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ENGINEERING PROPERTIES OF ALPHONSO MANGO STONE

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ABSTRACT

Mango (*Mangifera indica* Linn.) is one of the most important tropical fruits in the world, especially in the India, in the Konkan region of Maharashtra state and it is greatly relished for its succulence, exotic flavor and delicious taste in most countries of the world. During processing of mango, by-products such as peels and mango stones are generated. In the mango stones various important nutritious values like protein, crude oil, ash, carbohydrate, energy etc. are contents. The determined physical properties of the Alphanso mango stones are required to designing the mango stone decorticator to increase its market value.

The physical properties of the mango stone was determined in spatial dimensions, i.e. length, breadth, thickness, geometric mean diameter and Sphericity for Grade – A of Alphanso mango stone was to be 59.95 mm, 32.30 mm, 10.10 mm, 28.31mm and 0.42 respectively, for Grade – B 67.74 mm, 36.76 mm, 13.10 mm, 31.80 mm and 0.47 respectively, and for Grade – C 77.93 mm, 41.85 mm, 17.14 mm, 35.81mm and 0.53 respectively. The bulk density and true density for Alphanso mango stone was to be 257 kg/m^3, 381.9 kg/m^3. The compressive stress and tensile stress for Alphanso mango stone was to be 182.9 k-N/m^2, 113.1 k-N/m^2 respectively.

Keywords: Mango stone, mango kernel, physical properties, mechanical properties.

INTRODUCTION

Mango (Mangifera indica Linn.) is one of the most important tropical fruits in the world, especially in the India, in the Konkan region of Maharashtra state and 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 1973). Mango production in 2010 was 39 million tonnes

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(including mango stones and guava). The production in India during year 2011-2012 was 16196 MT in 2378 thousand ha area and in Maharashtra was 503 MT in 482 thousand ha area (Anonymous 2013).

Mango is seasonal fruit; about 20 per cent of 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 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 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. The seed content of different varieties of mangoes ranges from 9 % to 23 % of the fruit weight (Palaniswamy *et al*., 1974) and the kernel content of the seed ranges from 45.7 % to 72.8 % (Hemavathy *et al*., 1988). Physical properties of mango stone will help to know about their shape, size, their holding, transport, storage and hopper design of particular machine for processing. Mechanical properties describe the behavior of material under various types of loading. The knowledge of mechanical properties helps in designing of structures and equipment's used to handle mango stone. We are interested in their hardness, and how these properties change with temperature. We are mostly interested in decortications of mango kernel from mango stone.

MATERIALS AND METHODS

Materials:

The materials used for the experiment were Hot air oven, weighing balance, Vernier calliper, Measuring cylinder, Beaker, frictional apparatus, Universal testing machine, etc.

Chemical Reagent: Toluene solution was used for determining true density of the stone.

Methods:

Determination of Moisture Content

The moisture content of mango stone was determined with the help of air oven method. The process of moisture determination was as follows.

First of all measure the empty sample box (w_1). Then the mango stone sample was put into the sample box. After that measured the weight of the sample box plus weight of sample (w_2). Then

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the unlid sample box was put into the air oven having temperature 105˚C for 24 hrs (Mohsenin, 1998). After 24 hrs the box along with sample are removed from the oven and put it into desiccator for 15 minute. After that measure the weight of the oven dried sample (w_3). The moisture content of the mango stone was calculated by using the following formula;

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

Where, W_1 = Weight of sample box (g),
W_2 = Weight of sample box with lid and Alphanso mango stone (g),
W_3 = Weight of sample box with lid and Alphanso mango stone after drying (g).

Geometric mean diameter

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

$$D_g = (L \times B \times T)^{\frac{1}{3}}$$

Where, L = Length, mm
B = Breadth, mm
T = Thickness, mm

Sphericity

It is defined as ratio of surface area of sphere having same volume as that of the mango stone to the surface area of the mango stone. The sphericity is used to describe the shape of the mango stone. Thus, the sphericity (Sp) was accordingly computed as per formula given by Sahay and Singh. (1994).

$$S_P = \frac{Dg}{L}$$

Where, D_g = Geometric mean diameter,
L = Length, mm.

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Roundness

It is a measure of the sharpness of the corners in the solid. Several methods have been proposed for estimating roundness.

$$\text{Roundness} = \frac{Ap}{Ac}$$

Where, A_P = Largest projected area of object in natural rest position,

A_C = Area of smallest circumscribing circle.

