# PHYSICAL AND MECHANICAL PROPERTIES OF THREE VARIETIES OF MANGO


**Abstract**

Physical properties of three varieties of mango were studied at 13.75% and 8.74% moisture content levels. Some selected properties such as geometric mean, arithmetic mean, angle of repose, sphericity and crushing force were determined. The average tri-axial dimensions of the seeds gave 38.00 $\pm$ 6.8, 42.23 $\pm$ 4.12, 33.95 $\pm$ 6.91 as average major diameter; 35.60 $\pm$ 5.68, 39.18 $\pm$ 3.95, 31.44 $\pm$ 7.56 as average intermediate diameter and 24.76 $\pm$ 5.2, 28.42 $\pm$ 5.59, 23.08 $\pm$ 3.67 as average minor diameter for Kerosene, Sheri and Sugar mango respectively. The average sphericity of the three varieties of mango seed was 0.74, 0.77 and 0.67 while that of the angle of repose was $40.43^0$, $08.03^0$ and $09.76^0$ for Kerosene, Sheri and Sugar mango respectively. The average crushing force determined using the universal testing machine gave 21.00 N, 10.58 N and 9.46 N for Kerosene, Sheri and Sugar mango respectively. Statistical analysis shows that there is a significant difference in the geometric mean between Kerosene mango and Sheri mango and no significant difference between Sheri mango and Sugar mango, while the average value of the calculated arithmetic mean was found to be statistically different within the three varieties but no significant difference in sphericity. Kerosene mango has the highest value for the angle of repose and crushing force.



**Keywords:** Size, Sphericity, Crushing Force, angle of repose, Kerosene mango, Sheri mango, Sugar mango


## 1. Introduction

Mango (*Mangifera indica L.*) is a member of the family Anacardiaceae. It has become naturalized and adapted throughout the tropics and subtropics. There are over 500 classified mango varieties, some of them have evolved and have been described throughout the world. The genus of *Mangifera* consists of 69 species and mostly restricted to tropical Asia. The highest variety of mango occurs in Malaysia, particularly in the peninsular area and about 28 species are found in this region (Karunanithi *et al.,* 2015).

It is one of the most important tropical fruit in the world; it is greatly relished for its succulence, exotic flavour and delicious taste in most countries of the world. Apart from its delicacy, it is a nutritionally important fruit being a good source of vitamin A, B and C, and minerals (Bhatnagar and Subramanyam, 2011). Mango production in 2010 was 39 million tonnes (including mango stones and guava). Mango is seasonal fruit and about 20 percent of the fruits are processed for products such as puree, nectar, leather, canned slice and chutney, juices, ice cream, fruit bars, and pies. During the processing of ripe mango, its peel and seed are generated as a waste, which is approximately 40 - 50 % of the total fruit weight (Ashoush and Gadallah 2011).

Mango seed is a single flat oblong seed that can be fibrous or hairy on the surface, depending on the variety. Inside the seed coat, 1-2 mm thick is a thin lining covering a single embryo, 4-7 cm long and 3-4 cm wide (Anonymous 2013). Mango seed consists of a hard coat enclosing the kernel called the Endocarp. The seed content of different varieties of mangoes ranges from 9 % to 23 % of the fruit weight (Palaniswamy *et al*., 2012) and the kernel content of the seed ranges from 45.7 % to 72.8 % (Hemavathy *et al*., 2011).

Information on the physical properties of mango seed will help to know about their shape and size which will then be relevant in designing equipment for grading, sorting, cleaning, dehulling and packaging. The density with specific gravity is used for calculating thermal diffusivity in heat transfer and terminal velocity (Oh *et al*., 2001; Urena *et al*., 2002). Mechanical properties describe the behavior of the material under applied forces. From the force-deformation curve, mechanical properties like rupture force and energy of the tested specimen can be obtained.

