Selected Physio-Chemical Properties for the Processing of Cashew Apple (*Anacardium Occidentale*)

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**Abstract.** Selected physical, mechanical and chemical properties of cashew apple were investigated which includes length, width, thickness, mass, volume, density, angle of repose, static coefficient of friction on plywood, glass, mild steel and stainless steel surfaces, compressive force required to rupture the cashew apple, energy to break, Youngs modulus. Cashew apple was found to have length of 6.49 cm, width of 3.81 cm and thickness of 3.58 cm, average moisture content of 85% wet basis. The mean values of coefficient of static friction on glass (0.29) was the highest while that of wood was the lowest, while the average value of angle of repose was 15.45°. The compressive force needed to rupture the cashew apple is 22.56N while the energy to break is 0.0025 J. The mean proximate compositions of the cashew apple were: pH (4.3), Vitamin C (123.5 mg/ml), Tannin (261.3 mg/ml), Total sugar (11.88 mg/ml), Fibre (4.1%) Protein (2.14 %). The mean mineral composition of the cashew apple has Potassium (69.7 ± 0.35 ppm) as the highest and the lowest of Zinc (0.06 ± 0 ppm). The properties stated constitute an important baseline for the design and development of various machines for handling and processing of the cashew apple.

1. **Introduction**

The cashew apple (*Anacardium occidentale*), also named cashew fruit, is the fleshy and succulent part of the cashew fruit that is attached to the cashew nut. 6-10 % of cashew apple produce in Nigeria is either consumed as fresh fruit or produce to fruit drink while the remaining percentage of the produce are left to waste [1]. The juice content obtainable in the cashew apple is about 85%, and as researched, it is shown that a minimum of 65% of this juice content in the cashew apple can be extracted with efficient locally manufactured equipment [2].

The selected engineering properties of the cashew apple, is of necessity for the design of machines and equipment’s to process the cashew apple into juice for consumption. These determined properties are dependent on many factors such as its size, mass, shape, angle of repose, density coefficient of static friction, compressive force, energy to break and chemical constituents such as pH, tannin, total sugar, magnesium, etc. Besides, the data of the compressive force of the cashew apple is necessary to design the machine for processing cashew apple juice [3].

2. **Material and Method**
2.1. Sample Preparation.
Fresh cashew apples were obtained from the catholic environ at “Obanla” in the Federal University of Technology, Akure (FUTA). The fruits were sorted visually for size, maturity level and physical damage.

2.2. Determination of Physical Properties

2.2.1. Size. The cashew apples dimensions were measured in three equal perpendicular axes with Vernier calliper. For each cashew apple, the measured dimensions consisted of the length, and three diameters of the transverse section. Geometric mean diameter, \( D_g \) of the cashew apple was derived using the following relationship given by [5-7]. As

\[
D_g = (WTL)^{1/3}
\]

Where \( W \) is the width, \( L \) is the length and \( T \) is the thickness

2.2.2. Sphericity and Surface area. According to [8], the degree of sphericity \( \phi \), can be expressed as follows

\[
\phi = \left(\frac{WLT}{L}\right)^{1/3}
\]

Where \( W \) is the width, \( L \) is the length and \( T \) is the thickness

Also, the surface area, \( S \) is given by

\[
S = \pi D_g^2
\]

Where \( D_g \) is the geometric mean diameter

2.2.3. Volume and Density. The density of the cashew apples was determined by weighing each cashew apple on an electronic equilibrium and its quantity using a water displacement technique comparable to that outlined by [9].

2.2.4. Weight. Both the initial and final weight was measure to 0.001g using an electronic weighing balance.

2.2.5. Moisture Content. The moisture content of the cashew apple samples was measured using the gravimetric method. To achieve this, the initial weight \( (W_i) \) of the apples was recorded and after concluding all the experimental measurements, the cashew apples were oven dried at 105ºC for 24hrs after which the final weight \( (W_f) \) of each of the cashew apple is taken. The moisture content was measured on wet basis by using the following equation 20 [4].

\[
MC_{wb} = \frac{W_i - W_f}{W_i}
\]

2.2.6. Angle of Repose and Coefficient of Friction. Determination of angle of repose and frictional properties: Static friction coefficient is the proportion of force needed to slide the cashew apple over a split surface by the normal force pressing the cashew apple against the ground. Coefficient of static friction was measured using a frictional device i.e. the sliding box with the wood, mild, glass and stainless-steel. This was done using the inclined plane technique, earlier described in the literature by [10].

2.3. Determination of Mechanical Properties
The mechanical properties investigated in this study include; angle of repose, coefficient of static friction, compressive force, energy at break, and Youngs modulus. The processed cashew apples were
tested for their strength properties under compression when loaded under an Instron Universal Testing Machine (UTM) (Testometric Machine, Model M500 - 25KN). These properties are the Breaking Force, Stress at Break, Energy at Break, and Deformation at Break. The experiment was based on the strength-deformation features of the cashew apple. The machine has three primary parts, a driving unit and a data acquisition system, which are stable up and movement bottom of the platform. The cashew apple sample was put on the stable up platform during the compressive exam and was compressed at a steady velocity with a movement probe until the specimen broke. The dynamometer and data acquisition system evaluated the rupture force of the sample and the mechanical parameters of the experiment were automatically produced by the device as it was programmed to determine the mechanical characteristics of the cashew apple.

