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Physical properties of raw PTS 10 turmeric variety

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Abstract

A sample of 30 turmeric rhizomes (var. PTS 10) was selected for analysing their physical properties. The average values of their geometric properties viz. length (90.73 ± 12.12 mm), breadth (22.03 ± 2.25 mm), thickness (20.64 ± 2.2mm), Geometric mean diameter (34.45 ± 2.96 mm), Arithmetic mean diameter (44.46 ± 4.49 mm), Square mean diameter (44.46 ± 4.49 mm), Equivalent diameter (48.18 ± 4.41 mm), Aspect ratio (0.25 ± 0.04), Unit volume (12413.53 ± 3185.09mm^2), Surface area (3451.72 ± 585.75mm^3), sphericity (0.38 ± 0.04), shape factor (0.97 ± 0.03) were reported. The gravimetric properties viz. Bulk density (468.417 ± 3.304kg m^{-3}), True density (785.13±9.141 kg m^{-3}) and Porosity (0.403±0.009 %) were reported. The frictional properties viz. Angle of repose (50.47º), Coefficient of friction for Stainless steel (1.128±0.13), Coefficient of friction for Mild steel (1.172 ±0.097), Coefficient of friction for Galvanized iron (0.903 ±0.012) and Coefficient of friction for Aluminium (0.903±0.023). The rhizomes were classified based on size into different grades.

Keywords: Turmeric, geometric properties, diameter, friction

Introduction

Turmeric, a spice belonging to Zingiberaceae family, is the dried rhizome of Curcuma longa, a herbaceous plant, native to South East Asia but is now widely cultivated in the tropical and subtropical regions of the world. It has its importance as a spice, flavouring agent, colorant, and it is used in most of the treatment of various illnesses. Turmeric is extensively used in traditional Indian medical practice to cure biliary disorders, anorexia, cough, diabetic wounds, heptic disorders, rheumatism and sinusitis (Ravindran *et al*., 2007) [11]. It is also used in textile industry, in the preparation of oils, ointments and poultice, in cosmetic product to prepare natural and herbal creams, lotion and hair dye (Kamble *et al*., 2011) [8].

The study of basic physical properties like the bulk density, true density, porosity and coefficient of static friction was done by Athmaselvi & Varadharaju (2002) [1] and advanced study of physical properties for IISR Alleppey Supreme was made by S Balasubramanian *et al*. (2012) [2].

The study of turmeric physical properties aids in the design of various agricultural machines used in its processing chain like the washers, graders, boilers, driers, polishers and storage devices. Its understanding gives a greater insight into various physical processes of handling during harvesting, in transportation from field to processing unit and within the processing unit, shipping. If the handling system is not efficiently designed it can lead to excessive cost (Moustapha Ahmed Boudh *et al*, 2015) [4]. Hence its calculation leads to the determination of various dimensions of the machines.

2. Materials and methods

A study of physical properties was conducted in Tamil Nadu Agricultural University, Coimbatore. The sample (PTS-10 variety) was procured from Erode district. The moisture content was then determined using dean and stark apparatus.

The basic dimensions were determined at the moisture content of 80% (w.b.).Two kg of the sample was drawn from the bulk and after mixing thoroughly 30 rhizomes from each sample were randomly selected. The dimensions along three mutually perpendicular axes, namely major (length, a), intermediate (width, b) and minor (thickness, c) of each rhizome were measured using a digital vernier calliper having anaccuracy of 0.02 mm.

