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PHYSICAL PROPERTIES OF FINGER TURMERIC RHIZOMES OF C.V. *"PDKV WAIGAON"* UNDER FRESH AND TRAY DRIED CONDITION

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ABSTRACT

Turmeric (*Curcuma longa* L.) is valued as a spice, natural colourant, preservative, and a major source of curcumin. The physical and engineering properties of turmeric rhizomes are critical for designing machinery, postharvest handling, and processing operations. In this study, freshly harvested rhizomes of the variety *"PDKV waigaon"* were evaluated under two conditions: fresh and tray dried. As a moisture content of fresh turmeric rhizomes decreased from 80.37 % to 10.86%, the average linear dimensions such as length, breadth, thickness decreased from 95.54, 23.48, and 20.54 mm (fresh) to 50.62, 12.86, and 10.78 mm (tray dried). Similarly, the geometric, arithmetic, and square mean diameters reduced from 35.59, 46.19, and 67.96 mm (fresh) to 18.99, 24.75, and 36.37 mm (tray dried), respectively. The bulk density declined from 495.24 kg/m^3 to 407.89 kg/m^3, while the true density decreased from 1168.05 kg/m^3 to 899.09 kg/m^3, resulting declined porosity **(**53.59 %**)** in tray dried rhizomes compared to fresh (59.99 %). The sphericity remained constant (0.38), and the angle of repose slightly increased from 27.37° to 29.59°. Tray drying significantly reduced size axial, geometrical dimensions and bulk density, true density, porosity while increased the angle of repose, providing essential data for optimizing turmeric processing and storage.

Keywords **:** Turmeric Rhizome, Bulk density, True density, Porosity, Sphericity etc.

Introduction

Turmeric (*Curcuma longa* L.) is a non-traditional crop in some part of Vidarbha region of Maharashtra. However, the climate and soil conditions seem to be suitable for its cultivation of turmeric in this region. The successful introduction of a favorable variety of turmeric crop for such a large area will provide an opportunity to generate income and also create option for crop diversification. Dr. PDKV Akola introduce new variety of turmeric having name "*PDKV waigaon*". Due to high curcumin percentage farmer produce turmeric of this variety on large quantity nowadays, hence it is necessity to study the physical and engineering properties of the turmeric rhizomes for storage, post-harvest unit operation and thermal processing. The present investigation was therefore undertaken to study the physical properties of fresh, tray dried turmeric rhizomes.

Material and Methods

The entitled "Physical Properties of Finger Turmeric Rhizomes of C.V. *"PDKV waigaon"* under Fresh and Tray Dried Condition" was carried out at experimental learning unit of Department of Agricultural Process Engineering, College of Agricultural Engineering and Technology, Akola. Freshly harvested turmeric rhizomes of variety "*PDKV waigaon*" were procured from department of vegetable science. The different physical properties of turmeric mother rhizomes such as geometrical observations like rhizome moisture content (mc.), Length (*l*), Breadth (*b*), Thickness (*t*), sphericity, geometric mean diameter (GMD), arithmetic mean diameter (AMD) and square mean diameter (SMD), true density, bulk density,

porosity, and angle of repose were determined before and after drying.

Moisture content

The moisture content of fresh finger turmeric rhizome was estimated by using hot air oven method. The weighed samples of turmeric finger rhizome were subjected to remove moisture at 105±2 °C for 24 hours. After which it was kept inside a desiccator for cooling to ambient temperature and the change in mass (measured using electronic weighing balance) was noted (AOAC 2000). The moisture content was expressed as % (wb) or (db). The moisture content was determined by using following equation,

$$MC\ (\%\ wb) = = \frac{W1 - W3}{W2 - W3} \quad (1)$$

Where,

W_1 = Initial mass of the test sample (g)

W_2 = Final mass of the test sample (g)

W_3 = Mass of empty sample box (g)

Linear dimensions of turmeric rhizomes

Linear dimensions of randomly selected 100 samples of finger turmeric rhizomes were measured on the source of three dimensions such as Longest Dimensional (length) Axis, Intermediate Dimension (width) axis, and Short Dimension (thickness) axis by digital vernier calliper of accuracy 0.01 mm. The arithmetic means diameter (Da); Equivalent mean diameter (De); Geometric mean diameter (Dg) aids to determine surface area (Sa) of the wood apple fruit which are calculated by standard formulas. A hundred observations were made to get average values of length, width and thickness of the turmeric rhizomes. (Mohsenin *et al*., 1986; Murakonda *et al*., 2022; Pathak *et al.*, 2019)

