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Physico-chemical and frictional characteristics of tamarind (*Tamarindus indica* L.) for pharmaceutical applications

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Abstract
Tamarindus indica L. commonly known as tamarind, is cultivated throughout country, except in the Himalayas and western dry regions. Tamarinds comprise of fruits with seeds enclosed within an encapsulated pod. Tamarind is one of the most important spice in Indian food due to its sweet and sour test. Tamarind fruit pulp has been an important culinary ingredient in India for a very long time. Almost all parts of the tree find some use or other in food, chemical, pharmaceutical and textile industries, and as fodder, timber and fuel. Knowledge of physical, chemical and frictional properties needed to analyze the behaviour of tamarind during handling and designing of processing equipments. In this context, the paper explored some physical, chemical and frictional properties of tamarind. Physical dimensions of whole and decorticated tamarind and its seed, moisture content, bulk density, true density, porosity, angle of repose, co-efficient of friction and pH were determined. All the experiments were carried out at 08 - 11% moisture content on dry basis and pH of tamarind was found 2.486. Average length breadth and thickness of whole and decorticated tamarind and its seed were found to be 89.83, 20.67 and 19.46 mm, 84.71, 15.92 and 15.95 mm, 12.24, 10.01 and 5.79 mm respectively. Bulk density, true density and porosity were found 613.01kg/m^3, 872.81kg/m^3 and 29.52% respectively. Angle of repose was found 71.11°. Among the average values of coefficient of friction, the maximum value of 0.596 was obtained for glass surface followed by mild steel. The higher value of coefficient of friction for tamarind fruits shows that these surfaces exert more friction to tamarind and minimum friction was experienced on wood and stainless steel.

Keywords: Tamarind, physical properties, frictional properties, chemical properties

Introduction

Tamarind is one of the most important multipurpose tree species in the Indian sub-continent. It is a large evergreen tree with an exceptionally beautiful spreading crown, and is cultivated throughout almost the whole country, except in the Himalayas and western dry regions (Rao *et al*., 1999) [16]. Tamarinds belong to the family of leguminous plants called fabaceae, which means that they comprise of fruits with seeds enclosed within an encapsulated pod (Soni, 2018) [18]. Tamarinds are tropical or semi-tropical evergreen trees that can reach a maximum height of 80 feet. However most of the tamarind that grows in tropical regions usually reaches a maximum height of 20 feet. Tamarind grows very slowly and withstand drought for extensive period of time (Pakhare *et al*., 2015) [14].

The bark is thick and is usually brown in colour with dense foliage that can often extend for a length of 20 to 30 feet, Tamarind fruits are indehiscent, beanlike, curved pods 3 to 20 cm long weighing 15 to 20 g. Fruits have a scurfy brown, woody, fragile shell with 8 to 10 blackish brown, hard, shiny seeds (Hernandez-Unzon and Lakshminarayana, 1982) [6] contained in loculi, enveloped by a tough, leathery membrane, called endocarp. Outside the endocarp is the light-brownish, red, sweetish acidic, edible pulp, traversed by a number of branched, ligneous strands. Tamarind fruits are about 30% shell, 30% pulp, and 40% seeds (Lewis and Neelakantan 1964; Soni *et al*., 2020) [11, 19]. There are also fruit with red pulp; these are not commonly cultivated. However, the reddish-flesh types are distinguished in some regions and are regarded as superior in quality. Fruits are eaten at the green-mature stage or when the shell pod has become brittle and the pulp brown. Tamarind is a good source of calcium, phosphorous, and iron and an excellent source of riboflavin, thiamin, and niacin; but it contains only small amounts of vitamins A and C. The outermost covering of the pod is fragile and easily separable. The pods begin to ripen from February to May (Anonymous, 2016) [1].

India is the world's largest producer of tamarind. National Horticulture Board, India, 2017 reported that India has been produced about 191,000 Metric tons in 49000 hectare area in year 2014-2015 (Anonymous, 2017) [2]. It is abundantly produced in Madhya Pradesh, Bihar, Andhra Pradesh, Karnataka, Tamil Nadu, Orissa and West Bengal. In Bajapur, in the Deccan plateau, it is famous for its fine varieties and is cultivated extensively. Since ancient times, India has been exporting processed tamarind pulp to western countries, mainly the European and Arab countries and more recently the United States of America. Recently, Thailand has become a major producer of tamarind with sweet and sour varieties in production (Singh *et al*., 2007) [17].

