International Journal of Environment and Climate Change

Volume 13, Issue 11, Page 2180-2190, 2023; Article no.IJECC.108461
ISSN: 2581-8627
(Past name: British Journal of Environment & Climate Change, Past ISSN: 2231–4784)

Physical Properties of Ginger Based on Different Varieties

T. Mahesh Babu [a*] and Preman P. S. [a]

[a] Department of Farm Machinery and Power Engineering, Kelappaji College of Agricultural Engineering and Technology, Tavanur, Kerala Agricultural University, Thrissur, India.

Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJECC/2023/v13i113380

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/108461

Original Research Article

Received: 25/08/2023
Accepted: 31/10/2023
Published: 03/11/2023

ABSTRACT

Ginger is a plant recently gaining attention in the food and pharmaceutical industries because of its spice and medicinal importance. The measurements of physical properties were conducted at the Food Processing Laboratory, Kelappaji College of Agricultural Engineering and Technology in Tavanur Kerala. The physical and engineering properties of different ginger varieties viz., Athira, Aswathy, Chithra and Karthika were determined to design the hopper and cell sizes, better flowability in the hopper without any clogging in the electronic seed metering unit of a sensor-based tractor drawn ginger planter. The research looked at some physical properties of ginger (Zingiber officinale) rhizomes such as major, minor, intermediate diameters, geometric mean, sphericity, bulk volume, bulk density, surface area, angle of repose and coefficient of friction which are essential for the design of hopper. The properties were determined using ASAE standards. The average value obtained for ginger rhizomes those are, major diameter, minor diameter, intermediate diameter, geometric mean, sphericity, surface area, bulk density, bulk volume, moisture content and angle of repose of the different varieties of the ginger rhizomes are geometric mean of the athira variety of ginger having major diameter is 69.72 mm (X), intermediate diameter is 20.6 mm (Y), minor diameter is 51.84 mm (Z). Geometric mean is 40.24 mm, Sphericity is 0.58, Surface area is 5086.5 cm^2, Bulk density is 0.43 g/cm^3, 24 cm^3, Moisture content is 71.1%, and angle of repose is 34.43°

**Corresponding author: E-mail: maheshbabutumati7@gmail.com;*

respectively. The coefficient of friction was obtained three different structural materials, the obtained values are 0.58 on wood, 0.52 on mild steel and 0.48 on stainless steel. Aswathy variety of ginger having major diameter is 88.96 mm, minor diameter is 53.84 mm, intermediate diameter is 20.92 mm, Geometric mean is 44.02 mm, sphericity is 0.50, surface area is 6240.2 cm^2, bulk volume is 25 cm^3, bulk density is 0.38 g/cm^3, moisture content is 74.53 % and angle of repose is 36.87° and obtained values of the coefficient of friction was 0.60 on wood, 0.58 on mild steel and 0.50 on stainless steel. Chithra variety of ginger having major diameter is 81.2 mm, minor diameter is 55.32 mm, intermediate diameter is 18.64 mm, geometric mean is 41.88 mm, sphericity is 0.52, surface area is 5571 cm^2, bulk density is 0.43 g/cm^3, bulk volume is 40 cm^3, moisture content is 72.45 % and angle of repose 36.54°. The obtained values of the coefficient of friction were 0.54 on wood, 0.51 on mild steel, 0.46 on stainless steel. Karthika variety of ginger having major diameter is 85.08 mm, minor diameter is 49.8 mm, intermediate diameter is 17.2 mm, geometric mean is 38.96 mm, sphericity is 0.48, surface area is 5078 cm^2, bulk volume is 20 cm^3, bulk density is 0.38 g/cm^3, moisture content is 76.01, angle of repose is 38.24°, and coefficient of friction were 0.59 on wood, 0.53 on stainless steel and 0.45 on stainless steel respectively.

Based on the physical properties of ginger, it was concluded that above mentioned parameters are sufficient to design the hopper and cell sizes are suitable for the mechanical planters or any other sensor-based tractor drawn ginger planters. All the physical properties of ginger based on varieties are measured and showed in this research.

Keywords: Geometric mean; sphericity; surface area; bulk density; bulk volume; moisture content; angle of repose.

1. INTRODUCTION

India, often referred to as the "Land of Spices," cultivates ginger (Zingiber officinale Roscoe) in both irrigated and rain-fed regions. This tropical plant thrives even in subtropical climates like the high ranges and it holds a significant place in Indian ayurvedic medicine. Beyond its medicinal uses, ginger is a staple for culinary purposes, enhancing the flavors of dishes. Renowned as the oldest cultivated rhizome, it is treasured as a spice, acclaimed for its unique pungent and fiery taste attributed to its oily component, gingerol.

India boasts a rich heritage of spices, many of which are indigenous to the country. Consequently, India has earned the moniker of the world's spice hub and proudly stands as the largest producer, consumer and exporter of these aromatic treasures. Notably, India contributes a substantial 30.27% to the global ginger production. As of 2020-21, ginger cultivation covered an expanse of 175,764 ha, yielding a total of 1.86 MT. In the state of kerala, ginger is cultivated across approximately 2,752 ha, with a productivity rate of about 19.99 tons per ha in the same period.