## 2. Materials and Methods

### 2.1 Collection of mango fruits

Three varieties of mango fruits were purchased differently at different towns in Ekiti State. Kerosene mango from Omuo-Ekiti, Sheri mango from Oja-Oba, Ado-Ekiti and Sugar mango from Aba-Erinfun, Ado-Ekiti based on the availability of the seeds. The seeds were then peeled in order to reveal the seed. The seeds were sundried for 5 days to a moisture content of 10.12% to release the kernels for easy cracking and avoid breakage of the kernels.

### 2.2.1 Physical Properties

**i. Determination of moisture content**

After the removal of mango pulp with a knife, the seeds were weighed before sun-drying it. After sun-drying for between 3-6 days, the seeds were weighed using the digital electric weighing balance and their moisture content was taken. Results were obtained for twenty replicates and the average was recorded. The moisture content was then calculated using the formula.

$$\text{Moisture content } (M_c) = \frac{W_2 - W_3}{W_3 - W_1} \times 100$$

$W_1$ = Weight of container, (g)

$W_2$ = Weight of wet sample + container, (g)

$W_3$ = Weight of dry sample + container, (g)

**ii. Shape determination**

The shape was determined by tracing the longitudinal and lateral cross-section of the kernel on cardboard and compared with the shapes listed on the charted standard, then descriptive terms were used to define the shape (Sunmonu *et al.,* 2015).

**iii. Size determination**

Twenty (20) kernels were selected at random from both samples. The three principle diameters (axial dimension); major diameter (a), intermediate diameter (b) and minor diameter (c) were measured using Vernier caliper and the average was taken.

**iv. Geometric Mean Diameter**

To determine the geometric mean diameter of the mango seed, spatial dimensions like length (L), breadth (B), thickness (T) was measured with the help of digital Vernier calipers. The geometric mean diameter (Dg) of samples was found using the following formula given by Kacharu et al (1994);

$$\text{Geometric mean diameter } (Dg) = (a \times b \times c)^{1/3}$$

Where, a = Major Diameter

b = Intermediate Diameter and

c = Minor Diameter

**v. Arithmetic Mean Diameter**

The arithmetic mean diameter of the kernel was determined from the three-principle diameter using the relationship by (Sunmonu *et al.,* 2015):

$$Da = \frac{(a + b + c)}{3}$$

Where a = Major Diameter

b = Intermediate Diameter and

c = Minor Diameter

**vi. Surface Area**

The surface area was determined by using the following equation as cited by Sacilik *et al*., (2003), Tunde-Akintunde and Akintunde (2004) and Altuntas *et al*., (2005):

$Sa = \pi GMD^2$

Where; Sa = surface area ($mm^2$) and

GMD = geometric mean diameter (mm)

**vii. Sphericity**

The sphericity of the kernel was calculated by using the following relationship (Sunmonu *et al.,* 2015).

$$\text{Sphericity } (\Phi) = \frac{Dg}{a} \times 100, (\%)$$

Where, Dg = Geometric mean diameter (mm)

a = major diameter

**viii. Density**

The density of the kernel was determined using the ratio of weight to the volume

Where,

$$\text{Density } (\rho) = \frac{W}{V}$$

Where, W = Weight (g)

Volume ($cm^3$) and

= ($g/cm^3$)

**ix. Angle of repose**

The angle of repose is the angle with the horizontal at which the material will stand when piled. The angle of repose is the angle made by mango seed with the horizontal wooden surface when piled from a known height with help of empty cylindrical cone of particular height and diameter (Divekar et al., 2016). Mango seed sample was piled over a horizontal surface. The radius of the pile was calculated from the circumference of the pile and the height of the pile was determined. The angle of repose was calculated using for formula (Kaleemullah and Gunasekar, 2002).

$$\text{Angle of repose} = tan^{-1}\frac{h}{r}$$

Where, h = height of piled, cm

r = radius of the piles, cm

### 2.2.2 Mechanical Properties

**Fracture force and strain at yield**

A universal testing machine (Testometric M500-100AT) was used to obtain the fracture force of the kernel. The slots were screwed to compress the kernel placed between them. The counter reading was taken immediately the first cracking sound was heard. The strain at yield was also recorded during the test on the Universal Testing Machine. The deformation at yield was also recorded during the test on the Universal Testing Machine. Compressive strength was calculated by dividing the fracture force with the area in contact with the kernel (Sunmonu *et al.,* 2015).