Sphericity

The sphericity value of fresh and tray dried 100 finger turmeric rhizomes shows the closeness of its shape to a sphere, this property is useful in the design of hopper and dehulling equipment for agricultural products, it determines the tendency of a material to roll when placed on a particular orientation. Sphericity of turmeric rhizome was calculated by using following equation, (Singh and Sahay 2001).

$$\Phi = \frac{(lbt)^{1/3}}{l} \quad (2)$$

Geometric mean diameter

The geometric mean diameter of 100 fresh and tray dried finger turmeric rhizomes was determined by first measuring their principal linear dimensions length (L), width (W), and thickness (T) in accordance with the method suggested by Mohsenin (1970). These measurements were then used to calculate the arithmetic mean diameter (AMD) geometric mean diameter (GMD), square mean diameter (SMD) which served as the size determining parameter.

The GMD was computed as the cube root of the product of the three main axes of each rhizome, represented by major length (l), breadth (b), and thickness (t). The corresponding relationship and formula used for this calculation are provided below

$$(GMD) = (lbt)^{1/3} \quad (3)$$

Arithmetic mean diameter was determined as below,

$$(AMD) = \frac{l+b+t}{3} \quad (4)$$

Square mean diameter was also determined by using below formula,

$$(SMD) = (lb+bt+tl)^{1/2} \quad (5)$$

Bulk density (BD)

The bulk density randomly selected 15 samples of fresh and tray dried tfinger turmeric rhizomes was determined as the ratio between the mass of fresh, tray dried finger turmeric rhizomes in a container to its volume. Rhizomes were filled in a box of volume 30 cm length, 20 cm width and 15 cm height. The mass of contents was determined. Bulk density of steam boiled, tray dried rhizomes was calculated by using following formula, (Singh and Sahay, 2001).

$$\text{Bulk density} = \frac{\text{Mass of finger rhizome}}{\text{Volume of box}} \left(\frac{Kg}{M^3}\right) \quad (6)$$

True density (TD)

For finding out the actual volume of rhizome it is essential to know the true density in this view this property was calculated by the formula. In this method toluene solution ($C_6H_5CH_3$) was used to determine the true density of fresh, tray dried finger turmeric rhizomes due some properties such as little tendency to soak into the material, a low surface tension, enabling it to flow smoothly over the material surface, little solvent action on constituents of the material especially fats, a fairly high boiling point and it has low specific gravity (kg/m^3), (Singh and Sahay 2001).

$$\text{True density} = \frac{\text{Mass of displaced toluene by rhizome}}{\text{Density of toluene}} \left(\frac{Kg}{M^3}\right) \quad (7)$$

Porosity

Porosity is the percentage of volume of voids in the test sample at given moisture content. Porosity of

fresh, tray dried rhizomes was calculated as the percentage of volume of voids for finger turmeric rhizomes, (Mohsenin *et al*. 1986; Singh and Sahay 2001).

$$\text{Porosity} = \frac{\text{True density} - \text{Bulk density}}{\text{True density}} * 100 \qquad (8)$$

Angle of repose

The angle of repose is the angle made by fresh and tray dried finger turmeric rhizomes with the horizontal surface when heaped from a known height. About 15 kg of turmeric rhizomes was heaped over the horizontal surface slowly from a height of 50 cm. The slanted height of the heap was measured and diameter of the heap was calculated from the circumference of heap. The angle of repose fresh and then tray dried was then computed using the standard formula, (Singh and Sahay 2001, Shirsat *et al.* 2018, Pathak *et al*., 2019).

$$\theta = \text{Tan}^{-1}\frac{H}{D/2} \qquad (9)$$

Where,

θ = Angle of repose in

H = Height of the heap in cm,

D = Diameter of the heap in cm.

Statistical analysis

Physical & engineering properties of fresh and tray dried finger turmeric rhizomes were subjected to analysis of variance (ANOVA) and the means separation by least significance difference at probability level 5%. Relation among the different physical properties were computed by using simple paired T-test Anova by using Web Agri stat method (Megha *et al*., 2022).

