International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
www.chemijournal.com
IJCS 2020; 8(3): 725-730

Received: 09-03-2020
Accepted: 11-04-2020

Basavaraj
Ph.D Scholar, Department of Farm Machinery and Power Engineering, KCAET, Tavanur, Kerala, India

Jayan PR
Professor and Head, Department of Farm Machinery and Power Engineering, KCAET, Tavanur, Kerala, India

Corresponding Author:
Basavaraj
Ph.D Scholar, Department of Farm Machinery and Power Engineering, KCAET, Tavanur, Kerala, India

Biometric and engineering properties of ginger rhizome towards the development of root crop harvester

Basavaraj and Jayan PR

DOI: https://doi.org/10.22271/chemi.2020.v8.i3i.9290

Abstract
Ginger (*Zingiber officinale* Roscoe,) is one of the most important cash crop and principal spice of India and abroad. The biometric and engineering properties which are relevant to the study were measured for ginger rhizome. The biometric properties viz., number of leaves, height of pant, depth of rhizome, plant density, spacing, soil rhizome composite, rhizome weight, rhizome fingers per hill and weight of rhizome with plant and engineering properties which include both physical and frictional properties of ginger viz., size (major, minor and intermediate diameter), geometric mean, sphericity, rhizome index, surface area, bulk volume. bulk density, the angle of repose, coefficient of friction, angle of repose and texture (firmness). The mean values observed for biometric properties such as number of leaves, height of pant, depth of rhizome, plant density, spacing, soil rhizome composite, rhizome weight, rhizome fingers per hill and weight of rhizome with plant were 9.20, 39.50 cm, 18.15 cm, 10.60, 23.90 cm, 18.60 cm, 0.61 kg, 8.20 and 1.39 kg, respectively. The mean values for obtained for engineering properties of size (major, minor and intermediate), geometric mean, sphericity, rhizome index, surface area, bulk volume, bulk density, the angle of repose, coefficient of friction, angle of repose and texture (firmness) were (16.52, 9.75, 4.08 cm), 8.80 cm, 0.53, 42.18, 235.2 cm^2, 211.20 m^3, 491.82 kg m^{-3}, 34.33 deg, 0.50 (stainless steel), 0.56 (plywood), 0.54 (GI) and 214.2 N, respectively. These properties are essential in the design and development of the digging unit and soil separator unit of the root crop harvester.

Keywords: Ginger rhizome, root crop harvester, rhizome index and soil rhizome composite

Introduction

India is world's largest producer of vegetables after China and contributed about 34 per cent of world vegetable production in the year 2016-17. In vegetables, potato, ginger, turmeric, yam, onion, sweet potato, carrot and coleus are some of the common root crops. Ginger (*Zingiber officinale* Roscoe,) is one of the most important cash crop and principal spice of India and abroad (Bartley and Jacobs, 2000). It is a perennial plant that grows to a height of 600 to 900 mm from underground rhizomes in tropical and subtropical climate (Mendi *et al*., 2009). Ginger can be grown under both rain fed and irrigated conditions. For successful cultivation of this crop, a moderate rainfall at sowing period till the rhizomes sprout, fairly heavy and well distributed showers during growing period and dry weather for about a month before harvesting are necessary. Ginger thrives best in well drained soils like sandy loam, clay loam, red loam or lateritic loam. Ginger is one of the spices that support large number of farmers in the states of Kerala, Karnataka, Arunachal Pradesh, Orissa, West Bengal, Sikkim and Madhya Pradesh (Karthick *et. al*., 2015). However, Kerala, Karnataka, Orissa, Assam, Meghalaya, Arunachal Pradesh and Gujarat together contribute 65 per cent of the country's total production. During 2018-19, the ginger production in India was reported as 1451 thousand tonnes from an area of 175 thousand ha with an average productivity of 8.3 tonnes per ha (www.indiastat.com). Ginger attains full maturity in 210-240 days after planting. Harvesting of ginger for vegetable purpose starts after 180 days based on the demand. However, for making dry ginger, the matured rhizomes are harvested at full maturity i.e. when the leaves turn yellow and start drying. Normally, the crop is harvested between the months of January and March in India. Ginger occupied nearly 1.68 per cent area under the cultivation of spices & condiments in our state and is cultivated in all districts. Area, production and productivity of ginger in Kerala (2017-18) were 4370 ha, 86270 tones and 19.74 MT while in India (2018-19) were 175 thousand ha, 1451 thousand tones and 8.3 MT, respectively.