The average geometric mean diameter, sphericity (φ), arithmetic mean diameter (AMD), square mean diameter (SMD), equivalent diameter (ED), aspect ratio (AR) were determined by using the following equations (Mohsenin, 1986) [10].

a. Dimensions of turmeric rhizomes

2.1. Geometric properties

2.1.1. Geometric mean diameter

The Geometric mean diameter was calculated using the following formula given by Mohsenin (1986) [10]

Geometric mean diameter = $\sqrt[3]{abc}$ (1)

2.1.2 Sphericity
Mohsenin assumed that the volume of the solid is equal to the volume of a triaxial ellipsoid with intercepts a, b and c and that the diameter of the circumscribed sphere is the longest intercept a of the ellipsoid. Degree of sphericity was given by:

Sphericity $=\frac{\sqrt[3]{abc}}{a}$ (2)

2.1.3 Arithmetic mean diameter
The Arithmetic mean diameter is calculated using the following formula given by Mohsenin (1986) [10]

Arithmetic mean diameter = $\frac{a+b+c}{3}$ (3)

2.1.4 Square mean diameter
The Square mean diameter was calculated using the following formula given by Mohsenin (1986) [10]

Square mean diameter = $\sqrt{ab+bc+ca}$ (4)

2.1.5 Equivalent diameter
The Equivalent diameter was calculated using the following formula given by Mohsenin (1986) [10]

Equivalent diameter = $\frac{AMD+GMD+SMD}{3}$ (5)

2.1.6 Aspect ratio
The Aspect ratio was calculated using the following formula as given by Mohsenin (1986) [10]

Aspect ratio = $\frac{b}{a}$ (6)

2.1.7 Unit volume and surface area
The unit volume (V) and surface area (S) were determined as per the following equations (JainandBal, 1997) [6].

Surface area = $\frac{\pi B a^2}{2a-B}$ (7)

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

where, B = $\sqrt{bc}$

2.1.8. Shape Factor
Shape factor (γ) based on the unit volume and surface area was determined (McCabe & Smith 1984) [9] as:

Shape factorγ=D/C (9)

Where $C=\frac{V}{b^3}$&$D=\frac{S}{6b^2}$

2.2 Gravimetric properties
The Bulk density, True density and porosity were calculated as follows:

2.2.1 Bulk Density
Bulk density was calculated as the ratio between mass and bulk volume of turmeric rhizomes. As the size of turmeric rhizomes was larger than grains, the following random method was adopted to determine the bulk density. One bag of rhizomes (25 kg) was piled (poured) over a horizontal surface from a height of 50 cm slowly and the rhizomes were allowed to fall freely. The slant height (l) of the pile was determined by measuring it at different places and taking the average. The radius (r) of the pile was calculated from the circumference of the pile formed. Using slant height l, radius of the pile r, volume of the pile was determined and then the bulk density was calculated.

$$h=\sqrt{\left(l^2-r^2\right)} \quad (10)$$

$$BD=\frac{\text{mass of turmeric}}{\text{Bulk volume of turmeric}} \quad (11)$$

2.2.2. True density
The true density of turmeric rhizomes was determined by the platform scale method (Mohsenin, 1986) [10]. The turmeric samples were first weighed on a precision electronic balance having a least count of 0.01 g and then immersed in water in a container placed above the electronic balance. The mass of displaced water was recorded and used in the following expression to determine the true volume. True density of the turmeric rhizomes was determined by taking ten replications of all the four samples.

$$\text{True volume, }(m^3)=\frac{\text{Mass of displaced water, (kg)}}{\text{Density of water, }(kg\ m^{-3})} \quad (12)$$

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

$$\rho_t=\frac{W_a}{V_t} \quad (13)$$

Where, ρ_t is the true density of turmeric rhizomes, kg m^{-3},W_a is the mass of turmeric rhizomes in air, kg, V_t is the true volume of turmeric rhizomes, m^3

2.2.3 Porosity
The porosity of the turmeric rhizomes was computed using the following formula. The porosity (ε) wascalculated as the percentage of volume of voids (Mohsenin 1986; Kaleemullah and Kailappan, 2003) [10, 7].

$$\varepsilon=1-\left(\frac{\rho_b}{\rho_t}\right)\times 100 \quad (14)$$

where,ε is the porosity, %, ρ_b is the bulk density, kg m^{-3} and ρ_t is the true density, kg m^{-3}

