C. Statistical analysis

The obtained data was statistically analysed using Statistical Analysis System (SAS) (2007) and Microsoft Excel (2007) packages for Analysis of Variance (ANOVA) and descriptive statistics.

111. RESULTS AND DISCUSSION

Principal geometrical properties of including mean length, width, thickness, mass unit, arithmetic and geometric mean diameter, sphericity, volume, 1000 unit mass and surface area for velvet tamarind seeds and fruits investigated at moisture content 9.85 % dry basis for are presented in Table 1. The mean length, width and thickness of velvet tamarind seeds and fruits were 9.6 mm, 6.56 mm and 3.30 mm with coefficient of variation of 11.2, 7.5 and 6.1% respectively. The average length, width and thickness of velvet tamarind fruits were 17.63 mm, 12.56 mm and 3.30
mm with coefficient of variation of 9.74, 8.62 and 7.95% respectively. Davies and Mohammed [31] stated the mean length, width and thickness of soursop seeds were 13.25±0.65 mm, 8.97±0.87 mm and 5.63±0.12 mm respectively. The average length, width and thickness of simarouba fruits were 21.26 mm, 13.81 mm and 11.03 mm respectively [32].

Dimensional characteristic of any biomaterial like seed and fruit shapes is imperative because it gives information on horticultural research purposes [33 34]. These parameters are imperative in the investigation of consumer preference and determination of heritability of fruit and seed shape traits [35]. The arithmetic and geometric mean diameter of velvet tamarind seeds were 6.29 mm and 5.80 mm with correlation variation of 8.7% and 8.2%.

<table>
<thead>
<tr>
<th>Properties</th>
<th>Sample no</th>
<th>Mean Seed</th>
<th>Coefficient variation (%)</th>
<th>Standard deviation</th>
<th>Mean Fruit</th>
<th>Coefficient variation (%)</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length (mm)</td>
<td>100</td>
<td>9.00</td>
<td>11.2</td>
<td>0.47</td>
<td>17.63</td>
<td>9.74</td>
<td>0.09</td>
</tr>
<tr>
<td>Width (mm)</td>
<td>100</td>
<td>6.56</td>
<td>7.5</td>
<td>0.63</td>
<td>12.45</td>
<td>8.62</td>
<td>0.56</td>
</tr>
<tr>
<td>Thickness (mm)</td>
<td>100</td>
<td>3.30</td>
<td>6.1</td>
<td>0.55</td>
<td>7.22</td>
<td>7.95</td>
<td>0.72</td>
</tr>
<tr>
<td>Arithmetic mean Diameter (mm)</td>
<td>100</td>
<td>6.29</td>
<td>8.7</td>
<td>0.82</td>
<td>12.10</td>
<td>7.23</td>
<td>0.19</td>
</tr>
<tr>
<td>Geometric mean Diameter (mm)</td>
<td>100</td>
<td>5.80</td>
<td>8.2</td>
<td>0.85</td>
<td>11.34</td>
<td>6.83</td>
<td>0.95</td>
</tr>
<tr>
<td>Equivalent diameter</td>
<td>100</td>
<td>6.04</td>
<td>9.65</td>
<td>0.28</td>
<td>11.72</td>
<td>9.61</td>
<td>0.43</td>
</tr>
<tr>
<td>Sphericity (%)</td>
<td>100</td>
<td>93.4</td>
<td>7.9</td>
<td>0.84</td>
<td>94.6</td>
<td>5.56</td>
<td>0.74</td>
</tr>
<tr>
<td>Aspect ratio (%)</td>
<td>100</td>
<td>73</td>
<td>10.8</td>
<td>0.53</td>
<td>65</td>
<td>9.15</td>
<td>0.50</td>
</tr>
<tr>
<td>Surface area (mm²)</td>
<td>100</td>
<td>88.72</td>
<td>13.7</td>
<td>0.65</td>
<td>339.31</td>
<td>14.37</td>
<td>1.91</td>
</tr>
<tr>
<td>Volume (mm³)</td>
<td>100</td>
<td>61.22</td>
<td>15.3</td>
<td>1.64</td>
<td>417.07</td>
<td>15.61</td>
<td>1.74</td>
</tr>
<tr>
<td>1000 - Unit mass (g)</td>
<td>100</td>
<td>107.63</td>
<td>17.1</td>
<td>1.85</td>
<td>293.54</td>
<td>15.02</td>
<td>1.86</td>
</tr>
<tr>
<td>Packaging coefficient</td>
<td>1000</td>
<td>85.5</td>
<td>12.9</td>
<td>2.18</td>
<td>78.3</td>
<td>10.4</td>
<td>3.75</td>
</tr>
</tbody>
</table>