Harvesting of ginger rhizome was done by manually using spades, kodali and fork. In designing a machine for digging and separating of rhizomes, physical properties such as weight, mean and major diameter, shape factor, height, texture and coefficient of friction on different surfaces are important parameters. In recent years, many researchers have reported physical and mechanical properties of different crop relevant to different machines. But there are few studies on the biometric and engineering properties of ginger rhizome for mechanical harvesting. The determination of physical properties of agricultural materials are important to design machines and processes for harvesting, handling and storage of these materials and requires understanding for converting these materials into food and feed. The main dimensions are considered in selecting and designing the suitable size of the screen perforations. The physical properties of ginger measured showed some deviations from the mean value which is typical of biomaterials. The physical properties of the rhizome determined as a function of moisture content varied significantly with the moisture content. 2. The axial dimensions, geometric mean diameter, surface area, angle of repose and true density showed an ascending relationship with moisture rise while the bulk density, porosity and sphericity which has a descending relationship on moisture gain. These properties would provide important and essential data for efficient process and equipment design Bhawna *et al*., (2018) [5]. Ajiv and Ogunlade studied the physical properties of ginger and observed physical properties increased with an increased in the moisture content except the spherecity and bulk density which decrease as the moisture content increases. Knowledge of frictional properties of rhizomes is needed for the design of handling equipment. The physical properties increase with an increase in the moisture content except the sphere city and bulk density which decrease as the moisture content increases. (Mohsenin, 1986) [8] Biometric and engineering properties of root crops like weight of plant, plant length, size of ginger and angle of rolling resistance affects the design parameters of harvester. These properties influences design parameters as spacing between the rods of soil separator, material handling capacity of soil separator, etc. In harvest handling systems of ginger designed without taking biometric and engineering properties consideration lead to inadequate applications which in turns a reduction in efficiency and increase in harvesting losses. There is few published data on biometric and engineering properties of ginger. Therefore, the present work was undertaken with objective to biometric and engineering properties of ginger rhizome towards the development of root crop harvester.