Tamarind is one of the most common and important spice, which is widely used in cooking (Jarimopas *et al*., 2008) [9]. Tamarind fruit pulp has been an important culinary ingredient in India for a very long time. Almost all parts of the tree find some use or other in food, chemical, pharmaceutical and textile industries, and as fodder, timber and fuel (Dagar *et al*., 1995; George and Rao, 1997) [4-5].

Edible part of tamarind fruit is relatively poor in protein 87.9 g/kg and oil 25.3 g/kg, but the seed are good source of calcium, phosphorus, magnesium and potassium. It also contains phytic acid and labile trypsin inhibitors and the mineral content of tamarind pulp is calcium 81.-466.0 mg/100g, phosphorus 86.0-190.0 mg/100g, magnesium 72.0 mg/100g, potassium 62.0-570 mg/100g, sodium 3.0-76.7 mg/100g, copper 21.8 mg/100g, iron 1.3-10.9 mg/100g, zinc 1.1 mg/100g (Ishola *et al*., 1990) [7]. Tamarind contains P 0.19%, K 0.82%, Ca 0.52%, Mg 0.24% and S 0.03%. and the quantity of Fe, B, Cu, Zn Al, Sr, Ba and Mo is 48, 13, 14, 25, 32, 47, 4 and 1.02 ppm respectively (Chouhan *et al*. 1991) [3].

Materials and Methods

Materials

The ripened and matured tamarinds were selected for performing trial of developed machine. The raw tamarinds which were matured enough and suitable for harvest were selected randomly and purchased as a bulk from the farmers in Vallabhnagar, Udaipur district of Rajasthan for experiment.

Determination of characteristics of tamarind

The physical dimensions of selected tamarinds were determined at maturity state. For determination of physical dimensions, 100 tamarind fruits were randomly selected from a lot to make uniform sample. The observations were recorded on tamarind fruit, decorticated tamarind and seed to determine the length, breadth and thickness. Length, breadth and thickness of randomly selected 100 tamarind fruits were recorded in both conditions before and after removing cover as well as of seeds using a vernier caliper (PRECISE 0-300mm Digital Caliper) with least count as 0.01 mm.

Length of the tamarind from base to the apex of the fruit was considered as length and was measured with the help of vernier caliper. While maximum linear distance between two shoulders and between the two edges were too measured as breadth and thickness respectively with the help of vernier caliper. The randomly selected fruits were used for study. The randomly selected tamarind fruits were used for study. Same procedure is repeated with decorticated tamarinds and tamarind seeds.

Moisture content was determined using hot air oven method. 100 g of tamarind samples were kept in an oven for 3 days at 105 °C. Weight loss on drying to a final constant weight was recorded as moisture content (Jahromi *et al*., 2008) [8]. Bulk density was determined as the ratio between mass and bulk volume of tamarind (Mohsenin, 1986) [12]. As the size of tamarind was larger than grains, the following method (Pandian *et al*., 2013) [15] was adopted to determine the bulk density. One bag of tamarind (5 kg) was piled over a horizontal surface slowly from some height. Slant height (l) of the pile was measured at different places and the average value was taken. Radius (r) of the pile was calculated from the circumference of the pile. Using slant height (l), radius of the pile (r) and the height of the pile (h) which was in cone shape was calculated using Pythagoras theorem and volume of the pile was determined and then the bulk density was calculated. The bulk density was calculated by taking ten replications and the average value of all readings was considered as bulk density. True density of tamarind was determined by using platform scale method. A sample of tamarind was first weighed on a weighing balance in air and then immersed in toluene in a container. Volume of toluene raised in the container was measured which gave the volume. The quantity of toluene absorbed by tamarind was considered as negligible. 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 ar to its true volume (Pandian *et al.*, 2013) [15]. The volume measurement was replicated ten times and thus the true density was determined. Porosity was calculated as the ratio of the difference between the true and bulk density to the true density value and was expressed in percentage. The porosity of the tamarind was computed and expressed in percent (Mohsenin, 1986) [12].

