

Original article

Effect of polishing on chemical and engineering properties of yellow and black turmeric

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Abstract

Effect of polishing on chemical and engineering properties of yellow and black turmeric rhizomes was studied and reported. The percentage of moisture content, protein, fat, carbohydrate, pH and curcumin of fresh and polished yellow turmeric were found to be 60.23, 1.30, 0.78, 34.04, 6.47 and 2.19; and 12.3, 1.20, 1.28%, 76.3, 6.28 and 4.26; respectively. Similarly, for fresh and polished black turmeric, percentage of moisture content, protein, fat, carbohydrate, pH and Curcumin per cent of fresh and polished was found to be 13.47, 0.69, 0.67, 80.8, 5.52 and 0.31; and 8.11, 0.93, 0.56, 83.38, 5.96 and 0.45, respectively. Physical properties like arithmetic mean diameter, geometric mean diameter, sphericity, aspect ratio, and surface area of fresh and polished yellow turmeric were found to be 41.85 mm, 37.73 mm, 56.29, 51.29, and 4455.07 mm²; and 33.69, 27.81, 44.72, 40.36, and 2429.93 mm², respectively. Similarly, for fresh and polished black turmeric, the arithmetic mean diameter, geometric mean diameter, sphericity, aspect ratio, and surface area were found to be 39.56, 36.17, 56.93, 49.59 and 4109 mm²; and 26.90, 21.29, 39.57, 27.45 and 1423 mm², respectively. Engineering properties like bulk density, true density, porosity and frictional properties of angle of repose of fresh and polished yellow turmeric were found to be 810 kg/m³, 1780 kg/m³, 99.54%, and 42.510; and 663.33 kg/m³, 1658 kg/m³, 99.34%, and 31.210, respectively. Similarly, for fresh and polished black turmeric, the bulk density, true density, porosity, and frictional properties of angle of repose were found to be 802 kg/m³, 1966 kg/m³, 99.59%, and 39.680; and 696 kg/m³, 1560 kg/m³, 99.53% and 33.470, respectively. The results indicated that polishing affected the chemical and engineering properties of yellow and black turmeric rhizomes.

Key words: Polishing, yellow turmeric, black turmeric, physicochemical and engineering properties

1. Introduction

The Turmeric (*Curcuma longa* L.), is a tropical herb and belongs to the family Zingiberaceae. It is widely used as spices, colorants, cosmetics and drugs as well as medicine to cure numerous diseases. India produces about 4.76 lakhtones of turmeric and consumes about 80 per cent of it. Indian turmeric is the best in the world market because of its high curcumin content (Turmeric Outlook, 2018). In India, Erode in Tamil Nadu state is world's largest producer of and also the most important trading center for turmeric followed by Sangli in Maharashtra (Mane and Kshirsagar, 2018). After harvesting, turmeric undergoes post-harvest processes like cleaning, grading, slicing, drying, polishing, powdering and storage. Poor appearance, rough dull outer surface with scales, wrinkles and root bits of dried turmeric reduces the market value and acceptability (Sampathu *et al.*, 1988) and (Gunasekar *et al.*, 2006) investigated that the turmeric processing and drying enhanced the curcumin content of polish turmeric. So, the appearance is improved by polishing the outer surface of turmeric. Polishing can be done by

two ways, *i.e.*, manual and mechanical polishing. Manual polishing is rubbing the dried turmeric rhizomes against a hard surface. It gives rough appearance and dull colour (Jayashree *et al.*, 2015) and it requires more manpower for polishing (Moghe *et al.*, 2012). Mechanical polishing is done by drum mounted on a central axis and the sides of the drum are made up of expanded metal screen. The drum filled with turmeric is rotated by hand or motor. Abrasion developed during rotation of drum polishes the turmeric. Turmeric is directly used for making value-added products, such as, ground spices, mixes, oleoresins and spice oil extract which have vast industrial applications. Pandey and Pandey (2017) have been reported phytochemical analysis of turmeric has revealed a large number of compounds, including curcumin, volatile oil and curcuminoids.

Polishing affects the chemical and physical properties of turmeric, due to caused by the friction between turmeric rhizome and rough surface. Usually 5 to 8% and 2 to 3% of the weight reduction occurs during full and half polishing of turmeric, respectively. Polishing affects the weight and quality of turmeric and also affects the engineering properties which are important to design harvesting, handling, processing, sorting and storage machines (Eze and Agbo, 2011). The shape of rhizome is very important in sorting and sizing and to determine how many rhizomes can be placed in shipping containers or plastic bags (Keramat-Jahromi *et al.*, 2008). Rhizome

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volume, shape and density are important to design fluid velocities for transportation (Mohsenin, 1986). Jayan and Kumar (2004) used engineering properties of seeds to design a planter.

