

Engineering Properties of Ginger Rhizomes (*Zingiber officinale* Roscoe) cv Rio-de-Janeiro Grown in Karnataka

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Abstract Ginger (*Zingiber officinale* Roscoe) is recently gaining attention in the food and pharmaceutical industries because of its spice and medicinal importance. In India, several varieties are being grown and cv Rio-de-Janeiro is being preferred for its high oleoresin content. The variety is being cultivated in Karnataka in large scale and processed into different value added products. In order to design the processing equipments to suit the variety, engineering properties of cv Rio-de-Janeiro rhizomes were studied. The average value of major, minor and intermediate diameter were found to be 135.00 ± 10.00 , 75.00 ± 16.00 and 43.00 ± 10.00 mm, respectively. The mean value of geometric mean was 72.48 ± 5.11 mm. The average values of bulk volume and bulk density

were 84.30 ± 4.70 cm³ and 502.45 ± 10.50 kg. m⁻³. The average value of surface of fresh ginger rhizomes was found to be 165.88 ± 13.35 cm². The average values of coefficient of friction for stainless steel, plywood and galvanised iron were found to be 0.57 ± 0.02 , 0.50 ± 0.02 and 0.70 ± 0.04 , respectively. The mean value of angle of repose was $35.50 \pm 1.50^\circ$. Similarly, the mechanical properties of fresh ginger rhizomes viz., penetration, cutting and compression were determined. The average force, distance and time required for penetration of fresh ginger rhizome was found to be 14.85 N, 163.20 mm and 14.43 s, respectively whereas, for cutting and compression tests the force, distance and time required was determined to be 165.93 N, 163.40 mm and 20.55 s and 265.23 N, 125.55 mm and 10.22 s, respectively.

Keywords Engineering properties, Size, Angle of repose, Density.

Introduction

Ginger (*Zingiber officinalis* Roscoe), a monocotyledonous herbaceous perennial belong to *Zingiberaceae* family, which is characterized by a pale-yellow pungent aromatic rhizome, which is the important part of this spice. Ginger consists of the fresh or dried roots of *Zingiber officinale*. The ginger family is a tropical group especially abundant in Indo-Malaysia, consisting of more than 1200 plant species in 53 genera. The genus *Zingiber* includes about 85 spe-

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Table 1. Test setting of texture analyzer to determine mechanical properties of ginger rhizomes.

Sl. No.	Test parameter Type of probe	Penetration test P2N Needle	Cutting force test HDP/BSK Blade	Compression test P-75 Platen
1	Test module	Measure force in compression	Measure force in compression	Measure force in compression
2	Test option	Return to start	Return to start	Return to start
3	Pre-test speed (mm s ⁻¹)	1.0	1.0	1.0
4	Test speed (mm s ⁻¹)	0.5	0.5	0.5
5	Post-test speed (mm s ⁻¹)	5.0	5.0	5.0
6	Distance (mm)	10	20	5
7	Trigger force (g)	10	10	10
8	Load cell (kg)	50	50	50

cies of aromatic herbs from East Asia and tropical Australia. The name of the genus, *Zingiber*, derives from a Sanskrit word denoting horn-shaped, in reference to the protrusions on the rhizome [1].

Ginger is cultivated in several regions of the world viz., India, China, Japan, Indonesia, Australia, Nigeria and West Indies islands. Among these, India and China are the dominant suppliers to the world market. In India, ginger is cultivated in Kerala, Karnataka, Mizoram, Arunachal Pradesh, Assam, Meghalaya, Nagaland, Manipur, Sikkim, Orissa and Madhya Pradesh [2]. However, Karnataka, Orissa, Assam, Meghalaya, Arunachal Pradesh and Gujarat together contribute 65% of the country's total production. During 2015-2016, the ginger production in India was reported as 0.760 million tonnes from an area of 0.142 million ha, with an average productivity of 5.4 tonnes/ha. However, in Karnataka the ginger production was 0.019 million tonnes from an area of 0.0524 million ha, with an average productivity of 2.80 tonnes/ha (www.indiastat.com) [3].

