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Physical and biochemical parameters of fresh and dry ginger (*Zingiber officinale* Roscoe)

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Abstract

The physical and biochemical properties of fresh and dry ginger (*Zingiber officinale*) (cv: Himachal) obtained from Nemmara (Palakkad District, Kerala), useful for the design of processing machineries, were determined. The average moisture content of fresh and dry rhizomes were 81.70% and 8.85%, respectively. The average length, width and thickness of fresh rhizome were 14.99 cm, 8.17 cm and 4.49 cm, respectively and the corresponding values for dry rhizome were 9.74 cm, 5.56 cm and 4.49 cm. The mean values of cylindricity for primary, secondary and tertiary finger rhizomes were 0.46, 0.51 and 0.56, respectively and the corresponding values for dry finger rhizomes were 0.48, 0.53 and 0.58. The average mass, volume and surface area of fresh rhizomes were 103.45 g, 85.0 cm^3 and 194.52 cm^2, respectively and the corresponding values for dry rhizomes were 31.62 g, 22.10 cm^3 and 65.84 cm^2. The bulk density, true density and porosity for fresh rhizomes were determined as 471.49 kg m^{-3}, 1107.01 kg m^{-3} and 66.80%, respectively, and for dry rhizomes the values were 460.09 kg m^{-3}, 1013.22 kg m^{-3} and 54.09%. The angle of repose increased from 34.6° to 39.5° after drying. Mild steel surface offered more frictional resistance than other surfaces and the coefficient of friction for fresh and dry ginger against mild steel was 0.74 and 0.54, respectively. The average meat : peel ratio of the whole fresh rhizome was 10.7:1. The average recovery of dry ginger was 23.01%. The dry ginger obtained had 1.6% essential oil, 3.5% oleoresin and 2.7% crude fibre.

Keywords: ginger, physical properties, quality, *Zingiber officinale.*

Introduction

Ginger, the rhizome of *Zingiber officinale* Roscoe is one of the most widely used spice of the family Zingiberaceae. India is the largest ginger producing country in the world and is cultivated in most of the Indian states. Ginger grown in different parts of the country varies considerably in its intrinsic physical and biochemical properties and its suitability for processing. The important quality parameters of ginger are its fibre, volatile oil and non-volatile ether extract. The

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size of ginger rhizome is particularly important when it is processed to dry ginger. Ginger types with bold rhizomes, which are marketed as fresh ginger, are sometimes unsuitable for converting to the dry spice due to its high initial moisture content. This causes difficulties in drying and frequently a heavy wrinkled product is obtained and the volatile oil content is often low and below standard requirements (Balakrishnan 2005).

Since fresh ginger is subjected to various unit operations like washing, peeling and drying or sometimes it is sliced or made into cubes to obtain value added products, and dry ginger to size reduction to get ginger powder, there is a need for machines to perform these operations when they are processed in large quantities. As a first step in the design of these machines, the properties of fresh and dry ginger need be known. However, the information available on the physical properties of fresh and dry ginger is limited. Hence, this study was undertaken with an objective to determine the physical and quality parameters of ginger, so that the knowledge gained can be used in optimizing machine design parameters.

Materials and methods

Studies on determining the physical and quality parameters of fresh and dry ginger were conducted at the College of Agricultural Engineering, Tamil Nadu Agricultural University, Coimbatore, during January 2009. Freshly harvested ginger (cv. Himachal) which is widely used to produce dry ginger, obtained from Nemmara (Palakkad District, Kerala) was used for the study. Ginger, grown in raised beds of 4 m x 1 m size, harvested about 8 months after planting during January 2009 was hand peeled and dried under open sun. The physical properties like moisture content, size, shape, bulk density, true density, porosity, angle of repose, surface area and coefficient of friction were determined for fresh and dry ginger. The quality parameters studied for fresh ginger were meat : peel ratio and dry recovery whereas, biochemical parameters like essential oil, oleoresin and crude fibre were determined for dry ginger.

Moisture content

Moisture content of the fresh ginger rhizome sample was determined by toluene distillation method (ASTA 1968). The moisture content was determined for three samples.