Subramoniam (2014) suggested the importance of medicinal plant research on healthcare products like phytomedicines/nutraceuticals/food supplements/conventional drugs for human welfare. Further, the knowledge of frictional properties of rhizomes is needed for the design of handling equipment (Mohsenin, 1986). It was understood that, very few studies reported the effect of polishing on chemical, physical and engineering properties of turmeric and very few studies have been done on black turmeric. Therefore, this was undertaken to study the effect of polishing on chemical, physical and engineering properties of turmeric.

2. Materials and Methods

2.1 Sample preparation

Yellow (cv. Salem) and black turmeric rhizomes procured from Punjab Agricultural University, Ludhiana, India. Rhizomes were cleaned and unwanted materials were removed manually, boiled and then dried (sun drying and tray drying) for determining physical and engineering properties. The same rhizomes were powdered for chemical property analysis, using hammer mill at Central Institute of Post-Harvest Engineering and Technology, Ludhiana.



Figure 1: Yellow turmeric rhizomes

2.2 Determination of chemical properties

The moisture content of the turmeric rhizomes was estimated according to ASAE Standard S358.2 (1983). Crude fat, nitrogen, ash, crude fiber and total carbohydrate content of the sample was determined by AOAC (2005) method. The percentage of crude fat, nitrogen, ash, crude fiber and total carbohydrate content calculated using the equations 1 to 5. Crude fat and ash content were estimated using Soxhlet and muffle furnace, respectively. Curcumin is known to have various pharmacological activities such as anti-inflammatory activity (Subramoniam *et al.*, 2013 and Subramoniam, 2014).



Figure 2: Black turmeric rhizomes

Curcumin content was determined as per method given by FSSAI (2016) and calculated using equation (6).

$$\text{Crude fat (\%)} = \frac{W1-W2}{S} \times 100 \quad \dots (1)$$

$$\text{Nitrogen (\%)} = \frac{T_s - T_b \times N \times 0.014}{S} \times 100 \quad \dots (2)$$

$$\text{Protein (\%)} = \text{Nitrogen} \times 6.25$$

$$\text{Ash content (\%)} = \frac{AW}{IW} \times 100 \quad \dots (3)$$

$$\text{Crude fiber (\%)} = \frac{W1-W2}{S} \times 100 \quad \dots (4)$$

$$\text{Carbohydrate\%} = (100 - (\text{Moisture Content \%} + \text{Fat\%} + \text{Protein \%} + \text{Ash\%} + \text{Fiber \%})) \quad \dots (5)$$

$$\text{Curcumin, \%} = \frac{a \times 100}{l \times A \times S} \quad \dots (6)$$

where, W1 is the empty weight of beaker, W2 is the final weight of beaker after drying,

Ts is Titre volume of the sample (ml); TB is Titre volume of Blank (ml); 0.014= M eq. of N2. N is the normality of acid. AW is Weight of Ash and IW is the Initial weight of dry matter. A is the Absorptive of curcumin, a is the absorbance of sample at 425 nm, L is the path length, S is the sample weight in gram.

2.3 Determination of physical properties

2.3.1 Geometrical properties

Hundred rhizomes were randomly selected and three major perpendicular dimensions of the rhizomes such as length(L), thickness (T), and width (W) were measured using digital caliper (0.01). The geometric mean diameter and surface area of the turmeric rhizomes were calculated using the equations 7 and 8 (Mohsenin, 1986). Sphericity was determined using the measured geometric dimensions by equation (9).

$$D_g = (L \times W \times T)^{1/3} \quad \dots (7)$$

$$S = \pi (Dg)^2 \quad \dots (8)$$

$$\phi = \left[\frac{(L \times W \times T)^{1/3}}{L} \right] \times 100 \quad \dots (9)$$

where L is the length, W is the width and T is the thickness, all in mm, Dg is the Geometric mean diameter in mm, ϕ is Sphericity, S is the surface area in mm^2 .

2.3.2 Bulk density, true density and porosity

Bulk density was determined by filling turmeric rhizomes in known volume of beaker. The weight of filled rhizomes and volume of the container were used to calculate the bulk density.

True density was determined by the toluene displacement method and the porosity was computed using equations 10 and 11.

$$\rho_b = \frac{m}{V} \quad \dots (10)$$

$$\varepsilon = \left(1 - \frac{\rho_b}{\rho_a}\right) \times 100 \quad \dots (11)$$

where ε is the porosity in %, ρ_b is the bulk density in kg/m^3 and ρ_a is the true density in kg/m^3 .