Ginger is a spice-producing perennial plant that is cultivated on an annual basis, thrives in warm and humid climates. Its cultivation spans from coastal plains to altitudes of 1500 meters above sea level, either in areas with substantial rainfall (150-300 cm/year) or with access to irrigation. Ideal soil types for ginger include sandy or clayey loam, red loam or laterite loam, all of which boast effective drainage and humus content. Propagation of ginger is achieved vegetatively through its rhizomes. The size of the planting material varies according to location and ginger variety. Planting ginger involves manual labor: digging the soil, placing the seeds and covering them with soil using hands. These seed pieces derived from parent seeds, typically measure 3-5 cm in length and weigh around 15-20 grams (with 15 grams being optimal), containing at least one or two buds. For optimal planting, a seed rate of approximately 1500-2000 kg h^{-1} is recommended. The spacing strategy for ginger planting involves maintaining 25-45 cm distances between rows and 20-25 cm gaps between individual ginger plants as stipulated by [1].

In recent times, spice crops have gained higher market value in comparison to other horticultural crops. These aromatic treasures present lucrative opportunities to enhance farmers' income, even in arid regions. The current research places focus on ginger due to its elevated unit productivity and the immense potential it holds for value addition. Achieving greater productivity hinges on the timely execution of farm tasks. To ensure this, the employment of appropriate farm machinery becomes pivotal. However, the availability of labor in rural areas has been diminished due to migration.

Consequently, the development of suitable machinery becomes imperative to not only boost the productivity of ginger cultivation but also mechanize farm operations. This aspect was highlighted by Kandiannan *et al*. (2008). This research mainly focusses on different varieties of ginger by Okunade et al. [2], those are athira, aswathy, chithra, and Kartika. Pertaining to their engineer-related physical, mechanical, electrical, and thermal properties. These properties serve as essential insights for engineers designing machinery tailored for biomaterial processing. Among these attributes, the physical property takes precedence as it forms the initial consideration in designing cup feed-type metering mechanisms. Drawing a parallel, Jayan and Kumar [3] previously devised a planter based on the physical properties of specific seeds. This emphasizes the importance of comprehending material properties in order to design agricultural machinery that is both efficient and effective. The aim of this study was to determine some physical properties of ginger based on different ginger varieties.

2. MATERIALS AND METHODS

Sampling Process: Fresh ginger rhizomes were obtained from Kerala Agricultural University (KAU) Nursery for the study. These rhizomes were carefully cleansed by hand to eliminate any extraneous elements, including dirt, stone fragments, and damaged rhizomes. Subsequently, the measurement of physical properties was conducted at the Food Processing Laboratory, Kelappaji College of Agricultural Engineering and Technology in Tavanur Kerala. Each rhizome was assigned a distinct label as illustrated in Fig. 1. Facilitating precise sample identification. Notably, the research encompassed a total of four ginger varieties.

Moisture Content Determination: The moisture content of the ginger rhizomes was obtained according to ASAE Standard S358.2 (1983). The sample was dried in an electric oven at a temperature of 105 °C for 24 hours and weighed using a weighing balance at every 6 hours interval to obtain four different levels of moisture content. The moisture content of the sample in percent dry basis was calculated using Equation 1.

