

## Physical Properties of Ginger Based on Different Varieties

**Comment [U1]:** Suggested: Rhizome characteristics of Ginger Varieties

### ABSTRACT:

Ginger is a ~~importance spice and medicinal~~ plant recently gaining attention in ~~the~~ food and pharmaceutical industries because of its ~~spice and medicinal importance~~. The ~~plant~~ physical and engineering properties ~~of different ginger varieties~~ viz., Athira, Aswathy, Chithra and Karthika were ~~determined~~ used to design ~~the~~ hopper with better ~~flowability~~ flow ability without any clogging in ~~the~~ seed metering unit ~~of during~~ 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 were found to be~~ essential for ~~the~~ hopper design of ~~hopper~~. The properties were ~~determined~~ estimated using ASAE standards procedures. The average ~~value scores of physical properties~~ such as major diameter, minor diameter, intermediate diameter, geometric mean, sphericity, surface area, bulk density, bulk volume, moisture content, angle of repose ~~obtained~~ recorded for ~~athira~~ ginger rhizomes ~~those are~~ major diameter, minor diameter, intermediate diameter, geometric mean, sphericity, surface area, bulk density, bulk volume, moisture content, angle of repose of ~~the different varieties of the ginger rhizomes~~ are, ~~athira variety of ginger having are~~ 69.72 mm, 51.84 mm, 20.6 mm, 40.24 mm, 0.58, 5086.5 cm<sup>2</sup>, 0.43 g/cm<sup>3</sup>, 24 cm<sup>3</sup>, 71.1%, and 34.43° respectively. The coefficient of friction ~~was obtained~~ recorded ~~at three different structural materials~~, ~~the obtained values are~~ were 0.58 on wood, 0.52 on mild steel and 0.48 on stainless steel. The respective physical properties of rhizome of Aswathy ginger variety of ginger having were 88.96 mm, 53.84 mm, 20.92 mm, 44.02 mm, 0.50, 6240.2 cm<sup>2</sup>, 25 cm<sup>3</sup>, 0.38 g/cm<sup>3</sup>, 74.53 %, 36.87° and ~~the collected scores~~ obtained values of ~~the~~ coefficient of friction ~~was for the variety were~~ 0.60 on wood, 0.58 on mild steel and 0.50 on stainless steel. Similarly, Chithra ginger variety of attributed ginger having 81.2 mm, 55.32 mm, 18.64 mm, 41.88 mm, 0.52, 5571 cm<sup>2</sup>, 0.43 g/cm<sup>3</sup>, 40 cm<sup>3</sup>, 72.45 %, 36.54°, respectively and ~~obtained values of the scored~~ recorded for coefficient of friction ~~was~~ 0.54 on wood, 0.51 on mild steel, 0.46 on stainless steel. Furthermore, Karthika ginger variety of attributed ginger having 85.08 mm, 49.8 mm, 17.2 mm, 38.96 mm, 0.48, 5078 cm<sup>2</sup>, 20 cm<sup>3</sup>, 0.38 g/cm<sup>3</sup>, 38.24°, and respectively and coefficient of friction ~~were was~~ 0.59 on wood, 0.53 on stainless steel and 0.45 on stainless steel respe

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**Comment [U3]:** Used for...

**Comment [U4]:** Of which parameter or character?

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**Comment [U9]:** The same

etively. All the physical properties measured and showed which is typical of the research.

**Keywords:** Ginger rhizome, rhizome physical properties, medicinal plant, spice plant  
Geometric mean, Sphericity, Surface area, bulk density, bulk volume,  
Moisture content and angle of repose

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## 1. Introduction

Ginger (*Zingiber officinale* Roscoe) is cultivated as a tropical plant thrives even in subtropical climates and holds a significant place in Indian ayurvedic medicine. 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.~~ Besides medicinal uses, ginger is a staple plant for culinary purposes. It is renowned as the oldest cultivated rhizome treasured as a spice being used in 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.

