Environment & Ecology 35 (3) : 1647—1654, July—September 2017
Website: environmentandecology.com ISSN 0970-0420

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

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Received 29 August 2016 ; Accepted 26 September 2016 ; Published online 13 October 2016

**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 values of major, minor and intermediate diameter were found to be 135±10, 75±16 and 43±10 mm, respectively. The mean value of geometric mean was 55.62±5.50 mm. The average values of bulk volume and bulk density were 800000±25000 $mm^3$ and 502.45±10.50 kg $m^{-3}$. The average values of coefficient of friction for stainless steel, plywood and galvanized 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±1.50°. 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, Ginger.

## Introduction

Ginger (*Zingiber officinalis* Roscoe), a monocotyledonous herbaceous perennial belongs 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 species 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,

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Karnataka, Mizoram, Arunachal Pradesh, Assam, Meghalaya, Nagaland, Manipur, Tripura, 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 [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 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.

(The authors acknowledge University of Agricultural Sciences, Raichur for providing financial assistance to carry out the research.)

## 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 (2005). The engineering properties namely, physical and mechanical properties were determined.

### Moisture content

The moisture content of the fresh and dried ginger

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

| Sl. No. | Test parameter Type of probe | Penetration test $P_2N$ 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 |

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. 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 [12].

Geometric mean diameter

The geometric mean diameter (Gm) of the fresh ginger rhizome was determined by measuring the major, minor and intermediate axes of the rhizome (Mohsenin, 1986) [11].

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

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

Bulk volume and density

The bulk volume and 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 (2014). 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.

**Table 2.** Physical properties of fresh ginger rhizome.

| Sl. No. | Property | Mean value | |
|---|---|---|---|
| 1 | Moisture content (%) | 85.00 | |
| 2 | Major diameter (mm) | 135 | ± 10 |
| 3 | Minor diameter (mm) | 75 | ± 16 |
| 4 | Intermediate diameter (mm) | 43 | ± 10 |
| 5 | Geometric mean (mm) | 55.62 | ± 5.50 |
| 6 | Bulk volume ($mm^3$) | 800000 | ± 25000 |
| 7 | Bulk density ($kg/m^3$) | 502.45 | ± 10.50 |
| 8 | Surface area ($mm^2$) | 9853 | ± 350 |
| 9 | Coefficient of friction | | |
| | i. Stainless steel | 0.577 | ± 0.02 |
| | ii. Plywood iron | 0.50 | ± 0.02 |
| | iii. Galvanised iron | 0.70 | ± 0.04 |
| 10 | Angle of repose (°) | 36.5 | ± 1.50 |

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

## Surface area

The surface area is an important property that helps in understanding the drying behavior of ginger. The surface area of ginger rhizomes was determined by using the method adopted by Ajav and Ogunlade (2014).

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

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 (Ajav and Ogunlade, 2014).

$$\mu = \tan\theta$$

Where, $\mu$ = Static coefficient of friction (decimal), $\theta$ = 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. A bag containing 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 following formula:

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

Where, $\theta$ = 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 Crop., Stable Microsystems Ltd, UK Model: TA–XT2i) under test conditions (Table 1) adopted by Jayashree and Visvanathan (2011b).

## 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 ($P_2N$). 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

**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 | 265.23 | 125.55 | 10.22 |

of 10 mm was taken from the force deformation curve [8].

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 [8].

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 [8].

## 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 presents in Table 2.

Moisture content

The results obtained on the moisture content of fresh ginger rhizomes were found to be 85.00% and are presented in Table 2. The results obtained were less than the results obtained by Jayashree and Visvanathan (2012) [12] who reported that the moisture content of fresh ginger rhizome had 80–82% (w.b.) for cv Himachal. El-Ghorab et al. (2010) [13] reported the higher value of moisture content as 88.5±0.39% (w.b.) for ginger rhizome. This variation might be due to geographical location, type of cultural practice and the variety.

Size

The size of the fresh ginger rhizomes viz., major, minor and intermediate axis were found to be 135±10, 75±16 and 43±10 mm, respectively. The results obtained were similar to the findings of Ajav and Ogunlade (2014) reported the major, minor and intermediate axis of ginger rhizomes were found to be 76.1–133, 23–44.0 and 60–82.0 mm, respectively. Jayashree and Viswanathan (2011a) reported that the major, minor and intermediate dimensions for ginger rhizomes cv Himachal had 149.9±15.3, 44.2±2 and 81.7±17.4 mm, respectively. The variation in size of ginger might be due to variety of ginger, maturity stage of ginger, location and other cultural practices.

Geometric mean

The geometric mean of the fresh ginger rhizome was found to be 55.62±5.5 mm. The results of geometric mean of fresh ginger rhizome lies within the literature values of Ajav and Ogunlade (2014) who reported geometric mean of ginger had 50.4 to 78.3 mm, respectively. The variation in the geometric mean might be due to varietal difference, maturity stage of ginger and location.