### 2.3 Method of Data Analysis

Analysis of variance using SPSS was carried out to determine the level of significance between the geometric mean of the three varieties and between the arithmetic mean of the three varieties of mango.

## 3. Results

The averages of the tri-axial dimensions major, intermediate and minor diameter of the seeds are given in Table 1. The result gave 38.00 ± 6.8, 42.23 ± 4.12, 33.95 ± 6.91 as average major diameter; 35.60 ± 5.68, 39.18 ± 3.95, 31.44 ± 7.56 as average intermediate diameter and 24.76 ± 5.2, 28.42 ± 5.59, 23.08 ± 3.67 as the average minor diameter for Kerosene, Sheri and Sugar mango respectively. All dimensions are in millimeter (mm).

**Table 1.** Measured and calculated physical parameters of the three varieties of mango

| Varieties of mango | Geometric mean (mm) | Arithmetic mean (mm) | Average minor diameter (mm) | Average major diameter (mm) | Average intermediate diameter (mm) |
|---|---|---|---|---|---|
| **Kerosene** | 33.45 | 34.04 | 24.76 ± 5.2 | 38.00 ± 6.8 | 35.60 ± 5.68 |
| **Sheri** | 35.95 | 36.44 | 28.42 ± 5.59 | 42.23 ± 4.12 | 39.18 ± 3.95 |
| **Sugar** | 26.89 | 20.16 | 23.08 ± 3.67 | 33.95 ± 6.91 | 31.44 ± 7.56 |

**i. Geometric mean diameter**

The average geometric mean diameter of the three varieties of mango seed was 33.45 mm, 35.95 mm and 26.89 mm for Kerosene, Sheri and Sugar mango respectively.

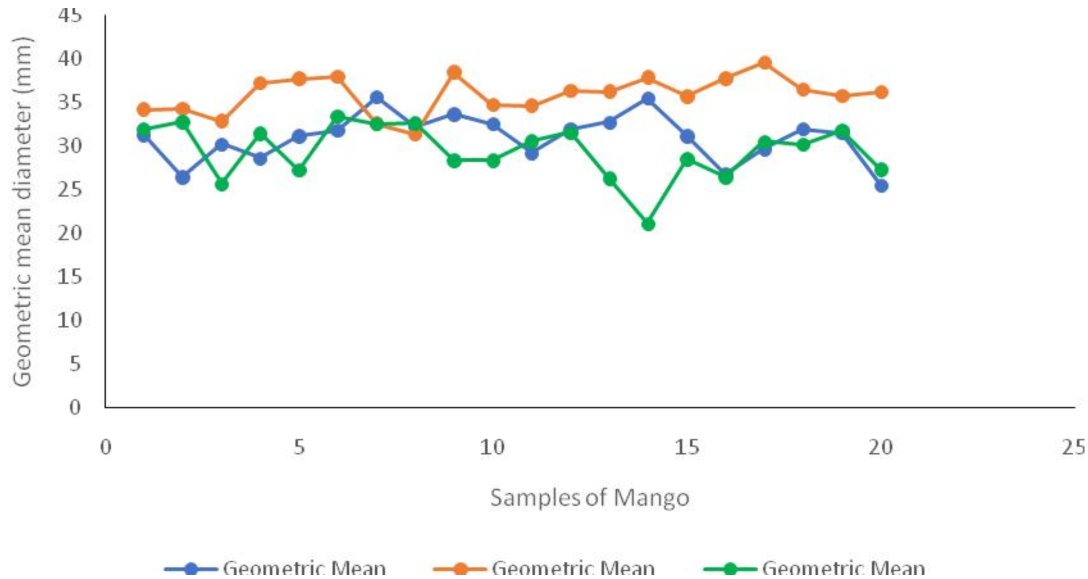


Fig. 1: Geometric mean comparison among the three varieties of mango

The analysis carried out on the results shows that a highly significant difference was observed between the geometric mean of Kerosene mango and Sheri mango and between Sheri mango and Sugar mango while there is no significant difference between the geometric mean of Kerosene mango and Sugar mango at 5% level of significance.