The arithmetic and geometric mean diameter of velvet tamarind fruits were 12.10 mm and 11.34 mm with correlation variation of 7.23% and 6.83%. Geometric and arithmetic average diameters of palm fruit ranged between 21.36 and 29.23 mm and 20.80 and 27.80 mm [36]. The average surface area of velvet tamarind seeds was 88.72 mm² with correlation variation of 13.7%. Davies and Mohammed [31] revealed that the surface area of Soursop seeds ranged from 195.10±7.73 mm² to 385.05±4.75 mm². The mean surface area of velvet tamarind fruits was 339.31 mm² with correlation variation of 14.37%. Gbafilo fruits had surface area ranged between 1584.80 and 2455.90 mm² [37]. There is a strong positive relationship between surface area and weight of any seeds and fruits. Surface area of seeds and fruits can be used to evaluate spray coverage, residues removal, respiration rate, light reflectance, and colour. It has a significant effect on the rate of reaction during biochemical processes. The volume of velvet tamarind seeds and fruits were 61.22 mm³ and 339.31 with correlation variation of 15.3% and 15.61%. Volume of any seeds or fruits can be used evaluate the diffusion coefficient of shrinking systems. The average sphericity of velvet tamarind seeds and fruits were 93.4.4% and 94.6%. The sphericity of three different species of melon seeds was obtained for C. lunatus, 53%, C. edulis, 47% and C. vulgaris, 45% [38]. Baland Mishra [39] and Garnyak [40] reported that any grain, fruit and seed having sphericity value of more than 70% is taken to be spherical. Thus, velvet tamarind seeds and fruits are spherical.
The average aspect ratio of velvet tamarind seeds and fruits were 93.4.4% and 94.6% were 73.0% and 65.0% with their respective correlation variation of 10.8 and 9.15%. This parameter gives useful information in the design of hoppers and also to determine if velvet tamarind seeds and fruits will slide or roll. The mean 1000 unit mass of velvet tamarind seeds and fruits were 107.63 g and 293.54 g with their respective correlation variation of 17.1 and 15.02%. The average 1000 unit mass of bitter kola nut ranged between 3087.02 and 4200.35 g [31]. Many scientists reported 1000-unit mass of some seeds and fruits like jatropha seeds and kernel, arigo seeds, simarouba fruits and kernel, maize, red gram, wheat, green gram, chickpea, faba bean, pigeon pea were 1322.41 g, 688 g, 1124.7 g, 1120 g, 330.26 g, 268.30 g, 102 g, 346 g, 30.15 g, 120 g and 75 g respectively [12 32 41 42].

Table 2. The porosity of velvet tamarind seeds and fruits were 36.90 and 47.29%. The air circulation through the products will be more prominent in velvet tamarind fruits compared to its seeds. The corresponded average values of true and bulk densities for hog plum fruits and nuts were 1023.51, 652.90, 431.48 and 837.70 kg/m$^3$ [43]. Information on the coefficient of static friction of biomaterial is important in the design of pneumatic conveying systems, screw conveyors as well as hoppers.

