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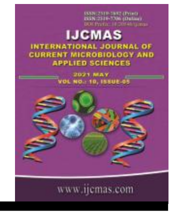

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Physical and Engineering Properties of Turmeric Fingers

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A B S T R A C T

Turmeric (*Curcuma longa*) fingers (Salem) sample was divided into three grades (I: 30–40 mm, II: 40–50 mm and III: 50–60 mm) according to its major dimension to study physical properties. Geometric properties viz., length, breath, thickness, arithmetic mean diameter, geometric mean diameter, square mean diameter, equivalent diameter, sphericity, aspect ratio, unit volume, surface area and shape factor were determined and found to be in the range of 30.18-48.54 mm, 9.72-10.62 mm, 5.12-6.38 mm, 14.72-22.84 mm, 12.72-14.64 mm, 23.21-26.54 mm, 0.24-0.38, 0.18-0.32, 1591-2904 mm^3 772-1268 mm^2 and 1.61-1.74 for Grade I, II and III respectively. The gravimetric and frictional properties such as bulk density, true density, porosity and angle of repose were 264-348 kg/m^3, 1340-1358 kg/m^3, 72.51-78.90 % and 35.57-37.90°, respectively. Also, coefficient of friction with surfaces namely plywood sheet were found to be in the range 0.82-0.88, respectively. The results of the study will help in designing the feed hoppers, metering mechanisms and planting equipment.

Keywords

Physical Properties of Turmeric fingers, Angle of repose, Geometric Property, Coefficient of Friction, Turmeric fingers, etc

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Introduction

Spices are valued for their distinctive flavours, colours and aromas and are among the most versatile and widely used ingredients in food preparation and processing throughout the world. The fingers of the Turmeric plant (*Curcuma longa L.*), is a tropical herb of the *Zingiberaceae* family native to southern Asia has a traditionally important role as a colouring component. It is widely used as a spice and common food and additive (Govindarajan, 1980). Curcumin (Diferuloyl methane), the main yellow coloured bioactive component of turmeric has been shown to have a broad spectrum of biological actions. The determination of physical properties of agricultural materials is important to design machines and processes conveying, for designing feed hoppers and metering mechanisms and storage of these materials and requires understanding for converting these materials into food and feed. For agricultural materials, dimensions (length, diameter, thickness) are widely used to describe them.

Fingers physical dimension, particularly shape, is very important in sorting and sizing, and determines how many Fingers can be placed in shipping containers or plastic bags of a given size (Keramat-Jahromi *et al.*, 2008).

Fingers skin color is an attribute that determines consumer's behavior and it is accepted as one of the most important external quality parameters (Ercisli *et al.*, 2007). Fingers volume, shape and density are important to design fluid velocities for transportation (Mohsenin, 1986).

On the other hand, knowledge of frictional properties of Fingers is needed for the design of planting and handling equipment (Mohsenin, 1986).

Materials and Methods

20 kg of fresh Turmeric Fingers from the Yavatmal District Market were purchased to measure the properties. The physical properties determined for Turmeric Fingers were size, shape, bulk density, true density, porosity, the angle of repose, surface area and coefficient of friction. The methods adopted for estimating these parameters are given below.

Dimensions of Turmeric Fingers

Turmeric Finger was randomly chosen for measuring dimensions. Length, width and thickness of each Finger were measured using vernier caliper (least count 0.01 cm). A Hundred observations were made to get average values of length, width and thickness of the Turmeric Rhizome.

Geometric Mean Diameter (GMD)

The geometric mean diameter for the 100 fingers was determined using the measured geometric dimensions of length (L), width (W) and thickness (T) (Mohsenin, 1986). The equation is given below.

$$GMD = (LWT)^{\frac{1}{3}} \quad (1)$$

Sphericity

Sphericity (S) is defined as the ratio of the surface area of a sphere having the same volume as the Finger to the surface area of the Rhizome.

The shape of a food material is usually expressed in terms of its sphericity. It is an important property used in fluid flow and heat and mass transfer calculations. Sphericity was determined using the measured geometric dimensions (Eqn 2).

$$S = \frac{(LWT)^{\frac{1}{3}}}{L} \quad (2)$$

In order to gather more information about the shape of the Rhizome, aspect ratio (R) of the Finger was determined using the following relationship.