Bulk density

It is the ratio of mass per unit volume. Bulk density is important parameter in designing of different processing machineries. The process of bulk density determination is to first of all measure the empty weight of the known volume 5 lit. of measuring container (W_1). After that mango stone sample was poured into the measuring cylinder and weighing it (W_2).The original weight of sample by subtracting above two weights (W3). Then find out the bulk density by dividing original weight of sample to the volume of cylinder. It was determined by the formula given by Kacharu et.al (1994).

$$\rho_b = \frac{weight\ of\ sample}{volume}$$

True density

The true volume was determined using the liquid displacement method. Toluene (C_7H_8) was used instead of water because it is absorbed by acorns to a lesser extent. In addition, its surface tension is low, so that it fills even shallow dips in an acorn, and its dissolution power is low (Mohsenin, 1978). The process of bulk density determination is to first of all measure the unit mass of mango stone. Then sample is submerged in a known volume (V) of toluene in a beaker. Then measure the volume displaced by sample (V") and find out the true value of volume displaced by sample. Finally True density (ρt, kgm-3) of samples was calculated by dividing the unit mass of each sample by its true volume. True density of mango stone was determined by the formula

$$\text{True density} = \frac{\text{mass}}{\text{displaced volume}}$$

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Porosity

The porosity (ε) of mango stone was computed from the values of bulk density and true density using the relationship given by Sahay and Singh (1994).

$$\text{Porosity} = \frac{\text{True density} - \text{Bulk density}}{\text{True density}} \times 100$$

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 stone with the horizontal wooden surface when piled from a known height with help of empty cylindrical cone of particular height and particular diameter. Mango stone 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 the formula (Kaleemullah and Gunasekar, 2002);

$$\Theta = \tan^{-1} \left[\frac{h}{r}\right]$$

Where, h = height of piled, cm,
r = radius of the piles, cm.

Determination of coefficient of friction

The experimental apparatus used in the friction studies was similar to that reported by Kaleemullah and Kailappan (2003). The apparatus consisted of a frictionless pulley fitted on a frame, a bottomless rectangular container, loading pan and test surfaces. The bottomless container placed on the test surface was filled with a known quantity of tamarind and weights were added to the loading pan until the container began to slide. The mass of mango stone and the added weight represent the normal force and frictional force respectively. The Coefficient of static friction was calculated as the ratio of frictional force to the normal force as,

$$\text{Coefficient of friction} = \frac{W_2 - W_1}{W}$$

Where, W_1 = Weight to caused sliding of empty box (g),
W_2 = Weight to caused sliding of filled box (g),
W = Weight of material inside the box (g).

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Stress

It is force acting per unit area which is perpendicular to the direction of force, usually expressed in N/m^2.

$$P = \frac{p}{A}$$

Where, P = Intensity of stress, N/m^2,
p = Load of force acting on body, N,
A = Area of Cross section, m^2.

Compressive Stress

Compressive stresses are used for determining the rupture point of the mango stone with the help of universal testing machine. This device, a SHIMAZDU (Tehran, Iran), has three Load cell Moving platform PC card Monitor main components, a moving platform, a driving unit and a data -acquisition system (load cell, PC card, software and monitor). The sample was placed on the moving platform at the 5 mm min-1 speeds and pressed with a plate fixed on the load cell until rupture occurred, as denoted by a bio - yield point in the force - deformation curve. To determine the compressive stress the procedure adopted was as follows the readings of length, width and thickness of the mango stone was set on the computer. Then sample is placed on the holding die assembly by selecting the manual button on the Universal testing machine. Before starting machine calibration should be done at zero strokes. Then pressing auto button on Universal Testing Machine and select the start button on computer load is automatically going to increase on sample with a speed of 10 mm / min. up to their maximum break point then increasing load should stop from computer. Then graph is plated on computer of break force verses break stress and then note down the readings from graph.

Tensile Stress

Tensile stresses are used for determining the rupture point of the mango stone with the help of universal testing machine. To determine the tensile stress the procedure adopted was as follows the specimen of the mango stone, Measure and record specimen dimensions (length, breadth, thickness) in a table provided for the calculation of the tensile. Fit the specimen on to the Universal Testing Machine in their upper and lower gripping jaw with pressing manual button on Universal Testing Machine and maintain their spacing. Then pressing auto button on Universal Testing Machine and select the start button on computer load is automatically going to increase on sample with a speed of 10 mm / min. Then record load and extension for the construction of

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stress - strain curve of each tested specimen. Calculate tensile strength and tensile force. Analyse the fracture surfaces of broken specimens using stereoscope, sketch and describe the results.