![Table 2](image)

<table>
<thead>
<tr>
<th>Properties</th>
<th>Fruit</th>
<th>Seed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Mean</td>
</tr>
<tr>
<td>Bulk density (kg/m$^3$)</td>
<td>410.87(14.48)</td>
<td>687.82 (7.86)</td>
</tr>
<tr>
<td>True density (kg/m$^3$)</td>
<td>779.43 (12.58)</td>
<td>1090 (18.42)</td>
</tr>
<tr>
<td>Porosity (%)</td>
<td>47.29(3.27)</td>
<td>36.90 (5.69)</td>
</tr>
<tr>
<td>Angle of repose (°)</td>
<td>36°(7.81)</td>
<td>31°(5.68)</td>
</tr>
<tr>
<td>Coefficient of static friction</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stainless steel,</td>
<td>0.41(6.43)</td>
<td>0.35(9.15)</td>
</tr>
<tr>
<td>Rubber sheet</td>
<td>0.53 (7.94)</td>
<td>0.44(8.79)</td>
</tr>
<tr>
<td>Plywood sheet</td>
<td>0.51(9.61)</td>
<td>0.42(5.46)</td>
</tr>
<tr>
<td>galvanized iron sheet,</td>
<td>0.47(4.31)</td>
<td>0.39(10.04)</td>
</tr>
<tr>
<td>Mechanical properties</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$F_x$, Vertical fracture force (N)</td>
<td>56.75 (6.08)</td>
<td>1774.51 (16.35)</td>
</tr>
<tr>
<td>$F_y$, Horizontal fracture force (N)</td>
<td>47.93 (9.74)</td>
<td>1653.58 (19.69)</td>
</tr>
</tbody>
</table>

The static coefficients of friction of velvet tamarind fruits and seeds on four structural surfaces; stainless steel, rubber sheet, plywood sheet and galvanized iron sheet were 0.41 (6.43) and 0.35(9.15), 0.53(7.94) and 0.44(8.79), 051(9.61) and 0.42(5.46) and 0.47(4.31) and 0.39(10.04) respectively (Table 2). Lowest and highest static coefficient of friction values were stainless steel and rubber sheet. Cornelian cherry and Juniperus drupacea fruits had the highest static coefficient of friction corresponded to rubber surfaces [44 45]. Present result contradicted the observation experienced by Bahmasawy et al. [46] that the highest coefficient of static friction of Egyptian onion cultivars corresponded to plywood followed by rubber surfaces. The average angle of repose of velvet tamarind fruits and seeds were 36° (7.81) and 31° (5.68). The static coefficient of friction and angle of repose are imperative for the design of conveyor and hoppers for planting of seeds machines.
The force required to rupture velvet tamarind fruits and seeds on the vertical and horizontal loading were 56.75 (6.08) N and 1774.51 (16.35) N and 47.93 (9.74) and 1653.58 (19.69) respectively. The average rupture forces for hog plum nut on the horizontal and vertical loading were reported to be 1007.95 N and 1214.50 N. While rupture force for bitter kola nut and shell on horizontal and vertical orientations were 295±3.76, 321.6±10.49 and 21±0.19 N, 24.0±1.05 N [31].

CONCLUSION

The physical properties of velvet tamarind fruits and seeds such as average length, width, thickness, arithmetic and geometric mean diameter, sphericity, surface area, 1000 unit mass, spherity and aspect ratio were determined.

1. The mean major, minor and intermediate diameter of velvet tamarind fruits and seeds were 9.00 mm, 6.65 mm and 3.30 mm with coefficient of variation of 11.2, 7.5 and 6.1% respectively.
2. The arithmetic mean diameter and geometric mean diameter velvet tamarind fruits were 6.29 and 5.80 with CV of 8.7% and 8.2%.
3. The Sphericity, aspect area, surface area, volume and 1000 unit mass of velvet tamarind fruits were 93.4, 73.0%, 88.72 mm², 61.22 mm³ and 293.54 g respectively.
4. The average true and bulk densities, porosity, angle of repose were determined the velvet tamarind fruits and seeds. The obtained results were 779.43, 1090 and 410.87, and 687.82 kgm⁻³, 47.29%, and 36 °, 30° respectively.
6. Among the four surfaces rubber had the highest coefficient of static friction for velvet tamarind fruits and seeds.
7. More force is required in the vertical orientations of velvet tamarind fruits and seeds to start rupture.

REFERENCES