2.4. Determination of Proximate and Mineral Composition
The cashew apple proximate composition (fibre, fat, ash, protein, moisture content and carbohydrate), mineral composition (potassium, calcium, sodium, magnesium, iron, zinc and copper) including total sugar, tannin and Vitamin C was determined using the method presented by (11).

3. Results and Discussion

3.1. Results
According to the experiments carried out, the summary of the results for all the measured parameters for cashew apple (Anacardium occidentale) at average moisture content 85% are shown in the Table 1, 2 and 3 respectively.

Table 1 Physical properties of cashew apple (Anacardium occidentale)

| Properties                  | Mean   | SD      | Min   | Max   |
|-----------------------------|--------|---------|-------|-------|
| Length                      | 6.49261| 1.217603| 4.01  | 8.92  |
| Width                       | 3.80835| 0.549707| 2.283 | 5.078 |
| Thickness                   | 3.57611| 0.476038| 2.383 | 4.683 |
| Geometric Mean Diameter     | 4.431669| 0.533824| 3.1666| 5.678011 |
| Sphericity                  | 0.697099| 0.103739| 0.521902 | 1.023538 |
| Surface Area                | 62.59433| 14.81319| 31.50714 | 101.2975 |
| Volume                      | 68.73  | 18.44668| 20    | 120   |
| Mass                        | 62.4375| 17.78455| 21.56 | 110.11 |
| Density                     | 0.908171| 0.081667| 0.6775| 1.173846 |
| Angle of Repose             | 15.4825| 5.81428| 4.5   | 30.5  |
### Coefficient of Friction

| Material         | Coefficient of Friction | Moisture Content |
|------------------|-------------------------|------------------|
| Wood             | 0.26677                 | 0.116785         |
| Glass            | 0.2961                  | 0.126644         |
| Mild steel       | 0.28973                 | 0.133317         |
| Stainless steel  | 0.27506                 | 0.14496          |
| Moisture content | 85.00884                | 1.153939         |
Table 2  Mechanical properties of cashew apple (*Anarcadium occidentale*)

| Sample number | Force (N) | Energy (J) | Young modulus (MPa) |
|---------------|-----------|------------|---------------------|
| Mean          | 22.557    | 0.002494   | 1.2451              |
| SD            | 3.475281  | 0.001626231| 0.437363            |
| Min           | 18.41     | 0.00104    | 0.557               |
| Max           | 28.17     | 0.00616    | 2.001               |
| Proximate composition     | sample A | sample B | sample C | Mean  | SD   | Min  | Max  |
|---------------------------|---------|---------|---------|-------|------|------|------|
| pH                        | 4.3     | 4.2     | 4.4     | 4.3   | 0.1  | 4.2  | 4.4  |
| Vitamin C (mg/ml)         | 122.377 | 123.601 | 124.451 | 123.5 | 1.04261 | 122.377 | 124.45 |
| Tannin (mg/ml)            | 261.1   | 260.3   | 262.5   | 261.3 | 1.11355 | 260.3  | 262.5 |
| Total sugar (mg/ml)       | 11.89   | 11.86   | 11.9    | 11.88 | 0.02082 | 11.86  | 11.9  |
| moisture (%)              | 82.04   | 80.202  | 81.57   | 81.27 | 0.95486 | 80.202 | 82.04 |
| fat (%)                   | 1.886   | 1.92    | 1.894   | 1.9   | 0.01778 | 1.886  | 1.92  |
| fibre (%)                 | 4       | 4.25    | 4.05    | 4.1   | 0.13229 | 4      | 4.25  |
| Ash (%)                   | 4.34    | 4.34    | 4.34    | 4.34  | 0      | 4.34  | 4.34  |
| Protein (%)               | 2.1     | 2.275   | 2.05    | 2.142 | 0.11815 | 2.05   | 2.275 |
| CHO (%)                   | 5.634   | 7.113   | 7.086   | 6.611 | 0.84621 | 5.634  | 7.113 |

**Mineral composition**

| Mineral               | sample A | sample B | sample C | Mean  | SD   | Min  | Max  |
|-----------------------|---------|---------|---------|-------|------|------|------|
| Potassium (k)(ppm)    | 69.5    | 69.5    | 70.1    | 69.7  | 0.34641 | 69.5  | 70.1 |
| Calcium (Ca) (ppm)    | 43      | 42      | 43      | 42.67 | 0.57735 | 42    | 43   |
| Sodium (Na) (ppm)     | 0.44    | 0.42    | 0.4     | 0.42  | 0.02  | 0.4  | 0.44 |
| Magnesium (Mg) (ppm)  | 0.63    | 0.62    | 0.64    | 0.63  | 0.01  | 0.62 | 0.64 |
| Zinc (Zn) (ppm)       | 0.06    | 0.06    | 0.06    | 0.06  | 0     | 0.06 | 0.06 |
| Copper (Cu) (ppm)     | 0.09    | 0.08    | 0.08    | 0.083 | 0.00577 | 0.08  | 0.09 |
| Iron (Fe) (ppm)       | 0.07    | 0.07    | 0.08    | 0.073 | 0.00577 | 0.07  | 0.08 |