2.3 Frictional Properties
The angle of repose and co efficient of friction were calculated as follows:

2.3.1 Angle of repose
The angle of repose is the angle made by the material with the horizontal surface when piled from a known height. Fifteen kg of turmeric rhizomes were piled over a horizontal surface. The radius of the pile was calculated from the circumference of the pile and the slant height of the pile was determined by measuring the actual slope of the pile. Angle of repose was determined by taking ten replications of the samples. The angle of repose was calculated using the following formula.

$$\theta=\tan^{-1}\frac{h}{r} \quad (15)$$

Where, θ is the angle of repose, degrees, r is the radius of the pile, cm and h is the slant height of the pile, cm

2.3.2 Coefficient of friction

The coefficient of friction apparatus was used for its calculation. The test surfaces used in the experiment were galvanized iron, mild steel, aluminium and stainless steel. Experiments were replicated 5 times by emptying and refilling the container with different samples every time and the average value was determined and recorded as the average static coefficient of friction. The co-efficient of static friction was calculated as the ratio of the frictional force to the normal force as, (Sahay and Singh, 1994) [12]:

Table 1: Values of various geometric, gravimetric and frictional properties of turmeric.

Properties	Grade I	Grade II	Grade III
Geometric property			
Length (mm)	69.45±3.56	85.47±0.67	103.51±0.93
Breadth (mm)	18.89±3.04	21.57±0.89	24.65±1.34
Thickness (mm)	18.45±5.72	21.74±1.26	25.12±0.84
Arithmetic mean diameter (mm)	35.60±1.35	42.92±1.24	51.09±1.75
Geometric mean diameter (mm)	28.91±0.81	34.20±1.21	39.98±0.74
Square mean diameter (mm)	54.22±1.67	64.56±1.97	75.93±1.67
Equivalent diameter (mm)	39.57±1.27	47.23±1.41	55.67±1.33
Sphericity	0.42±0.012	0.40±0.014	0.39±0.02
Aspect ratio	0.27±0.021	0.25±0.015	0.24±0.021
Unit volume (mm^3)	7328.95±555.21	12019±1196.112	19015±1065.98
Surface area (mm^2)	2350.98±142.63	3326.77±203.87	4591.76±196.48
Shape factor	1.01±0.03	0.996±0.02	0.992±0.03
Gravimetric property			
Bulk density (kg m^{-3})	468.42±3.30	455.12±2.84	446.68±1.94
True density (kg m^{-3})	785.13±9.141	776.54±8.43	764.18±8.11
Porosity (%)	36.4±0.006	38.64±0.007	40.3±0.009
Frictional property			
Angle of repose (°)	48.64	49.52	50.47
Coefficient of friction			
Stainless steel	1.128±0.13	1.084±0.11	1.067±0.09
Mild steel	1.172±0.097	1.158±0.085	1.147±0.078
Galvanized iron	0.903±0.012	0.843±0.010	0.859±0.011
Aluminium sheet	0.903±0.023	0.860±0.021	0.857±0.018

$$\mu = \frac{F}{N} \qquad (16)$$

where, μis theco-efficient of friction, F is the frictional force, kg and Nis the normal force, kg

3. Results and Discussion

The average length of the rhizomes was found to be 69.45±3.56 (grade I), 85.47±0.67 (grade II) and 51±0.93 (grade III). The trend is found to increase from grade I to grade III.The average breadth of the rhizomes was found to be 18.89±3.04 (grade I), 21.57±0.89 (grade II) and 24.65±1.34 (grade III) and the average thickness was found to be 18.45±5.72 (grade I), 21.74±1.26 (grade II) and 25.12±0.84 (grade III).

There exists an increasing trend among the grades in the breadth and the thickness.

The average Arithmetic mean diameter, geometric mean diameter, square mean diameter and equivalent diameter of the rhizomes were found to have a gradually increasing trend from grade I to grade III.

