Influence of different moisture content on engineering properties of tamarind seeds

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Abstract: Engineering properties of tamarind seeds were evaluated on the basis of different moisture content, along with whole and split seeds. Tamarind seeds at a moisture content (8.24% d.b.) were regulated at 5%, 10% and 15% (db) moisture content. Geometric mean diameter and sphericity values were in the range (8.79 to 9.87) and (0.62 to 0.70) for 5%, 10% and 15% moisture content of tamarind seeds. The results for bulk and true density varied as 708 to 688 kg m^{-3} and 963 to 768 kg m^{-3}, respectively in the varying range of moisture content. Textural properties such as toughness and hardness showed a decreasing trend with an increase in moisture content. The coefficient of static friction was found highest on a plywood surface, then for cast iron sheet and stainless steel. Engineering properties varied accordingly with moisture content, the density values decreased, but geometrical and frictional properties increased with the increasing moisture content.

Keywords: engineering, tamarind, seed and texture

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1 Introduction

Tamarind tree from the old time is known for its major imperative in agribusiness, because it is one of the major sources of human nutrition. It is a source which contains high quality starch, cholesterol and saturated fatty acids (Bhattacharya et al., 1993). It is consumed and utilized by several Indian cuisines of the Indian subcontinent, South East Asia and America, particularly in Mexico. Tamarind is one of the major sources for developing the edible film as it contains the dietary fibers like mucilage, pectin and tannins from which pectin is isolated and used as thickening agent and clear sets when it gels (Mohite et al., 2016). The proper designs of machines and processes, in order to harvest, handle and store agricultural materials and then convert these materials into food, require an understanding of their physical and mechanical properties. The shape and physical dimensions are important in screening solids to separate foreign materials from seeds and grains. The quality differences in grains and seeds can often be detected by differences in densities. Volumes and surface areas of seeds must be known for accurate modeling of heat and mass transfer during cooling and drying. The porosity affects the resistance to airflow through bulk solids. The static coefficient of friction and angle of repose is necessary to design conveying machine and hoppers which are used in planter machines. When cereal grains and seeds are ground in mills, the rupture force and energy must be known in order to achieve desirable properties without unnecessary expenditure of energy (Mollazade et al., 2009).

Several investigators have reported the moisture dependent physical and mechanical properties of agricultural materials such as dimensions, geometric mean diameter, sphericity, unit volume, surface area, thousand seed mass, bulk density, true density, and porosity, angle of repose, coefficient of friction, rupture force, deformation and energy absorbed. Researchers such as (Singh and Goswami, 1998) for cumin seed; (Murthy and Bhattacharya, 1998) for black pepper;

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(Altuntas et al., 2005) for fenugreek; (Ozturk and Esen, 2008) for barley; and (Sahoo and Srivastava, 2002) for okra seeds.

A countable research has been conducted on the physico-mechanical properties of tamarind seeds. The knowledge of moisture dependence is useful for investigator on drying and milling of the seeds (Mohite and Sharma,2018). Thus, the attempt was made to investigate some selected engineering properties of tamarind with whole, split and different moisture content regulated seeds.

2 Materials and methods

Tamarind (*Tamarindus indicia L.*) of *Yogeshwari* variety was procured from Bulandshahr district, Uttar Pradesh, India. Tamarind was cleaned manually by removing adhered foreign matter, immature and split ones, if any. Whole seeds were selected for the present study were having a maroon coat on it, whereas seeds regulated at different moisture were pretreated to remove its coat from seed cotyledon. Initial moisture content of seeds, was determined by AOAC method (1995) and was found to be 8.24% on dry basis (db). The moisture content of the tamarind seeds was maintained at 5%, 10% and 15% db by the process described by Murthy and Bhattacharya (1998). The samples were dried using a tray dryer at 55°C till the desired moisture content of 5% (db) was obtained by recording moisture content at every 15 min interval. To achieve 10% and 15% (db) moisture content, the samples were added to calculate amount of distilled water.