Angle of repose is the angle made by tamarind with the horizontal surface when piled from a known height. A known mass 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 as the angle made between h and r. (Pandian *et al.*, 2013) [15]. The coefficient of friction was determined by using a frictionless pulley fitted on a frame, loading pan and test surfaces (Kaleemullah and Kailappan, 2003) [10]. The co-efficient of static friction was calculated as the ratio of frictional force to the normal force. The experiment was performed with test surfaces of glass, wood, mild steel, and stainless steel sheets. Experiment was replicated ten times by emptying and refilling with different samples in the container every time and the average value was recorded (Pandian *et al.*, 2013) [15].

The pH of the tamarind pulp was determined by using digital pH meter. The pH meter was first calibrated using buffer of pH 4.0 & pH 7.0 at room temperature. The sample solution was then taken in 100 ml beaker, stirred & electrode of pH meter was put in it and direct reading from pH meter was recorded when the reading stabilized (Nazir *et al.*, 2013) [13].

Results and Discussion

The physical dimensions *i.e.* length, breadth and thickness of tamarind fruit, decorticated tamarind and seed were find out and results have been presented in Table 1. Physical properties of the tamarind fruit such as bulk density, true density, porosity were find out and results have been presented in Table 2. The frictional properties of tamarinds like Co-efficient of friction of the tamarind for glass, stainless steel, mild steel and wood surfaces and angle of repose were find out and the results have been presented in Table 3.

Table 1: Physical dimensions of selected tamarind fruits and seeds

Variables	Minimum Value	Maximum Value	Mean value ± standard deviation
Tamarind whole fruit			
Length (mm)	46.89	123.17	89.83±14.96
Breadth (mm)	15.28	29.11	20.67±02.45
Thickness (mm)	12.91	25.51	19.46±02.45
Decorticated Tamarind			
Length (mm)	42.19	118.53	84.71±14.80
Breadth (mm)	11.35	24.70	15.92±02.81
Thickness (mm)	10.78	22.01	15.95±02.28
Tamarind Seed			
Length (mm)	9.03	19.42	12.31±01.71
Breadth (mm)	7.59	11.96	09.92 01.06
Thickness (mm)	4.87	10.08	05.85±00.62

Table 2: Physical properties of selected tamarind fruits

Property	Minimum Value	Maximum Value	Mean value ± standard deviation
Moisture Content (%)	8.59	14.74	10.87±01.85
Bulk density (kg/m^3)	529.62	711.47	613.01±57.74
True density (kg/m^3)	833.64	930.26	872.81±28.59
Porosity (%)	14.75	43.07	29.52±08.54
pH	2.460	2.487	2.480±0.008

Table 3: Frictional properties of selected tamarind fruits

Minimum Value	Maximum Value	Mean value ± standard deviation	Minimum Value
Co-efficient of friction			
Glass	0.540	0.650	0.596± 0.04
Stainless Steel	0.431	0.507	0.471±0.03
Mild Steel	0.452	0.553	0.515±0.03
Wood	0.426	0.500	0.451±0.02
Angle of repose			
Angle of repose	70.53	72.86	70.11±0.80

All the experiments were carried out when the moisture content of the tamarind was at 11 per cent moisture content on dry basis. The physical properties such as size and shape are very much important in designing processing equipments. It is inferred from Table 3 that among the average values of coefficient of friction, the maximum value of 0.596 was obtained for glass surface followed by mild steel. The higher value of coefficient of friction for tamarind fruits shows that these surfaces exert more friction to tamarind and minimum friction was experienced on wood and stainless steel.

Conclusion

Physical dimensions of whole and decorticated tamarind and its seed, moisture content, bulk density, true density, porosity, angle of repose, co-efficient of friction and pH were determined. All the experiments were carried out at 08 - 11% moisture content on dry basis and pH of tamarind was found 2.486. Average length breadth and thickness of whole and decorticated tamarind and its seed with standard deviation were found to be 89.83±5.07, 20.67±1.22 and 19.46±1.08 mm, 84.71±5.41, 15.92±1.92 and 15.95±0.89 mm, 12.24±0.76, 10.01±0.45 and 5.79±0.11 mm respectively. Bulk density, true density and porosity were found 613.01±57.74 kg/m^3, 872.81±28.59 kg/m^3 and 29.52±8.54 respectively. Angle of repose was found 71.11°±0.8°. Co-efficient of friction for glass, stainless steel, mild steel and wood were found 0.596±0.04, 0.471±0.03, 0.515±0.03 and 0.451±0.02 respectively.

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