The average Sphericity, shape factor and the aspect ratio of the rhizomes were found to have a decreasing trend. This may be attributed to the fact that the rhizomes are irregular in nature. The Unit volume (mm^3) and the surface area of the rhizomes increased gradually owing to the increasing dimensions of the rhizomes from grade I to grade III.

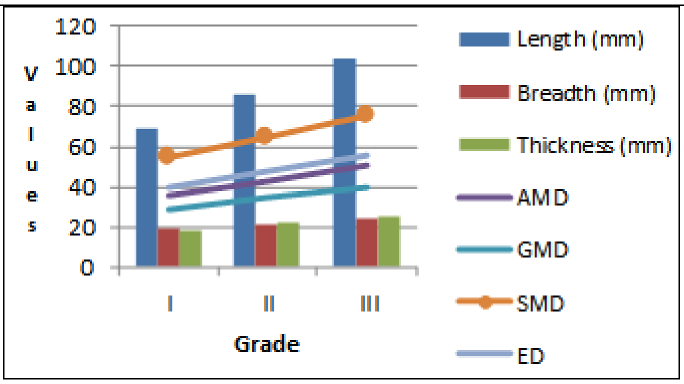

Fig 1: Trends in geometric properties length, breadth, thickness, sphericity, aspect ratio and shape factor with varying grades. AMD: Arithmetic Mean Diameter.
GMD: Geometric Mean Diameter.
SMD: Square Mean Diameter.
ED: Equivalent Diameter.

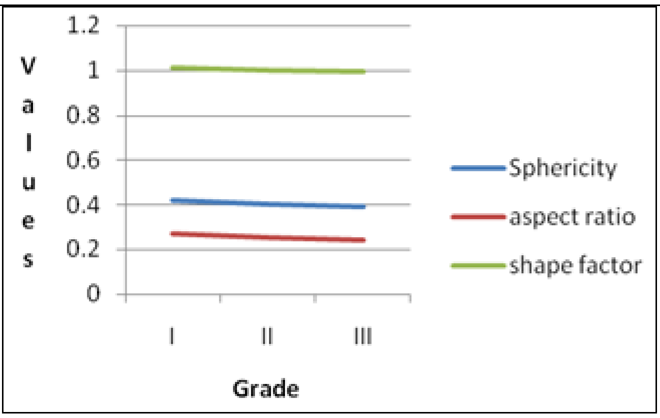

Fig 2: Trends in geometric properties length, breadth, thickness, sphericity, aspect ratio and shape factor with varying grades.

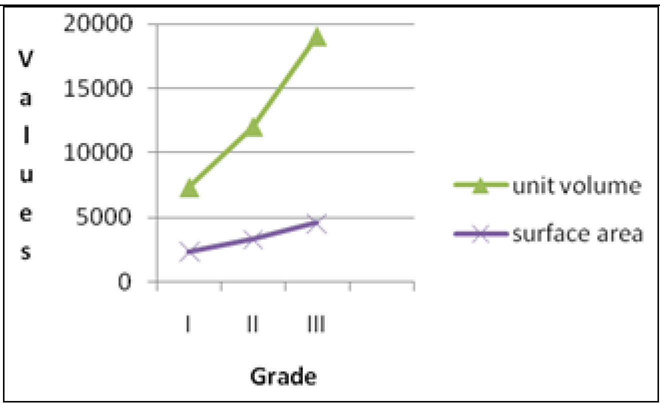

Fig 3: Trends in geometric properties unit volume and surface area with varying grades