2.3.3 Angle of repose

The angle of repose (ϕ) was calculated using height of the heap formed by naturally falling rhizomes on circular plate and diameter.

$$(\phi) = \tan^{-1} \left(\frac{2H}{D} \right) \quad \dots (12)$$

Where, ϕ is the Angle of repose, H is the Height in mm, D is the Diameter in mm.

2.3.4 Static coefficient of friction

The coefficient of static friction on different surfaces namely

plywood, galvanized steel sheet, rubber and glass was determined. Each rhizome was placed on the surface and raised gradually by screw until the rhizome 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 (μ_s) was calculated using the following equation:

$$\mu_s = \tan \theta \quad \dots (13)$$

where μ_s is the coefficient of friction and α is the angle of tilt in degrees.

2.4 Statistical analysis

Data were taken in triplicate and the experiments were conducted in triplicates and mean and standard deviation values were calculated using Microsoft excel (2010) software..

3. Results

3.1 Proximate analysis of yellow and black turmeric rhizomes

Table 1 showed the proximate analysis of rhizomes. The fat content of yellow and black turmeric was found to be 1.28 and 0.56 per cent for polished rhizomes. The carbohydrate content of polished yellow turmeric and black turmeric was found to be 67.28 and 69.38 per cent, respectively. The ash and fiber of yellow and black turmeric rhizomes were recorded as 7.2, and 5.36 per cent, and 1.72 and 1.45 per cent; respectively. The curcumin content of yellow and black rhizomes was recorded to 4.26 and 0.35 per cent, respectively. The pH of polished yellow turmeric and black turmeric was found to be 6.28 and 5.96 per cent, respectively. It was found that the percentage of fat, protein, ash, fiber and curcumin content of yellow turmeric was more than the black turmeric. The percentage of carbohydrate of yellow turmeric was less than the black turmeric.

Table 1: Chemical properties of turmeric rhizome

Sr.No	Properties	Salem turmeric		Black turmeric	
		Fresh rhizomes	Polished rhizomes	Fresh rhizomes	Polished rhizomes
1.	Moisture (%)	60.23 ± 1.03	12.3 ± 0.39	56.47 ± 0.38	13.47 ± 0.53
2.	Total fat (%)	0.78 ± 0.16	1.28 ± 0.13	0.67 ± 0.26	0.56 ± 0.23
3.	Carbohydrates (%)	34.04 ± 0.14	76.3 ± 0.09	80.8 ± 0.17	83.38 ± 0.41
4.	Protein (%)	1.30 ± 1.01	1.20 ± 0.07	0.69 ± 0.25	0.93 ± 0.5
5.	Ash (%)	2.86 ± 0.78	7.2 ± 0.01	2.13 ± 0.22	5.36 ± 0.76
6.	Crude fiber (%)	0.79 ± 0.12	1.72 ± 0.03	1.04 ± 0.06	1.45 ± 0.1
7.	Curcumin (%)	2.19 ± 0.59	4.26 ± 0.17	0.31 ± 0.88	0.45 ± 1.03
8.	pH value	6.47 ± 0.24	6.28 ± 0.12	5.52 ± 0.37	5.96 ± 0.22

3.2 Physical properties of turmeric rhizomes

The chemical properties such as moisture, total fat, total carbohydrates, total protein, ash, crude fiber, curcumin, pH, acidity were given in Table 1 and physical properties of turmeric rhizomes such as major, minor, and intermediate diameter, mass, volume, bulk density, true density, geometric mean, porosity, sphericity, and rolling frictional properties were given in Table 2.

3.2.1 Effect of polishing on moisture content

The moisture content found to be decrease from 60.23 to 12.3% for yellow and 56.47 to 13.47% for black turmeric after polishing. The percentage of moisture reduction was 20.42 and 23.85 for yellow and black turmeric, respectively. It was found that the percentage

of moisture content reduction of yellow turmeric was less than the black turmeric as depicted in Figure 3.

3.2.2 Effect of polishing on arithmetic mean and geometric mean diameter

The percentage of reduction length, width and thickness after polishing was found to be 92.20, 118.79 and 72.52%, respectively for yellow turmeric and 46.87, 58.73 and 51.41% for black turmeric. The percentage reduction of length, width and thickness dimensions for yellow turmeric was found to be higher than the black turmeric.

Figure 4 depicted that the arithmetic mean values of both fresh and polished turmeric. For yellow turmeric, the arithmetic mean reduced

from 41.85 to 33.69 mm and the percentage reduction was 80.50. Similarly, for black turmeric, the arithmetic mean reduced from 39.56 to 26.90 mm and percentage reduction was found to be 67.99. The percentage of arithmetic mean reduction of yellow turmeric was less than the black turmeric. Figure 5 depicted that the geometric mean values of both fresh and polished turmeric. The geometric mean diameter of yellow turmeric reduced from 37.73 to 27.81 mm and the percentage reduction was 73.70. Similarly for black turmeric, the reduction was from 36.17 mm to 21.29 mm. The percentage of reduction was found to be 58.86. The percentage of reduction of yellow turmeric was greater than the black turmeric.