In India, different varieties of ginger are being grown viz., IISR Varadha, Suprabha, Suruchi, Suravi, Himagiri, IISR Mahima, IISR Rajetha, China, Assam, Maran, Himachal, Nadia and Rio-de-Janeiro, respectively [4]. However, in Karnataka the popularly cultivated ginger varieties are Basavakalyana, Banavasi, Bidar, Haveri, Himachal Pradesh, Hirekerur, Humnabad, Karkal, Kundapur, Maran, Rio-de-Janeiro, Suravi, Suruchi, Wynad, respectively [5]. Among these varieties, the Rio-de-Janeiro was reported to grow abundantly in Karnataka.

The fully matured crop is ready for harvest in about 8 months after planting when the leaves turn yellow and start drying up gradually. The maturity of ginger rhizome is also ascertained by pressing the rhizomes with the nail of thumb. The force exerted by the thumb finger is felt by the person who senses the maturity of the rhizome. This varies from person to person and the need for quantification of the applied force for various post harvest operation arises. Harvesting of rhizomes is done manually with a spade or by using a digging fork and the clumps are lifted carefully and then separated from the dried-up leaves, roots and adhering soil [6].

The important quality parameters of ginger are its fiber, volatile oil and non-volatile ether extract. The 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 [7].

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 to dry ginger. The dried ginger is subjected to size reduction to get ginger powder. Hence, there is a need for machines to perform these operations when they are processed in large quantities [8]. As a first step in the design of these machines, the properties of fresh ginger need to be

Table 2. Physical properties of fresh ginger rhizome.

Sl. No.	Property	Mean value
1	Major diameter (mm)	135.00 ± 10.00
2	Minor diameter (mm)	75.00 ± 16.00
3	Intermediate diameter (mm)	43.00 ± 10.00
4	Geometric mean (mm)	72.48 ± 5.11
5	Bulk volume (cm ³)	84.30 ± 4.70
6	Bulk density (kg/m ³)	502.45 ± 10.50
7	Surface area (cm ²)	165.88 ± 13.35
8	Coefficient of friction	
	i. Stainless steel	0.57 ± 0.02
	ii. Plywood	0.50 ± 0.02
	iii. Galvanised iron	0.70 ± 0.04
9	Angle of repose (°)	36.50 ± 1.50

known [9]. However, the information available on the physical and mechanical properties of fresh ginger cv Rio-de- Janeiro is limited. Hence, this study was undertaken with an objective to determine the engineering properties of ginger cv Rio-de-Janeiro, so that the data generated can be used in optimizing machine design parameters.

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Materials and Methods

Location

The experiment was conducted at the Department of Processing and Food Engineering, College of Agricultural Engineering, University of Agricultural Sciences, Raichur, Karnataka. Raichur is situated on the latitude of 16°15' North, longitude of 77°21' East and at an elevation of 389 m above mean sea level which is considered as North Eastern Dry Zone of Karnataka.

Procurement of raw materials

Fresh ginger cv Rio-de-Janeiro was procured from the progressive farmer of Shimoga District and the moisture content was determined using AOAC [10]. The engineering properties namely, physical and mechanical properties were determined.

Moisture content

The moisture content of the fresh and dried ginger rhizomes were determined by following AOAC method (AOAC, 2005: Method No. : 925.10) [10]. A brief description of the method is as follows. 5 g of ginger samples were kept in a pre-dried moisture box. The mass of the sample was recorded as W_1 . The box was placed in the hot air oven maintained at 105 °C for 24 h. After drying, the box was kept in the desiccator and then weighed. The mass of the dried sample was recorded as W_2 . All measurements were replicated thrice and the average moisture content was calculated. The moisture content of the sample was calculated by using the following equation;

$$\text{Moisture content (\%)} = \frac{W_1 - W_2}{W_1} \times 100$$

where, W_1 = Initial weight of sample, g, W_2 = Final weight of sample, g.

Physical and mechanical properties of ginger

Physical properties of fresh ginger rhizome, which is the first consideration among different properties for the design of the post-harvest handling and sorting equipment [9]. The physical properties of fresh ginger rhizome of cv Rio-de-Janeiro viz., size, geometric mean, sphericity, bulk volume, bulk density, surface area, co-efficient of friction and angle of repose were determined by following the standard procedure.