**ii. Arithmetic mean diameter**

The average arithmetic mean diameter of the three varieties of mango seed was 34.04 mm, 36.44 mm and 20.16 mm for Kerosene, Sheri and Sugar mango respectively.

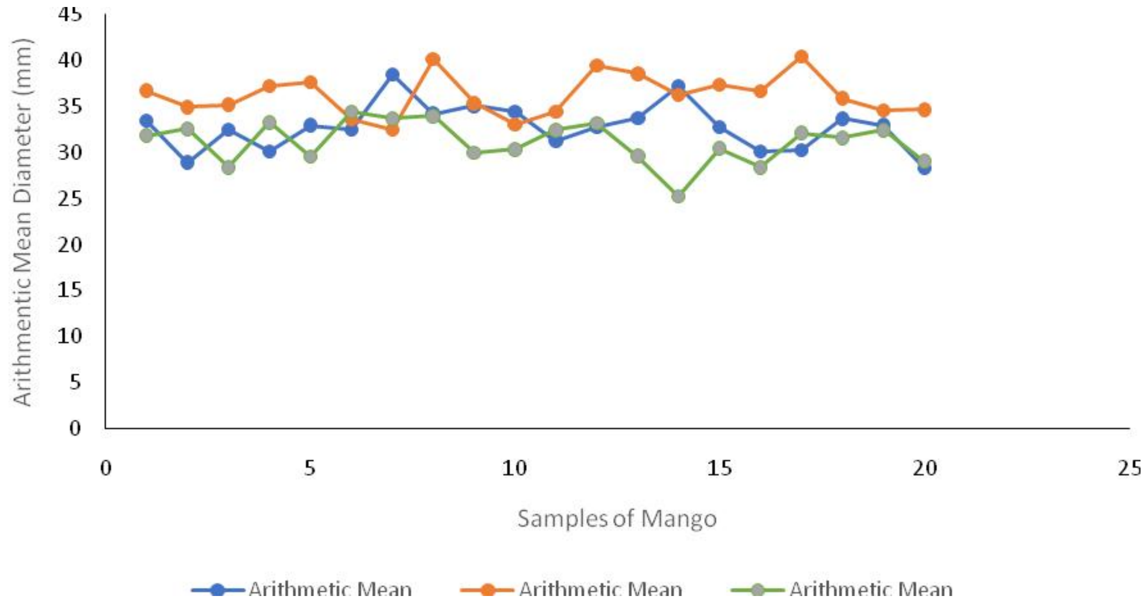


Fig 2: Arithmetic mean comparison among the three varieties of mango

The arithmetic mean of the three varieties was highly significant within each other 5% level of significance while for sphericity, there was no significant difference between any of the three varieties of mango at 5% level of significance.

**iii. Sphericity**

The average sphericity of the three varieties of mango seed was 0.74, 0.77 and 0.67 for Kerosene, Sheri and Sugar mango respectively. The analysis carried out on sphericity shows that there was no significant difference between any of the three varieties of mango at 5% level of significance.