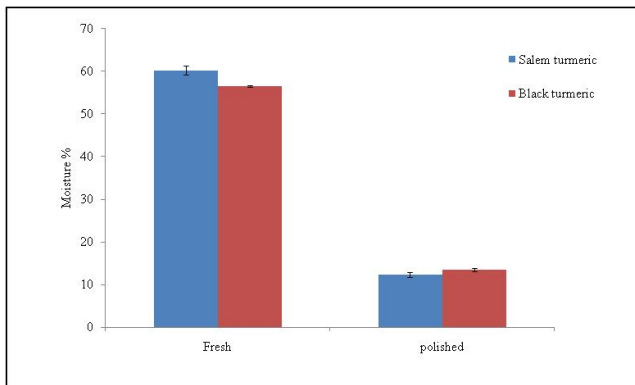


Figure 3: Effect on moisture content after polishing of yellow and black turmeric rhizomes.

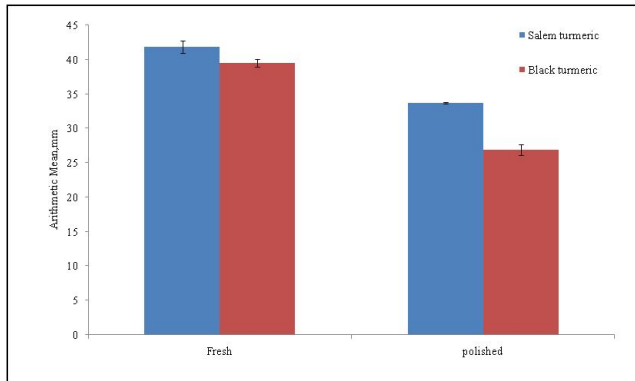


Figure 4: Effect of polishing on arithmetic mean of yellow and black turmeric rhizomes.

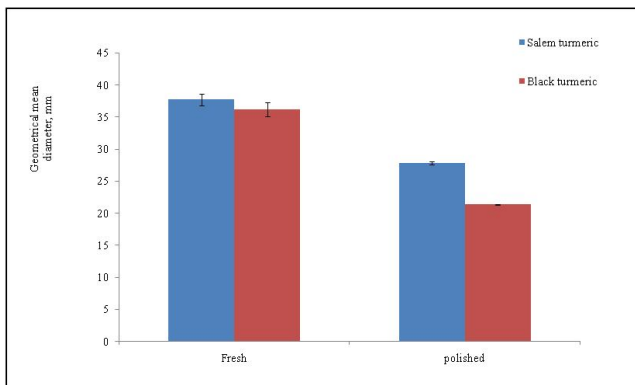


Figure 5: Effect of polishing on geometric mean of yellow and black turmeric rhizomes.

3.2.3 Effect of polishing on sphericity and aspect ratio

The sphericity of yellow turmeric and black turmeric reduced from 56.29 to 44.72 and from 56.93 to 39.57 after polishing, respectively (Figure 6). The reduction percentage was found to be 79.45 and 69.50% for yellow and black turmeric, respectively. The percentage of Sphericity reduction of yellow turmeric was greater than the black turmeric. After polishing, aspect ratio of yellow turmeric was found to be reduced from 51.29 to 40.36 and black turmeric was reduced from 49.59 to 27.45. Figure 7 represents that the percentage of aspect ratio reduction of yellow turmeric (78.68) was greater than the black turmeric (55.35).

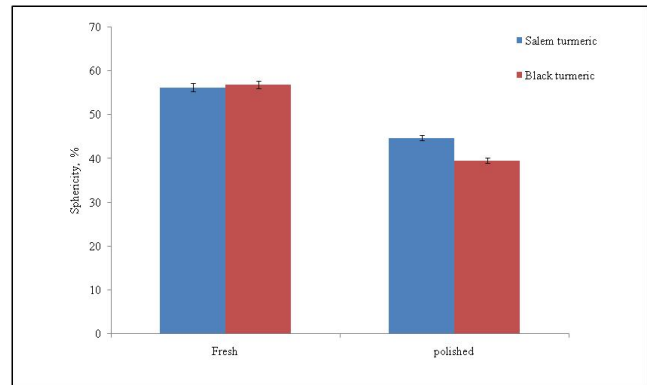


Figure 6: Effect of sphericity on yellow and black turmeric rhizomes.