Result and Discussion

Moisture content

Moisture content of the produce determines the shelf life and the keeping quality of the turmeric. The initial moisture content of the turmeric rhizomes was determined by oven drying method and the average moisture content was found to be in range of 78.67-80.37 % (wb). Turmeric rhizomes were dried up to 10.86-11.32 % moisture content and engineering properties were measured (Shirsat *et al*. 2018) reported the engineering properties of turmeric rhizomes at moisture levels ranging from 76.18% to 78.84% (wb). In a related investigation, (Pooja *et al*., 2022) characterized these properties at a higher average moisture content of 81.26% (wb)

Linear dimensions of turmeric rhizomes

The linear dimensions such as length, width and thickness of 100 samples of fresh turmeric rhizomes & then tray dried turmeric rhizomes were measured. After tray drying of fresh turmeric rhizomes, the mean values of length, width and thickness get decreased and it varies from 95.54-50.62 mm, 23.48-12.86 mm, 20.54-10.78 mm respectively. and it was varied in the range of 51.91 to 119.62 mm, 15.18 to 34.93 mm, and 14.45 to 29.77 mm respectively. The mean value of sphericity was 0.38 and it varies from 0.382 to 0.387. The geometric mean diameter, arithmetic mean diameter and square mean diameter get decreased as moisture content get decreased. It was ranged from 35.71-18.99 mm, 46.19-24.75 mm, 68.12-36.37 mm respectively. From paired T-test statistical analysis, it was concluded that linear dimensions fresh turmeric rhizomes to tray dried turmeric rhizomes was varied with 5 % level of significance (Khambalkar *et al*., 2017) and (Shirsat *et al*., 2018) also reported similar trends regarding average values of length, width and thickness of turmeric rhizomes. (Parveen *et al*., 2013) reported that the turmeric finger rhizomes recorded 50.54 % reduction in thickness and 27.38 % reduction in length and an average volume reduction of 76.80 % when the moisture content was reduced from 411.25 to 7.81 % (db.).

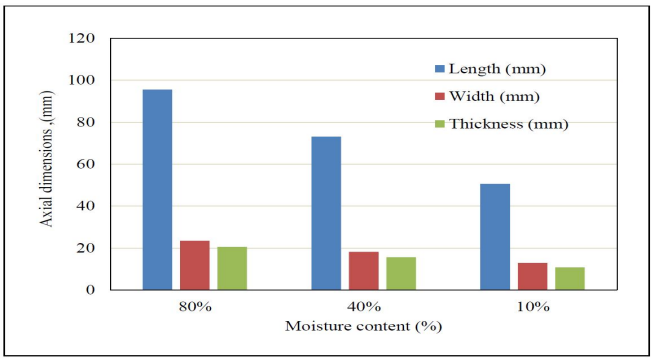

Fig. 1 : Axial dimensions of turmeric rhizomes of C.V. *"PDKV waigaon"* under different moisture level.

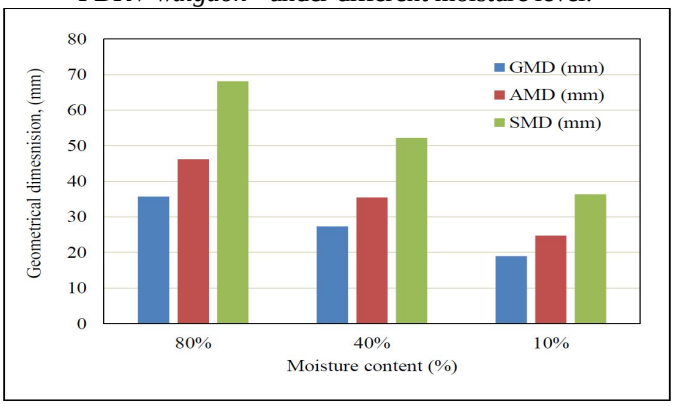

Fig. 2 : Geometrical dimensions of turmeric rhizomes of C.V. *"PDKV waigaon"* under different moisture level.

Bulk density

Mean values regarding bulk density of fresh and tray dried turmeric rhizomes varies from 495.24 kg/m^3 - 407.89 kg/m^3. Bulk density of fresh turmeric rhizomes varies from 476.29-505.92 kg/m^3 while, in case of tray dried rhizomes it varies from 343.43-456.25 kg/m^3. From *figure 3 and table 1,2* it was found that bulk density is directly proportional to the moisture content of the turmeric rhizomes. It was observed that average bulk density of fresh turmeric rhizomes was decreased as moisture content decreased and it was observed in the varied from 495.24 to 407.89 kg/m^3. From paired T-test statistical methods, it was concluded that bulk density was significantly vary with 5 % level of significance.

Similar observations regarding bulk density were recorded as 485.97 kg/m^3 and 529.66 kg/m^3 by (Jayashree and Vishwanathan, 2011) and (Khambalkar *et al.,* 2017) respectively. Similar trend regarding bulk density of fresh and tray dried turmeric rhizomes were reported by (Subhashini *et al.,* 2015) and (Balkrishnan *et al*., 2020). Similarly (Wandkar *et al.,* 2012) observed that bulk densities decreased from and 749.1 to 644.4 kg/m^3 as a moisture content decreased from 15.80% to 7.37% (db).

