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Determination of Physical – Mechanical Properties of Freshly Harvested Areca Nut Fruit

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A B S T R A C T

The physical properties of freshly harvested areca nut fruit were determined. Such properties are benefited to design and develop the areca nut harvesting, handling and processing machineries. Hence, the experiment was undertaken at 66.43 % (w.b.) moisture content of freshly harvested areca nut (ripe stage). The mean diameter, sphericity, volume, nut surface area, bulk density, true density, porosity, angle of repose. The mean values of length, breadth and thickness for areca nut were, 54.13 (± 3.87), 47.25 (± 2.53) and 41.73(±2.96) mm, respectively and geometric mean diameter, sphericity, bulk density, true density and porosity were 47.21 (± 2.40) mm, 0.87(± 0.043), 196.72 kg/m^{3,} 1.06 g/cc and 81.61 per cent, respectively. While, surface area and volume of areca nut fruit were 22035.16 mm^2 and 19488.3 mm^3, respectively. Mechanical properties of areca nut fruit and tree were measured. Mean values of static coefficient of friction were obtained on steel, plywood and glass was 0.24, 0.18 and 0.15, respectively. While, average force required for breaking of freshly harvested areca nut was 3.7 kN.

Introduction

India is the largest producer and consumer of areca nut in the world. India ranks first in both area (49 per cent) and production (50 per cent) of areca nut. Areca nut is an important cash crop and popular as a mastication used either with betel leaves or as plain or as scented supari. Areca nut is a crop in areas where abundant rainfall is present as it cannot tolerate drought or low rainfall. There are mainly two types of areca nuts, viz.; chali (ripe sun dried nuts) and red boiled type (tender or mature nuts). About 20 per cent of total areca nut production in the country is consumed as ripe fruit. (Anoynomous, 2010).

The major physical and mechanical properties such as shape, size density, porosity, coefficient of internal friction and angle of repose are important in the analysis of behavior of product in material handling. Also, the spatial dimensions such as length, breath and thickness are important in design of areca nut harvesting and handling machines.

Materials and Methods

Freshly harvested areca nut were measured with the digital vernier caliper to find out length (L), breadth (B) and thickness (T) of the sample with least count of 0.01 mm. Longitudinal cross section of areca nut fruit is shown at Fig. 1.

To determine the size and shape of the areca nut, a random method of sampling reported by (Mohsenin, 1986) was followed. The fruit size was determined by picking 100 randomly selected fruits.

For individual areca nut, the three principle dimensions, namely length, width and thickness, were measured using digital vernier caliper (least count 0.01 mm) and longitudinal axis of areca nut fruit is shown at Fig 2. This was done by holding nuts between the two jaws of the calliper at the maximum of the dimension shown at Fig 3.

The major axis was termed as length, while intermediate was termed as width and the minor as the thickness. To obtain mass, each nuts were weighed individually on a precision electronic balance (Contech, 100, 0.001 g).

Geometric mean diameter

The geometric mean diameter of the areca nut was calculated by using the following relationship (Mohsenin, 1986).

$$Dg = (LBT)^{1/3}$$

Where,

L = Length, mm,

B = Width, mm

T =Thickness, mm.

Sphericity

The sphericity, defined as ratio of the surface area of a sphere with the same volume as the seed to the surface area of the areca nut was determined (Mohsenin, 1986).

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

Where,

φ = Sphericity, dimensionless

Dg = Geometric mean diameter

Surface area

The surface area 'S' of the areca nuts was determined by analogy with a sphere of same mean diameter (Singh *et al.*, 2010).

$$S = Dg^{2}$$

Where,

S = Surface area, mm^2

Dg = Geometric mean diameter

Volume

The volume 'V' of the areca nuts in mm^3 was calculated (Swami and Swami, 2010).

$$V = \frac{\pi B^2 L^2}{6(2L - B)}$$

$$B = (WT)^{0.5}$$

Where,

W = Width, mm

Bulk density

The bulk density 'δ_{bd}' in kg/m^3 was calculated from the mass of the nuts and the volume of the container. It is based on the volume occupied by the bulk sample. Bulk density was determined by filling an empty plastic container of predetermined volume and mass with fruits that were poured from a constant height, and weighed (Jahromi *et al.,* 2008). The container was weighed empty to determine its mass and then it was filled with the sample and weighed once again. The bulk density was determined by dividing the mass of the material by the volume of the container (Singh and Goswami, 1996). The areca nut were weigh on an electronic balance and the bulk density was estimated. Twenty replications were made and average value was reported and expressed as kg/m^3 (Singh *et al.,* 2010).

$$\rho_{bf} = Wf / Vv$$

Where,

Wf– weight of fruits, kg

Vv– volume of container, m^3

ρ_{bf}– bulk density of fruit, kg/m^3

True density

True density is defined as the ratio of the mass of the sample to the true volume of the particles. The true density of areca nuts was determined by the toluene displacement method (Deshpande *et al.,* 1991).