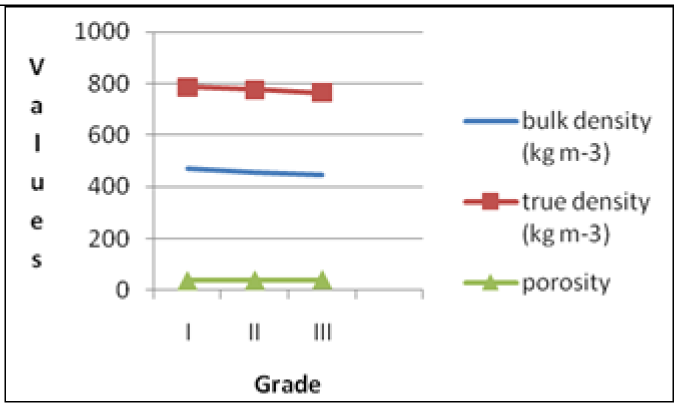

Fig 4: Trends in gravimetric properties unit volume and surface area with varying grades

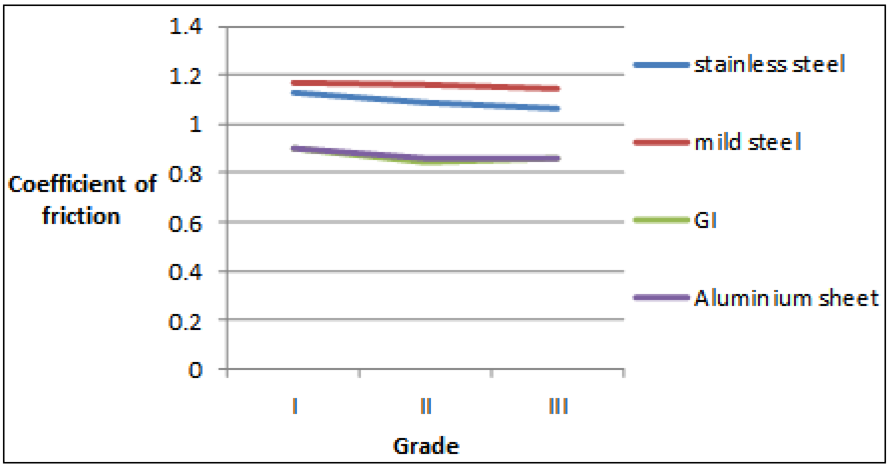

Fig 5: Trends in frictional properties unit volume and surface area with varying grades.

Among the gravimetric properties the average bulk density (kg m^{-3}) and the true density (kg m^{-3}) of the rhizomes was found to decrease from grade I to grade III. The Porosity (%) of the rhizomes increased from grade I to grade III because the bulk density and the true density reduced.

Among the frictional properties the Angle of repose (°) of the rhizomes was found to be 48.64° (grade I), 49.52° (grade II) and 50.47° (grade III). The trend is found to increase from grade I to grade III. The coefficient of friction varied for different surfaces. For the Stainless steel rhizomes was found to be 1.128±0.13 (grade I), 1.084±0.11 (grade II) and 1.067±0.09 (grade III). The trend is found to decrease from grade I to grade III.For the Mild steel rhizomes was found to be 1.172±0.097 (grade I), 1.158±0.085 (grade II) and 1.147±0.078 (grade III). The trend is found to decrease from grade I to grade III.The Galvanizediron surface showed the co efficient of friction for the rhizomes to be 0.903±0.012 (grade I), 0.843±0.010 (grade II) and 0.859±0.011 (grade III). The trend is found to decrease from grade I to grade III.Whereas for Aluminium sheet the coefficient was found to decrease with values0.903±0.023 (grade I), 0.860±0.021 (grade II) and 0.857±0.018 (grade III).

4. Conclusion

The investigations of various geometric, gravimetric and frictional properties revealed the following. The grade of the turmeric increased with increase in the dimensions. The length, breadth and thickness increased with the better grades. Accordingly AMD, GMD, SMD and ED increased linearly with the grades. The sphericity and aspect ratio decreased non-linearly with the grades. The unit volume increased non-linearly and surface area increased linearly whereas the shape factor decreased non-linearly and the bulk density and true density decreased linearly with better grade whereas the porosity linearly increased. The angle of repose increased non- linearly for grade I to grade III. The co-efficient of friction for Stainless steel was linear and non-linear for Mild steel, Galvanised Iron and Aluminium sheet.

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