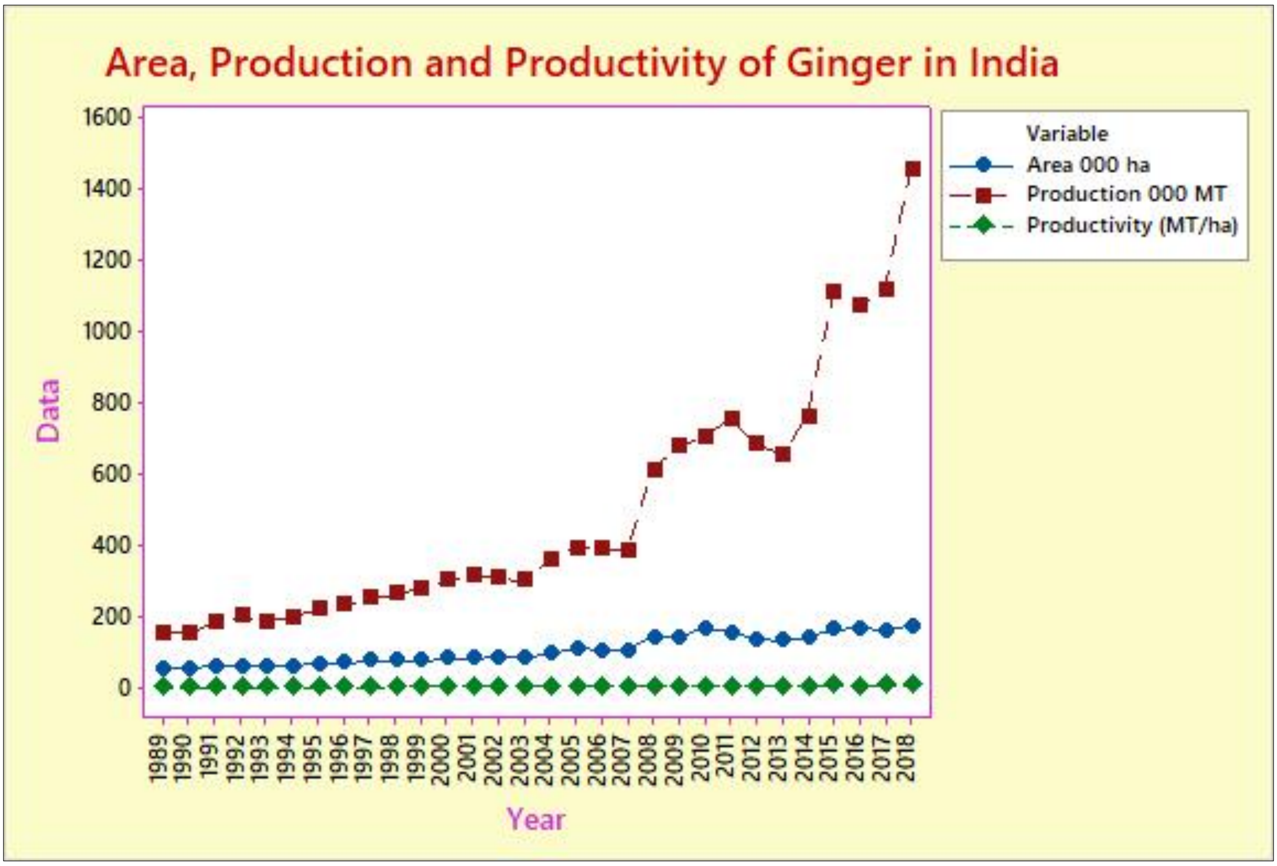

Fig 1: Area, production and productivity of ginger in India

Materials and Methods

The biometric and engineering properties which are relevant to the study were measured for ginger rhizome. The biometric properties viz., number of leaves, height of pant, depth of rhizome, plant density, spacing, soil rhizome composite, rhizome weight, rhizome fingers per hill and weight of rhizome with plant and engineering properties which include both physical and frictional properties of ginger viz., size (length, width and thickness), shape, geometric mean, sphericity, rhizome index, surface area, bulk volume. bulk density, the angle of repose, coefficient of friction, angle of repose and texture (firmness). The methods used the measurement of parameters are given below.

Biometric properties of ginger

Biometric properties of ginger are important for design of a root crop harvester. These properties were measured at the time of harvesting of crop with the help of measuring scale and vernier caliper.

Number of leaves
The crop canopy is indicated by number of leaves spread on cultivated beds. Twenty five beds of 10 m length were randomly selected and number of leaves were counted.

Height
The height of the plant was the decided factor for design of the throat and total length of soil separator unit for proper soil separation. The height of plant decides the handling of crop during harvesting by the machine.

Depth of rhizome
The depth of rhizomes in soil was estimated to find the volume of soil to be handled by digging and soil separator units of the harvester. Randomly selected twenty five plants each from ginger in the study area were measured by using a scale and a flat plate. Vertical soil section was first cut along the plant to expose the rhizome of a standing plant. A flat plate was kept on the ground and a scale was placed vertically to the soil up to the bottom of root crop plant.

Plant density
The density of plant is an important parameter in determining the volume of crop handled by the digging and soil separator units of the harvester.

Spacing
The ginger were planted in raised bed system with a bed width of 900 mm and covering two to three rows as shown in Fig.1. The height of raised bed was 300 to 450 mm. The spacing between the rows 200 to 300 mm and plants as 150 to 200 mm were kept to facilitate easy uprooting of the rhizomes.