True density

Average values of true density regarding fresh turmeric rhizomes and tray dried turmeric rhizomes were observed as 1168.05 kg/m^3 & 899.09 kg/m^3 respectively. True density of fresh turmeric rhizomes varies from 1078.11-1262.42. kg/m^3 while, in case of tray dried rhizomes it varies from 846.66-932.17 kg/m^3. The average value of true density of fresh to tray dried turmeric rhizomes was varied within the range of 1168.05 to 899.09 kg/m^3. From T-test statistical analysis the results proved that that true density of turmeric rhizomes sample varies with 5 % level of significance during drying. From (figure 3 and table 1, 2) it was found that true density is directly proportional to the moisture content of the turmeric rhizomes. The true density of fresh turmeric rhizomes was observed as 1018.95 kg/m^3 by (Khambalkar *et al.* in 2017).

Similar trend regarding true density of turmeric rhizomes was recorded by (Shirsat *et al.* in 2018) and (Jayashree and Vishwanathan 2011) was found to be varies in range of 1317.55-951.10 kg/m^3 and 1099.13-1011.47 kg/m^3. Similarly (Wandkar *et al.,* 2012) observed that true densities decreased from and 1250 to 1111.11 kg/m^3 as a moisture content decreased from 15.80 % to 7.37% (db).

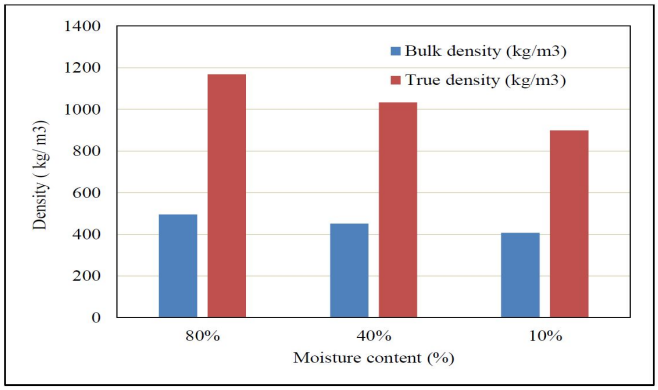

Fig. 3 : Bulk density and true density of turmeric rhizomes of C.V. *"PDKV waigaon"* under different moisture level.

Porosity

Average values of porosity regarding fresh and tray dried turmeric rhizomes was 59.99 and 53.59 % respectively. Porosity of fresh turmeric rhizomes varies from 58.42-62.68 % while, in case of tray dried rhizomes it varies from 46.11-56.88. From (figure 4 and table 1, 2) it was observed that the porosity is directly proportional to moisture content. The average value of porosity of the fresh turmeric rhizome gets decreased as moisture content get decreased and it varied from 59.99 to 53.59 %. Results shows that porosity of fresh and tray dried turmeric sample varies with 5% of significance. The porosity of freshly harvested turmeric rhizome was observed by (Shirsat *et al.,* 2018) and it was ranged from 66.94-56.81 %. The porosity of turmeric rhizomes was ranges from 32 to 63 % respectively was observed by (Khambalakar *et al.,* 2018). Similar results were reported by (Subhashini *et al.,* in 2015) and (Balkrishnan *et al.,* 2020). Also (wandkar *et al*., 2012) observed that porosity increased from 40.07% to 41.9%. As the moisture content increased from 7.37% to 15.80% (db).

Angle of repose

The angle of repose of fresh and then tray dried turmeric rhizomes gets increased as moisture content get decreased and average values of fresh and tray dried turmeric rhizomes 27.37 & 29.59° respectively. Similarly angle of repose of tray dried turmeric rhizomes get varied from 25.24 to 34.77. Samples of fresh and tray dried shows 5 % level of significance. (Kambalkar *et al*., 2017) reported the average value of angle of repose for Salem variety was 26.20°. Similarly (Shirsat *et al*., 2018) reported angle of repose 22.61 to 28. 76°. (Jayashree and Vishwanathan, 2011) reported that angle of repose of finger rhizomes get increases from 34.9 to 40.2° as fresh rhizomes get dried. Similar results were reported by (Subhashini *et al*., 2015) and (Balkrishnan *et al*., 2020). As the moisture content increased from 7.37% to 15.80% (db) angle of repose as found to increase from 26.35° to 30.96° (Wandkar *et al*., 2012).