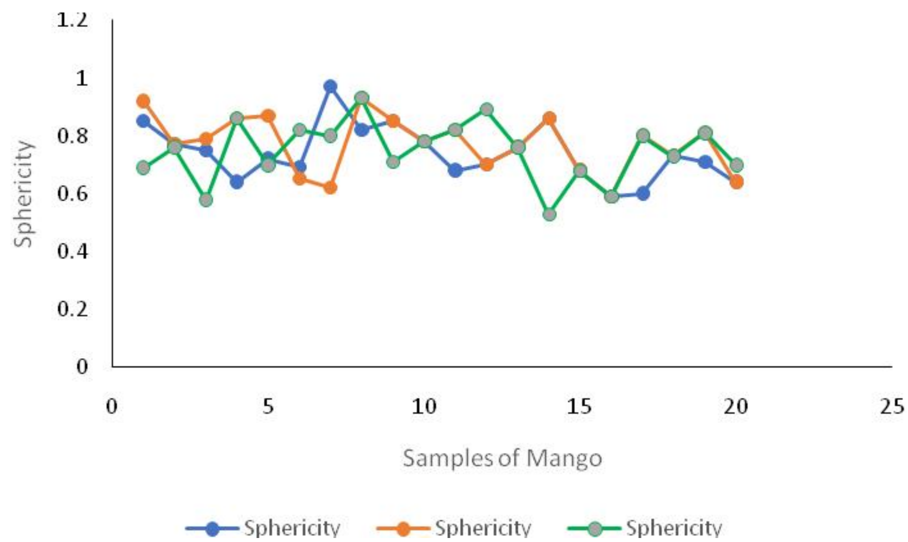


Fig 3: Comparison of sphericity among the three varieties of mango

**iv. Angle of repose**

The angles of repose for the three varieties of mango seeds were $40.43^0$, $08.03^0$ and $09.76^0$ for Kerosene, Sheri and Sugar mangoes respectively. The result is shown in table 2 below.

**Table 2.** Determination of angle of Repose

| Varieties of mango | $Tan^{-1}\Theta$ | $\Theta$ ($^0$) |
|---|---|---|
| **Kerosene** | 0.852 | 40.43 |
| **Sheri** | 0.141 | 08.03 |
| **Sugar** | 0.172 | 09.76 |

**v. Moisture content**

Results showed the moisture content of Sheri mango, Sugar mango, and Kerosene mango was 6.43%, 11.9%, and 6.81% respectively. The three moisture content levels were observed to be the range at which the mango kernel can be extracted with the least percentage of crushing. Further decrease in the moisture content will make the kernel to be brittle, while a higher moisture level will make the kernel to stick to the shell, therefore, resulting in crushing if cracked.

**Table 3.** Moisture content of mango varieties

| Varieties of mango | Moisture Content (%) |
|---|---|
| **Kerosene** | 6.81 |
| **Sheri** | 6.43 |
| **Sugar** | 11.9 |

**vi. Mechanical properties of mango seed**

Mechanical properties of mango seed such as compressive stress was calculated from Universal Testing Machine.

**Table 4.** Crushing force of the mango varieties

| Varieties of mango | Average Crushing Force (N) |
|---|---|
| **Kerosene** | 21.00 |
| **Sheri** | 10.58 |
| **Sugar** | 9.46 |

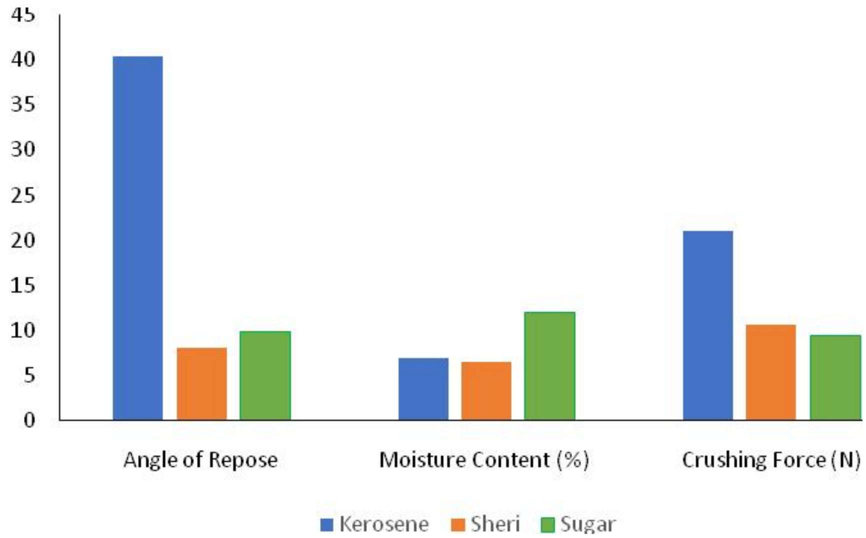


Fig. 4: Comparison of Angle of repose and moisture content and crushing force among the three varieties of mango

The angle of repose in Fig. 4 shows that kerosene mango has the highest value while that of Sheri and Sugar mango were closely related. A material with a high angle of repose such as Kerosene mango has the potential to backfill into the fill head and limit the amount of material that can be placed in the container, thus, this information is useful in handling, storage, and transportation of the three varieties of mango.