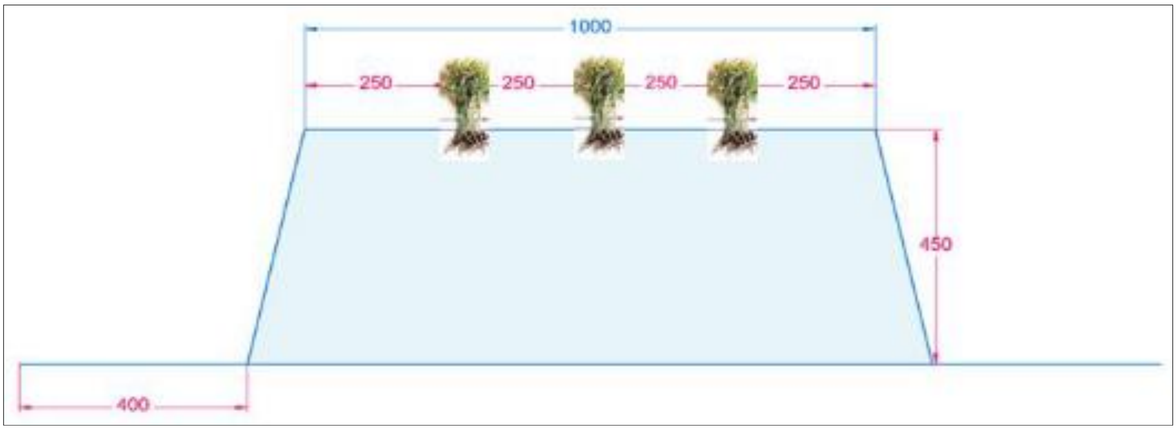

Fig 2: Raised beds for ginger rhizome

Soil rhizome composite
The spread of rhizome in soil lateral and vertical directions varied w.r.t the varieties. Rhizome spread affect the design of digging unit. The spread of twenty five clumps were selected at random and measured using a scale by digging the soil adjacent to the plant on the raised bed. The weight of rhizome alone varies from 250 to 500 g for different varieties of ginger. Soil is adhered all around the rhizome when it was dug out and hence the complete weight was measured. The weight rhizome without soil was separately weighed and the difference in weight was recorded as weight of the soil. The overall weight of the soil rhizome composite determines the material handling capacity of the machine.
Each hill contains one or more mother rhizomes which produces 4 to 10 primary fingers. Later stages the secondary fingers were usually come out with 8 to 20 shoots. The total number of fingers per hill influences the volume of crop to be handled.

Physical properties of ginger rhizome
The physical properties of ginger *viz*., size, shape, bulk volume, bulk density, rhizome index and surface area were determined by using standard procedures.

Size
The size of rhizome was determined by measuring the dimensions along the three principal axes namely, major (length), intermediate (width) and minor (thickness) using vernier callipers least count of 0.01 cm and thickness were measured using digital callipers. The size was recorded for ten rhizomes and an average size was computed (Jayashree and Visvanathan, 2011) [6]. The geometric mean of the ginger were determined by measuring the major, minor and intermediate axes of the rhizome. The geometric mean was calculated using the equation described by Mohsenin (1986) [8].

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

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

Fig 3: Measurement of size for ginger rhizome

Sphericity
The sphericity is defined as the ratio of the diameter of the largest circumscribing sphere (mm) to the diameter of the

smallest circumscribing sphere (mm). Diameters of the rhizome at the larger and smaller circumscribing sphere were recorded and sphericity was calculated.

$$S = \frac{\sqrt[3]{yz}}{x} \quad \text{.... (2)}$$

Where,
S = Sphericity

Bulk volume

The bulk volume of the rhizomes was determined by using Archimedes's principle as described by Nelkon (2005) [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.

Bulk density

The bulk density of the ginger was determined as the ratio of bulk weight of rhizome to the bulk volume of rhizome (Ajav and Ogunlade, 2014) [1]. A container of known volume of inner dimensions 550 x 280 x 350 mm was taken and weighed in a physical balance. Then it was completely filled with freshly harvested rhizome and was weighed again. The bulk density was calculated by using the formula,

$$B_R = \frac{W_{tc} - W_c}{V_c} \quad \text{... (3)}$$

Where,
B_R = Bulk density of rhizome, kg m^{-3}
W_{tc} = Weight of container filled with rhizome, kg
W_c = Weight of empty container, kg
V_c = Volume of container, m^3

Rhizome index (I)

rhizome index is the percentage ratio of rhizome's greater length to the product of greater width and greatest thickness of rhizome.

$$I = \frac{L}{WT} \times 100 \quad \text{... (4)}$$

Where,
I = rhizome index
L = Greatest length of rhizome, mm
W = Greatest width of rhizome, mm
T = Greatest thickness of rhizome, mm