Size

The size of fresh and dry ginger rhizomes was determined by measuring the dimensions along three principal axes, namely, major (length), minor (width) and intermediate (thickness) of each rhizome piece using vernier callipers (least count: 0.01cm). The size was determined for 25 rhizomes and their fingers.

Shape

As the shape of ginger rhizomes was irregular, the primary, secondary, tertiary and quaternary fingers were separated from the rhizomes and all the measurements were recorded for whole rhizome and for individual fingers separately. Shape of ginger was determined in terms of cylindricity (Kaleemullah & Kailappan 2003) for 25 rhizomes and their fingers.

Mass, volume and surface area

The mass of ginger rhizomes and fingers were determined separately using a precision electronic balance (readability: 0.01 g). Volume of rhizome was determined as true volume by immersing the rhizomes in water contained in a measuring cylinder and determining the volume of water displaced (Mohsenin 1986). The surface area was determined by tracing the periphery of rhizome (primary, secondary and tertiary fingers separately) on a graph sheet for all the four sides and counting the number of squares within the outline traced (Mohsenin 1986). The sum of all the areas gives the surface area of the rhizome. Mass, volume and surface area were determined for 25 rhizomes and their fingers.

Bulk density, true density and porosity

The bulk density was determined as the ratio between the mass of ginger rhizome in a container to its volume (Kaleemullah & Kailappan 2003). Rhizomes were filled in a container of 45 cm height and 30 cm diameter and the mass of contents was determined. The true density of rhizome was determined by platform scale method (Mohsenin 1986). Both the densities were determined for 10 replications.

The porosity of fresh and dry ginger rhizomes was computed using the formula:

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

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

Angle of repose and coefficient of friction

The angle of repose is the angle made by ginger rhizomes with the horizontal surface when heaped from a known height (Kaleemullah & Kailappan 2003). One bag (25 kg) of ginger rhizomes was heaped over a horizontal surface. The slant height of the heap was determined and radius of the heap was calculated from the circumference of the heap. The angle of repose was calculated by using the formula:

$$\theta = \cos^{-1}\left(\frac{r}{l}\right)$$

where, θ is the angle of repose, r is the radius of the heap, cm; l is the slant height of the heap, cm. The experiment was replicated three times.

The experimental apparatus used to determine coefficient of friction was similar to that suggested by Kaleemullah & Kailappan (2003). The apparatus consisted of a frictionless pulley fitted on a frame, a bottomless cylindrical container (94 mm diameter and 98 mm height), loading pan and test surfaces. The bottomless container placed on the test surface was filled with a known quantity of rhizomes and weights were added to the loading pan until the container began to slide. The mass of rhizomes and the added weights represent the normal force and frictional force, respectively. The co-efficient of static friction was calculated as the ratio of frictional force to the normal force as,

$$\mu = \frac{F}{N_f}$$

where, μ is the co-efficient of friction, F is the frictional force, kg; N_f is the normal force, kg. The experiment was performed using test surfaces of hardboard, galvanised iron, mild steel, aluminium and stainless steel sheets. The experiment was replicated three times by emptying and refilling with different samples in the container every time.

Quality

The meat : peel ratio of fresh ginger rhizome was determined by manually separating the peel from 100 g of rhizome and the mass of rhizome meat and peel was determined to calculate the meat : peel ratio. Dry recovery was determined by drying 100 g of rhizomes under open sun and the quantity of dry ginger obtained was found. The quality of dry ginger was estimated in terms of essential oil content by AOAC (1975) method, oleoresin by ASTA (1968) method and crude fibre by the method described in Sadasivam & Manickam (1992).

Results and discussion

Moisture content

The average moisture content of fresh and dry ginger whole rhizomes was 81.70% and 8.85%, respectively (Table 1). In case of fresh primary, secondary and tertiary finger rhizomes, the average moisture content was 81.36%, 81.62% and 81.13%, respectively, and the corresponding values for the dry rhizomes were 8.93%, 8.86% and 8.76%. Moisture content of the produce determines the shelf life and keeping quality of ginger. Sreekumar *et al.* (2002) have suggested drying of fresh ginger from about 85% moisture to a residual moisture content of about 10% for safe storage and further processing.

