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Physical and thermal properties of turmeric rhizomes

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Abstract: The physical and thermal properties of three varieties of turmeric rhizomes *viz.* BSR I, BSR II and Erode local were studied. BSR I had the highest primary finger length (82 mm) over the other varieties. The Erode variety showed higher weight for 1000 rhizomes. The bulk density, true density, moisture content, coefficient of friction, specific heat and thermal conductivity increased with increase in moisture content, for all the three varieties tested. Multiple regression equations were developed to predict all the physical and thermal properties of turmeric rhizomes as a function of moisture content.

Key words : Turmeric, Rhizomes, Physical property, Thermal property.

Introduction

Turmeric is the dried rhizome of *Curcuma longa* L., a herbaceous plant native to tropical South East Asia. Turmeric is mainly cultivated in India, Jamaica, Pakistan, China, Peru, Bangaldesh, Taiwan, Srilanka, Indonesia and Myanamar. India has a prime position in the world production of turmeric. It is estimated that over 80 per cent of the production is from India (George, 1993). Knowledge of the physical properties of turmeric is essential for design of the equipment for handling, processing and storing. Review of literature revealed that very few studies had been made in the past to determine the physical and thermal properties of turmeric rhizome. Hence, an attempt was made to study the various physical properties of turmeric namely moisture content, size of rhizomes, weight of 1000 rhizomes, bulk density, true density, static coefficient of friction, hardness and the thermal properties like thermal conductivity and specific heat.

Materials and Methods

Three ruling turmeric varieties, *viz.* BSR I, BSR II and Erode local were selected for the investigation. The physical and thermal properties were determined at different moisture contents. The study was undertaken in the year 1999 at the Dept. of Agricultural Processing, Tamil Nadu Agricultural University, Coimbatore.

Physical Properties

Moisture content

Moisture content of turmeric rhizomes were determined by toluene distillation method using Den Stark apparatus as per the (AOAC, 1975).

Size

The size of the turmeric rhizomes namely the length and breadth of the primary and secondary fingers were determined with the help of a vernier caliper having a least count of 0.1 mm. Ten samples were randomly selected for each variety and the mean values are reported as the size of the turmeric rhizomes.

Weight

The weight of 1000 turmeric rhizomes was obtained by weighing 50 rhizome selected at random in an electronic balance of 0.01 g accuracy. From the weight of 50 rhizomes, the weight of 1000 rhizomes was calculated.

Bulk and true density.

The bulk density was determined by filling a container of known volume and weighing the content. The container used had 300 mm diameter and 300 mm height. The bulk density was expressed as the ratio of weight to volume. The true density was determined by the toluene displacement method.

able 1. Size of turmeric rhizomes

	Length, mm						Breadth, mm					
	BSR I		BSR II		Erode		BSR I		BSR II		Erode	
	I.M.C. (82%, w.b.)	F.M.C (10%, w.b.)	I.M.C. (82%, w.b.)	F.M.C (10%, w.b.)	I.M.C. (82%, w.b.)	F.M.C (10%, w.b.)	I.M.C. (82%, w.b.)	F.M.C (10%, w.b.)	I.M.C. (82%, w.b.)	F.M.C (10%, w.b.)	I.M.C. (82%, w.b.)	F.M.C (10%, w.b.)
Primary finger	82	51	76	44	80	48	17.5	11	26	9.5	17	11
Secondary finger	34	21	29	12.5	34	20	12	7	18	6	11	7

I.M.C. : Initial moistuer content; F.M.C. : Final moisture content

Table 2. The effect of moisture content on physical properties

M.C.	BSR I			BSR II			Erode		
	Weight of 1000 rhizomes, kg	Bulk density kg/m³	True density kg/m³	Weight of 1000 rhizomes, kg	Bulk density kg/m³	True density kg/m³	Weight of 1000 rhizomes, kg	Bulk density kg/m³	True density kg/m³
10	4.94	779.8	1295.2	4.77	693.6	1282.7	5.4	753.2	1293.2
20	7.88	788.2	1298.2	7.07	716.5	1287.6	8.91	760.6	1300.2
30	10.83	792.5	1301.6	9.43	739.3	1293.0	12.42	767.3	1303.7
40	14.27	796.5	1303.8	12.6	762.0	1298.2	15.94	773.4	1307.2
70	21.84	809.3	1315.0	20.99	853.1	1317.8	24.6	801.8	1315.8

