Physical and Engineering Properties of Tamarind Fruit

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Abstract

The average length, width, thickness, geometric mean diameter, sphericity index, surface area, bulk density, true density and porosity of tamarind fruit at the moisture content of 25 % on dry basis were determined. Angle of repose during filling and emptying were in an average of 33.53^o and 49.72^o, respectively. Coefficient of friction for tamarind fruits on different surfaces namely, hard board, mild steel, stainless steel, aluminium and galvanized iron sheet were found to be 0.43, 0.59, 0.41, 0.48 and 0.58, respectively.

Keywords: Tamarind, Physical properties, Engineering properties, Sphericity index, Coefficient of friction, Surface area, Bulk density.

I. INTRODUCTION

Tamarind (*Tamarindus indica L*) is an important spice in Indian food and India is the largest producer of tamarind. The knowledge of physical and mechanical properties helps to analyze the behaviour of tamarind during handling and designing of process equipments. In this context, the paper explored some physical and engineering properties of tamarind. Some industrially important physical and engineering properties of tamarind seed were studied by Battacharya *et al*. (1993). Ogunjimi *et al*. (2002) found some engineering properties of locust bean namely: size, 1000 seed weight, true density, bulk density, porosity, static coefficient of friction on wood, angle of repose, specific heat and cracking force. The physical properties of okro fruit at a moisture content of 11.42 per cent (wet basis) were found by Owolarafe and Shotonde (2004). Akar and Aydin (2005) evaluated some physical properties of gumbo fruit varieties as functions of moisture content.

The physical properties such as size, sphericity index, aspect ratio, true density, bulk density and porosity of two varieties of fresh oil palm fruit (dura and tenera) were investigated by Owolarafe *et al*. (2007a). Owolarafe *et al*. (2007b) studied the characterization of palm fruit by determining some macro-structural (physical and mechanical) properties of palm fruit (tenera variety) at different processing conditions, such as sterilization time and duration of digestion.

Haydar *et al*. (2007) studied the physical and chemical characteristics of the six samples of apricot (*Prunus armeniaca* L.) fruits. The frictional properties (emptying and filling angles of repose and static coefficient of friction on five structural surfaces) of five Iranian commercial varieties of pistachio nut and its kernel (namely; Akbari, Badami, Kalle-Ghuchi, Momtaz and O'hadi) were evaluated as a function of moisture content (Razavi *et al*., 2007a). Geometrical properties of five major commercial Iranian pistachio varieties as a function of moisture content were reported by Razavi *et al.* (2007b). Ebubekir and Mehmet (2007) carried out a study to determine the effect of moisture content on some physical properties and mechanical behaviour under compression load of faba beans. Jahromi *et al*. (2008) advocated characterizing the date fruits (cv. Dairi). Dry-basis moisture content of date fruit was found to be 10.45 per cent (10.88 per cent for pitted dates and 7.87 per cent for their pits).

II. MATERIAL AND METHODOLOGY

Physical properties of tamarind

Local variety of tamarind from the farmers in Hosur, Krishnagiri District was purchased to determine the engineering properties. The physical properties determined for tamarind were moisture content, size, shape, bulk density, true density, porosity, angle of repose, surface area and coefficient of friction. The methods adopted for estimating these engineering parameters are detailed below.

Moisture content

Moisture content was determined using hot air oven method. 15 g of three samples were kept in an oven for 3 days at 105^{o}C. Weight loss on drying to a final constant weight was recorded as moisture content by AOAC (1984) recommended method (Jahromi *et al.*,2008).

Dimensions of tamarind

Tamarinds were randomly chosen for measuring dimensions.Length, width and thickness of each tamarind fruit were measured using vernier caliper (least count 0.01 cm). Hundred observations were made to get average values of length , width and thickness of the tamarind fruits.

Bulk density and True density

Bulk density was calculated as the ratio between mass and bulk volume of tamarind. As the size of tamarind was larger than grains, the following method was adopted to determine the bulk density. One bag of tamarind (12.5 kg) was piled over a horizontal surface slowly from a height of 50 cm. The slant height (l) of the pile was measured at different places and the average value was taken. The radius (r) of the pile was calculated from the circumference of the pile. Using slant height (l), radius of the pile (r), volume of the pile was determined and then the bulk density was calculated.

The true density of tamarind was determined by platform scale method. The sample of tamarind was first weighed on a weighing balance (Make: M/s. Avery, India; model: EWS 887 and readability: ± 1g) in air and then immersed in water in a container. The second reading of the scale with tamarind submerged minus the mass of the container with water alone gives the volume. True density of the tamarind was determined by taking ten replications. The quantity of water absorbed by tamarind was considered as negligible.

$$True\,volume = \frac{mass\ of\ displaced toluene(kg)}{density of\ toluene(kg/m^3)} \quad \ldots (1)$$

By knowing the mass of the tamarind in air and the true volume, the density of tamarind was obtained as the ratio between the mass of tamarind in air to its true volume.

$$\rho_t = \frac{W_a}{V_a} \quad \ldots (2)$$

where,

ρ_t = true density of tamarind, kg/m^3

W_a = mass of tamarind in air, kg

V_a = true volume of tamarind, m^3

Geometric mean diameter, Sphericity index and Surface area

Geometric mean diameter (D_g), Sphericity index (ϕ) and surface area (S) were calculated by using the following equations.