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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 area of 175,764 hectares, 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 perennial plant grown ~~yearly for its use as a spice, thrives~~ in warm and humid climates. Its cultivation spans from coastal plains to ~~altitudes of~~ 1500 meters above sea level, ~~either in areas receiving~~ with substantial rainfall (of 150-300 cm/year) or with access to irrigation. ~~Ideal soil types for ginger include sandy~~ Soils like sandy or clayey loam, red loam, or laterite loam characterized with effective drainage and humus content, are ideal soil types for ginger production all of which boast effective drainage and humus content. ~~Ginger is~~ Propagation ~~propagated 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, manually.~~ These seed pieces, The planting materials of ginger derived from rhizomes of parent seeds/plants, 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~~ A seed rate of approximately 1500-2000 kg per hectare is recommended for optimal planting density. 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 KAU's guidelines in 2016.

**Comment [U10]:** May be define the abbreviations for the first time

In recent times, spice crops have gained higher market value in comparison to other horticultural crops. These aromatic treasures present attributes of spice offered lucrative opportunities to enhance farmers' income, even in arid regions. The current research review places focus on ginger due to its the 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

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appropriate farm machinery becomes pivotal. However, the availability of labor in rural areas has been diminished due to migration.

Comment [U11]: Rewrite in brief.

Consequently, therefore, in order to boost the productivity of ginger cultivation and mechanize the farm operations, 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), who stated... The research delves into engineer-related physical, mechanical, electrical, and thermal properties of four ginger varieties: Athira, Aswathy, Chitra, and Kartika. Pertaining to their engineer-related physical, mechanical, electrical, and thermal properties, these properties serve as essential insights for engineers in 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 (2004) previously devised a planter based on the physical properties of specific seeds. This underscores the significance of understanding the material properties to engineer efficient and effective agricultural machinery.

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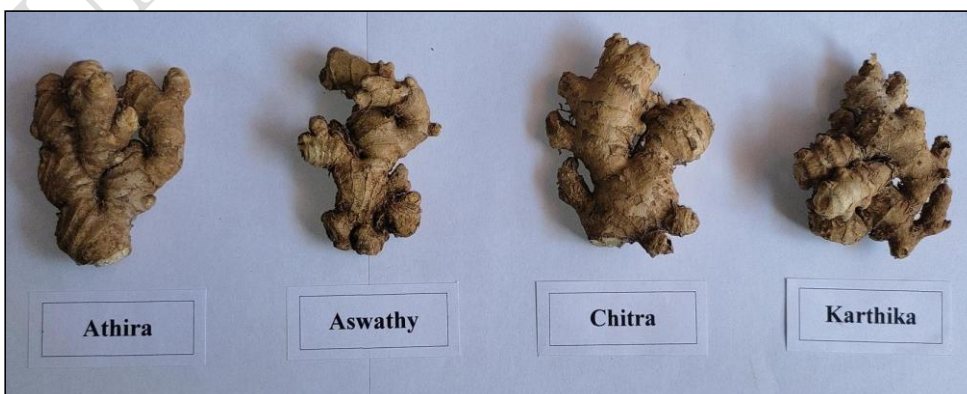
## 2. Materials and Methods

Sampling Process: Fresh ginger rhizomes were obtained from KAU Nursery for the study. These rhizomes were carefully cleaned 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 of Kelappaji College of Agricultural Engineering and Technology in Tavanur. Each rhizome was assigned a distinct label as illustrated in Figure 1, facilitating precise sample identification. Notably, the research encompassed a total of four ginger varieties.

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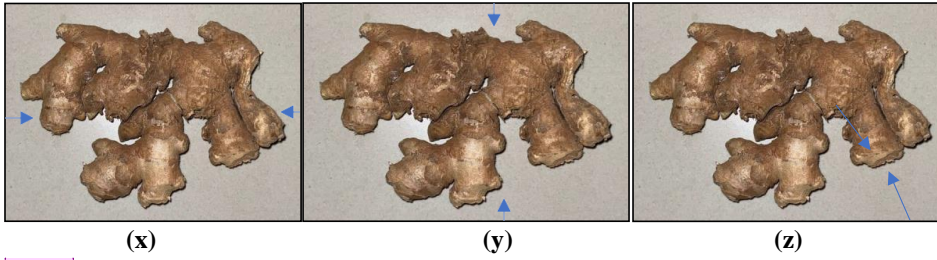
Comment [U14]: Of... state sample size or weight from each variety

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**Fig.1.Typesgingervarieties**

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

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Moisture Content Determination: The moisture content of the ginger rhizomes of each variety was obtained/estimated according to ASA E Standard S358.2(1983). The samples/was/were 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.