As the seeds varied widely in the size, they were selected randomly to minimize the sampling error. The axial dimension was measured using digital Vernier callipers (0.01 mm, LC) for selected 100 tamarind seeds. For the determination of geometric, gravimetric and frictional properties, the experiment was repeated 5 times. The geometric mean diameter (GMD) was considered as the size criterion and was expressed as the cube root of three axes of seeds using the major dimension (*a*), medium (*b*) and minor dimension (*c*). The geometric mean diameter, sphericity (*φ*), arithmetic mean diameter (AMD), square mean diameter (SMD), equivalent diameter (EQD), aspect ratio (AR) were determined by using the following equations (Balasubramanian et al, 2012).

$$\text{GMD} = \sqrt[3]{abc} \quad (1)$$

$$\text{AMD} = \frac{a*b*c}{3} \quad (2)$$

$$\text{SMD} = \sqrt{ab*bc*ca} \quad (3)$$

$$\text{EQD} = \frac{AMD + GMD + SMD}{3} \quad (4)$$

$$\text{AR} = \frac{b}{a} \quad (5)$$

The volume (V) mm^3 and seed surface area (S) mm^2 of pearl millet seed was studied by Jain and Bal (1997) are expressed as

$$S = \frac{\pi B a^2}{2a - B} \quad (6)$$

$$V = \frac{\pi B^2 a^2}{6(2a - B)} \quad (7)$$

where, $B = \sqrt{bc}$, *a*, *b*, and *c* are the length, breadth and thickness (mm).

Bulk density was determined by the method followed by Balasubramanian and Viswanathan (2010). Tap density was determined in triplicates by filling a measuring cylinder of 10 ml with tamarind seeds, tapping until no further decrease in the volume was noticed, and weighing the sample. True density was determined using a toluene displacement method. A known quality of toluene was filled in the measuring cylinder and the known weight of tamarind seeds were placed in it. The increment in volume of measuring cylinder was measured. Porosity is represented as the ratio of difference between true density and bulk density to the true density, i.e. percentage of volume of voids (Mohsenin, 1986).

$$\varepsilon = \frac{\rho_t - \rho_b}{\rho_t} \times 100 \quad (8)$$

where, ε = porosity (%), ρ_t = true density (kg m^{-3}) and ρ_b = bulk density (kg m^{-3}).

Tamarind seeds were discharged through a horizontal hopper opening; a conical shaped heap was formed. To determine the angle of repose, the tamarind seeds fed into a tapering iron hopper having a dimension of 250 mm × 250 mm from top and bottom whole 20 mm × 20 mm was allowed to fall freely on a circular disc of 100 mm and 150 mm diameter. A horizontal sliding gate provided right below the hopper for sudden stops and open the hole during the test (Sahoo and Srivastava, 2002).

$$\theta = \tan^{-1}\left(\frac{2H}{D}\right) \quad (9)$$

where, H = height of the cone; D = diameter of the circular base of the cone

Static coefficient of friction (μ) of tamarind seed for various surfaces viz., Stainless steel, plywood, and galvanized iron was determined (Ozturk and Esen, 2008). During the experiment, a levelled rectangular box was filled of material and moved on the frictional surface using a friction lens rope and pulley. The frictional force and normal strength was noted and repeated for different frictional surfaces and moisture content. It was calculated by using the following equation.

$$\mu = \frac{F}{N_f} \quad (10)$$

where, F is the measured force and N_f is the normal strength of the samples.

Toughness and hardness of tamarind seeds were determined at different moisture content, whole and split, seeds of randomly selected 20 seeds from the bulk sample. A texture analyzer (*TA-HDi, Stable micro system, UK*) with 5kg load cell and test mode speed 0.2 mm s^{-1}; pre and post test speed of 2mm s^{-1} and 2 mm s^{-1} was used with test probe P5.