Surface area

The surface area was estimated using the relationship given by Asairo and Anthony (2011) [3]. The surface area was measured for ten samples and the mean value was calculated.

$$S = \pi Gm^2 \quad \text{... (5)}$$

Where,
S = Surface area, mm^2
Gm = Geometric mean diameter, mm

Moisture content

Moisture content of rhizome is an important parameter which has direct impact on harvesting and quality of the rhizome. The moisture content of rhizome was measured by gravimetric method. 50 g of sample were weighed and put in the empty weighed moisture box, the weight of sample with box were recorded. The moisture box is kept in hot air oven at 105°C ± 2 °C for 24 hours. After 24 hours the weight of the moisture box with sample is measured. The moisture content of rhizome can be measured by using the following formula.

$$M_w = (M_2 - M_3)/(M_2 - M_1) \quad \text{................ (6)}$$

Where,
M_w = Moisture content, % (w.b)
M_1 = weight of moisture box, g
M_2 = weight of moisture box + rhizome before drying, g
M_3 = weight of moisture box + rhizome after drying, g

Frictional properties of rhizome

The frictional properties of ginger rhizome *viz*., coefficient of friction, angle of repose and texture (firmness) were determined by the following standard procedures.

Coefficient of friction

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 rhizomes of ginger were placed parallel to the direction of motion and the table was raised gently by a screw device. The angle at which the rhizomes begin to slide (the angle of inclination) was observed on a graduated scale fitted on the tilting table. This was repeated three times for each material. The coefficient of friction was calculated as the tangent of this using the equation given by (Olaoye, 2000) [10].

$$\mu = \tan\theta \quad \text{... (7)}$$

Where,
μ = Static Coefficient of friction, decimal
θ = Angle of Inclination, deg

Fig 4: Measurement of coefficient of friction

Angle of repose

The angle of repose is an angle made by rhizomes with the horizontal surface when heaped from a known height (Olaoye, 2000) [10]. 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 formula:

$$\theta = \tan^{-1}\left(\frac{h}{l}\right) \quad \ldots (8)$$

Where,
θ = Angle of repose, deg
h = Height of the heap of rhizomes, cm
l = Bottom diameter of heap formed from the rhizomes, cm

Texture
Important quality parameters which affect the consumer acceptability of ginger is firmness. This parameter was determined using Texture Analyzer. The instrument Shimadzu (EZ) texture analyser has Trapezium texture analyzer software installed to a personal computer. The instrument consists of the test-bed and the adjustable controller. It is a system with a maximum stroke of 500 mm and a capacity of 500 N. It has a test speed range from 0.001 to 1000 mm m^{-1} (at all loads) and the maximum return speed is 1500 mm/min. This system is ideal and effective for testing of texture profile analysis. It can be fixed with a variety of jigs and fixtures. The sample was kept on the test bed of the instrument and was subjected to compression by tooth pushed jig with depth of 50 mm. From interactive data processing screen of the texture analysis software, the force deformation curve was used for the measurement the firmness or hardness (peak force).

Table 1: Biometric observations of rhizome in the field at the time of harvesting

S. No.	Parameter	Ginger	
		Range	**Mean**
1	Number of leaves	10 - 29	19.60
2	Height of plant, cm	16-35	24.70
3	Depth of rhizome,cm	11 - 20	16.45
4	Plant density, no/m^2	9 - 12	10.70
5	Plant to plant spacing, cm	20 - 25	24.20
6	Row to row spacing, cm	25 - 30	28.90
7	Rhizome spread, cm	11 - 21	17.45
8	Rhizome weight, kg	0.35 - 1.3	0.76
9	No. of rhizome finger per hill,	5 - 14	10.0
10	Weight of rhizome with plant, kg	0.5 - 1.2	1.35