3.2. **Physical properties**

At the moisture content level of 85% wb, the average length, width, thickness and geometric mean were 6.49±1.22cm, 3.81±0.55cm, 3.58±0.48cm and 4.43±0.53cm respectively as shown in Table 1.
The average mass and volume of cashew apple are 62.44 ± 17.78 g and 68.73 ± 18.44 cm³ respectively while the density was 0.91 ± 0.08 g/cm³. The density of cashew apple aids in material selection, machine frame and the design of hopper capability in the fabrication of a cashew apple processing plant.

From the results of the experiment carried out on the cashew apple, the mean values of coefficient of static friction were 0.2668 ± 0.11 on wood, 0.2961 ± 0.12 on glass, 0.2897 ± 0.13 on mild steel and 0.2751 ± 0.14 on stainless steel, with wood having the lowest coefficient of static friction and higher on the glass surface with 0.2961 ± 0.12 while the mean angle of repose for all the surfaces was given as 15.48 ± 5.81 degrees which was higher than that reported for black plum fruit with angle of repose on wood and mild steel surfaces as 6 and 6 degrees respectively [3] but lower than that reported for apple on glass and wood surfaces which were 26.3 and 26.8 degrees respectively [12] and 21.44 degrees for moringa seeds [13]. The angle of repose is very useful in the design of machine for handling and processing of the cashew apple. The use of stainless steel is very important in food processing. The stainless material does not rust easily; it possesses a good machinability factor and prevents contamination of food products. They are used for many processing equipment though they are more expensive.

3.3. Mechanical Properties
The values of the result obtained in the determination of the mechanical properties of cashew apple are shown in the table 4.2. The compressive force is needed to cause the crop to rupture. The force required to rupture the cashew apple was about 22.56 ± 3.48 N whereas it is lower when compared with the results gotten on onion as reported by [14], the crushing load decreased with an increase in onion stems ranging from 443.3 N to 819.7N for white onions, from 341.4 to 980.7 N for red onions and from 400 to 780 for yellow onions, while the penetration load decreased with an increase in onion stems ranging from 26.9 to 35.9 N for white onions, from 26.1 to 43.0 for red onions and from 27.6 to 45.5 N for yellow onions.

Toughness or strain energy is described as the energy that the cashew apple absorbs before the rupture of the cashew apple per unit quantity [15]. Results showed toughness of the cashew apple as 0.002494 ± 0.0016 Joules (J)

Young modulus is the measure of the cashew apple’s stiffness and rigidity. In other words, it demonstrates how easy it is to deform the cashew apple surface. The experimental findings indicated that the value was 1.25 ± 0.44 Mpa.

3.4. Chemical Properties
The values of the result obtained in the determination of the mechanical properties of cashew apple are shown in the table 4.3. From the results obtained, the mean value of the proximate composition was as follows; pH (4.3 ± 0.1), Vitamin C (123.5 ± 1.04) mg/ml, Tannin (261.3 ± 1.11) mg/ml, Total Sugar (11.88 ± 0.02) mg/ml, moisture (81.27 ± 0.95) %, fat (1.9 ± 0.02) %, fibre (4.1 ± 0.13) %, ash (4.34 ± 0) %, protein (2.14 ± 0.12) %, CHO (6.61 ± 0.85) %. This result of the pH value is similar to that obtained by [11] in the mineral and proximate composition of cashew apple, while the vitamin C, tannin and total sugars content were than lower the one obtained by [11] at a close range.

Mineral composition: The mineral compositions were as follows; Potassium (69.7 ± 0.35) ppm, Calcium (42.67 ± 0.58) ppm, Sodium (0.42 ± 0.02) ppm, Magnesium (0.63 ± 0.01) ppm, Zinc (0.06 ± 0). ppm, Copper (0.08 ± 0.006) ppm, Iron (0.07 ± 0.006) ppm. The result showed potassium to be the highest, followed by calcium which was also reported by [11]. The concentrations of zinc, copper and iron were much lower and ranged from 0.06 - 0.08 ppm to 0.05 - 0.08mg/100ml [11].

4. Conclusion
It is observed that the cashew apple showed a density of 0.91 ± 0.08 g/cm³ and a moisture content range of 82.89% – 86.69% (wet basis), glass showed the highest coefficient of friction, followed by mild steel, stainless steel and wood in descending order. The compressive force required to rupture the cashew apple was 22.56 ± 3.48N. The engineering characteristics determined in this research represent
significant baseline information for the science design and growth of different devices for the cashew apple handling and processing.

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