In this method 20 randomly selected areca nuts were weighed and poured in 50 ml toluene solution taken in measuring cylinder of 100 ml capacity shown at Fig. 4.4.

The change in volume of sample was measured. Ten replications were made and average value of true density was reported and expressed as kg/m^3. Similarly, true density of each areca nuts sample, was determined.

Porosity

Porosity of areca nut was determined from their bulk density and true density values (Mohsenin, 1986).

$$\text{Porosity } \% = \left(1 - \frac{\text{bulk density}}{\text{true density}}\right)$$

Angle of repose

A box of acrylic sheet, measuring 450 x 450 mm, was made to determine angle of repose. The box was placed on a horizontal floor and filled with freshly harvested areca nuts. The front side of the box was then quickly removed, allowing the nuts to slide down and assume a natural slope. The angle of repose was calculated from the measurements of the height (*x*) of the free surface of the areca nuts from the floor surface and the diameter (*y*) of the heap formed outside the box (Baryeh, 2002; Singh *et al.*, 2010). Twenty such replications were made for nuts and average value was reported. The angle of repose for areca nuts was determined.

$$\theta = \tan^{-1}\left(\frac{2HD}{D}\right)$$

Where,

H = height of heap, mm; and

D = diameter of the heap, mm.

Determination of coefficient of friction

The static coefficient of friction of areca nut was determined for surfaces made of material such as plywood, glass and galvanized iron sheet. Test was replicated five times with each type of structural material. The experimental apparatus used in the friction studies consisted of a frictionless pulley fitted on a frame, a bottomless rectangular box, a loading pan and test surfaces. A topless and bottomless plywood box of dimensions 150 x 100 x 40 mm^3 was filled with areca nut fruit and placed on the horizontal test surface. Weights were then added to the loading pan until the box began to slide along the test surface. The normal force applied N_f was the weight of the fruits in the box and the frictional force F was the weights added to the pan (Chaudhari *et al.,* 2013).

$$\mu = \frac{Nf}{F}$$

Where,

N_f= weight of the shells, g

F = weights added to the pan, g

Breaking force

During harvesting, probability of falling of areca nuts during harvesting operation from certain height and during handling operation is common problem which may cause breakage to kernel. Therefore, breaking force of freshly harvested areca nut has been measured which was evaluated by using UTM (Universal Testing Machine). The samples of areca nuts were selected by randomization method. With the help of calibrated UTM machine, the samples were placed on the platform under load cell with probe maintaining the areca nut position. The pre-programmed UTM machine was allowed to be operated against the sample through load cell and probe. There were two observations recorded in the software *viz.,* the force required to initiate breaking and peak force required during breaking. 20 replications from randomly selected samples were taken. To avoid such damage to fruit, areca nut bunch holder or catcher should be provided to catch the areca nut bunch after harvesting.

Results and Discussion

Spatial dimensions of areca nut fruit

Spatial dimensions of freshly harvested areca nut fruit (variety-Shrivardhan) were determined and presented at Table 5.1. It was observed that, mean values for length, breadth and thickness of areca nut were 54.13 (±3.87), 47.25 (±2.53) and 41.72 (±2.96) mm, respectively. The mean values for GMD and sphericity of were 47.21 (± 2.40) mm and 87 (± 0.042) per cent, respectively.

According to Balasubramanian (1985), length and diameter of areca nut fruit were 40 and 19.7 mm, respectively. Aware *et al.,* (2013) reported that the major, medium and minor diameters of areca nut fruit for mean values were 48.9 mm, 30.2 mm and 29.2 mm, respectively.

The average geometric mean for fruit and kernel were 34.9 and 22.1 mm, respectively. The sphericity of kernel varied between 82.4 and 98.0 per cent with a mean value of 91.6 per cent.

These properties were measured to develop areca nut bunch catcher for mechanical harvester and also for development of container for placement of harvested areca nut bunches.

Surface area

The surface area of freshly harvested areca nut fruit was calculated. The mean value was 22035.2 mm^2.