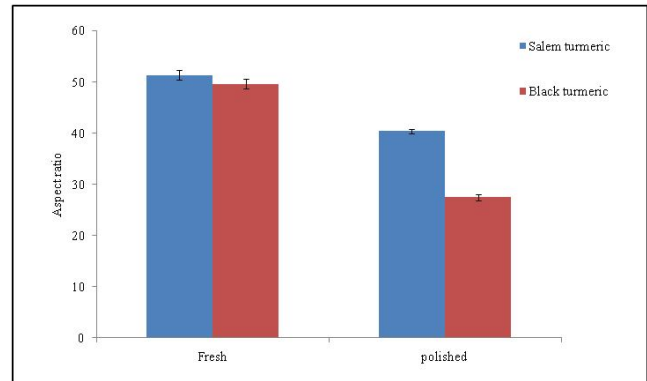


Figure 7: Effect of polishing on aspect ratio of yellow and black turmeric rhizomes.

3.2.4 Surface area

The results indicated in Figure 8 depicted that for yellow turmeric, the surface area reduces from 4455.07 mm² to 2429.93 mm² and the percentage reduction was 54.54. Similarly, for black turmeric, the surface area reduces from 4109.23 mm² to 1423.24 mm². The percentage of surface area reduction was found to be 34.63.

3.2.5 Effect of polishing on bulk density of yellow and black turmeric rhizomes

After polishing, the bulk density of yellow turmeric and black turmeric reduced from 810 to 663.33 kg/m³ and 802.04 to 696.13 kg/m³, respectively. Figure 9 depicted that the percentage of reduction of bulk density after polishing was found to be 81.89 and 86.79, respectively. It was found that the bulk density for both turmeric rhizomes decreased with decreasing moisture content.

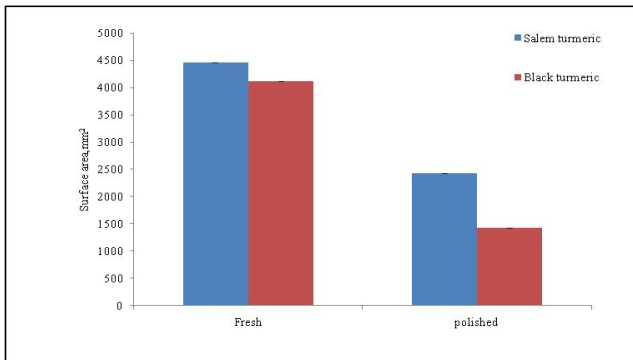


Figure 8: Effect of polishing on surface area of yellow and black turmeric rhizomes.

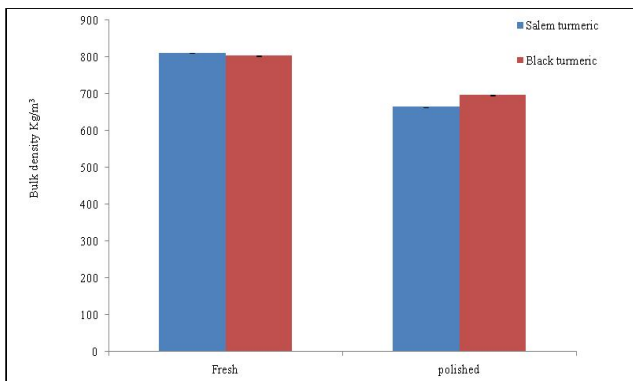


Figure 9: Effect of polishing on the bulk density of yellow and black turmeric rhizomes.

True density of yellow and black turmeric reduced from 1780 to 1658 kg/m³ and 1966.01 to 1560.08 kg/m³, respectively. The percentage reduction was 93.14 for yellow turmeric and 79.35 black turmeric. The percentage of true density reduction of yellow turmeric was greater than the black turmeric as shown in Figure 10.

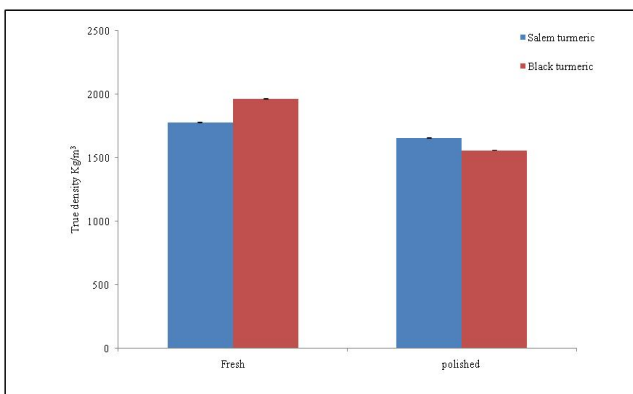


Figure 10: Effect of polishing on true density of yellow and black turmeric rhizomes.