RESULT AND DISCUSSION

Physical Properties of Mango Stone

Physical properties of mango stone such as moisture content, spatial dimensions, geometric mean diameter, sphericity, roundness, bulk density, true density, angle of repose, coefficient of friction were determined. The total 500 numbers of samples were taken for determination of spatial dimensions for Alphonso mango stone were divided in three Grades of A, B and C respectively, which are shown below;

Table No. 1 Spatial dimensions of Alphonso mango stone for Grade – A

Sr. No.	Particular	Unit	Average
1	Length	Mm	59.95
2	Breadth	Mm	32.20
3	Thickness	Mm	10.10
4	Geometric mean diameter	Mm	28.31
5	Sphericity	-	0.42

Table No. 2 Spatial dimensions of Alphonso mango stone for Grade - B

Sr. No.	Particular	Unit	Average
1	Length	mm	67.34
2	Breadth	mm	36.76
3	Thickness	mm	13.10
4	Geometric mean diameter	mm	31.80
5	Sphericity	-	0.47

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Table No. 3 Spatial dimensions of Alphonso mango stone for Grade – C

Sr. No.	Particular	Unit	Average
1	Length	mm	77.93
2	Breadth	mm	41.85
3	Thickness	mm	17.14
4	Geometric mean diameter	mm	35.81
5	Sphericity	-	0.53

Moisture content of Mango Stone

The moisture content of mango stone was determined by air oven method. The temperature of air oven was maintained at 105˚C for 24 hours and all weight loss was considered to be moisture, according to the standardized procedure for moisture content determination by ASABE standard, (2007).The average moisture content of Alphonso mango stone was found 15.81 %, w.b. respectively during the project work.

Spatial dimension of mango stone

The spatial dimension of mango stone includes length, width and thickness which are useful to determine geometric mean diameter and sphericity of mango stone. The total 500 numbers of samples were taken for the project work of variety Alphanso mango stone. The samples of mango stones were divided in three grades, grade – A (16 %), grade – B (74.8 %) and grade – C (8.4 %) for each two varieties alphonso mango stone to measurement of spatial dimensions at three perpendicular dimensions of the mango stones using digital Vernier calliper.

Length

The average length of Alphonso mango stone for grade - A was 59.95 mm, the average length for grade - B was 67.74 mm and the average length for grade - C was 77.93 mm respectively.

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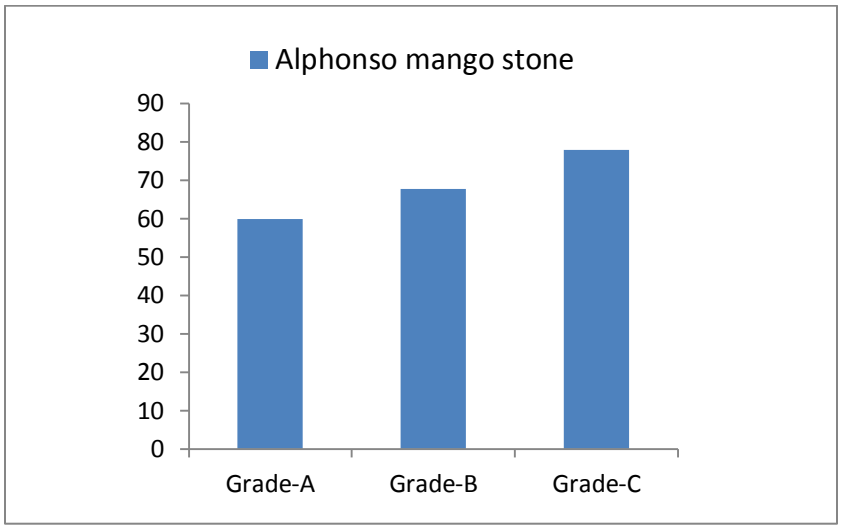

Fig. 1 Length of Alphonso mango stone

Breadth

The average breadth of Alphonso mango stone for grade - A was 32.30 mm, the average breadth for grade - B was 36.76 mm and the average breadth for grade - C was 41.85 mm respectively.