$$Ms = \frac{100(wi - wf)}{wf} \quad (1)$$

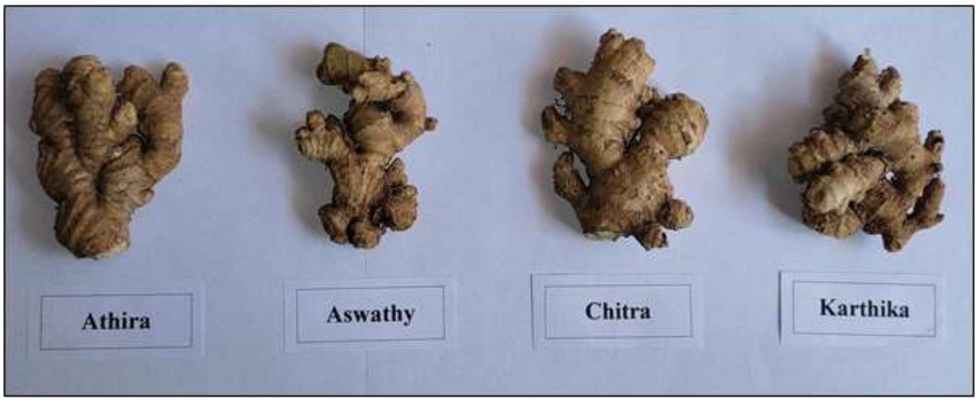

Fig. 1. Types ginger varieties

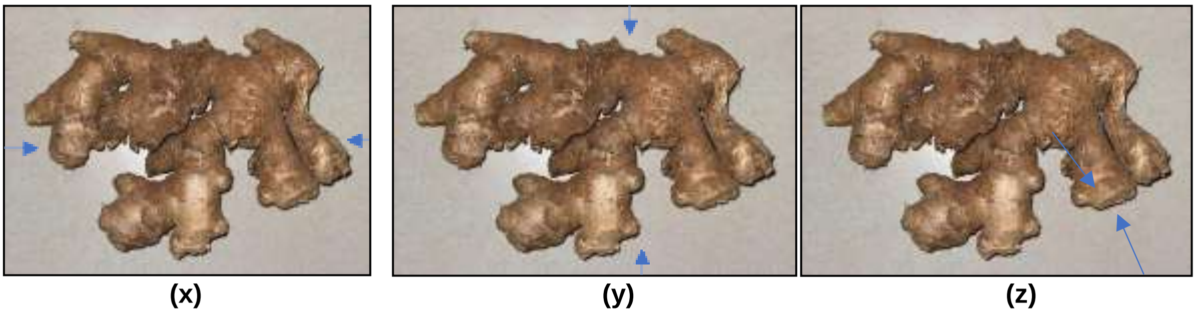

Fig. 2. Measurement of major (x), Intermediate (y) and Minor diameter (z) of a gingerrhizome

Where: Ms is the Moisture Content of Ginger rhizomes (in % dry basis), Wi is the Initial Mass of ginger rhizomes before oven drying (in grams) Wf is the Final Mass of the rhizomes after oven drying (in grams).

Physical properties:

i. Determinations of axial dimensions

The axial dimensions of ginger rhizome varieties, which include major, intermediate, and minor diameters, were measured using a Vernier caliper with a precision of 0.001 mm. These dimensions, also interchangeably known as length, width, and thickness, were represented by the alphabets x, y, and z, respectively.

ii. Determination of geometric mean

The geometric mean was calculated using Equation 2 described by Mohsenin [4]

$$Gm = (xyz)^{1/3} \quad (2)$$

Where: Gm is the Geometric Mean,

x is the Major Diameter of the rhizome,
y is the Intermediate Diameter of the rhizomes,
z is the Minor Diameter of the rhizomes (all in mm)

iii. Determination of sphericity

Sphericity Value Significance: A material's sphericity value indicates its proximity to a spherical shape. This attribute bears significance in the formulation of agricultural equipment like hoppers and dehulling mechanisms. Furthermore, it governs a material's inclination to roll when positioned in a specific orientation. To assess the sphericity of ginger rhizomes, Equation 3, as outlined by Mohsenin [4] was employed.

$$\emptyset = \frac{(xyz)^{1/3}}{x} = \frac{Gm}{x} \quad (3)$$

Where: Φ is the Sphericity in decimal and other parameters remain as defined above.

iv. Determination for bulk volume

The bulk volume of the ginger rhizomes was ascertained through the application of Archimedes' principle, following the method elucidated by Nelkon [5]. In this approach, the sample was weighed and then submerged within a measuring cylinder, which contained a pre-determined volume of water. Subsequently, this immersion resulted in an augmentation (rise) in the water volume within the cylinder. The disparity between the initial water level and the newly reached water level within the cylinder represented the bulk volume of the seed.

v. Determination of bulk density

The bulk density (g/cc) of the ginger rhizomes was determined as the ratio of bulk weight of gingerto the bulk volume (g/cc).

vi. Determination of surface area

The surface area S in mm^2 was estimated by the relationship given by Asoiro and Anthony [6] as:

$$S = \pi Gm^2 \quad (4)$$

Where: Gm is the geometric mean diameter (mm)
S is the surface area of the ginger rhizomes (mm^2)

vii. Determination of coefficient of friction

The static coefficient of friction was evaluated in relation to three distinct structural materials on a tilting table: stainless steel, plywood and glass. The ginger rhizomes were positioned parallel to the direction of movement and a gradual elevation of the table was achieved using a screw mechanism. As the table was elevated, the point at which the rhizomes commenced sliding (known as the angle of inclination) was determined by referencing a graduated scale present on the tilting table. This process was repeated thrice for each of the

structural materials. The coefficient of friction was calculated as the tangent of this angle as shown in Equation 5 [7,8]; (and Pliestic *et al.,* 2006).

$$\mu = \tan\theta \quad (5)$$

Where: μ is the Static Coefficient of Friction (decimal), θ is the Angle of Inclination (degrees)

viii. Determination of angle of repose

To ascertain the angle of repose, a specially designed container constructed without a top or bottom was employed. Crafted from plywood, this container featured a removable front panel, adhering to the methodology outlined by Dutta et al. [9] and Olaoye [7]. The container was loaded with ginger rhizomes and positioned on the ground. Upon promptly removing the front panel, the rhizomes would descend, naturally adopting their inclined configuration. This parameter carries relevance in the formulation of agricultural equipment like hoppers and conveyors. The angle of repose was deduced from two key measurements: the height (h) of the seeds' free surface and the length (l) of the heap formed outside the container. These measurements were utilized to compute the angle of repose using the correlation presented by Bamgboye and Adejumo [10].

$$\theta = tan^{-1}\frac{h}{l} \qquad (6)$$

Where: θ is the Angle of Repose (degrees), h is the Height of the free surface of the rhizomes and l is the Length of the heap formed outside the box.