Analysis of variance for engineering properties was carried out using Statistical software (*Version 3.01, Pascal International Software Solution, USA*). Statistical procedures described to examine the effect of moisture level and nature of seed ($p\leq0.05$) on engineering properties.

3 Results and discussions

Dimensions (major, medium and minor), geometric mean diameter, sphericity, unit volume, surface area, aspect ratio, arithmetic mean diameter, equivalent mean diameter and square mean diameter values were found to be (15.63, 11.96, and 6.7 mm), 10.46 mm, 0.67, 656.12 m^3, 345.96 mm^2, 0.77, 11.43 mm, 131.53 mm and 19.23 mm respectively for whole tamarind seeds. Bulk and true density varied as 736.94; 883 kg m^{-3} and porosity as 16.82, respectively. For split seed values of geometric mean diameter, arithmetic mean diameter, equivalent mean diameter and square mean diameter values showed an increasing trend as 7.65, 8.93, 77.45 and 14.58 mm respectively but found lower values when compared to whole seeds. Lower value trends observed, may be due to the splitting of seeds in two halves which reduced their dimensions. Similarly, values for bulk and true density varied as 654 and 785 kg m^{-3} which were also found lower compared to the whole seeds. The values found for geometrical mean diameter and surface area concluded that moisture content and type of seeds had influence on their properties which can also be proved by statistical analysis ($P\leq0.05$). Balasubramanian et al. (2012a) for turmeric rhizomes and Altuntas et al. (2005) for fenugreek found the similar results.

Values of 5% moisture content seeds found for major, medium and minor dimensions, geometric mean diameter, sphericity, unit volume, surface area, arithmetic mean diameter, aspect ratio, equivalent mean diameter and square mean diameter were found as (13.58, 7.0 and 6.0 mm), 8.79 mm, 0.65, 389.7 m^3, 244.58 mm^2, 9.53 mm, 11.43 mm, 0.64, 92.28 mm and 16.0 mm respectively. The result of bulk and true density varied as 688.94 ; 768.12 kg m^{-3} and Porosity 10.41, respectively. Similarly, 10% moisture content values were in the range of (14.13, 11.38 and 6.45 mm), 9.87mm, 0.70, 543.6 m^3, 305.8 mm^2, 10.65 mm, 0.81, 115.39 mm and 18.58mm respectively. The results for bulk and true density varied as 692; 865 kg m^{-3} and Porosity 20.20 respectively. From the Table 1, it can be proved that most of the engineering properties for tamarind seed tests were fundamentally non-significant ($P>0.05$).

The values of 15% moisture content for major, medium, minor, geometric mean diameter, sphericity, unit volume, surface area, aspect ratio, arithmetic mean diameter, equivalent mean diameter and square mean diameter values were in the range of (14.73, 8.38, 6.55 mm), 9.03 mm, 0.62, 426.02 m^3, 258.72 mm^2, 0.57, 9.88 mm, 98.04 mm and 16.5 mm respectively. The result of bulk and true density varied as 708 kg m^{-3}, 963 kg m^{-3} and Porosity 16.5, respectively. The above results showed increasing trends as the moisture increased which made increment in length, breadth and thickness, and the physico-mechanical properties had close relation to dimensions.

Table 1 ANOVAs for engineering properties of tamarind seeds

Source	GMD	Sphericity	UV	Surface area	AMD	EMD	SMD	BD	TD
Intercept	102.60	93.17	103.3	103.15	104.61	103.68	103.74	94.81	89.20
Std Error Estimate	1.82	1.63	1.82	1.82	1.81	1.81	1.82	1.60	1.26
Std Error Predicted	7.81	11.42	2.87	4.12	9.41	9.41	8.87	8.66	7.69
R^2	0.33	0.44	0.32	0.33	0.32	0.32	0.33	0.48	0.71
F	0.02*	0.74**	0.12**	0.01*	0.29**	0.07**	0.23**	0.89**	3.22**
P	0.96	0.45	0.60	0.97	0.87	0.93	0.88	0.41	0.17

Note: * Significant at 5%, ** Non Significant.