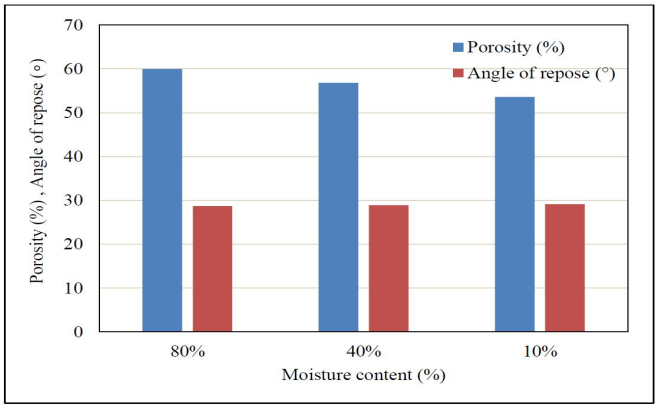

Fig. 4 : Porosity and angle of repose of turmeric rhizomes of C.V. *"PDKV waigaon"* under different moisture level.

Statistical analysis

Relationships among the various engineering properties of fresh and tray dried were examined using paired T-tests by employing the Web Agri-Stat statistical software (Megha *et al*., 2022). Length, breadth, thickness, geometric mean diameter, arithmetic mean diameter and square mean diameter bulk density, true density porosity and angle of repose of both fresh and tray dried samples shows significant difference at 5% level of significance. while sphericity does not show significant difference.

Table 1: Summary of physical properties of fresh turmeric rhizomes (*Curcuma longae. L.)* having moisture content varies from 78.67- 80.37 % on wet basis.

Property	No. of replications	Mean	SD	Min.	Max.	CV
Length (mm)	100	95.54	14.92-15.74	51.91	119.62	15.864-15.944
Width (mm)	100	23.48	3.79-3.81	15.18	34.93	16.15-16.23
Thickness (mm)	100	20.54	2.85-2.86	14.45	29.77	13.87-13.94
Sphericity (dec)	100	0.38	0.0174-0.0175	0.36	0.43	4.60-4.63
GMD (mm)	100	35.71	5.40-5.43	22.5	44.97	15.13-15.21
AMD (mm)	100	46.19	7.12-7.16	27.18	61.56	15.42-15.50
SMD (mm)	100	68.12	10.38-10.43	41.92	93.82	15.24-15.32
BD (kg/m^3)	15	495.24	7.24-7.50	476.29	505.92	1.46-1.51
TD (kg/m^3)	15	1168.05	50.56-52.34	1078.11	1262.42	4.32-4.48
Porosity (%)	15	59.99	1.44-1.49	58.42	62.68	2.40-2.49
Angle of repose (°)	15	27.37	1.89-1.96	21.49	29.47	6.93-7.18

Table 2: Summary of physical properties of tray dried turmeric rhizomes (*Curcuma longae. L.)* having moisture content varies from 10.86-11.32 % on wet basis.

Property	No. of replications	Mean	SD	Min.	Max.	CV
Length (mm)	100	50.62	8.62-8.66	34.33	76.86	17.03-17.11
Width (mm)	100	12.86	2.22-2.23	8.12	22.11	17.26-17.35
Thickness (mm)	100	10.78	2.31-2.32	6.17	18.66	21.47-21.58
Sphericity (dec)	100	0.38	0.0513-0.0513	0.25	0.5	13.49-13.55
GMD (mm)	100	18.99	2.50-2.52	13.4	27.96	13.21-13.27
AMD (mm)	100	24.75	3.87-3.82	18.07	33.74	13.59-13.66
SMD (mm)	100	36.37	4.64-4.67	26.59	52.08	12.75-12.82
BD (kg/m^3)	15	407.89	26.86-27.80	343.43	456.25	6.58-6.81
TD (kg/m^3)	15	899.09	23.87-24.70	846.66	932.17	2.65-2.74
Porosity (%)	15	53.59	2.80-2.90	46.11	56.88	5.24-5.42
Angle of repose (°)	15	29.59	2.43-2.52	25.24	34.77	8.22-8.51

Note- SD (Standard Deviation), Min. (Minimum), Max. (Maximum), GMD (Geometric Mean Diameter), AMD (Arithmetic Mean Diameter), SMD (Square Mean Diameter), CV (Coefficient of Variation)

Conclusion

Based on the experimental results, the study showed that the properties of turmeric rhizomes changed a lot with moisture content. When freshly harvested, washed, cleaned turmeric get tray dried from 78.67- 80.37 % moisture content to around 10.86-11.32 %, its size and shape become smaller due to shrinkage. Linear dimensions such as length, width, thickness get decreased as moisture content get decreased. The bulk density decreased; true density and porosity get decreased. The sphericity remains

almost the same, and the angle of repose increased slightly. Overall, drying has a clear effect on the physical properties of turmeric, and this information is useful for improving its drying, processing, handling, and storage methods.

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