Table 1. Moisture content of fresh and dry ginger rhizomes

Category	Average moisture content (%)	
	Fresh ginger	Dry ginger
Whole rhizome	81.70	8.85
Primary finger	81.36	8.93
Secondary finger	81.62	8.86
Tertiary finger	82.13	8.76

Size

Mature rhizome of ginger (cv. Himachal) is highly irregular in size and shape and consists of primary, secondary and tertiary finger rhizomes. The average length of the whole fresh rhizome was 14.99 cm and varied as 9.53 cm, 5.19 cm and 2.91 cm for primary, secondary and tertiary finger rhizomes, respectively (Table 2). In case of dry ginger, the average length of the whole dry rhizome was 9.74 cm and the values varied as 6.74 cm, 3.74 cm and 1.98 cm for primary, secondary and tertiary finger rhizomes, respectively. Thus, there was 35.02% reduction in the length of rhizome during drying. The reductions in length for primary secondary and tertiary fingers were 29.27%, 27.94% and 31.96%, respectively.

The average width of fresh whole ginger rhizome was 8.17 cm and varied as 3.79 cm, 2.34 cm and 1.74 cm for primary, secondary and tertiary finger rhizomes, respectively. In case of dry ginger, the average width of the rhizome was 5.56 cm and the values corresponding to primary, secondary and tertiary finger rhizomes were 2.60 cm, 1.50 cm and 1.20 cm, respectively. Thus, there was 31.95% reduction in the average width of the rhizome during drying. The reductions in width for primary, secondary and tertiary finger rhizomes were 31.39%, 35.89% and 31.10%, respectively.

The average thickness of the fresh whole ginger rhizome was 4.49 cm and varied as 3.27 cm, 1.99 cm and 1.51 cm for primary, secondary and tertiary finger rhizomes, respectively. In case of dry ginger, the average thickness of the whole rhizome was 3.06 cm and the values corresponding to primary, secondary and tertiary finger rhizomes were 2.21 cm, 1.33 cm and 1.20 cm, respectively. Thus, there was 31.85% reduction in the average thickness of whole rhizome during

Table 2. Axial dimensions of fresh and dry ginger rhizomes

Category	Dimension (cm)		Decrease in dimension (%)
	Fresh ginger	Dry ginger	
	Length (Major axis, l)		
Whole rhizome	14.99 ± 1.53	9.74 ± 0.92	35.02 ± 4.14
Primary finger	9.53 ± 1.86	6.74 ± 0.89	29.27 ± 4.21
Secondary finger	5.19 ± 1.76	3.74 ± 0.74	27.94 ± 4.79
Tertiary finger	2.91 ± 1.26	1.98 ± 0.85	31.96 ± 5.25
	Width (Minor axis, a)		
Whole rhizome	8.17 ± 1.74	5.56 ± 1.11	31.95 ± 1.87
Primary finger	3.79 ± 0.21	2.60 ± 0.25	31.39 ± 1.60
Secondary finger	2.34 ± 0.47	1.50 ± 0.24	35.89 ± 2.89
Tertiary finger	1.74 ± 0.47	1.20 ± 0.22	31.10 ± 3.31
	Thickness (Intermediate axis, b)		
Whole rhizome	4.49 ± 0.21	3.06 ± 0.19	31.85 ± 2.51
Primary finger	3.27 ± 0.16	2.21 ± 0.21	32.42 ± 2.38
Secondary finger	1.99 ± 0.29	1.33 ± 0.19	33.17 ± 3.44
Tertiary finger	1.51 ± 0.38	1.02 ± 0.22	32.45 ± 4.21

drying. The reductions in length for primary, secondary and tertiary finger rhizomes were 32.42%, 33.17% and 32.45%, respectively. The size and other axial dimensions help in determining the aperture size of machines, particularly in separation of materials. These dimensions are useful in estimating the size of machine components also (Owolarafe & Shotonde 2004). For example, it is useful in estimating the number of ginger pieces that is to be engaged at a time in case of ginger washer, the spacing of slicing discs and number of slices expected from an average piece in case of ginger slicer. The major axis has been found to be useful by indicating the natural rest position of the material and hence in the application of compressive force to induce mechanical rupture.