**Comment [U17]:** State the sample size

**Comment [U18]:** What four? Not clear

$$MS = \frac{100(w_i - w_f)}{w_f} \quad 1$$

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

### Physical properties:

#### i. Determination of axial dimensions

Alphabets x, y, z are used to represent axial dimensions; major, intermediate and minor diameters, respectively however, this can also be referred to as the length, width and thickness, respectively. Vernier calliper (0.001 mm accuracy) was used in taking the measurement of length, width and thickness. Figure 2 shows the measurement of major (x), intermediate (y) and minor (z) diameters.

**Comment [U19]:** Rewrite with corrected flow.. proceed the subject first:  
Axial dimensions of ginger varieties rhizome like major, intermediate and minor diameters was measured with Vernier calliper having 0.001 mm accuracy. The major, intermediate and minor diameter that can also be referred to as length, width and thickness was represented with alphabets x, y, z, respectively.

#### ii. Determination of geometric mean

The geometric mean of each ginger variety was calculated using Equation 2 described the procedure suggested by Mohsenin (1986) (Equation 2)

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

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)

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### 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, sphericity was assessed, Equation 3, as outlined by Mohsenin (1986), was employed, Equation 3.

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

Where:  $\phi$  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 (2005). 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.

Comment [U21]: What is the unit of expression?

### v. Determination of bulk density

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

### vi. Determination of surface area

The surface area ( $S$ ) in  $\text{mm}^2$  of rhizomes of each ginger variety was estimated by the relationship given by Asoiro and Anthony (2011) as:

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

Where:  $G$  is the geometric mean diameter (mm)

$S$  is the surface area of the ginger rhizomes ( $\text{mm}^2$ )

### 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 repositioned 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

agraduatedscalepresentonthetiltingtable.Thisprocesswasrepeatedthriceforeachofthe

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structural materials. The coefficient of friction was calculated as the tangent of this angle as shown in Equation 5 (Olaoye, 2000; Adejumo, 2003; and Pliestic *et al.*, 2006).

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

Where:  $\mu$  is the Static Coefficient of Friction (decimal),  $\theta$  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.* (1988) and Olaoye (2000). 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 Bangboye and Adejumo (2009).

$$\theta = \tan^{-1} \frac{h}{l} \quad 6$$

Where:  $\theta$  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 Discussions

The number of samples used for research, the range, and mean of the physical properties of ginger rhizomes.

### a. Moisture content

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

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Comment [U23]: Not complete! Remove or rewrite

Comment [U24]: Check the term meaning

Comment [U25]: discuss

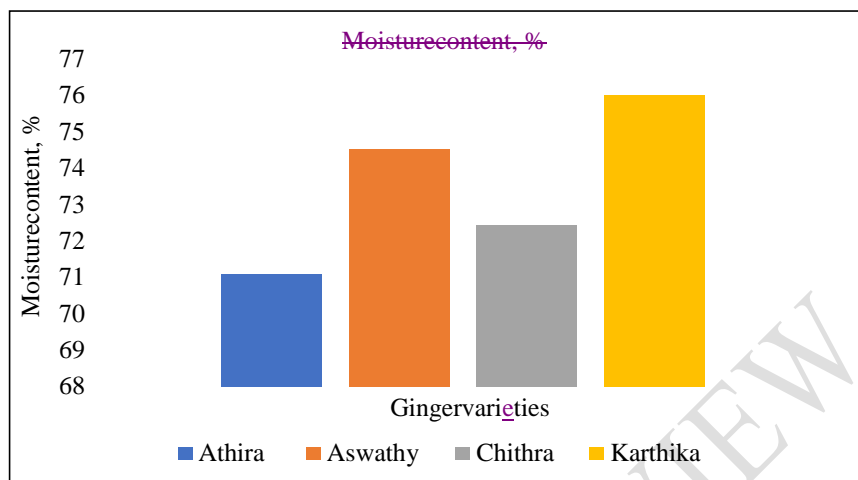


Fig. 3. Moisture content of the rhizomes of Effect of ginger varieties

on moisture content of the ginger Table 1. Summary Physical properties of the Athira ginger variety of ginger

