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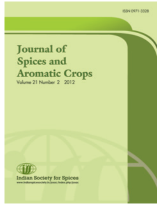

Physical properties of turmeric (*Curcuma longa* L.)

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Abstract

Turmeric (*Curcuma longa*) rhizome (var. IISR Alleppey Supreme) sample was divided into three grades (I: 25–35 mm, II: 35–45 mm, III: 45–55 mm) according to its major dimension to study its physical properties. The average values of geometric property *viz.*, length (30.38–50.60 mm), breadth (9.77–10.64 mm), thickness (5.18–6.44 mm), arithmetic mean diameter (15.82–21.91 mm), geometric mean diameter (12.77–13.76 mm), square mean diameter (24.24–28.58 mm), equivalent diameter (17.61–21.41 mm), sphericity (0.27–0.42), aspect ratio (0.20–0.35), unit volume (1641–2901 mm^3), surface area (771–1265 mm^2) and shape factor (1.63–1.77) for grades I, II & III are reported. The gravimetric property *viz.*, bulk density (260–348 kg/m^3), true density (1341–1354 kg/m^3) and porosity (74.53–80.93%), and frictional property *viz.*, angle of repose (37.57–38.90°) and coefficient of friction with respect to different surface *viz.*, aluminum sheet, mild steel sheet and plywood sheet for grades I, II and III were found to range between of 0.69–0.81, 0.84–0.94, 0.80–0.86, respectively.

Keywords: Geometric property, gravimetric property, frictional property, coefficient of friction, turmeric

Turmeric is a rhizomatous perennial herb having primary and secondary rhizomes that can be present in different forms, from spherical to slightly conical, hemispherical, and cylindrical. Rhizomes present a thin, slightly brown peel (peridermis layer) covering an orange-yellow flesh. Physical properties of turmeric like bulk density, true density, porosity and coefficient of static friction were determined by Athmaselvi & Varadharaj (2002). However, properties like geometrical, gravimetric and frictional have not been studied for turmeric. These play an important role in designing equipments for post harvest operations such as dryers, cleaners and graders.

The study was conducted at Central Institute of Post Harvest Engineering and Technology, Ludhiana. Turmeric rhizomes (var. IISR Alleppey Supreme) were obtained from the Indian Institute Spice Research, Kozhikode, Kerala. Rhizomes were cleaned manually and broken, split and immature rhizomes were

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separated from the sample. The initial moisture content of sample was determined on a dry basis (7.15±1%). As the rhizomes vary widely with size and to minimize its error, rhizomes were divided into three different grades namely I: 25–35mm, II: 36-45 mm, III: 46–55 mm with respect to its major dimension. The axial dimension was measured using digital vernier caliper (±0.01 mm, LC) for selected 100 turmeric rhizomes. For the determination of geometric, gravimetric and frictional properties, the experiment was repeated 10 times.

The geometric mean diameter (GMD) was considered as the size criterion and was expressed as the cube root of three axes of rhizome using the major dimension (a), medium (b) and minor dimension (c). The average 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 (Mohsenin 1986):

$$GMD = \sqrt[3]{abc} \tag{1}$$

$$\phi = \frac{\sqrt[3]{abc}}{a} \tag{2}$$

$$AMD = \frac{a+b+c}{3} \tag{3}$$

$$SMD = \sqrt{ab+bc+ca} \tag{4}$$

$$EQD = \frac{AMD + GMD + SMD}{3} \tag{5}$$

$$AR = \frac{b}{a} \tag{6}$$

The unit volume (V) and surface area (S) were determined as per the following equations (Jain & Bal 1997).

$$S = \frac{\pi B a^2}{2a - B} \tag{7}$$

$$V = \frac{\pi B^2 a^2}{6(2a - B)} \tag{8}$$

Where, $B = \sqrt{bc}$

Shape factor (ë) based on the unit volume and surface area was determined (McCabe & Smith 1984) as

$$\lambda = \frac{D}{C} \tag{9}$$

where, $C = \frac{V}{b^3}$ & $D = \frac{S}{6b^2}$ (10)

Bulk density (ρ_b) is the ratio of mass to its bulk volume of the sample. Bulk density of turmeric rhizomes was determined as per Balasubramanian & Viswanathan (2010). True density (ρ_t) was determined as the ratio of rhizome mass to its pure volume as determined using nitrogen gas replacement using pycnometer (model 2: Hymipyc and make IQI, USA). Then, the porosity (ε) was calculated as the percentage of volume of voids (Mohsenin 1986) using the following equation:

(11)

To determine the angle of repose ( ), rhizomes were fed in a tapering hopper having a dimension of 250 × 250 mm from top with bottom hole of 20 × 20 mm was allowed to fall freely on a circular disc of 100 mm diameter with a horizontal sliding gate provided below the hopper (Sahoo & Srivastava 2002).