Shape

In case of fresh ginger rhizomes, the mean value of cylindricity was 0.46, 0.51 and 0.56 for primary, secondary and tertiary finger rhizomes, respectively, and the corresponding values for dry rhizomes were 0.48%, 0.53% and 0.58% (Table 3). This property is indicative of the material to slide over another surface.

Mass, volume and surface area

The average mass of whole ginger rhizome before and after drying was 103.45 g and 31.62 g, respectively (Table 4). Thus, there was a reduction of 69.43% in the mass of rhizome after drying. Similarly, the decrease in the mass of primary, secondary and tertiary finger rhizomes was 68.94%, 70.02% and 70.62%, respectively. Onu & Okafor (2002) reported that the average mass of ginger reduced from 91.88 g at 81% moisture content to 10.8 g at 45.6% moisture content on wet basis (w.b).

The average volume of whole ginger rhizome before and after drying was 85.0 cm^3 and 22.1 cm^3, respectively (Table 4). Thus, after drying ginger, the volume decreased by 74%. Similarly, the decrease in volume after drying fresh primary, secondary and tertiary finger rhizomes was 79.22%, 75.17% and 74.46%, respectively. Reduction in volume of ginger from 64 cm^3 to 7.43 cm^3 was reported by Onu & Okafor (2002) as the moisture content reduced from 81% to 45.6% (w.b.), respectively.

The average surface area of whole ginger rhizome before and after drying was 194.52

Table 3. Cylindricity of fresh and dry ginger rhizomes

Particulars	Fresh ginger	Dry ginger	Increase in cylindricity (%)
	Primary finger		
Normal to length	0.55 ± 0.07	0.58 ± 0.03	5.17 ± 0.04
Normal to major diameter	0.42 ± 0.11	0.44 ± 0.07	4.55 ± 0.05
Normal to minor diameter	0.41 ± 0.10	0.43 ± 0.02	4.65 ± 0.06
Mean	0.46 ± 0.09	0.48 ± 0.07	4.16 ± 0.04
	Secondary finger		
Normal to length	0.56 ± 0.08	0.57 ± 0.02	1.75 ± 0.05
Normal to major diameter	0.52 ± 0.07	0.53 ± 0.10	1.87 ± 0.06
Normal to minor diameter	0.47 ± 0.05	0.48 ± 0.04	2.08 ± 0.04
Mean	0.51 ± 0.06	0.53 ± 0.04	3.77 ± 0.05
	Tertiary finger		
Normal to length	0.59 ± 0.02	0.60 ± 0.06	1.66 ± 0.04
Normal to major diameter	0.57 ± 0.04	0.58 ± 0.09	1.72 ± 0.08
Normal to minor diameter	0.54 ± 0.03	0.55 ± 0.03	1.82 ± 0.04
Mean	0.56 ± 0.03	0.58 ± 0.05	3.45 ± 0.06

Table 4. Mass, volume and surface area of single fresh and dry ginger rhizomes

Category	Fresh ginger	Dry ginger	Decrease in value (%)
	Mass (g)		
Whole rhizome	103.45 ± 10.01	31.62 ± 6.12	69.43 ± 6.53
Primary finger	44.82 ± 6.63	13.92 ± 4.51	68.94 ± 5.21
Secondary finger	18.08 ± 4.51	5.42 ± 2.20	70.02 ± 3.26
Tertiary finger	13.31 ± 3.62	3.91 ± 1.58	70.62 ± 3.21
	Volume (cm^3)		
Whole rhizome	85.00 ± 4.52	22.10 ± 0.31	74.00 ± 1.34
Primary finger	36.10 ± 1.06	7.50 ± 0.21	79.22 ± 1.05
Secondary finger	14.50 ± 0.70	3.6 0 ± 0.10	75.17 ± 0.91
Tertiary finger	4.70 ± 0.005	1.20 ± 0.09	74.46 ± 0.01
	Surface area (cm^2)		
Whole rhizome	194.52 ± 6.23	65.84 ± 4.23	66.16 ± 2.31
Primary finger	59.33 ± 7.23	27.67 ± 4.52	53.36 ± 2.13
Secondary finger	61.61 ± 5.34	24.02 ± 2.20	61.01 ± 2.64
Tertiary finger	49.05 ± 7.01	17.5 ± 2.09	64.32 ± 1.56