3.2.6 Effect of polishing on porosity of yellow and black turmeric rhizomes

The results indicated that for yellow turmeric, the porosity reduces from 99.54 to 99.34 and the percentage reduction was 99.79. Similarly for black turmeric, the porosity reduces from 99.59 to 99.53. Figure 11 depicted that the percentage of porosity reduction was found to be 99.93.

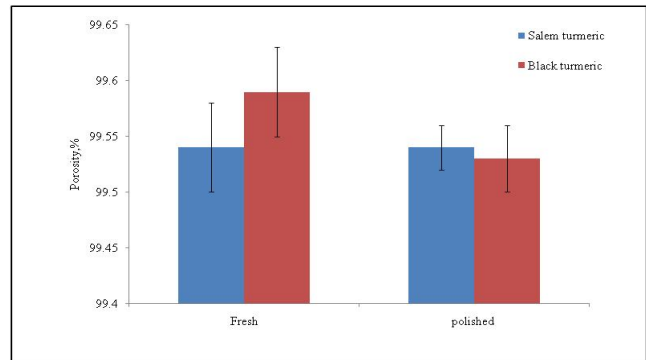


Figure 11: Effect of polishing on porosity of yellow and black turmeric rhizomes.

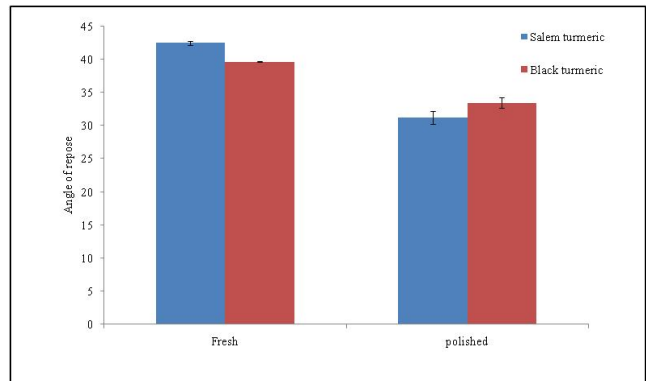


Figure 12: Effect of polishing on angle of repose of yellow and black turmeric rhizomes.

3.2.7 Effect of polishing on angle of repose of yellow and black turmeric rhizomes

The angle of repose reduced from 42.51 to 31.21 for yellow turmeric and 39.68 to 33.47 for black turmeric (Figure 12). The percentage of reduction was estimated to be 73.41 and 84.34 for yellow and black turmeric. The percentage of angle of repose reduction of yellow turmeric was greater than the black turmeric. The angle of repose decreased with decreasing moisture content.

3.2.8 Effect of polishing on coefficient of friction of yellow and black turmeric rhizomes

The results indicated that for yellow turmeric, the coefficient of friction on plywood sheet, mild steel sheet and aluminium sheet was found to be decreased from 0.88 to 0.86, from 0.93 to 0.95 and from 0.90 to 0.89 as depicted in Figures 13, 14 and 15, respectively. The percentage reduction was found to be 97.72, 102.15 and 98.88, respectively for plywood sheet, mild steel sheet and aluminum sheet. Similarly for black turmeric, the coefficient of friction on plywood sheet, mild steel sheet and aluminum sheet was found to be decreased from 0.82 to 0.83, from 0.94 to 0.9 and from 0.90 to 0.89, respectively. The percentage reduction was found to be 104.70, 104.44 and 106.02, respectively for plywood sheet, mild steel sheet and aluminum sheet. The present results showed that the percentage of plywood sheet reduction of yellow turmeric was less than the black turmeric. The coefficient of friction was linearly increased with moisture content.

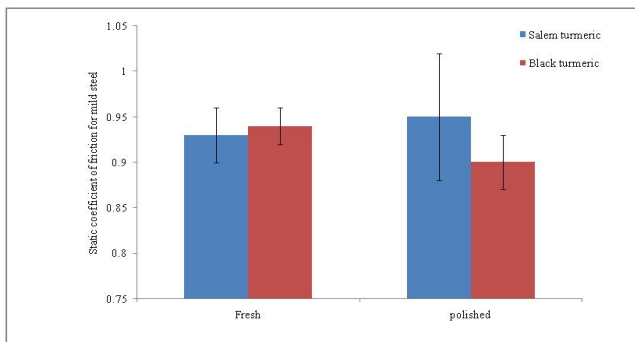


Figure 13: Effect of polishing on static coefficient of mild steel of yellow and black turmeric rhizomes.