(12)

Where, H=height of the cone, D=diameter of the circular base of the cone. Coefficient of friction (μ) for turmeric rhizome with respect to different surfaces namely aluminum, mild steel sheet and plywood was determined (Ozturk & Esen 2008) as

(13)

Where, F is the measured force and N is the normal force of the samples.

The average length of three grades was 30.38 mm, 40.57 mm, 50.60 mm. However, there is no trend for breadth (10.64 mm, 9.72 mm and 9.94 mm) and thickness (6.44 mm, 5.47 mm and 5.18 mm) among different grades. The arithmetic mean diameter, geometric mean diameter, square mean diameter and equivalent diameter showed an increasing trend with the increase in length, breadth and thickness of rhizomes. The sphericity, aspect ratio and shape factor of turmeric rhizomes decreased with increase in dimension. This may be attributed to the irregular shape of turmeric rhizomes. The unit volume and surface area of turmeric rhizomes showed a linear relationship with grade size.

Bulk density and porosity of turmeric rhizomes decreased with the increase in dimension of sample i.e. rhizome grade. However, true density of turmeric did not show any trend with dimension. It could due to variation in the medium and minor dimension.

The angle of repose increased with respect to grades (dimension) i.e. 37.57°, 38.44° and 38.90° for grade I, II and III, respectively. The coefficient of friction with respect to these grades on different structural surface *viz.,* aluminum (0.81–0.69), mild steel sheet (0.94–0.84) and plywood sheet (0.86–0.80) is depicted in Table 1. It was found that the coefficient of friction for aluminum was the lowest. This may be due to the smoother and more polished surface of aluminum sheet as compared to other frictional surfaces. The obtained data on the

Table 1. Physical properties of turmeric rhizomes

Properties	Grade I	Grade II	Grade III
Geometric property			
Length (mm)	30.38 ±1.41	40.57 ±1.79	50.60 ±4.79
Breadth (mm)	10.64 ± 0.69	9.77 ±1.07	9.94 ±2.67
Thickness (mm)	6.44 ±1.73	5.47 ±1.83	5.18 ±1.60
Arithmetic mean diameter (mm)	15.82 ±0.79	18.60 ±1.12	21.91±1.33
Geometric mean diameter (mm)	12.77 ±1.72	12.94 ±1.99	13.76 ± 2.10
Square mean diameter (mm)	24.24 ±1.08	25.92 ±1.59	28.58 ±1.32
Equivalent diameter (mm)	17.61 ±1.02	19.15 ±1.27	21.41 ±1.60
Sphericity	0.42 ±0.08	0.32 ±0.07	0.27 ±0.04
Aspect ratio	0.35 ±0.03	0.24 ±0.02	0.20 ±0.03
Unit volume (mm^3)	1641±20.14	2116 ±49.27	2901 ±31.42
Surface area (mm^2)	771±15.12	981 ±17.31	1265 ±27.92
Shape factor	1.77 ± 0.13	1.63 ±0.27	1.66 ±0.22
Gravimetric property			
Bulk density (kg/m^3)	348 ±6.30	291±7.94	260±5.11
True density (kg/m^3)	1354±7.89	1341 ±6.80	1349± 5.47
Porosity (%)	74.53±0.64	78.75±0.21	80.93±0.42
Frictional property			
Angle of Repose (°)	37.57±0.61	38.44±0.19	38.90±0.23
Coefficient of friction			
Aluminum sheet	0.81 ± 0.07	0.79 ± 0.03	0.69 ± 0.07
Mild steel sheet	0.94 ± 0.05	0.89 ± 0.06	0.84 ± 0.04
Plywood sheet	0.86 ± 0.08	0.96 ± 0.04	0.80 ± 0.06

physical properties of turmeric rhizomes will be useful in the designing of polishers and other processing gadgets.

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