3. RESULTS AND DISCUSSION

The number of samples were used for research, the range and mean of the physical properties of ginger based on different varieties.

a. Moisture content

Fig. 3 shows the interaction between Moisture content and ginger varieties. The average moisture content for four varieties of ginger were calculated based on the dry basis as explained in above section. The observed values were 71.1%, 74.53%, 72.45% and 76% for Aswathy, Aswathy, Chithra and Karthika varieties. Karthika variety has more moisture content compared to other varieties.

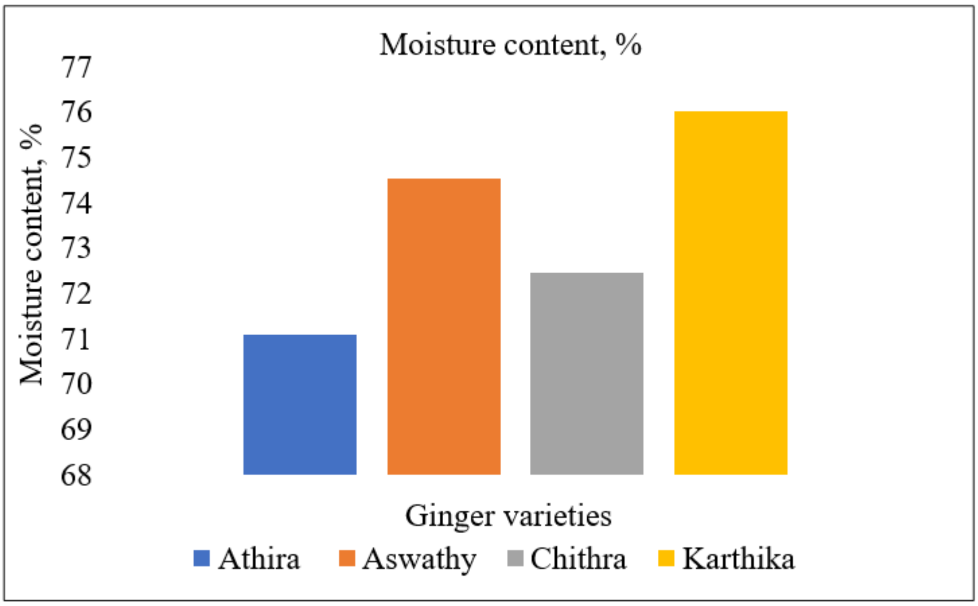

Fig. 3. Effect of ginger varieties on moisture content of the ginger

Table 1. Summary of the athira variety of ginger

Property	No of samples	Range	Mean value	Standard deviation
Major diameter (mm)	25	56 -100	69.72	9.67
Intermediate diameter (mm)	25	45 - 60	51.84	7.04
Minor diameter (mm)	25	16 - 29	20.6	4.51
Geometric mean (mm)	25	34.2-48.6	40.24	4.15
Sphericity (dec)	25	0.45 - 0.70	0.58	0.05
Surface area (cm^2)	25	36.7 - 74.2	50.86	10.80
Bulk volume (cm^3)	25	10 - 40	24	7.13
Bulk density g/cm^3	25	0.42 - 0.44	0.43	0.007

b. Geometric mean

Fig. 4 shows the size of the ginger at each variety decreased as well as increased, this was because of the reduced water content in the ginger causes a decrease in the size of the ginger, the size of ginger can be influenced by various chemical compounds. Ginger is a plant that can adapt to temperature differences. So, the shape and size of the ginger rhizome have various sizes because ginger is a plant that lives in clumps.

c. Sphericity

Fig. 5 shows that there is an interaction between ginger varieties on the sphericity of ginger. In this study, it is observed that the porosity is affected by the size of the ginger. Athira variety of ginger contains highest sphericity value 0.59 compare to all other varieties. The sphericity value of Chithra ginger increased by 0.5 due to a concurrent increase in the size of Chithra ginger, resulting in the elevated sphericity value. The sphericity value of ginger rhizome is influenced by the size of the ginger which is also influenced by the moisture

content of the ginger produced. This test reveals that the packaging aligns with the size and shape of round ginger, ensuring the optimization of available storage space for ginger. Ginger is packaged properly will be able to extend its shelf life and maintain its quality both physically and nutritionally.

d. Bulk volume

Fig. 6 illustrates the impact of interactions between various ginger rhizome varieties on bulk volume, it was observed that the bulk volume of the chithra variety is increased from 0-40 g/cc, then aswathy, athira, chithra varieties are varied from 0-25 g/cc 0-24 g/cc and 0-20 g/cc.