$$D_g = (LWT)^{1/3} \quad \ldots (3)$$

$$\phi = D_g/L$$

$$S = \pi D_g^2$$

where,L = length of the fruit, mm

W = width of the fruit, mm

T = thickness of the fruit, mm

Porosity

Porosity was calculated as the ratio of the difference between the fruit and bulk density to the fruit density value and expressed in percentage. The porosity of the tamarind was computed using the formula given below and expressed in per cent.

$$\varepsilon = 1 - (\frac{\rho_b}{\rho_t}) \times 100 \quad \ldots (4)$$

where,

ε = porosity, per cent

ρ_b = bulk density, kg/m^3

ρ_t = true density, kg/m^3

Angle of repose

The angle of repose is the angle made by tamarind with the horizontal surface when piled from a known height. One bag (12.5 kg) of tamarind 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:

$$\theta = \tan^{-1}(l/r) \quad \ldots (5)$$

where,

θ = angle of repose, degree

r	=	radius of pile, mm
l	=	height of pile, mm

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 cylindrical container (94 mm diameter and 98 mm height), 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 tamarind and the added weight represent the normal force and frictional force, respectively. The co-efficient of static friction was calculated as the ratio of frictional force to the normal force as,

$$\mu = \frac{F}{N_f} \quad \ldots (6)$$

where,

μ	=	co-efficient of friction
F	=	frictional force, kg
N_f	=	normal force, kg

The experiment was performed using test surfaces of hardboard, galvanized iron, mild steel, aluminium and stainless steel sheets. Experiments were replicated three times by emptying and refilling with different samples in the container every time and the average value was reported.

III. RESULTS AND DISCUSSION

Physical properties of the tamarind fruit such as size, shape, bulk density, true density, porosity, angle of repose and coefficient of friction were determined and the properties of the tamarind fruits are given in Table 1.

TABLE I

PROPERTIES OF TAMARIND FRUITS AT 25 PER CENT MOISTURE CONTENT (d.b.)

Property	**Number of observations**	**Average**
Length (mm)	100	64.32 (1.52)
Width (mm)	100	17.97 (0.19)
Thickness (mm)	100	10.24 (0.12)
Geometric mean diameter (mm)	100	21.12 (0.20)
Sphericity Index	100	0.33 (0.04)
Surface area (mm^2)	100	141.46 (2.86)
Bulk density (kg/m^3)	10	603.19 (125.41)
True density (kg/m^3)	10	1063.15 (99.33)
Porosity (per cent)	10	42.47 (14.12)
Filling angle of repose (degree)	10	33.53 (7.49)
Emptying angle of repose (degree)	10	49.72 (2.55)

Values in parenthesis represent standard deviation of the data

All the experiments were carried out when the moisture content of the tamarind was at 25 per cent moisture content on dry basis. The physical properties such as size and shape are very much important in designing processing equipments. The local tamarind variety purchased from Hosur, Krishnagiri district, Tamilnadu was used to determine the physical properties such as size, shape, true density, bulk density and angle of repose during filling and emptying. Average length, width and thickness of the tamarind were found to be 64.32 mm, 17.97 mm and 10.24 mm, respectively. The average geometric mean diameter, sphericity index and surface area were 21.12 mm, 0.33 and 141.46 mm^2, respectively. The average values of bulk density, true density and porosity were found to be, 603.19 kg/m^3, 1063.15 kg/m^3 and 42.47 per cent, respectively. Filling angle of repose and emptying angle of repose were determined as 33.53^o and 49.72^o, respectively.

The result showed that tamarind fruits are not a free flowing material. It required force to convey the material. The results and observations are comparable with the results reported by Owolarafe and Shotonde (2004) for the physical properties of okro fruit. The results on the average length, width, thickness, the geometric mean diameter, unit mass and volume of gumbo fruits of Sultani and Amasya variety reported by Akar and Aydin (2005) are comparable with the methods adopted for the present study.

TABLE II

COEFFICIENT OF FRICTION FOR TAMARIND FRUITS

Surface	Number of observations	Average
Hard Board	5	0.43 (0.04)
Mild Steel	5	0.59 (0.07)
Stainless Steel	5	0.41 (0.06)
Aluminium	5	0.48 (0.06)
Galvanized Iron Sheet	5	0.58 (0.02)

Values in parenthesis represent standard deviation of the data.

At 25 per cent moisture content of tamarind on dry basis, static coefficient of friction on different surfaces namely, hard board, mild steel, stainless steel, aluminium and galvanized iron sheet were determined and the results are presented in Table 2. The average values of coefficient of friction for tamarind fruit were found to be 0.43, 0.59, 0.41, 0.48 and 0.58, respectively for hard board, mild steel, stainless steel, aluminium and galvanized iron sheet. Among the average values of coefficient of friction, the maximum value of 0.59 was obtained for the mild steel surface followed by galvanized iron. The higher value of coefficient of friction for tamarind fruits shows that these surfaces exert more friction to tamarind whereas minimum friction was experienced on stainless steel sheet.

IV. CONCLUSION

The tamarind fruits at the moisture content of 25 % on dry basis possessed the average length, width and thickness of 64.32 mm, 17.97 mm and 10.24 mm, respectively. The mean values of geometric mean diameter, sphericity index and surface area were 21.12 mm, 0.33 and 141.46 mm^2, respectively. The average values of bulk density, true density and porosity were 603.19 kg/m^3, 1063.15 kg/m^3 and 42.47 per cent, respectively. Angle of repose during filling and emptying were in an average of 33.53^o and 49.72^o, respectively. The higher value of coefficient of friction for tamarind fruits was obtained for the mild steel surface followed by galvanized irons and minimum friction was experienced on stainless steel sheet.

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