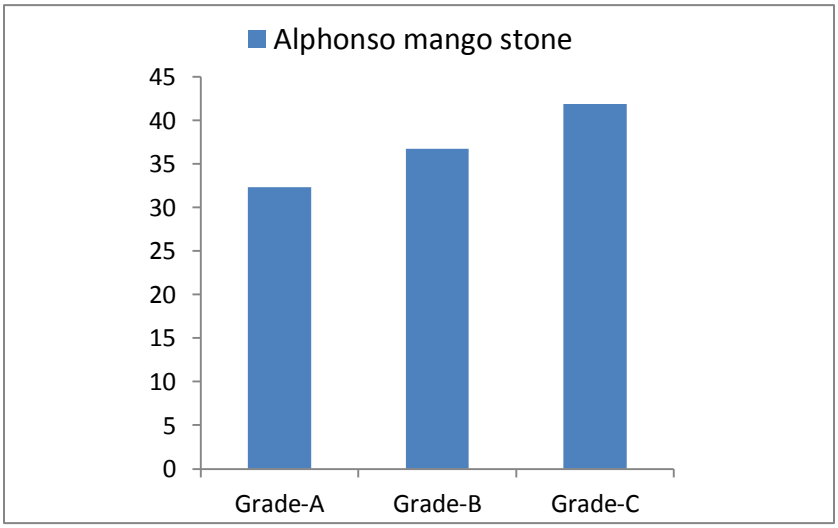

Fig. 2 Breadth of Alphonso mango stone

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Thickness

The average thickness of Alphonso mango stone for grade - A was 10.10 mm, the average thickness for grade – B was 13.10 mm and the average thickness for grade - C was 17.14 mm respectively.

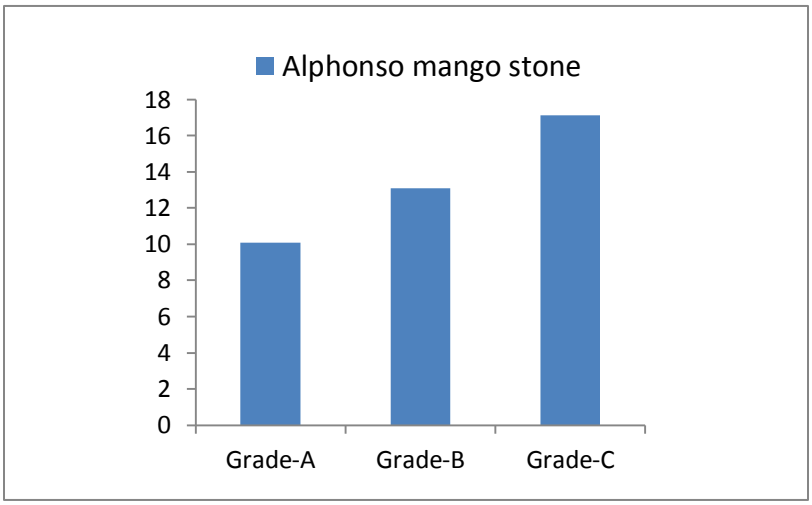

Fig. 3 Thickness of Alphonso mango stone

Geometric mean diameter

The average geometric mean diameter of Alphonso mango stone for grade - A was 28.31 mm, the average geometric mean diameter for grade - B was 31.80 mm and the average geometric mean diameter for grade - C was 35.81 mm respectively.

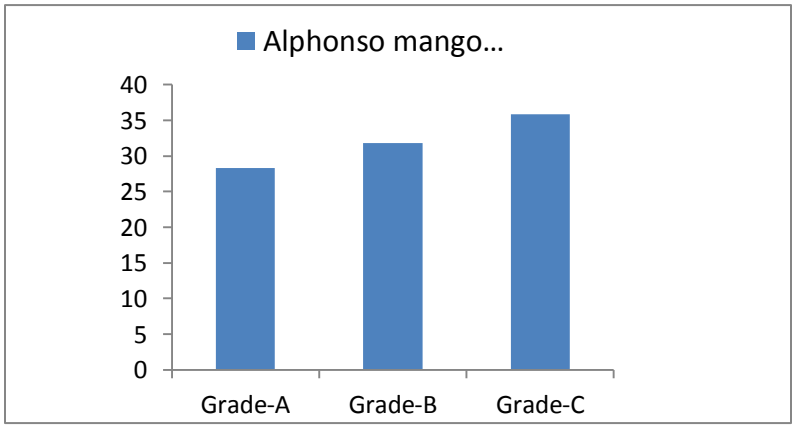

Fig 4 GMD of Alphonso mango stone

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Sphericity

The average Sphericity of Alphonso mango stone for grade - A was 0.42, the average sphericity for grade - B was 0.47 and the average sphericity for grade - C was 35.81 respectively.