Coefficient of friction

The static coefficient of friction was determined by platform method. The rhizomes were filled in the sample holder and the dead weights were added in the pan until the sample holder started sliding, overcoming the friction on the surface. The weight of the rhizomes and the dead weights comprise the normal force (W) and frictional force (F) respectively. The static coefficient of friction was calculated as m = F/W (Sreenarayanan *et al.* 1988).

Hardness

The hardness (crushing strength) was determined in a hardness tester provided with a load cell. The load cell was calibrated by loading dead weight of 1 kg_f increment and the corresponding output (millivolt) was noted. The relationship between the applied load and millivolt reading was established as follows:

$$h = -0.09 + 0.47 \ \text{mV}$$

The rhizome was placed over the load cell and the load was applied by turning the wheel till the rhizomes failed. The millivolt reading was noted and the actual load was calculated from the equation.

Thermal properties

Specific heat

The experiment was conducted using the method of mixtures for solid materials sinking in water (Sreenarayanan, *et al.* 1988).

Table 3. Static coefficient of friction of turmeric rhizomes

Moisture (% w.b)	Stainless steel	Aluminium	Galvanized	Mild steel
BSR I				
10	0.411	0.444	0.526	0.622
20	0.4273	0.4614	0.5331	0.6348
30	0.4436	0.4788	0.5403	0.6476
40	0.46	0.4962	0.5475	0.6604
70	0.5254	0.566	0.5762	0.7118
BSR II				
10	0.395	0.4817	0.438	0.508
20	0.4045	0.4802	0.4485	0.514
30	0.4141	0.4817	0.459	0.521
40	0.4237	0.4831	0.469	0.527
70	0.4621	0.4917	0.515	0.554
ERODE				
10	0.409	0.411	0.503	0.602
20	0.4238	0.4311	0.5115	0.6171
30	0.4387	0.4512	0.5201	0.6322
40	0.4536	0.4714	0.5287	0.6474
70	0.5132	0.552	0.563	0.708

Thermal conductivity

The experiment was conducted using line source transient heat flow method (Suter *et al.* 1975).

Results and Discussion

Moisture Content

The average moisture content of the variety BSR I and Erode local was 82 per cent (w.b.) and moisture content of BSR II was 86 per cent (w.b.) immediately after harvest.

Size of the rhizome

The dimension of turmeric rhizomes at initial and final moisture content is presented in Table 1. The size of rhizomes were measured as length and breadth of primary and secondary fingers. The BSR I had higher primary finger length followed by Erode and BSR II at initial and final moisture contents. BSR II recorded the highest breadth at initial moisture content and least breadth for primary and secondary fingers at final moisture content (10 per cent w.b.). The reduction in the breadth of the fingers was 64 per cent for BSR II and it was 36 per cent for BSR and Erode varieties. The more reduction in BSR II may be due to high initial moisture content (86 per cent) and inherent property of the variety (Venkateswara Rao, 1989 and Ranjan Jalgaonkar and Rajput, 1991).

Weight of 1000 Rhizome

The relationship of 1000 rhizome weight with moisture content is shown in Table 2. The weight of 1000 rhizome increased linearly with the moisture content.
The regression equations are

BSR I $W_r = 2.3404 + 0.3\ (M)$ ($R^2 = 0.996$)
BSR II $W_r = 1.6754 + 0.3\ (M)$ ($R^2 = 0.998$)
Erode $W_r = 2.597 + 0.3\ (M)$ ($R^2 = 0.996$)