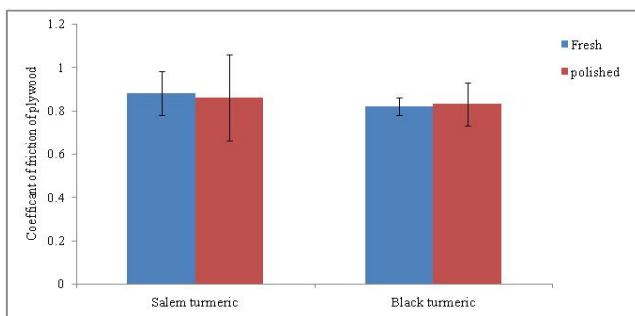


Figure 14: Effect of polishing on static coefficient of plywood on yellow and black turmeric rhizomes

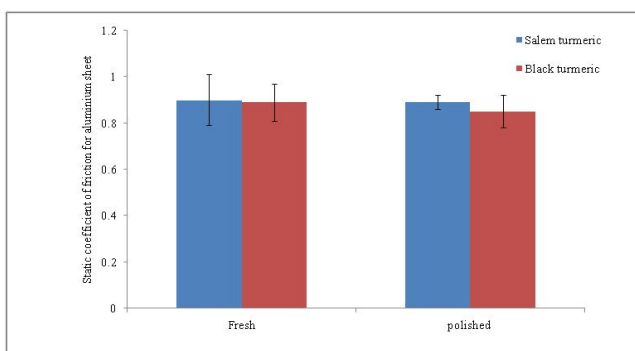


Figure 15: Effect of polishing on static coefficient of aluminum sheet of yellow and black turmeric rhizomes.

4. Discussion

The physical properties measured can be very useful for designing and development of process machinery. In the present investigation, the percentage of carbohydrate of yellow turmeric was less than the black turmeric. Similar range of values were reported by Ganpati *et al.* (2011). Esatbeyoglu *et al.* (2012) estimated chemical composition of dried turmeric rhizomes showed average composition of 69.4% of carbohydrates, 6.3% of proteins, 5.1% of fats, 3.5% of ash, 2.6% of fiber and the curcuminoids content varied between 2 and 9%, depending on geographic conditions. The effect of polishing on moisture may be due to difference in chemical composition and pores on the surface of the turmeric. Lokhande *et al.* (2013) reported that the polishing process had affected the moisture content of turmeric due to smooth surfaces.

The percentage of reduction of yellow turmeric was greater than the black turmeric. According to Dhinesh *et al.* (2016), arithmetic mean diameter and geometric mean diameter, showed an increasing trend with the increase in length, breadth and thickness of rhizomes. The size parameters, namely; length, width, and thickness of rhizomes were found to be increased linearly with an increasing in moisture content. The results obtained are in correspondence with Shelake *et al.* (2018). This may be attributed to the irregular shape of turmeric rhizomes and different storage methods. Also may be due to change in moisture content. Dhinesh *et al.* (2016) showed the sphericity and aspect ratio and shape factor of turmeric rhizomes decreased with increase in dimension. According to Ajav and Ogunlade (2014), the sphericity of ginger rhizomes decreases with an increase in moisture content, as moisture content of ginger increased.

The percentage of surface area reduction of yellow turmeric was greater than the black turmeric. According to Onu and Okafor (2002), the surface area was found to be directly proportional to the numerical dimensions, weight and slicing time of ginger rhizome. On the other hand, Onu and Okafor (2002) mention that slicing loss was found to be directly proportional to the moisture content and surface area of ginger rhizome. This is as a result of the brittle nature of fresh rhizome and the scratching effect of the blade on the rotating ginger rhizome with larger surface areas, relative to the slicing gap.

The effect of polishing on bulk density may be due to reduction of moisture content during drying before polishing. It was found that the bulk density for both turmeric rhizomes decreased with decreasing moisture content. Similar results were observed by Shelake *et al.* (2018) and Subhashini *et al.* (2015) for turmeric rhizomes. On contrast, according to Ajav and Ogunlade (2014), the bulk density of ginger decreased with an increase in moisture content of ginger. This may be because of increased moisture contained in the sample was higher than the volumetric expansion of the rhizomes bulk. The bulk density is important for the design of hopper. Bulk density has been reported to have practical applications in the calculation of thermal properties in heat transfer problems, in determining Reynolds number in pneumatic and hydraulic handling of materials and in predicting physical structure and chemical composition (Irtwange and Igbeka, 2002). The effect of polishing on true density of rhizomes increased with moisture contain. Similar results were reported by Athmaselvi and Varadharaja (2002).

The effect of polishing on porosity reduction of yellow turmeric was less than the black turmeric. There was increase in porosity with increasing moisture content, which may be due to the rate of increases of true density as compared to that of bulk density was more or less same results showed by shelake *et al.* (2018). 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 be due to variation in the medium and minor dimension. Same results showed by Dhineshkumar *et al.* (2016).

