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 and sphericity were determined while some selected mechanical properties such as crushing force were determined. The result of 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 Kerosene, Sheri and Sugar mango respectively. The result of 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. From the results, 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.

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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).

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It is one of the most important tropical fruit in the world; it is greatly relished for its succulence, exotic flavor 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; in 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*., 1988).

Information on the physical properties of mango seed will help to know about their shape and shape 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. M aterials 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. Other materials used

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for the experiment were hot air oven, weighing balance, Vernier caliper, measuring cylinder, beaker, frictional apparatus, universal testing machine, etc.

2.2 Methods

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 and their moisture content was taken according to the standardized procedure for moisture content determination by ASABE standard S352.2 (2007). The weight of the kernel was determined by using the digital electric weighing balance. 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

The shape of the mango seed is determined with the help of 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) and using the data of spatial dimensions.

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

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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).

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

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. 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).

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 shown in Figure 2.1. 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 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.

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3. Results

Physical properties of mango seed such as moisture content, tri-axial dimensions, geometric mean diameter, sphericity, angle of repose and coefficient of friction were determined. The total of 20 samples was taken for each variety for determination of tri-axial dimension. 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).

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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.

ii. **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.

iii. **Angle of repose**

A total number of 20 samples were taken for each variety to determine the angle of repose. The angle of repose for the three varieties of mango seed 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.

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Table 2: Determination of angle of Repose

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

iv. **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 4: Moisture content of mango varieties

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

v. **Mechanical properties of mango seed**

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

Table 3: Crushing force of the mango varieties

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

4. **Discussion**

From the analysis carried out on the results, 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.

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. This same trend was observed by Ehiem and Simonyan (2012) for wild mango fruit and Eke e*t al.* (2007) for Jackbean. This information will aid in developing machines and conveyors for processing and handling of any of the three varieties of mango.

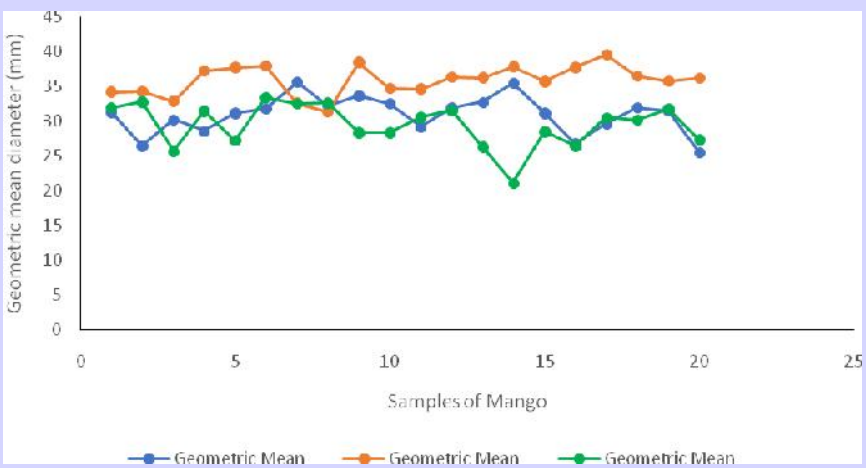

Fig. 1: Geometric mean comparison among the three varieties of mango

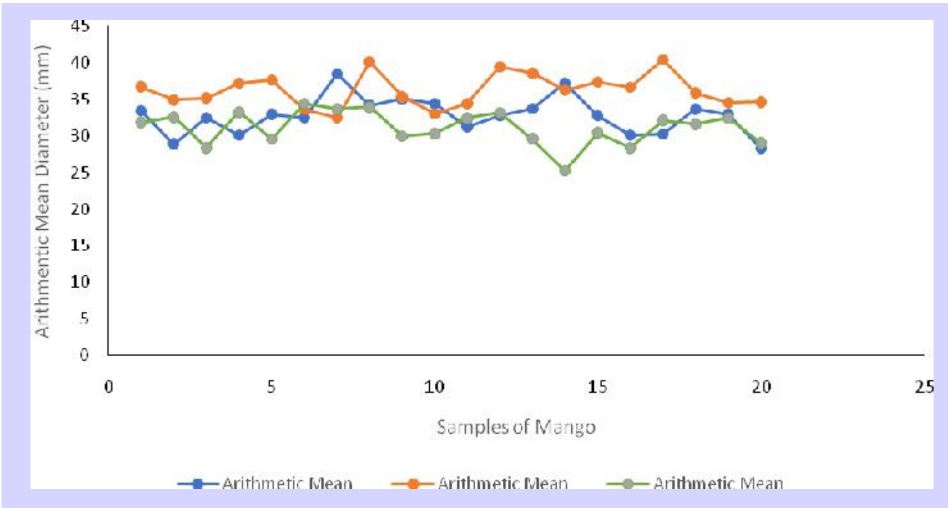

Fig 2: Arithmetic mean comparison among the three varieties of mango

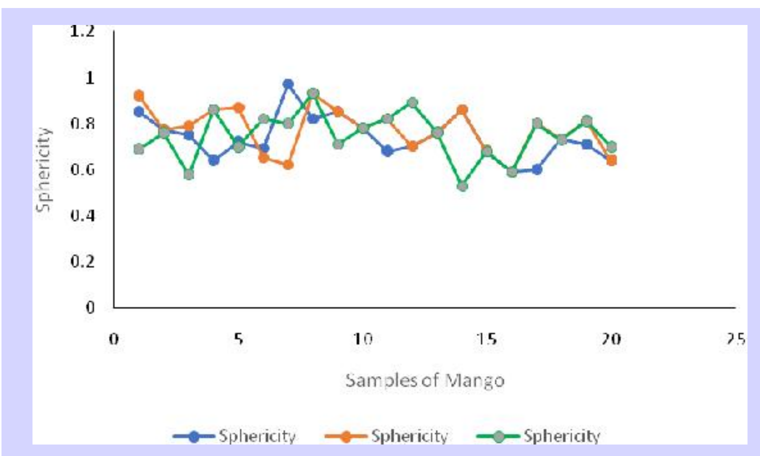

Fig 3: Comparison of sphericity among the three varieties of mango

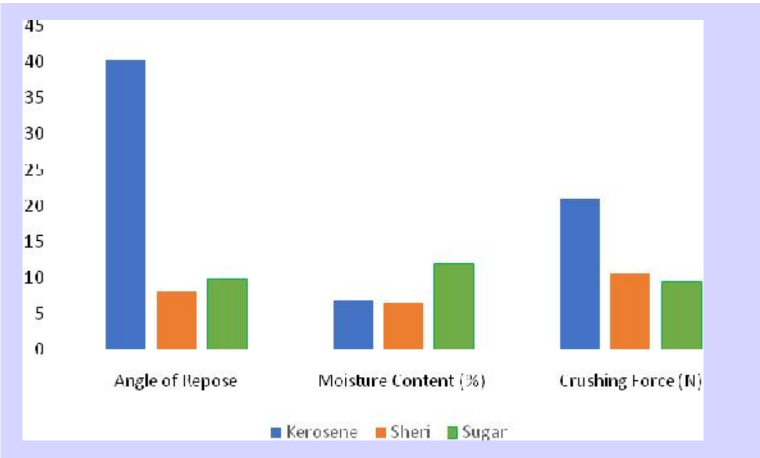

Fig. 4: Comparison of Angle of repose and moisture content and crushing force among the three varieties of mango

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.

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Your results were not properly discussed, The work was not adequately compared with similar work.

5. Conclusions

i. 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.

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

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

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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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