1000 Kernel Weight (TKW)

The mass of 100 Rhizomes weighed on a top loading electronic balance (EK 5350) with a resolution of 0.01g and the resultant weight was multiplied by 10 to get the 1000 fingers weight. This method was used by Tavakoli *et al.*, (2009) for barley grains and Gharibzahedi *et al.*, (2010) for pine nut.

Surface Area and Volume

The surface area and volume of Turmeric Finger were calculated based on the geometric mean diameter (GMD) in the following equations.

$$S = \pi\ (GMD)^2\ (4)$$
$$V = \frac{\pi}{6}\ (GMD)^3\ (5)$$

Radius of Curvature

This is an important property required for the design of conveyors and chutes. It determines the rollability of objects. The minimum radius of curvature (Rmin) and maximum radius of curvature (Rmax) was calculated using the followings equations

$$R_{min} = \frac{H}{2}\ (6)$$
$$R_{max} = \frac{H^2 + \frac{L^2}{4}}{2}\ (7)$$

Angle of Repose

The angle of repose is an important physical property for the design of processing, storage and conveying systems of particulate materials. When the material is smooth and rounded, the angle of repose is low. For sticky and fine materials the angle of repose is high. The angle of repose, therefore, indicates the cohesion amongst the individual units of the materials. It was determined using a bottomless cylinder (10 cm diameter and 15 cm height) which was also applied by Taser *et al.,* (2005). The cylinder was placed on a smooth surface and turmeric Finger were filled in. The cylinder was raised slowly permitting the sample to flow down and form a natural slope. The height (H) and diameter (D) of the heap were measured and the dynamic angle of repose was calculated by Eq 8.

$$\theta = tan^{-1} \frac{2H}{D}\ (8)$$

Bulk Density

Bulk density which is defined as the ratio of the mass of the sample to its container volume was evaluated by weighing a Turmeric Finger filled beaker of known weight and volume and calculated as Baryeh (2000). Where ρb (g/cm3) is bulk density and m is mass (g) of the sample.

$$\rho_b = \frac{Mass}{Volume} = \frac{m}{v}\ (9)$$

True Density

It is the ratio of the mass of the sample to its true volume. For Turmeric finger, true density was determined by the water displacement method (Abdullah, 2011). The true density was calculated using following equation:

$$\rho_t = \frac{Massofindividualfruit\ (kg)}{Volumeofindividualseed\ (m^3)}\ (10)$$

Porosity

Porosity is a vital physical property that characterizes the amount of air spaces in a bulk. It is needed in modeling and design of various hoppers. It is defined as the volume fraction of air in the bulk sample and is calculated by Eqn 11:

$$Porosity, P = \frac{\rho_t - \rho_b}{\rho_t} \times 100\ (11)$$

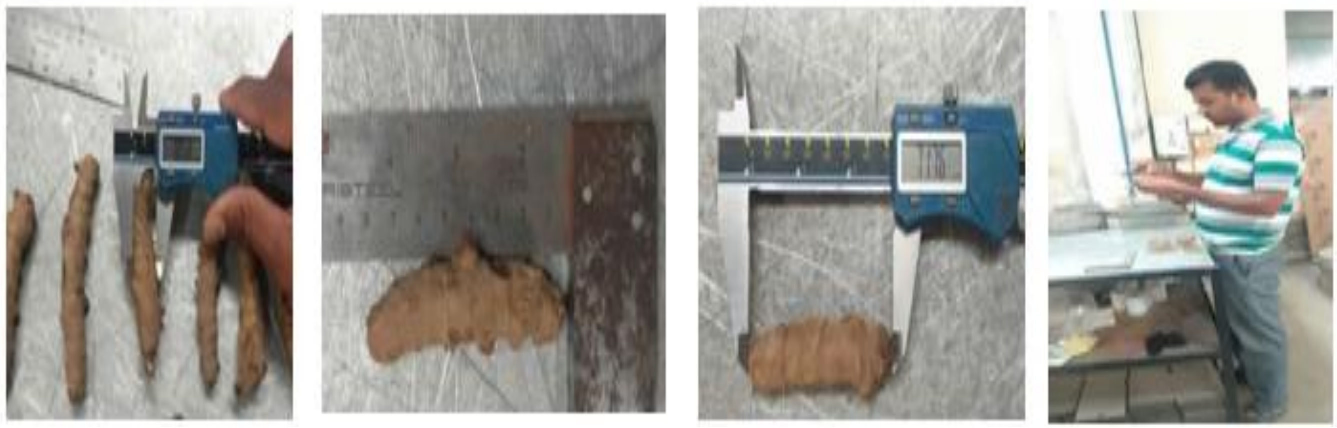
Table.1 Physical Properties of Turmeric Finger