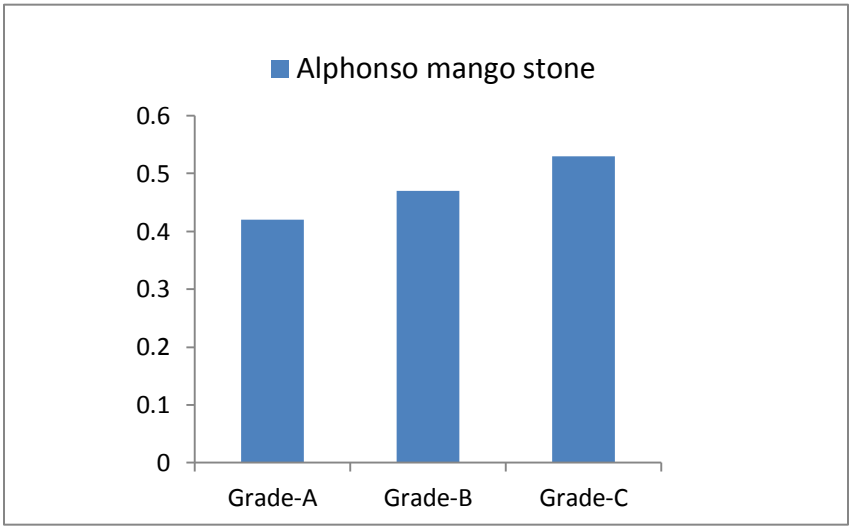

Fig. 5 Sphericity of Alphonso mango stone

Roundness

The value of the roundness will help to know the shape of the object. The total 30 numbers of samples were taken for the project work of variety Alphonso. The average roundness was 0.3424 respectively.

Bulk density

The total 30 numbers of samples were taken for the project work of variety Alphonso. The bulk density was lying between 251.1 kg/m^3 to 263 kg/m^3. The average bulk density was 257 kg/m^3 respectively.

True density

The total 30 numbers of samples were taken for the project work of variety Alphonso. The true density was lying between 600.2 kg/m^3 to 1583 kg/m^3. The average true density was 894 kg/m^3 respectively.

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Porosity

The total 30 numbers of samples were taken for the project work of variety Alphanso. The porosity of Alphonso mango stone was lying between 56.13 % to 83.61 %. Average porosity was 69.73 % respectively.

Coefficient of friction

The total 30 numbers of samples were taken for the project work of variety Alphonso. The coefficient of friction was lying between 0.71 to 0.845. The average coefficient of friction was 0.813 respectively.

Mechanical Properties of Mango Stone

Mechanical properties of mango stone such as compressive stress and tensile stress of mango stone were calculated from Universal Testing Machine.

Table No. 4 Mechanical Properties of Alphonso mango stone

Sr. No.	Particular	Unit	Average
1	Compressive stress	kN/m^2	102.9
2	Tensile Stress	kN/m^2	83.2

Compressive Stress

The compressive stress of the Alphonso mango stone load to the area of the impression made by indentor is found with help of Universal Testing Machine in three different axis at a particular sensitivity and displacement. The total 30 numbers of samples were taken for the project work of variety Alphonso. The compressive stress of Alphonso mango stone was lying between 38.2 k-N/m^2 to 142.7 k-N/m^2. Average compressive stress was 10.29 k-N/m^2 respectively.

Tensile Stress

The tensile stress of the Alphonso mango stone load to the area of the impression made by indentor is found with help of Universal Testing Machine in three different axis at a particular sensitivity and displacement. The total 30 numbers of samples were taken for the project work of

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variety. The tensile stress of Alphonso mango stone was lying between 57.0 k-N/m^2 to 186.97 k-N/m^2. Average tensile stress was 83.2 k-N/m^2 respectively.

CONCLUSIONS

1. The spatial dimensions Grade – A, Grade – B and Grade – C Alphonso mango stone were I) length 59.95mm, 67.74 mm and 77.93 mm respectively. II) breadth 32.30 mm, 36.76 mm and 41.85 mm respectively. III) thickness 10.10 mm, 13.10 mm and 17.14 mm respectively. IV) Geometric mean diameter 28.31mm, 31.80 mm and 35.81mm respectively. V) Sphericity 0.42, 0.47 and 0.53 respectively.
2. The bulk density, true density and porosity for Alphonso mango stone was 257 kg/m^3, 894 kg/m^3 and 69.73 % respectively.
3. The static coefficient of friction and roundness of Alphonso mango stone was to be for wooden plank 0.813 and 0.342 respectively.
4. The compressive stress and tensile stress for Alphonso mango stone and Kesar mango stone was 182.9 k-N/m^2 and 83.2 k-N/m^2 respectively.

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