| Property                       | No of samples | Range      | Mean value | Standard deviation |
|--------------------------------|---------------|------------|------------|--------------------|
| Majordiameter (mm)             | 25            | 56-100     | 69.72      | 9.67               |
| Intermediate diameter(mm)      | 25            | 45 -60     | 51.84      | 7.04               |
| Minordiameter (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               |
| Surfacearea (cm <sup>2</sup> ) | 25            | 36.7 -74.2 | 50.86      | 10.80              |
| Bulk volume (cm <sup>3</sup> ) | 25            | 10 -40     | 24         | 7.13               |
| Bulk density g/cm <sup>3</sup> | 25            | 0.42 -0.44 | 0.43       | 0.007              |

Comment [U26]: the data presented in Table not presented and Table not referred.

#### b. Geometric mean

The geometric mean readings of each ginger varieties rhizomes is depicted in Figure 4.

The figure showed that 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, other chemical compounds will increase can affect the size of the ginger. Ginger is a plant that can adapt to temperature differences. So, the shape and size of the ginger

Comment [U27]: Discuss the observation on the variables measured

Comment [U28]: Improve the manner of presenting the observation.

Comment [U29]: What size? Or geometric mean??  
rewrite

rhizome have various sizes because ginger is a plant that lives in clumps.

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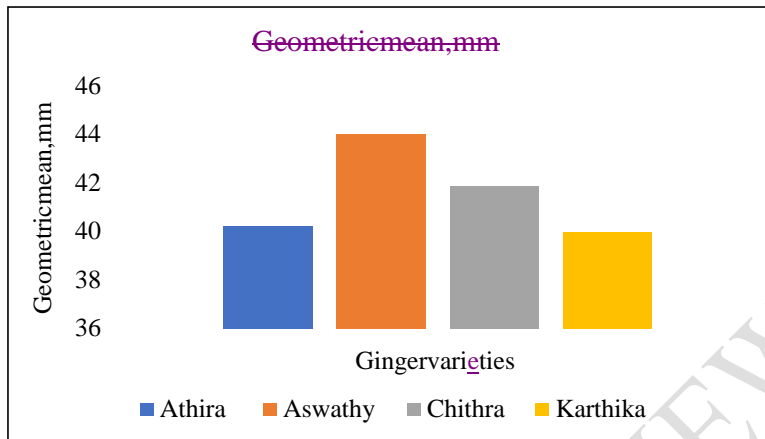


Fig. 4. Effect of ginger varieties on geometric

Geometric mean mm ginger varieties

Table 2. Summary of the aswathy variety of ginger

| Property                       | No of samples | Range      | Mean value | Standard deviation |
|--------------------------------|---------------|------------|------------|--------------------|
| Majordiameter (mm)             | 25            | 52 -108    | 88.9       | 15                 |
| Intermediate diameter(mm)      | 25            | 35 -76     | 53.8       | 10.5               |
| Minordiameter (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               |
| Surfacearea (cm <sup>2</sup> ) | 25            | 34.4 -88   | 62.4       | 21.4               |
| Bulk volume cm <sup>3</sup>    | 25            | 12 -40     | 25         | 8                  |
| Bulk density g/cm <sup>3</sup> | 25            | 0.38-0.41  | 0.38       | 0.03               |

c. Sphericity

Sphericity of rhizomes of ginger varieties is depicted in Figure 5. The figure showed shows that there is an interaction variation in sphericity between rhizomes of ginger varieties on the sphericity of ginger. Where the The porosity sphericity readings showed in influenced difference among the rhizomes of ginger varieties, by the size of the ginger where in this study athira Athira variety of ginger contains showed highest sphericity values score

Comment [U30]: Geometric mean for rhizomes of ginger varieties  
Show the discussion

Comment [U31]: The same

Comment [U32]: Change as commented

Comment [U33]: Check in abstract

Comment [U34]: Use the same term or variable stated

of 0.59 when compared to all other varieties. In chithra ginger ~~there variety was noticed~~ an increase in the sphericity ~~value score of is~~ 0.5 ~~this was because the~~ suggesting increase in sphericity ~~score~~ \_\_\_\_\_ as \_\_\_\_\_ size \_\_\_\_\_ ~~value~~ of chithra ginger also increased ~~so that the sphericity value also increased~~. The sphericity ~~value score~~ of ginger rhizome is influenced by the size of the ginger which is also influenced by the moisture

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content of the ginger produced. With this test, it can be seen that the packaging is in accordance with the size and shape of the roundness of ginger in order to maximize the existing ginger storage space. Ginger that is packaged properly will be able to extend its shelf life and maintain its quality both physically and nutritionally.