The crushing force of kerosene mango is also the highest as shown in Fig. 4 above while that of Sheri mango and Sugar mango are closely related, crushing force is essential when designing machine for processing the mango seeds for extraction of oil or in size reduction machines.

## 4. Discussion

The average major diameter of 38.00 ± 6.8, 42.23 ± 4.12, 33.95 ± 6.91; average intermediate diameter of 35.60 ± 5.68, 39.18 ± 3.95, 31.44 ± 7.56 and average minor diameter of 24.76 ± 5.2, 28.42 ± 5.59, 23.08 ± 3.67 for Kerosene, Sheri and Sugar mango respectively is smaller than that reported by Ehiem and Simonyan (2012) for two varieties of wild fruit mango; *Irvingia gabonensis* and *wombolu* which had the major diameter as 66.3 ±7.0 mm, intermediate diameter as 63.1 ± 7.4 mm and minor diameter as 60.5 ± 6.9 mm for *Irvingia gabonensis* and 61.3 ± 4.8 mm, 55.1 ± 3.9 mm and 48.9 ± 4.1 mm as major, intermediate and minor diameter for *Irvingia wombolu* and also smaller than that reported by Mannan et al., (2003) for Madrazi Tota, Sharmai Falzi and Indian Lota varieties which had the major, intermediate and minor diameter as 150.53 mm, 70.23 mm and 60.16 mm for Madrazi Tota, 120.31 mm, 50.23 mm, 50.60 mm for Sharmai Falzi and 60.33 mm, 50.30 mm and 40.52 mm for Indian Lota. This indicates that these varieties are bigger in size than any of the varieties under this study.

The geometric mean diameter of 63.2 mm for *Irvingia gabonensis* and 55.0 mm for *Irvingia wombolu* is also higher than any of the varieties under this study indicating that the varieties under this study is much smaller in size due to the genetic makeup of individual variety and the influence of environmental factors.

The sphericity of *Irvingia gabonensis* and *Irvingia wombolu* reported by Ehiem and Simonyan (2012) which is 0.95 and 0.90 respectively is also higher than any of Kerosene, Sheri and Sugar mango which are 0.74, 0.77 and 0.67 respectively.

In the study conducted by Bora et al., (2017) for some varieties of mango fruit; the highest fruit length was recorded in Mallika (120.5 mm) followed by Ambika (119.6 mm) and Pusa Arunima (118.8 mm). However, the mean value for fruit length ranged from 72.1 mm to 125.5 mm while the mean value for fruit width showed a range of 50.7 mm to 88.5 mm. These values however, are higher than the ones obtained in this study indicating that the varieties of mango in this study are smaller.

Adualrahman (2013) reported the length of three varieties of mango; Nyala, Edelfursan and Kaboom as 101 ± 0.01 mm, 113 ± 0.02 mm and 125 ± 0.01 mm respectively while the width are 83 ± 0.03 mm, 92 ± 0.01 mm and 95 ± 0.02 mm respectively. These varieties are also bigger in size than the one under this study.

## 5. Conclusions

The average value of the calculated geometric mean is highly significant between Kerosene mango and Sheri mango and no significant difference between Sheri mango and Sugar mango.

The average value of the calculated arithmetic means was found to be statistically different within the three varieties but no significant difference in sphericity.

Kerosene mango has the highest value for the angle of repose and crushing force.

## 6. Recommendations

The information on the selected physical properties and mechanical properties should be followed when designing machine for planting, handling, transporting and processing the mango varieties.

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