Size

Size is necessary to describe any object defined with some dimensional parameters. The size of fresh ginger rhizome was determined by measuring the dimensions along the three principal axes, namely, major (length), minor (width) and intermediate (thickness) using vernier callipers having (least count of 0.01 cm). The size was measured for 25 rhizomes and average size was recorded [11].

Geometric mean diameter

The geometric mean diameter (Gm) of the fresh ginger

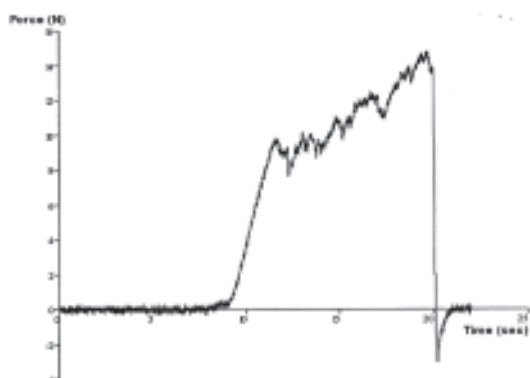


Fig. 1. TPA curve for penetration test of fresh ginger rhizome.

rhizome was determined by measuring the major, minor and intermediate axes of the rhizome [12]

$$\text{Geometric mean} = (xyz)^{1/3}$$

where, x = Major diameter of rhizomes, mm, y = Minor diameter of rhizomes, mm, z = Intermediate diameter of rhizomes, mm.

Volume and bulk density

The volume and bulk density of ginger rhizomes play an important role in drying, milling and storage applications. The bulk volume and bulk density of the fresh ginger rhizomes was determined by using the methods described by Ajav and Ogunlade [9]. The sample was weighed and immersed in a measuring cylinder containing a known volume of water thus leading to an increase (rise) in the water volume. The difference between the new level of water in the measuring cylinder and the initial level of water was recorded as the bulk volume of the rhizome.

The bulk density of the fresh ginger rhizomes was determined as the ratio of bulk weight of rhizomes to the bulk volume of rhizome.

Surface area

The surface area is an important property that helps

Table 3. Mechanical properties of ginger.

Sl. No.	Property	Force (N)	Distance (mm)	Time (S)
1	Penetration test	14.85	163.20	14.43
2	Cutting test	165.93	163.40	20.55
3	Compression test	165.23	125.55	10.22

in understanding the drying behavior of ginger. The surface area of ginger rhizomes was determined by using the method adopted by Ajav and Ogunlade [9].

$$\text{Surface area} = \pi Gm^2$$

where, Gm = Geometric mean diameter.

Coefficient of friction

The coefficient of friction is very important in bulk storage, grading and handling of fresh and dried rhizomes. The static coefficient of friction was determined with respect to each of the following three structural materials on the tilting table: stainless steel, plywood and glass. The ginger rhizomes were placed parallel to the direction of motion and the table is raised gently by a screw device, the angle at which the rhizomes begin to slide (the angle of inclination) was read from a graduated scale on the tilting table, this was repeated three times for each structural material. The coefficient of friction was calculated as the tangent of the angle using the equation given below [9].

$$\mu = \Theta$$

where, μ = Static coefficient of friction (decimal), Θ = Angle of Inclination (degrees).

Angle of repose

Angle of repose is one of the important physical property needed for the design of material handling systems and storage facilities for ginger. The angle of repose is the angle made by ginger rhizomes with the horizontal surface when heaped from a known height [6]. A bag containing 25 kg of ginger rhizomes was

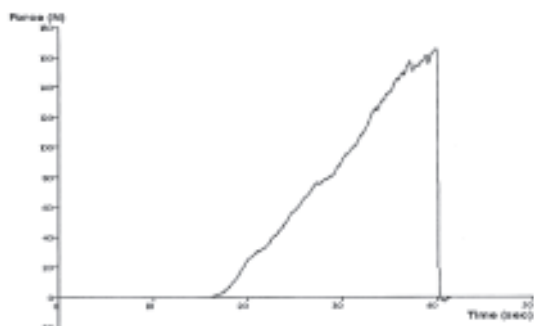


Fig. 2. TPA curve for cutting test of fresh ginger rhizome.