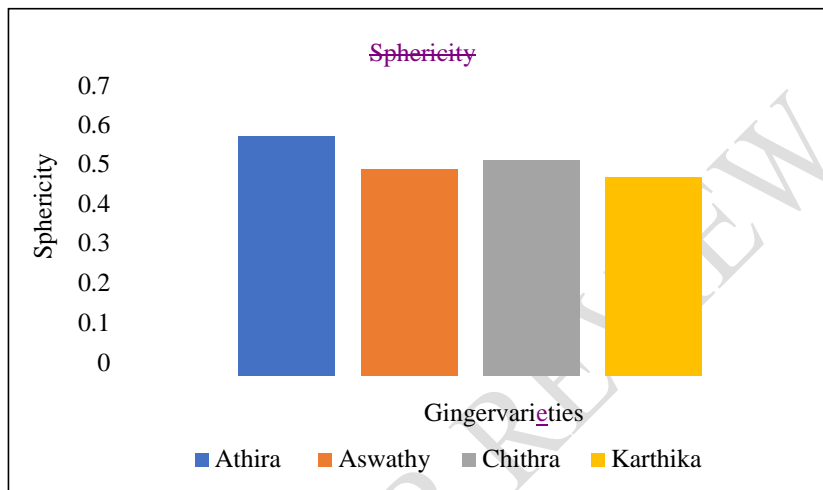


Fig.5. Effect of Sphericity of ginger varieties on sphericity of ginger

d. Bulk volume (g/cc)

Bulk volume of the rhizomes of different varieties of ginger is presented in Figure 6. The figure shows that interaction with the different varieties of ginger rhizomes on bulk volume, it was observed that the bulk volume of the chithra variety is raised 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.

Comment [U35]: No factor exposed for the interaction, hence improve the expression as commented

Comment [U36]: Not clear, write as reporting the findings

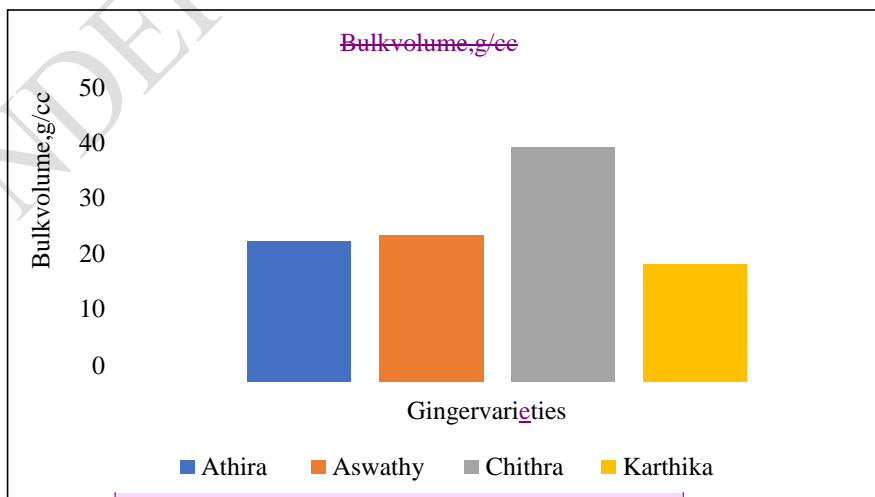
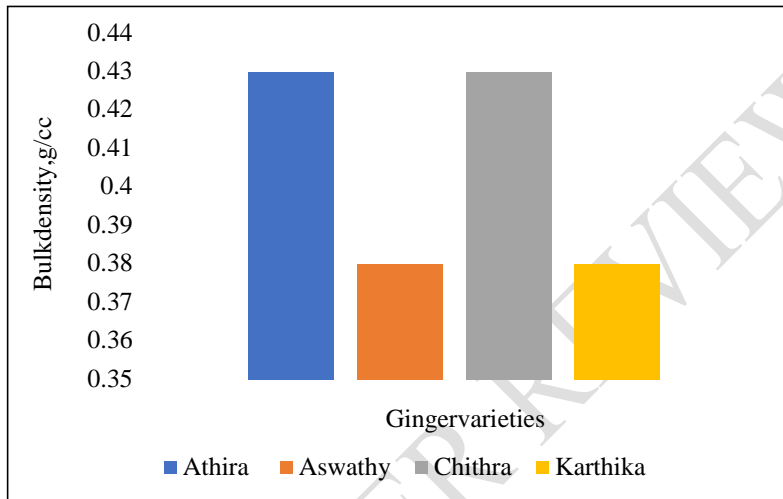