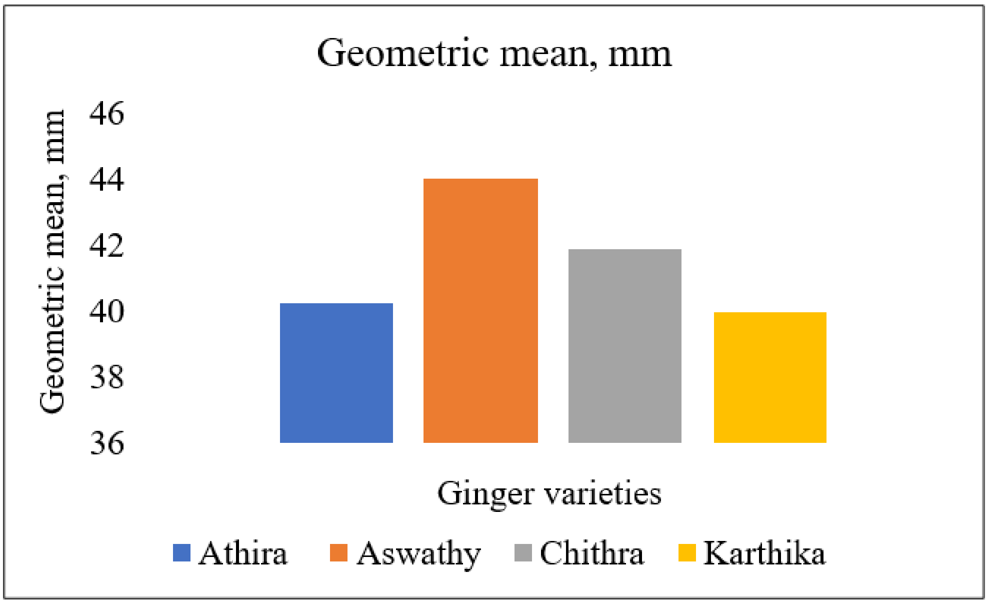

Fig. 4. Effect of ginger varieties on geometric mean

Table 2. Summary of the aswathy variety of ginger

Property	No of samples	Range	Mean value	Standard deviation
Major diameter (mm)	25	52 - 108	88.9	15
Intermediate diameter (mm)	25	35 - 76	53.8	10.5
Minor diameter (mm)	25	14 - 46	20.9	7.5
Geometric mean (mm)	25	33.3-65.1	44.02	7.14
Sphericity (dec)	25	0.40 - 0.67	0.50	0.07
Surface area (cm^2)	25	34.4 - 88	62.4	21.4
Bulk volume cm^3	25	12 - 40	25	8
Bulk density g/cm^3	25	0.38 -0.41	0.38	0.03