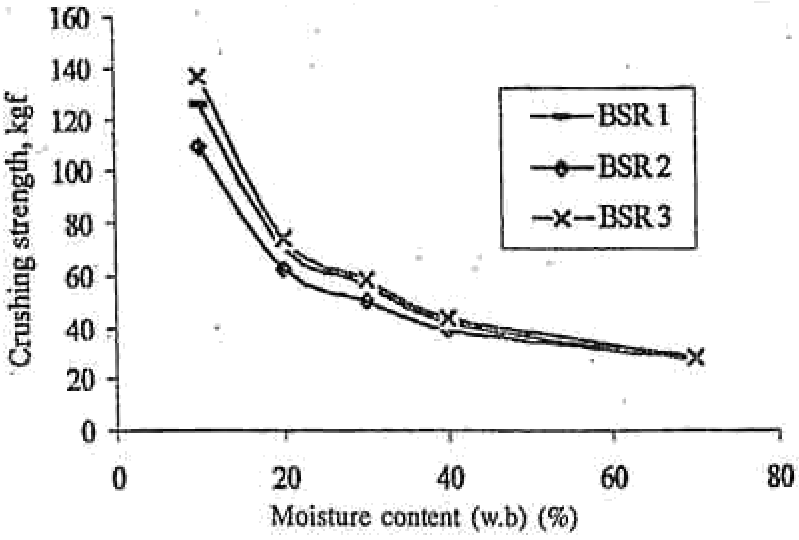

Fig.1. Effect of moisture content on crushing strength

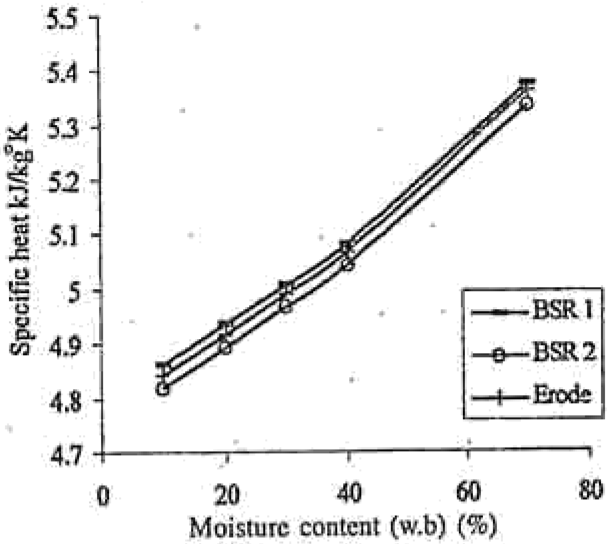

Fig.2. Effect of moisture content on specific heat

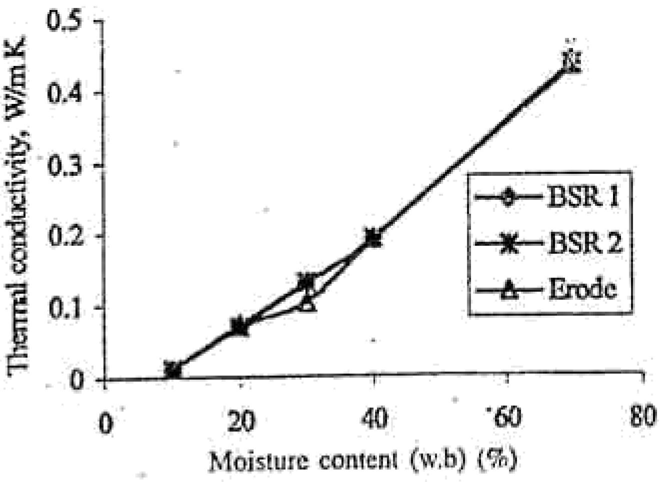

Fig.3. Effect of moisture content on thermal conductivity

Bulk density

Table 2 shows the relationship between moisture content and bulk density. The bulk density of BSR I was in the range of 779 to 809 kg m^{-3}, for BSR II 693 to 853 kg m^{-3} and for Erode 753 to 801 kg m^{-3} at the moisture range of 10 to 70 per cent (w.b) respectively. The bulk density increased with increase in moisture content (Shepherd and Bhardwaj, 1986).