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 following formula:

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

where, Θ = Angle of repose, r = Radius of heap, mm, l = Slant height of heap, mm.

Mechanical properties of ginger rhizome

Mechanical properties like penetration, cutting and compression force for freshly harvested ginger rhizomes were determined using texture analyzer (Make: Texture technologies Corp., Stable Microsystems Ltd, UK Model: TA-XT2i) under test conditions (Table 1) adopted by Jayashree and Visvanathan [6].

Penetration test

Penetration measures the firmness of rhizomes to estimate harvest maturity or post-harvest evaluation of firmness. For measurement of firmness, the probe carrier of texture analyzer was fitted with a 2 mm cylindrical probe (P2N). Ginger rhizomes were placed upon the flat plate of size 150 × 150 mm. The test was carried out at a probe speed of 0.5 mm s⁻¹. The maximum

force required to penetrate the rhizome surface to a depth of 10 mm was taken from the force deformation curve [6].

Cutting test

Cutting test was carried out to determine the force required to cut the ginger rhizome. The rhizomes were placed horizontally upon the flat plate of texture analyzer and a probe carrier fixed with a HDP/BSK blade set was brought in contact with the rhizome. Cutter speed of 0.5 mm s⁻¹ was used with 500 kg load cell. The load against depth of cut of 10 mm was recorded continuously [6].

Compression test

The ginger rhizome compression test simulates the condition of static loading that ginger rhizomes can withstand during mechanical handling and storage. Force deformation characteristics of rhizomes beyond the elastic limit may be important to simulate the destruction that occurs during bruising. Ginger rhizome was placed horizontally upon the flat plate of texture analyzer and a probe carrier fixed with a 65 mm diameter flat plate was brought in contact with ginger. A 50 kg load cell was used and compression force was applied at a speed of 0.5 mm s⁻¹ to compress the rhizome for 5 mm from the contact point. The firmness was expressed as the force required for compressing the rhizome to a distance of 5 mm [6].

Results and Discussion

The physical properties of fresh ginger rhizomes viz., moisture content, size, geometric mean, bulk volume, bulk density, surface area, co-efficient of friction and angle of repose were determined and the data are presented in Table 2.

Moisture content

The moisture content of fresh ginger rhizomes (85.00%) was higher than the results obtained by Jayashree and Visvanathan [6], who reported that the moisture content of fresh ginger rhizome cv Himachal had 80–82% (wb). El-Ghorab et al. [13] reported the higher value of moisture content as 88.5 ± 0.39% (wb)

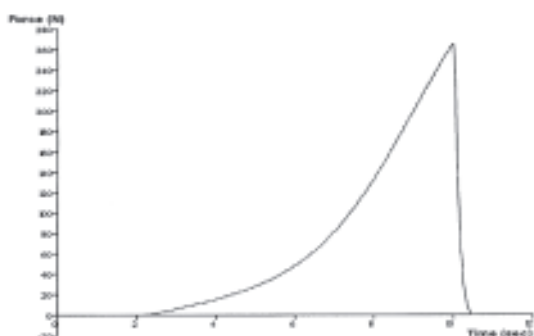


Fig. 3. TPA curve for compression test of fresh ginger rhizome.

for ginger cultivated in Pakistan.

Size

The size of the fresh ginger (cv Rio-de-Janeiro) rhizomes viz., major, minor and intermediate axis was 135 ± 10 , 75 ± 16 and 43 ± 10 mm, respectively. The values of major, minor and intermediate axis differed for each rhizome. The results obtained were on par with the higher values found by Ajav and Ogunlade [9], who reported the ranges of major, minor and intermediate axis as 76.10 to 133.00, 23.00 to 44.00 and 60.00 to 82.00 mm, respectively for Nigerian variety. Jayashree and Viswanathan [6] reported the major, minor and intermediate dimensions for ginger (cv Himachal) rhizomes as 149.90 ± 15.30 , 44.90 ± 20 and 81.70 ± 17.40 mm, respectively which were higher than the values obtained in the investigation.

Geometric mean

The average geometric mean of the fresh ginger (cv Rio-de-Janeiro) rhizome was 72.48 ± 5.11 mm which was within the range of 50.40 to 78.30 mm reported by Ajav and Ogunlade [9] for Nigerian ginger rhizomes.