Bulk volume and density

The bulk volume of the fresh ginger rhizome was found to be 800000±25000 $mm^3$. The results of bulk volume of fresh ginger rhizome were in good agreement with the literature values of Ajav and Ogunlade (2014) who reported that the bulk volume of ginger

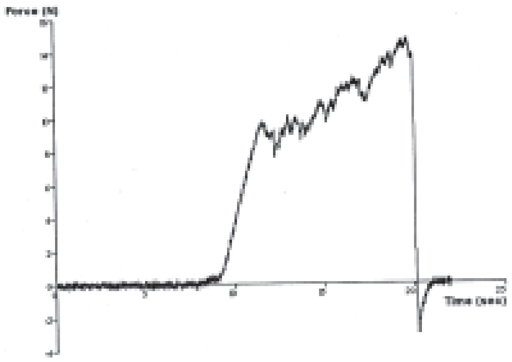


**Fig. 1.** TPA curve for penetration of fresh ginger rhizome.

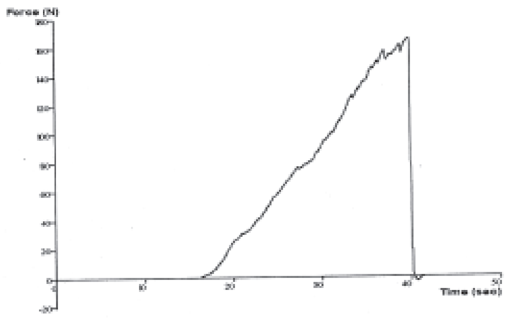


**Fig. 2.** TPA curve for cutting of fresh ginger rhizome.

had 660000–1120000 mm$^3$. This variation might be due to geographical area and varietal difference.

The bulk density of the fresh ginger rhizome was found to be 502.45±10.5 kg m$^{-3}$. The results of bulk density of fresh ginger rhizome were more than the literature values of earlier researcher (Jayashree and Visvanathan, 2011a) who reported that, the bulk density of ginger cv Himachal had 471.49±10.63 kg m$^{-3}$. This variation might be due varietal difference.

## Surface area

The surface area of ginger rhizome was found to be 9853±350 mm$^2$. The results of surface area of fresh ginger rhizome lies within the literature values of Ajav and Ogunlade (2014) reported that the surface area of ginger had 7980–19260 mm$^2$. This variation might be due to varietal difference.

## Co-efficient of friction

The co-efficient of friction of fresh ginger rhizome for stainless steel, plywood and galvanized iron were found to be in the range of 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 Visvanathan (2011a) who reported that, the coefficient of friction for stainless steel, plywood and galvanized iron for cv Himachal ginger had 0.57±0.02, 0.53±0.01 and 0.72±0.05, respectively. The variation in coefficient of friction might be due to the varietal difference and the area of cultivation.

## Angle of repose

The angle of repose for the fresh ginger rhizome was found to be in the range of 36.5±1$^0$. The results of angle of repose of fresh ginger rhizome were more than the literature values of Jayashree and Visvanathan (2011a) who reported that, the angle of repose of ginger had 34.6±1.1$^0$ for cv Himachal. This variation might be due to location of production and varietal difference.

## Mechanical properties

The mechanical properties viz., penetration, cutting and compression force of the fresh ginger rhizomes were determined and the data are given in Table 3.

## Penetration test

The penetration force of the fresh rhizome were measured in terms of force, distance and time and are depicted in Figure 1. From the figure and table, it is observed that the force required to penetrate (14.85 N) into the fresh ginger rhizomes was higher compared to the literature values of Jayashree and Visvanathan (2011b) who reported that, the penetra-

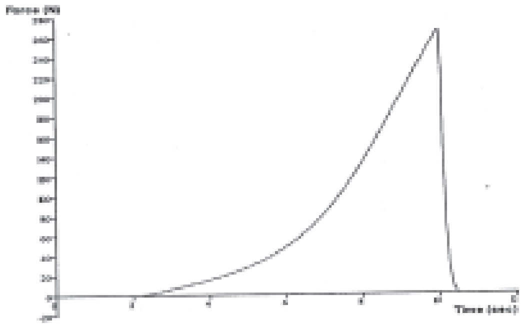

**Fig. 3.** TPA curve for compression of fresh ginger rhizome.

tion force required was 11.73 N for cv Himachal. The variation in force might be due to geographical area of planting and varietal difference.

Cutting test

The cutting forcer of ginger rhizomes were measured in terms of force, distance and time as shown in Figure 2. From the figure and table, it is noticed that the cutting force (165.93 N) required was much higher compared to the findings of Jayashree and Visvanathan (2011b) who reported that, the cutting force required had 131.58 N for cv Himachal. The variation in cutting force might be due to geographical area of production and varietal difference.

Compression test

The compressive force of the fresh rhizome was determined in terms of force, distance and time and are depicted in Figure 3. From the figure and table, it is seen that the compressive force (265.23 N) required was more than the force required were studied by Jayashree and Visvanathan (2011b) reported that, the compressive force required had 202.21 N for cv Himachal. The variation in compressive force might be due to geographical area of cultivation and varietal difference.

## 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±10, 75±16 and 43±10 mm), moisture content (85.00% w.b.), geometric mean diameter (55.62±5.50 mm), angle of repose ($35.50\pm1.50^0$), surface area (9853±350 $mm^2$), bulk density (502.45±10.50 kg. $m^{-1}$) 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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