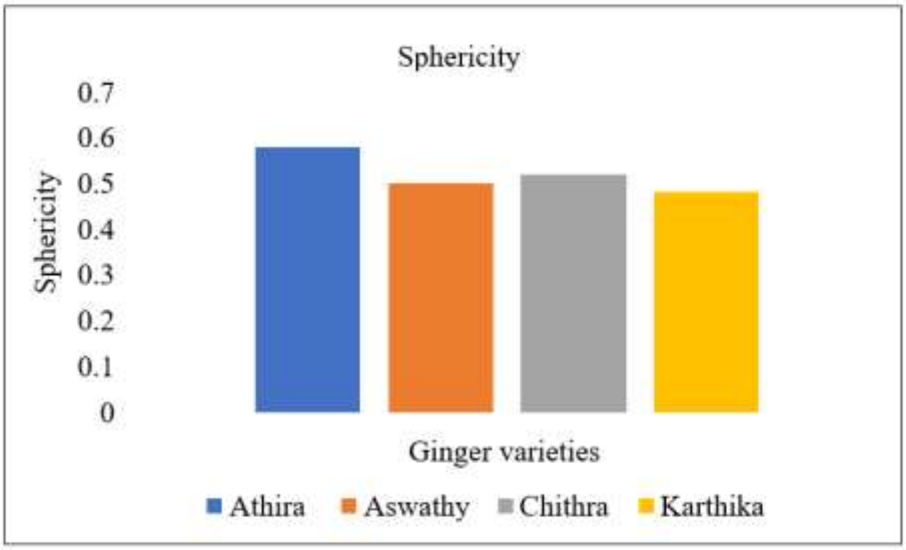

Fig. 5. Effect of ginger varieties on sphericity of ginger

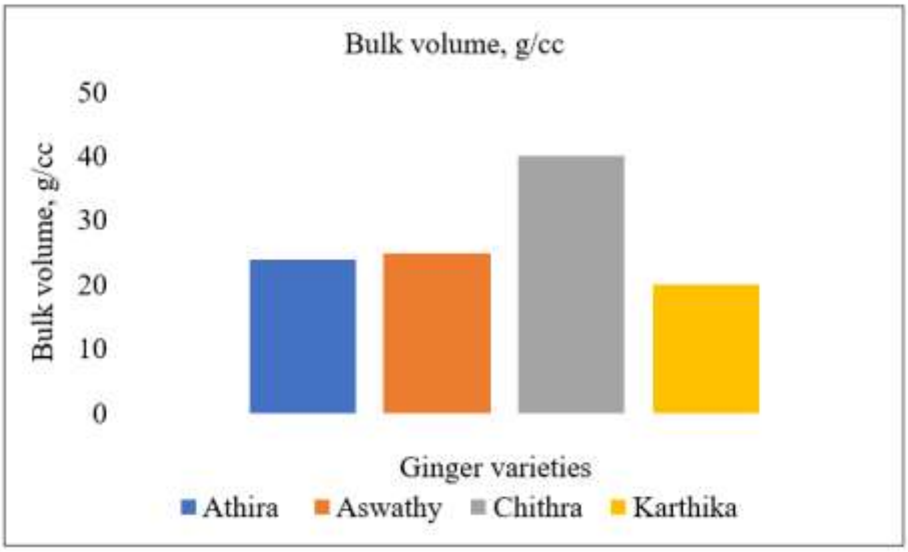

Fig. 6. Effect of ginger varieties on bulk volume of the ginger

e. Bulk density

Fig. 7 shows the bulk density of ginger increased and decreased with different varieties of ginger rhizomes. It was observed that maximum bulk density obtained from the athira and chithra varieties is 0.43g/cc and 0.4 g/cc. The remaining varieties are aswathy, and karthika. It contains 0.38 g/cc, and 0.38g/cc.

f. Surface area

Fig. 8 shows the interaction between the different ginger varieties and surface area. Surface area has a relationship with ginger size. In athira ginger, the value of the surface area decreased and the value of the surface area increased in aswathy variety of ginger as well as value of surface area increased and decreased in other two varieties of ginger, where the factor influenced from the ginger because of moisture content is more in ginger, then the surface area of ginger will be more. Stating the value of a small ginger size, the value of the surface area of ginger will also be small. Because of the moisture content in ginger greatly affects the size of the ginger, so it can also affect the surface area of the ginger. Ginger rhizome when viewed physically the size of ginger does not show a significant difference at the time of harvest. Just there is compaction of ginger due to reduced water content so that increasing the chemical content of ginger can also affect the surface area value of ginger. Other factors that can affect the surface area are the terrain where ginger is planted, soil conditions, weather conditions, rainfall climate, harvest age and varieties of ginger tubers that greatly affect the growth of ginger.

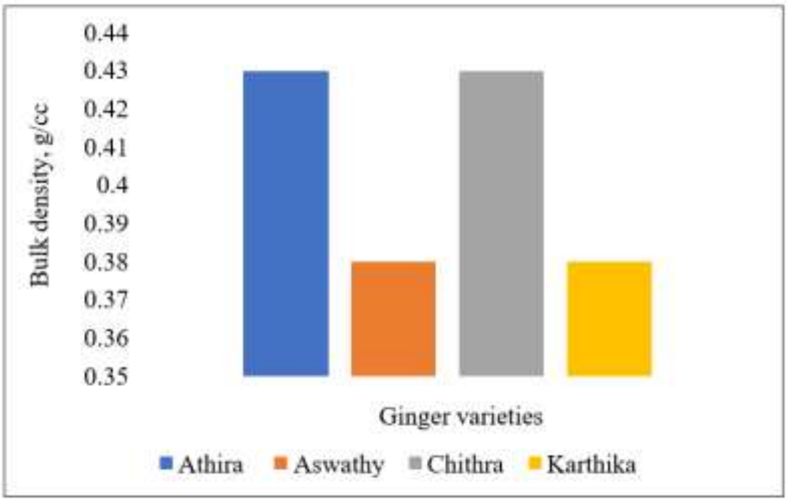

Fig. 7. Effect of the ginger varieties on bulk density

Table 3. Summary of the chithra variety of ginger

Property	No of samples	Range	Mean value	Standard deviation
Major diameter (mm)	25	48 - 100	81.2	13.5
Intermediate diameter (mm)	25	40 - 72	55.3	8.5
Minor diameter (mm)	25	14 - 23	18.6	2.3
Geometric mean (mm)	25	34.05 - 53.4	41.8	4.4
Sphericity (dec)	25	0.44 - 0.71	0.52	0.07
Surface area (cm^2)	25	34.4 - 88	55.7	12.05
Bulk volume (cm^3)	25	15 - 40	40	8.2