Volume and bulk density

The volume of the fresh ginger (cv Rio-de-Janeiro) rhizome was found to be 84.30 ± 4.70 cm³. The results of volume of fresh ginger rhizome were in good agreement with the literature values of Jayashree and

Viswanathan [6], who reported that the volume of ginger cv Himachal had 85.00 ± 4.52 cm³.

The bulk density of the fresh ginger (cv Rio-de-Janeiro) rhizome was found to be 502.45 ± 10.50 kg. m⁻³. The results of the bulk density of fresh ginger rhizome were higher than the literature values of Jayashree and Viswanathan [6], who reported that the bulk density of ginger cv Himachal had 471.49 ± 10.63 kg. m⁻³.

Surface area

The surface area of ginger (cv Rio-de-Janeiro) rhizome was found to be 165.88 ± 13.35 cm². The results of surface area of fresh ginger rhizome were lower than the literature values of Jayashree and Viswanathan [6], who reported that, the surface area of ginger cv Himachal had 194.52 ± 6.33 cm².

Co-efficient of friction

The co-efficient of friction of fresh ginger rhizome for stainless steel, plywood and galvanized iron were found to be 0.57 ± 0.02 , 0.50 ± 0.02 and 0.70 ± 0.04 . The results of co-efficient of friction of fresh ginger rhizome were in good agreement with the literature values of Jayashree and Viswanathan [6], who reported that, the coefficient of friction for stainless steel, plywood and galvanized iron had 0.57 ± 0.02 , 0.53 ± 0.01 and 0.72 ± 0.05 , respectively for cv Himachal.

Angle of repose

The angle of repose for the fresh ginger rhizome was found to be in the range of $36.5 \pm 1^\circ$. The results of angle of repose of fresh ginger rhizome were more than the literature value of Jayashree and Viswanathan [6], who reported that, the angle of repose of ginger cv Himachal had $34.6 \pm 1.1^\circ$. The variations observed in physical properties of fresh ginger rhizome with the literature values might be to the varietal difference, maturity stage and geographical area of cultivation and cultivation practices.

Mechanical properties of ginger rhizome

The mechanical properties of fresh ginger (cv Rio-de-

Janeiro) rhizome viz., penetration, cutting and compression tests were estimated and discussed hereunder (Table 3).

Penetration test

The penetration test on fresh ginger rhizome was conducted and the TPA is depicted in Figure 1. From the figure, it is observed that the force (14.85 N) required to penetrate into the fresh ginger rhizomes was higher than the literature value (11.73 N) Jsyashree and Visvanathan [6] for cv Himachal.

Cutting test

The cutting test on ginger rhizomes was determined and the TPA is shown in Figure 2. From the figure, it is observed that the cutting force (165.93 N) required was higher compared to the previous findings of Jayashree and Visvanathan [6], who reported that, the cutting force required was (131.58 N) for cv Himachal.

Compression test

The compression test of the fresh rhizome was conducted and the TPA is depicted in Figure 3. From the figure, it is noticed that the compressive force (265.23 N) required was higher than the earlier researcher [6], who reported that the compressive force required was (202.21 N) for cv Himachal. The variations observed in penetration, cutting and compression force might be due to the varietal difference, maturity stage and geographical area of cultivation and cultivation practices.

Conclusion

The research looked at some selected physical and mechanical properties of *Zingiber officinale* cv Rio-de-Janeiro which are essential in the design and development of the processing and handling equipments which play an important role in selecting the proper sorting, grading and cleaning equipment. The axial dimensions (135.00 ± 10.00 , 75.00 ± 16.00 and

43.00 ± 10.00 mm), moisture content (85.00% wb), geometric mean diameter (72.48 ± 5.11 mm), angle of repose ($36.50 \pm 1.50^\circ$), surface area (165.88 ± 13.35 cm²), volume (84.30 ± 4.70 cm³) bulk density (502.45 ± 10.50 kg m³) and coefficient of friction properties (0.57 ± 0.02 , 0.50 ± 0.02 and 0.70 ± 0.04) would provide an important and essential data for efficient process and equipment design. The mechanical properties determined help in development of suitable size reduction machinery.

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