Fig.6. Effect of ginger varieties on bulk volume of the ginger

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**e. Bulk density**

Figure 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, then the remaining varieties those are Aswathy, and Karthika. It contains 0.38g/cc, and 0.38g/cc.



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

**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 <sup>2</sup> ) | 25            | 34.4 -88    | 55.7       | 12.05              |
| Bulk volume (cm <sup>3</sup> )  | 25            | 15 -40      | 40         | 8.2                |

**Comment [U38]:** Do the same improvement  
Write as result and discussion format

**Comment [U39]:** Do the same

**Comment [U40]:** The same

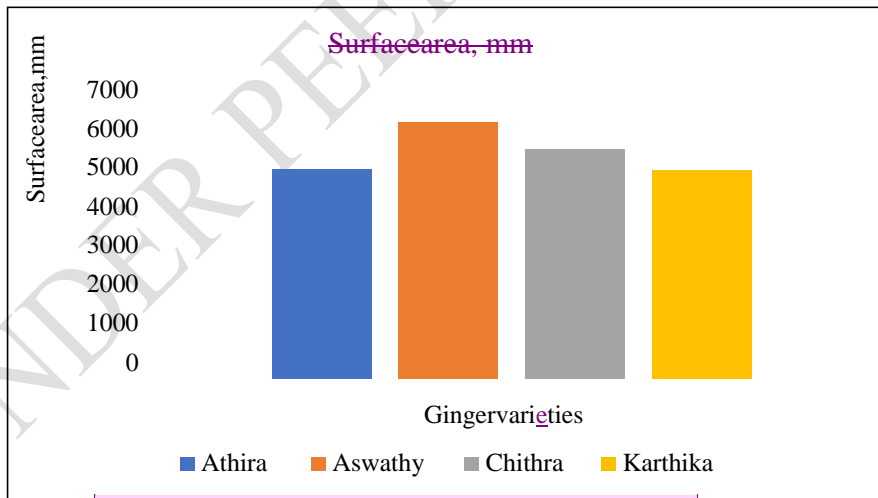
**Comment [U41]:** Do the same correction

**f. Surface area (mm)**

Surface area (mm) of the rhizomes different ginger varieties is depicted in Figure 8. The figure presented shows the interaction between the different ginger varieties and surface area. The figure presented showed the relationship between Surface area has a relationship with and 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 a value of surface area increased and decreased in the other two varieties of ginger, where the factor influenced this was the water content in ginger. Stating the value of a small ginger size, the value of the surface area of ginger will also be small. Because of the water 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 from each harvest age does not show a significant difference, it's just that 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.

**Comment [U42]:** Re write:  
Surface area score of rhizomes of ginger variety ... Showed smaller than the other varieties. Rhizomes of ginger variety ..... scored maximum () surface area. The scores observed suggested that.....