Volume

The average volume of freshly harvested areca nut fruit was calculated. The mean value was 19488.3 mm^3.

Bulk density

The bulk density of freshly harvested areca nut fruit was determined. The mean value of bulk density of areca nut fruit was 196.72 kg/m^3. Balasubramanian (1985), found that the bulk density of matured areca fruit was 286.7 kg/m^3.

According to Aware (2013) the average bulk density of matured areca fruit was 287.7 $kg/m^{3.}$ The main purpose to measure bulk density was development of container for placement of harvested areca nut bunches.

True density

The true density of freshly harvested areca nut was determined. The mean true density was found to be 1.06 g/cc. Balasubramanian (1985) reported that, the true density of matured areca nut fruit was 0.51 g/cc. while, according to Aware *et al.*, 2013 found that true density of matured areca fruit was 0.53 g/cc.

Fig.1 Longitudinal cross section of areca nut fruit

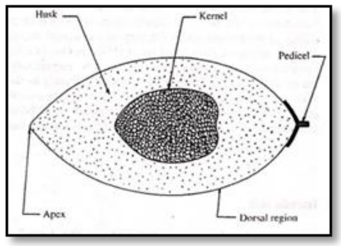


Fig.2 Principle dimensions of areca nuts

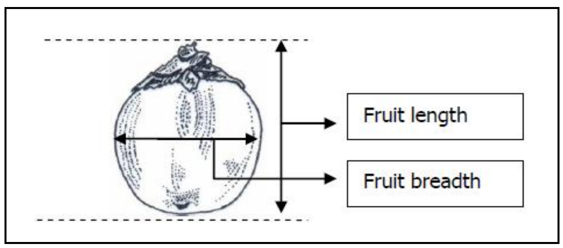
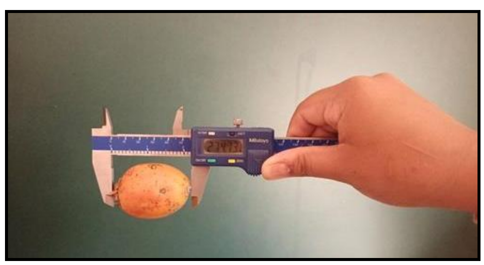


Fig.3 Measurement of geometric mean diameter



Porosity

The porosity was calculated for freshly harvested areca nut fruit. Mean porosity of the areca nut fruit was found to be 81.61 per cent. Balasubramanian (1985) reported that, the value of porosity for matured areca nut fruit was 43.8 per cent.

Angle of repose

The angle of repose of freshly harvested areca nut fruit was found to be 24 degree. According to Aware *et al.*, (2013) the angle of repose of matured areca nut fruits was 24.4 degree. Balasubramanian (1985) found that, angle of repose was of matured areca nut fruit was found 33.1 degree.

Static coefficient of friction of areca nut fruit

Coefficient of friction for areca nut fruit was measured. Three replications for each surface were taken. The average values of static coefficient of friction were obtained on steel, plywood and glass were 0.24, 0.18 and 0.15, respectively. Therefore, it was observed that coefficient of friction was high for plywood and minimum for glass. Similar trend was observed by Aware *et al.*, (2013).

Breaking force of areca nut fruit

Force required for breaking of freshly harvested areca nut fruit was measured. 10 replications were taken. These forces have been measured to observe the breakage of areca nut fruit. The force required to initiate breaking of freshly harvested areca nut was 3.7 kN have been found. Divekar and Rane (2011) observed that, the force required to initiate breaking of freshly harvested areca nut was 3.13 to 5.00 kN.

The main aim of conducting the experiment was to determine the physical and mechanical properties for development of harvesting and post-harvest management machineries.

The mean diameter, sphericity, volume, nut surface area, bulk density, true density, porosity, angle of repose were measured.

The mean values of length, breadth and thickness for areca nut were, 54.13 (± 3.87), 47.25 (± 2.53) and 41.73(±2.96) mm, respectively and geometric mean diameter, sphericity, bulk density, true density and porosity were 47.21 (± 2.40) mm, 0.87(± 0.043), 196.72 $kg/m^{3,}$ 1.06 g/cc and 81.6 1 per cent, respectively. While, surface area and volume of areca nut fruit were 22035.16 mm^2 and 19488.3 mm^3, respectively. Mechanical properties of areca nut fruit were measured. Mean values of static coefficient of friction were obtained on steel, plywood and glass was 0.24, 0.18 and 0.15, respectively. While, average force required for breaking of freshly harvested areca nut was 3.7 kN.

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