The regression equation relating bulk density and moisture content per cent (w.b) are

BSR I $P_d = 0.773 + 5 \times 10^{-4} (M) (R^2 = 0.98)$
BSR II $P_d = 0.6623 + 3 \times 10^{-3} (M) (R^2 = 0.99)$
Erode $P_d = 0.7441 + 1 \times 10^{-3} (M) (R^2 = 0.99)$

True density

The true density was found to vary from 1295.2 to 1315 kg m^{-3} for BSR I, 1282.7 to 1317 kg m^{-3} for BSR II and for Erode variety it was 1293.2 to 1315.8 kg m^{-3} (Table 2) for the moisture range of 10 to 70 per cent (w.b). The true density was found to increase with increase in moisture content. The regression equation relating the moisture content and true density are

BSR I $t_d = 1.2916 + 3 \times 10^{-4} (M) (R^2 = 0.99)$
BSR II $t_d = 1.2759 + 1 \times 10^{-3} (M) (R^2 = 0.996)$
Erode $t_d = 1.2919 + 4 \times 10^{-4} (M) (R^2 = 0.96)$

Static coefficient of friction

The static coefficient of friction of turmeric rhizomes of BSR I, BSR II and Erode with respect to moisture content on four metallic surfaces *viz.* aluminium, mild steel, galvanized iron and stainless steel is presented in Table 3. The static coefficient of friction increased with increase in moisture content of rhizomes in all the metal surfaces.

Hardness

The effect of moisture content on hardness of turmeric rhizomes is shown in Fig. 1. The hardness decreased linearly with increase in moisture content. This decreasing trend may be owing to rhizomes becoming softer at higher moisture content.

The relationship between the hardness and the moisture content is represented as

BSR I $h = 9.737 + 1.6 (M)$ $(R^2 = 0.99)$
BSR I $h = 11.05 + 1.4 (M)$ $(R^2 = 0.99)$
Erode $h = 6.824 + 1.8 (M)$ $(R^2 = 0.99)$

Specific heat

The relationship between moisture content and specific heat is shown in Fig. 2 for BSR I, BSR II and Erode. The specific heat ranged between 4.863 and 5.376 KJ/kg^{0}K in the moisture content range of 10 to 70 per cent (w.b). Specific heat of BSR I was higher than that of BSR II and Erode.

The specific heat of rhizomes increased linearly with increase of moisture content. Since the specific heat of water is more than the specific heat of rhizomes, the specific heat increased with increase in moisture (*Suter et al.* 1975).

The regression equations are obtained as

BSR I $C_{pt} = 4.5984 + 1 \times 10^{-2} (M) (R^2 = 0.99)$
BSR II $C_{pt} = 4.7615 + 1 \times 10^{-2} (M) (R^2 = 0.99)$
Erode $C_{pt} = 4.7391 + 4 \times 10^{-2} (M) (R^2 = 0.99)$

Thermal conductivity

The thermal conductivity ranged between 0.0113 and 0.4323 W/m ^{0}K for the moisture content range of 10-70 per cent w.b. The Fig.3 depicts the thermal conductivity of BSR I, BSR II and Erode at different moisture contents. Thermal conductivity of BSR I was higher than other two varieties. The thermal conductivity increased with increase in moisture content (Sreenarayanan, *et al.* 1988).

The regression equations are

BSR I $K = -0.0719 + 1 \times 10^{-4} (M)$ $(R^2 = 0.99)$
BSR II $K = -0.0717 + 1 \times 10^{-3} (M)$ $(R^2 = 0.99)$
Erode $K = -0.0713 + 4 \times 10^{-4} (M)$ $(R^2 = 0.99)$

Conclusions

The BSR I variety had the higher primary finger length than Erode local and BSR II.

Weight of 1000 rhizomes was 4.94 to 21.84 kg for BSR I, 4.77 to 20.99 kg for BSR II and 5 to 24.6 kg for Erode, for initial and final moisture contents of 82 and 10 per cent (w.b) respectively.

The static coefficient of friction increased with increase in moisture content in all the metal surfaces *viz.* aluminium, mild steel, galvanized iron and stainless steel for all the three varieties tested. The hardness (Crushing strength) decreased linearly with increase in moisture content.

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