Table 2: Physical properties of ginger

S. No	Size (cm)			Geometric mean, dia, (cm)	Sphericity	Rhizome Index	Surface area (cm^2)	Bulk volume (cm^3)	Bulk density (kgm^{-3})
	Length	**Width**	**Thickness**						
1	12.30	9.20	3.55	9.37	0.599	37.66	170.64	210	489.80
2	16.10	8.30	4.80	8.62	0.535	40.41	233.43	214	492.90
3	20.10	13.00	3.20	9.40	0.467	48.31	277.59	209	485.00
4	21.50	8.50	4.6	9.43	0.438	54.95	279.36	213	479.80
5	16.20	10.00	3.95	8.61	0.531	41.01	232.89	220	507.90
6	18.20	12.00	3.89	9.47	0.520	38.98	281.74	217	499.21
7	15.15	7.50	3.91	7.63	0.503	51.66	182.89	201	482.30
8	19.30	9.50	4.12	9.10	0.471	49.31	260.15	219	493.50
9	9.10	8.50	4.31	6.93	0.761	24.83	150.87	205	488.34
10	17.20	11.00	4.51	9.48	0.551	34.67	282.33	204	499.50
Range	12.40	5.50	1.60	2.55	0.323	30.12	131.5	19.0	28.10
Mean	16.52	9.75	4.084	8.804	0.537	42.18	235.2	211.20	491.82
S.D.	3.71	1.76	0.49	0.883	0.091	9.03	50.3	6.53	8.65
CV, %	22.44	18.06	12.01	10.03	16.95	21.41	21.39	3.09	1.76

Table 3: Frictional properties of ginger

S. No.	Coefficient of friction			Angle of repose (deg)	Firmness (N)
	Stainless steel	**Plywood**	**GI**		
1	0.53	0.66	0.56	31.69	163.44
2	0.51	0.61	0.58	33.77	277.96
3	0.52	0.54	0.59	35.08	193.23
4	0.49	0.51	0.48	36.40	257.79
5	0.45	0.50	0.50	34.75	178.63
Range	0.08	0.16	0.11	4.71	114.5
Mean	0.50	0.564	0.542	34.33	214.2
S.D	0.0316	0.068	0.049	1.754	50.60
CV,%	6.32	12.19	9.08	5.11	23.63

Results and discusion
Crop parameters such as biometric, physical and frictional parameters were studied ginger rhizome. The biometric parameters include with number of leaves, height of plant, depth of rhizome, plant density, spacing, rhizome weight and number of rhizome fingers per hill. The data related to these parameters were used in the design of functional components of the root crop harvester. The biometric observations of root crops in the field at the time of harvesting presented in table 1.
The number of leaves per plant varied from 11 to 29 for ginger with an average of 19.60. The plant height of root crops ranged from 16.0 to 35.0 cm with a average value of 24.7 cm for ginger. The depth of the rhizome in soil was varied from 11-20 cm with an average of 16.45 cm for ginger. The plant density of rhizome were found out as 9-12 numbers for ginger. Plant to plant spacing of rhizome were varied from 20-25 cm and an average values of 24.2 cm for ginger where as row to row spacing of rhizome varied from 25-30 cm with mean of 28.90 cm for ginger.
The rhizome soil composite varied from 11-21 cm with a mean of 17.45 cm for ginger was observed under field conditions. Also noted that distribution of the crops in

horizontal and vertical directions on the soil surface ranged from 10.60 to 20.70 cm with an average of 14.60 cm. The weight of the rhizome soil composite is an important parameter in the design of soil separator unit of the harvester. The weight of rhizome varied from 0.35 to 1.13 kg and the mean values were 0.764 kg for ginger. The number of fingers per hill is also an important parameter as it determines the volume of crop to be handled by the machine. The number of rhizome fingers per hill was ranged from 5-14 and mean value were 10.

The weight of rhizome with leaves is an important parameter which determines the total volume of crop to be handled by the machine as well as the length of the soil separator to be decided. The weight of rhizome with plant were ranged from 0.5 - 1.2 kg and the average values were 1.35 kg for ginger.

The physical properties of rhizomes *viz*., size, geometric mean diameter, sphericity, rhizome index, surface area, bulk volume and bulk density were determined and analyzed statistically and presented in Table 2. The major, minor and intermediate diameter of ginger were found out as 16.52, 9.75 and 4.08 cm. Accordingly the geometric mean diameters were found out as 3.56 cm for ginger. The average values of sphericity were 0.53 for ginger. The average bulk volume and bulk density were found out as 211.20 cm^3 and 491.82 kg m^{-3} for ginger, respectively. The bulk density of the rhizomes are important parameter in designing the soil separator unit. The rhizome index were found out as 42.18 per cent for ginger. The average surface area were determined 235.2 cm^2 for ginger. The moisture content of rhizomes at the time of harvest is another important parameter in digging out the rhizome from soil. The moisture content varied from 70.75 to 75.27 per cent (w.b.) with an average of 73.51 per cent. Since the moisture content of rhizomes at the time of harvest is very high, the soil has a tendency to adhere to the rhizome and it comes out along with the soil which increase the weight of rhizome soil composite by the machine. The physical properties increased with an increased in the moisture content except bulk density which decreased as the moisture content increased.