cm^2 and 65.84 cm^2, respectively (Table 4). Thus, the surface area reduced by 66.16% after drying. Similarly, the decrease in the surface area of primary, secondary and tertiary finger rhizomes was 53.36%, 61.01% and 64.32%, respectively. The surface area was found to reduce from 56.17 cm^2 to 13.34 cm^2 in Nigerian yellow bark ginger, after drying from 81% to 45.6% (w.b.) (Onu & Okafor 2002). These properties are useful to determine the load and space occupied by ginger during transportation (Owolarafe & Shotonde 2004).

Bulk density, true density and porosity

The average bulk density of fresh whole ginger rhizome was 471.49 kg m^{-3} and the corresponding value for dry ginger was 460.09 kg m^{-3} (Table 5). The bulk density for primary, secondary and tertiary rhizomes of fresh ginger decreased from 485.97 kg m^{-3}, 523.51 kg m^{-3} and 541.54 kg m^{-3} to 478.33 kg m^{-3}, 485.53 kg m^{-3} and 498.36 kg m^{-3}, respectively for dry ginger.

The average true density of fresh whole ginger rhizome was 1107.01 kg m^{-3} and the corresponding value for dry ginger was 1013.22 kg m^{-3} (Table 5). True density decreased from 1099.13 kg m^{-3}, 1106.27 kg m^{-3} and 1170.62 kg m^{-3} to 1013.22 kg m^{-3}, 1011.47 kg m^{-3} and 1002.33 kg m^{-3} for primary, secondary and tertiary finger rhizomes of fresh and dry ginger, respectively.

The average porosity of fresh whole ginger rhizome was 66.80% and the corresponding value for dry ginger was 54.09%. The porosity value decreased from 56.15%, 53.74% and 52.68% to 52.71%, 51.61% and 49.72% for primary, secondary and tertiary finger rhizomes of fresh and dry ginger, respectively. Onu & Okafor (2002) reported that the bulk density of ginger decreased from 1.51 kg l^{-1} to 1.50 kg l^{-1} as the moisture content of ginger decreased from 81.0% to 45.6%, respectively. Knowledge of these properties is useful during transportation of bulk materials and during the design of separators, especially when hydrodynamic separators are to be used (Owolarafe & Shotonde 2004).

Angle of repose and coefficient of friction

The angle of repose for fresh whole ginger rhizomes was 34.6° and for dry ginger the value increased to 39.5°. The values of angle of repose for fresh primary, secondary and tertiary finger rhizomes were 34.9°, 35.1° and 36° respectively, and the corresponding values

Table 5. Bulk density, true density and porosity of ginger rhizome before and after drying

Category	Fresh ginger	Dry ginger	Decrease in value (%)
Bulk density (kg m^{-3})			
Whole rhizome	471.49 ± 10.63	460.09 ± 6.12	2.41 ± 2.35
Primary finger	485.97 ± 12.31	478.33 ± 5.34	1.57 ± 2.65
Secondary finger	523.51 ± 11.52	485.53 ± 4.89	7.25 ± 1.57
Tertiary finger	541.54 ± 12.69	498.36 ± 3.94	7.97 ± 1.43
True density (kg m^{-3})			
Whole rhizome	1107.01 ± 26.76	1013.22 ± 2.65	8.47 ± 3.45
Primary finger	1099.13 ± 39.65	1011.47 ± 2.79	7.97 ± 3.68
Secondary finger	1106.27 ± 58.35	1003.43 ± 1.14	9.30 ± 4.12
Tertiary finger	1170.62 ± 53.39	1002.33 ± 0.96	14.38 ± 4.65
Porosity (%)			
Whole rhizome	66.80 ± 3.12	54.09 ± 3.43	19.03 ± 2.68
Primary finger	56.15 ± 2.64	52.71 ± 2.86	6.13 ± 1.64
Secondary finger	53.74 ± 3.06	51.61 ± 2.64	5.96 ± 1.32
Tertiary finger	52.68 ± 2.87	49.72 ± 2.26	5.62 ± 1.26