**Comment [U43]:** Rewrite as suggested



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

**Comment [U44]:** Do the same

**Table 4. Summary of the karthik variety of ginger**

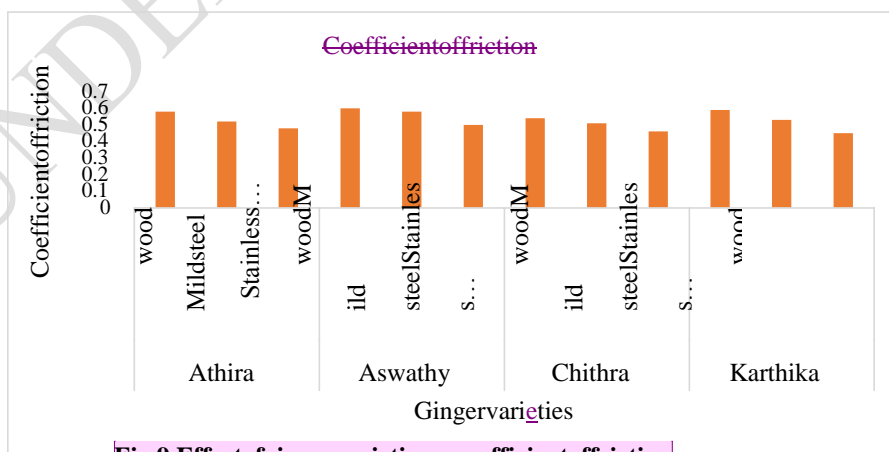
| Property                          | No of samples | Range      | Mean value | Standard deviation |
|-----------------------------------|---------------|------------|------------|--------------------|
| Majordiameter (mm)                | 25            | 25 -124    | 85.08      | 17.01              |
| Intermediate diameter(mm)         | 25            | 37 -65     | 49.8       | 8.3                |
| Minordiameter (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               |
| Surfacearea (cm <sup>2</sup> )    | 25            | 33.3 -65.8 | 50.78      | 11.5               |
| Bulk volume (cm <sup>3</sup> )    | 25            | 10 -32     | 20         | 5.8                |
| Bulk density (g/cm <sup>3</sup> ) | 25            | 0.36 -0.39 | 0.38       | 0.01               |

Comment [U45]: Apply the same correction

**g. Coefficient of friction**

Figure 9 shows the interaction between the ginger varieties and coefficient of friction. The 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 Karthik variety of ginger and the observed value is 0.45.

Comment [U46]: Improve with suggested form of presentation



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

Comment [U47]: The same

## h. Angle of repose

Figure 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  $34^{\circ}$ ,  $36.5^{\circ}$ ,  $37^{\circ}$  and  $38^{\circ}$ . This increasing trend of angle of repose with moisture content occurs in different varieties of ginger, because surface layer of moisture surrounding the particle holds the aggregate of grain together by the surface tension (Pradhane *et al.*, 2008) 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 (Oje and Ugbor, 1991).

Comment [U48]: The same correction

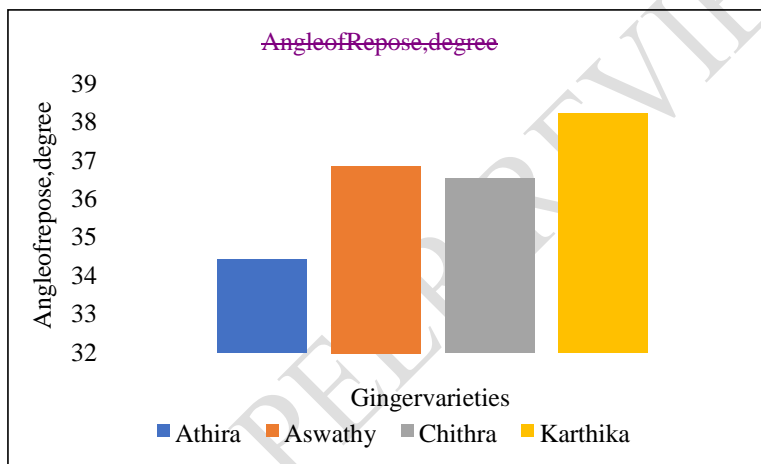


Fig.10 effect of ginger varieties on angle of repose

Comment [U49]: The same

## 4. Conclusion

The study examined various physical attributes of different rhizomes of ginger varieties, including their such as 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 varieties exhibited variations from the average values, as commonly observed in biomaterials. Based on these 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.

**Comment [U50]:** Not important

## 5. REFERENCES

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**Comment [U51]:** The style of referencing lack uniformity, check authors guide of the journal

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