The major frictional properties of ginger affecting the root crop harvester *viz*., coefficient of friction, angle of repose and texture were determined and analyzed statistically and presented in table 3. The range of coefficient of friction of ginger for stainless steel, plywood and galvanized iron were found out as 0.45 to 0.53, 0.50 to 0.66 and 0.48 to 0.59 respectively. The mean coefficient of friction for stainless steel, plywood and galvanized iron were found out as 0.50, 0.564 and 0.542, respectively. The coefficient of variation of stainless steel, plywood and galvanized iron were found out as 6.32, 12.19 and 9.08, respectively.

The angle of repose of ginger was measured as 34.33 deg. The angle of repose is the determining factor in the design of the lifting the fingers of the soil separator unit. The values obtained are in accordance with the results of Yerima *et al*., (2016) [11]. Firmness is the characteristic of a material expressing its resistance to permanent deformation. Firmness of ginger is an indicator of good edible quality of the rhizome with more consumer appeal. The maximum and minimum firmness for ginger were found out as 163.44 and 277.96 N, respectively. The average value, standard deviation and coefficient of variation of firmness for ginger were found out as 214.2 N, 50.60 and 23.63, respectively.

Conclusions

In this research work, biometric parameters of crop such as number of leaves, height of plant, plant density, rhizome spread, weight, spacing and rhizome fingers per hill which influence the design of root crop harvester. Physical and frictional properties of ginger such as diameter (major, minor and intermediate), geometric mean, sphericity, bulk density, volume, surface area, rhizome index, angle of repose, coefficient of friction and texture (firmness) which plays an important role selecting the proper design components of the harvester and are essential in the design and development of the digging unit and soil separator unit of the root crop harvester.

Acknowledgement

The authors are very grateful to the staff of KCAET, Tavanur and CSIR for their assistance.

References

1. Ajav EA, Ogunlade CA. Physical properties of ginger (*Zingiger Officinale*). Global J Sci. Frontier Res. 2014; 4(1):25-33.
2. Anonymous. Area, production and productivity of ginger and turmeric in India, Department of Agriculture, Cooperation and Farmers Horticulture Statistics Division, Agricultural Statistics at a glance, 2019.
3. Asairo FU, Anthony OA. Determination of some physical properties of African yam beans. The Pacific J Sci. Technol. 2011; 12(1):11-16.
4. Balasubramanian S, Mohite AM, Singh KK, Zachariah TJ, Anand T. Physical properties of turmeric. J of Spi. and Aro. Cr. 2012; 21(2):178-181.
5. Bhawna S, Shirsat S, Patel P, Borkar A, Bakane PH. Physical properties of fresh ginger (zingiber officinale) rhizomes. Mult. In Sci. 2018; 8(25):304-307.
6. Jayashree E, Visvanathan R. Physical and biochemical parameters of fresh and dry ginger (*Zingiber officinale* Roscoe). J Spices Aromat. Crops. 2011; 20(1):14-21.
7. Kerala Agricultural University. Package of Practices. Kerala Agricultural University, Thrissur, 2016, 237.
8. Mohsenin NM. Physical properties of plant and animal materials. 2nd edn. (Revised). J Gordon and Breach Sci. 1986; 14(2):25-30.
9. Nelkon M. Principles of physics for senior secondary schools. 6th Ed., Heinemann London, London, 2005.
10. Olaoye JO. Some Physical properties of castor nut relevant to the design of processing equipment. J Agric. Engg. Res. 2000; 77(1):113-118.
11. Yerima Y, Turu EM, Ngubi FW, Azuokwu AA, Obeta OP. Design related parameters of Nigerian ginger rhizomes. Int. J Sci. Eng. Res. 2016; 7(5):21-29.