The effect of polishing on angle of repose decreased with decreasing moisture content. This may be due to decreasing moisture content decreased the cohesive force. Singh and Goswami (1996) and

Table 2: Physical properties of fresh dry turmeric rhizome

Properties	Fresh		Polish ground turmeric	
	Yellow turmeric	Black turmeric	Yellow turmeric	Black turmeric
M.C (% db)	60.23 ± 1.03	56.47 ± 0.18	12.3 ± 0.14	13.47 ± 0.38
Arithmetic mean, mm	41.85 ± 0.91	39.56 ± 0.57	33.69 ± 0.677	26.90 ± 0.74
Geometrical mean diameter, mm	37.73 ± 0.091	36.17 ± 1.06	27.81 ± 0.38	21.29 ± 0.64
Sphericity, %	56.29 ± 0.88	56.93 ± 0.90	44.72 ± 0.66	39.57 ± 1.02
Aspect ratio	51.29 ± 0.95	49.59 ± 0.92	40.36 ± 0.81	27.45 ± 1.76
Surface area, mm ²	4455.07 ± 0.92	4109.23 ± 0.26	2429.93 ± 0.62	1423.24 ± 1.02
Bulk density, kg/m ³	810 ± 0.11	802.04 ± 0.3	663.33 ± 0.243	696.13 ± 1.10
True density kg/m ³	1780 ± 0.21	1966.01 ± 1.01	1658 ± 0.63	1560.08 ± 0.8
Porosity, %	99.54 ± 0.04	99.59 ± 0.04	99.34 ± 0.02	99.53 ± 0.03
Angle of repose	42.51 ± 0.31	39.68 ± 0.11	31.21 ± 1.01	33.47 ± 0.8
Plywood sheet	0.88 ± 0.01	0.82 ± 0.1	0.86 ± 0.01	0.83 ± 0.06
Mild steel sheet	0.93 ± 0.03	0.94 ± 0.03	0.95 ± 0.2	0.9 ± 0.07
Aluminium sheet	0.90 ± 0.11	0.89 ± 0.11	0.89 ± 0.06	0.85 ± 0.09

Shubhashini *et al.* (2015) found a similar results for cumin and turmeric, respectively. Ajav and Ogunlade (2014) and Pradhan *et al.* (2008) reported that the angle of repose increased as the moisture content increases, due to surface layer of moisture surrounding the particles hold the aggregate of grain together by the surface tension.

The percentage of plywood sheet reduction of yellow turmeric was less than the black turmeric. The coefficient of friction was linearly increased with moisture content. This may be due to the increased adhesion between the rhizome and the material surfaces at higher moisture values and similar results were found by Shelake *et al.* (2018) and Athmaselvi and Varadharaja (2002). Because Static coefficient of friction may be owing to smoother and more polished surface of the steel than the other materials used. The surface of the samples becomes stickier. Other researchers reported a similar trend that coefficient of friction increases as the moisture content increase (Pradhan *et al.*, 2008; Altuntas and Erkol, 2010). Pradhan *et al.* (2008) reported that the friction increases on the surface of the rhizomes as water content increases, thereby making the seeds less able to flow on one another. The obtained data on the physical properties of all type of turmeric rhizomes will be useful in the designing of values addition products machines, polishers and other processing gadgets, Balasubramanian *et al.* (2012). The coefficient of friction of turmeric rhizomes is required in the design of silos and hopper for processing machines.

5. Conclusion

Overall, it has been concluded that polished rhizomes exhibited good nutritional composition than fresh rhizomes. For instance, the fresh and Polish yellow turmeric rhizomes had high amount of curcumin content (4.26%) than black turmeric. It was found that the percentage of fat, protein, ash, fiber content of yellow turmeric was more than the black turmeric.

The percentage of carbohydrate of yellow turmeric was less than the black turmeric that may be of great use for the development and value addition in food products. The size parameters, namely; length, width, and thickness of rhizomes were found to be increased linearly with an increasing in moisture content. The percentage of aspect ratio reduction of yellow turmeric (78.68) was greater than the black turmeric (55.35). It was found that the bulk density for both turmeric rhizomes decreased with decreasing moisture content.

The percentage of angle of repose reduction of yellow turmeric was greater than the black turmeric. The angle of repose decreased with decreasing moisture content. The percentage of plywood sheet reduction of yellow turmeric was less than the black turmeric. The coefficient of friction was linearly increased with moisture content. Co-efficient of static friction increased gradually with increased moisture of the turmeric rhizomes and for the three frictional materials used. Mild steel sheet had highest values of co-efficient of friction, followed by Aluminum sheet. The properties measured will be used for process and equipment design.

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Conflict of interest

The authors declare that there are no conflicts of interest in the course of conducting the research. The authors had final decision regarding the manuscript and decision to submit the findings for publication.

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