Geometric property			
Length (mm)	34.38±1.42	44.42±1.76	52.60 ±4.76
Breadth (mm)	12.64 ±0.64	9.62±1.08	9.94±2.68
Thickness (mm)	7.44 ±1.71	6.46±1.83	5.18±1.60
Arithmetic mean diameter (mm)	13.82±0.75	15.50±1.12	21.91±1.33
Sphericity	0.32 ±0.04	0.34±0.07	0.27±0.04
Aspect ratio	0.36 ±0.06	0.25±0.02	0.20±0.03
Unit volume (mm^3)	1647±20.12	2118 ±49.27	2901±31.42
Surface area (mm^2)	775±15.11	970±17.31	1265±27.92
Shape factor	1.73 ±0.14	1.50±0.27	1.66±0.22
Gravimetric property			
Bulk density (kg/m^3)	343 ±6.34	282±7.94	260±5.11
True density (kg/m^3)	1352±7.86	1338 ±6.80	1349± 5.47
Porosity (%)	74.56±0.62	74.71±0.21	80.93±0.42
Frictional property			
Angle of Repose (o)	37.52±0.62	34.32±0.19	38.90±0.23
Coefficient of friction			
Plywood sheet	0.86 ±0.08	0.96 ±0.04	0.80± 0.06

Table.2 Symbols

1	L	major diameter with calyx (mm)	11	ρ_b bulk density (gr/cm^3)
2	W	intermediate diameter (mm)	12	E Porosity
3	T	minor diameter (mm)	13	ρ_t true density (gr/cm^3)
4	CPA	criteria projected area (mm^2)	14	Φ sphericity
5	R^2	coefficient of determination	15	φ angle of repose (degree)
6	D_g	geometric mean diameter (mm)	16	μ_s static coefficient of friction
7	M	mass (g)	17	W_{1000} thousand seeds mass (g)
8	PA1	first projected area (mm^2)	18	Vosp (cm^3)
9	PA2	second projected area (mm^2)	19	V volume (cm^3)
10	PA3	third projected area (mm^2)	20	Vsp volume of ellipsoid (cm^3)

Fig.1



Coefficient of Static Friction

This is the ratio of force needed to start sliding the sample over a surface by the weight of the sample. The coefficient of static friction was determined on wood surfaces, namely plywood, Each Finger was placed on the surface and raised gradually by screw until the Finger begin to slide. The angle θ of the inclined surface with the horizontal platform at the beginning of the sliding was measured. The coefficient of static friction (µs) was calculate using the following equation.

$$\mu_s = tan\,\theta \quad (12)$$

Results and Discussion

The physical properties of Turmeric Fingers are given in Table 1. The average length of three grades was 30.38 mm, 40.57 mm and 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 sphericity, aspect ratio and shape factor of turmeric fingers decreased with increase in dimension. This may be attributed to the irregular shape of turmeric fingers. The unit volume and surface area of turmeric rhizomes showed a linear relationship with grade size. The angle of repose increased with respect to grades (dimension) i.e. 37.57^{o}, 38.44^{o} and 38.90^{o} for grade I, II and III respectively. The coefficient of friction with respect to these grades on different structural surface viz., plywood sheet (0.86-0.80) is depicted in Table 1.

The physical properties measured can be very useful for designing and development of turmeric planting machine, feed hoppers, booth structure and other purposes.

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