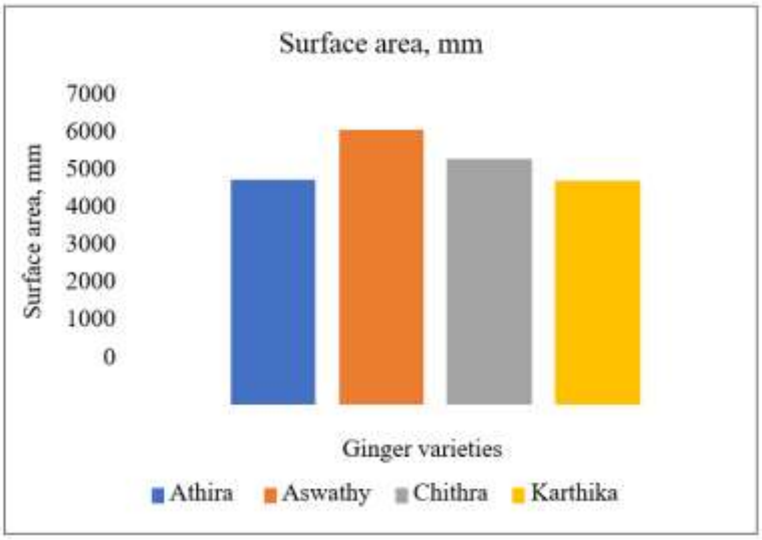

Fig. 8. Effect of ginger varieties on surface area of the ginger

Table 4. Summary of the karthika variety of ginger

Property	No of samples	Range	Mean value	Standard deviation
Major diameter (mm)	25	25 - 124	85.08	17.01
Intermediate diameter (mm)	25	37 - 65	49.8	8.3
Minor diameter (mm)	25	14 - 22	17.2	2.02
Geometric mean (mm)	25	33.8 - 50.8	39.9	4.4
Sphericity (dec)	25	0.37 - 0.58	0.48	0.06
Surface area (cm^2)	25	33.3 - 65.8	50.78	11.5
Bulk volume (cm^3)	25	10 - 32	20	5.8
Bulk density (g/cm^3)	25	0.36 - 0.39	0.38	0.01

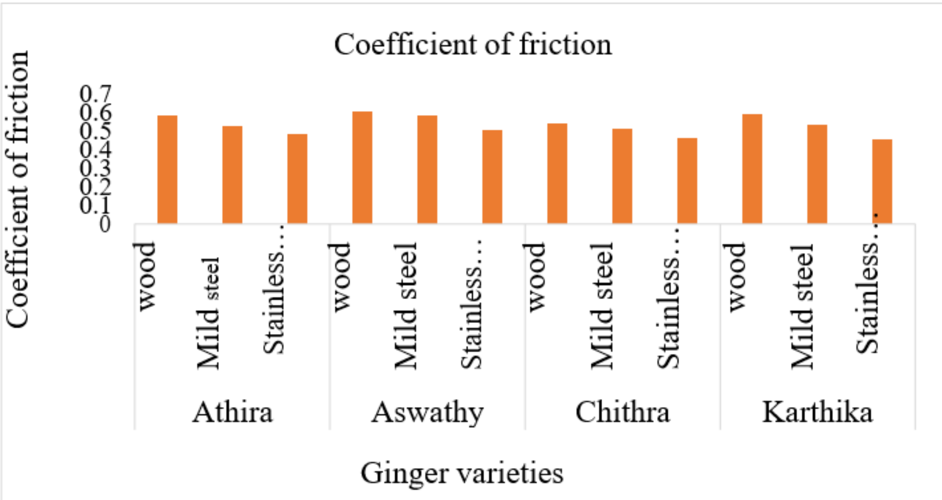

Fig. 9. Effect of ginger varieties on coefficient of friction

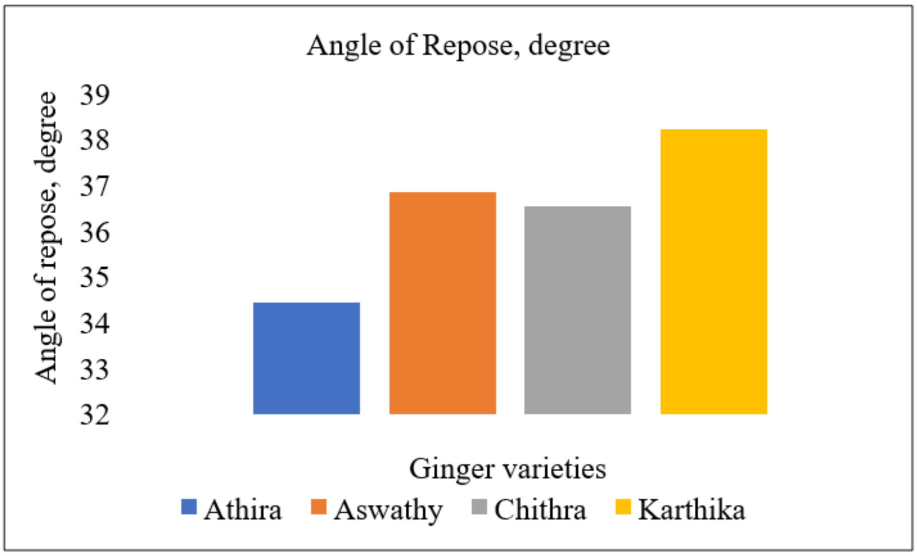

Fig. 10. Effect of ginger varieties on angle of repose

g. Coefficient of friction

Fig. 9 shows the interaction between the ginger varieties and coefficient of friction. Coefficient of friction of rhizomes is required in the design of silos and hopper for processing machines thus, it was determined with respect to wood, mild steel, and stainless- steel surfaces. It was observed that coefficient of friction highest on wood in aswathy variety of ginger and the observed value is 0.6, least value obtained on stainless steel in karthika variety ginger and the observed value is 0.45.