The observations for mechanical properties of whole and split as well as for seeds regulated on 5%, 10%, and 15% moisture contents showed different trends. Angle of repose of whole tamarind seeds was found to be increased in comparison to split tamarind seed 26.55°-32.61° as the decrease in dimensions increased their angle of repose values. Whereas for seeds of 5% moisture content, it was found as 26.55°, 27.47° for 10% and 30.11° for 15%. Similar trends were reported for coriander seeds (Coskuner and Karababa, 2007), and soybeans (Davies and Okene, 2009).

Static coefficient of friction increased linearly with increase in moisture content. It was found to be highest for plywood, followed by SS sheet and CI sheet. The values of coefficient of friction at 5%, 10% and 15% increased from 0.50-0.53, 0.32-0.44; 0.25-0.32, respectively with moisture content level. As the moisture level increases, seeds, rough and slipping characteristics decreases, therefore, the coefficient of static friction increases (Balasubramanian et al., 2012b). The hardness and toughness of tamarind seeds at different moisture are presented in Figure 1 and Figure 2. The results showed decease in textural properties of seeds with the increase in moisture content. Similarly, it was found higher hardness and toughness values for whole seeds compared to the split seeds. As the split seeds were separated into halves, the strength required to break the seeds was also less compared to the whole seeds. Researchers such as Vursauvus and Ozguven (2005) for Pine Nut, Murthy and Bhattacharya (1998) for black pepper seed have reported different trends. Reason can be, there is an increase in moisture content, the elastic behavior of seeds decreases and resistance to any form of load also decreases. Although the structural strength of tamarind seed is more than black pepper seed, but if the moisture content of the seed increases the applied force required for penetrating the seed also increases .

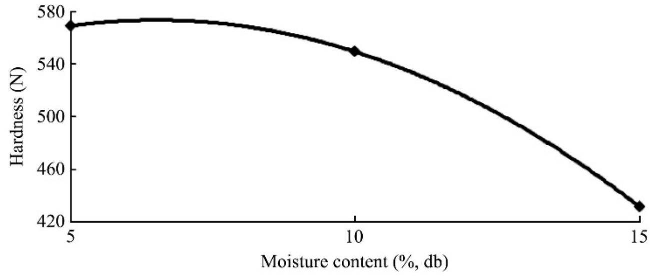

Figure 1 Hardness of tamarind seeds at different moisture content

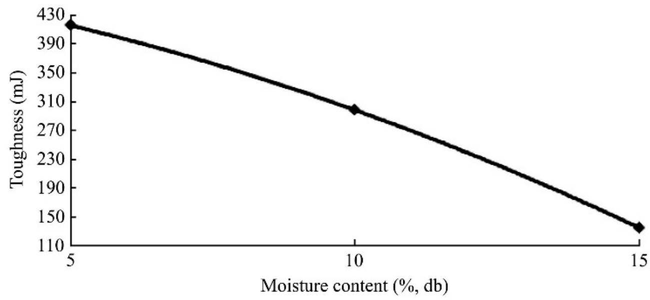

Figure 2 Toughness of tamarind seeds at different moisture content

4 Conclusions

Based on the results, the following conclusions were drawn. The engineering properties are different for seeds for their different moisture contents. Bulk density was found to show increasing trends with the increasing moisture content (5%-15% db). Similar trends were seen in true and tap densities. Angle of repose was found to increase for whole and split tamarind seed as well as for different moisture content regulated seeds. Coefficient of friction showed an increasing trend for all threes surfaces, i.e. plywood, cast iron and stainless steel for increasing moisture content (5%-15% db).Textural properties such as toughness and hardness, showed an decreasing trend with the increase in moisture content of tamarind seeds.

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