for dry fingers were 40.2°, 40.6° and 41.2° (Table 6). This property is important in the design of the handling system (Chandrasekar & Viswanathan 1999).

The coefficient of friction of fresh ginger rhizomes against plywood, stainless steel, aluminium, galvanized iron and mild steel surfaces were 0.53, 0.57, 0.68, 0.72 and 0.74, respectively. The corresponding values for dry ginger were 0.45, 0.46, 0.48, 0.52 and 0.54 (Table 6). These properties serve to select a suitable material whenever the produce has to be conveyed during processing.

Quality of dry ginger

The average meat : peel ratio of the whole fresh rhizome was 10.68 and varied as 10.60, 10.70 and 10.71 for primary, secondary and tertiary finger rhizomes, respectively (Table 7). The average dry recovery of whole ginger rhizome was 23.01%. Dry recovery of primary, secondary and tertiary rhizomes was

Table 6. Angle of repose and coefficient of friction of ginger rhizome before and after drying

Category	Fresh ginger	Dry ginger	Increase / decrease in value (%)
Angle of repose (°)			
Whole rhizome	34.6 ± 1.1	39.5 ± 0.9	(+) 14.3 ± 0.9
Primary finger	34.9 ± 1.1	40.2 ± 0.9	(+) 15.2 ± 0.9
Secondary finger	35.1 ± 1.2	40.6 ± 1.1	(+) 15.5 ± 1.1
Tertiary finger	36.0 ± 1.2	41.2 ± 1.1	(+) 14.5 ± 1.1
Coefficient of friction			
Ply wood	0.53 ± 0.01	0.45 ± 0.02	(-) 15.09 ± 2.32
Stainless steel	0.57 ± 0.02	0.46 ± 0.01	(-) 19.29 ± 2.41
Aluminium	0.68 ± 0.03	0.48 ± 0.01	(-) 29.41 ± 1.56
Galvanised iron	0.72 ± 0.05	0.52 ± 0.01	(-) 27.77 ± 1.89
Mild steel	0.74 ± 0.01	0.54 ± 0.03	(-) 27.03 ± 1.91

Table 7. Meat : peel ratio and dry recovery of fresh ginger rhizomes

Category	Meat : peel ratio	Dry recovery (%)
Whole rhizome	10.68 ± 2.15	23.01
Primary finger	10.60 ± 3.10	23.69
Secondary finger	10.70 ± 3.24	22.85
Tertiary finger	10.71 ± 3.96	22.08

Table 8. Quality analysis of dry ginger rhizomes

Category	Essential oil (%)	Oleoresin (%)	Moisture (%)	Crude fibre (%)
Primary finger	1.6	3.5	11	2.7
Secondary finger	1.6	3.5	11	2.7
Tertiary finger	1.6	4.0	11	2.8

23.69%, 22.85% and 22.08%, respectively. The quality of primary, secondary and tertiary dry ginger rhizomes in terms of essential oil content was 1.6%, 1.6% and 1.6%, oleoresin content was 3.5%, 3.5% and 4.0% and crude fibre content was 2.7%, 2.7%, and 2.8%, respectively. Cv. Himachal was reported to have 0.5% essential oil, 5.3% oleoresin and 3.8% crude fibre with an average dry recovery of 22.1% in earlier studies (IISR 2008).

Dry recovery and oleoresin content recorded for dry ginger obtained from the cv. Himachal was very high and is probably a major reason for the farmers in the region adopting the cultivar for producing dry ginger. The physical and biochemical properties thus studied will serve as primary data in the design and development of machineries for processing of dry and fresh ginger.

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