h. Angle of repose

Fig. 10 shows the interaction between the ginger varieties and angle of repose. Angle of repose determined at different varieties those are athira, aswathy, chithra and karthika, those obtained values ranging from 34^0, 36.5^0, 37^0 and 38^0. This increasing trend of angle of repose with moisture content occurs in different varieties of ginger, because surface layer of moisture surrounding the particle hold the aggregate of grain together by the surface tension [11] and it implies that friction increases on the surface of the rhizomes as water content increases, thereby making the seeds less able to flow on one another. The experimental values were seen to be higher than that of oil bean seed [12,13].

4. CONCLUSION

The study examined various physical attributes of different ginger varieties, including their axial dimensions (length, width, and thickness), geometric mean, sphericity, bulk density, bulk volume, surface area, angle of repose and coefficient of friction. These properties play a crucial role in designing and constructing cups of varying sizes tailored to different ginger varieties. The measured physical characteristics of ginger exhibited variations from the average values, as commonly observed in biomaterials. Based on the research findings, the following conclusions were drawn.

1. Physical properties of seeds are determined as a function of different ginger varieties varied significantly with ginger varieties.
2. The axial dimensions, geometric mean diameter, angle of repose, surface area, bulk density, coefficient of friction, sphericity showed an ascending and descending order with different varieties of ginger. These properties would provide important and essential data for efficient design process.
3. The coefficient of friction varies from one variety to another variety of ginger and the observed values for athira variety were 0.58, 0.52, and 0.48 for wood, mild steel and stainless-steel surface materials. The observed values for aswathy, chithra and karthika were 0.6, 0.58, 0.5; 0.54, 0.51, 0.46 and 0.59, 0.53, 0.45 for wood, mild steel and stainless steel surface materials.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. KAU (Keral Agricultural University). Package of practices recommendations: Crops (15th Ed.). Kerala Agricultural University, Thrissur. 2016;130-132.
2. Okunade AF, Agboola TI, Ogunsina BS, Ogunsina AO, Salau, Salami A. Physicochemical properties of four selected food spices of Nigerian origin: alligator pepper, black pepper, ginger and cloves. Ife J. Technol. 2019;26(1): 7-12.
3. Jayan PR, Kumar VJF. Planter design in relation to the physical properties of seeds. J. Trop. Agric. 2004;42(1-2): 69- 71.
4. Mohsenin NN. Engineering properties of plants and animal materials. Gordon and Breach Science publishers, New York, London. 2nd Edition; 1986.
5. Nelkon M. Principles of physics for senior secondary schools. 6th Ed., Heinemann London, London; 2005.
6. Asoiro FU, Anthony OA. Determination of some Physical Properties of African Yam Beans. The Pacific J. of Sci and Technol. 2011;12(1).
Available:http://www.akamaiuniversity.us/PJST.htm
7. Olaoye JO. Some physical properties of castor nut relevant to the design of processing Equipment. J. Agric. Eng. Res. 2000;77(1):113-118.
8. Adejumo OI. Physical properties of neem seeds. Landzun J. Eng. and Appr Technol. 2003;1(2):68-77.
9. Dutta SK, Nema VK, Bhardwaji RK. Physical properties of Sainfoin (*Onobrychis sativa* Lam.), Grasspea (*Lathyrus sativus* L.) and Bitter Vetch (*Vicia ervilia*) Seeds. J. of Appl. Sci. 1998;6(6):1373-1379.
10. Bamgboye AI, Adejumo OI. Physical properties of roselle (*Hibiscus sabdariffa*) Seed. Agric. Eng. Int. the CIGR Ejournal. Manuscript 1154. 2009;11.
11. Pradhan RC, Naik SN, Bhatnagar N, Swain SK. Moisture-dependent physical

properties of Karanja (*Pongamia pinnata*) kernel. Ind. Crops. Products. 2008; 28(2):155-161.
12. Oje K, Ugbor EC. Some Physical Properties of Oil bean Seeds. J. Agric. Eng. Res. 1991;50:305-313.
13. Jayashree E, Kandiannan K, Prasath D, Pervez R, Sasikumar B, Senthil Kumar CM, Srinivasan V, Suseela Bhai R, Thankamani CK. Ginger (Extension Pamphlet). Indian Institute of Spice Research. Calicut; 2014.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/108461