PhysicalPropertiesofGingerBasedonDifferentVarieties

ABSTRACT:

Ginger is a plant recently gaining attention in the food and pharmaceuticalindustriesbecauseofitsspiceandmedicinalimportance.Thephysicalandengineeringproperties of different ginger varieties viz., Athira, Aswathy, Chithra and Karthika weredetermined to design the hopper with better flowability without any clogging in the seedmetering unit of tractor drawn ginger planter. The research looked at some physical propertiesofginger(Zingiberofficinale)rhizomessuchasmajor,minor,intermediatediameters,geometric mean, sphericity, bulk volume, bulk density, surface area, angle of repose andcoefficient of friction which are essential for the design of hopper. The properties weredetermined using ASAE standards. The average value obtained for ginger rhizomes those are,major diameter, minor diameter, intermediate diameter, geometric mean, sphericity, surfacearea, bulk density, bulk volume, moisture content, angle of repose of the different varieties ofthegingerrhizomes are,athiravariety ofgingerhaving 69.72mm,51.84mm,20.6mm,40.24mm, 0.58, 5086.5 cm^2, 0.43 g/cm^3, 24 cm^3, 71.1%, and 34.43° respectively. The coefficient offrictionwasobtainedthreedifferentstructuralmaterials,theobtainedvaluesare0.58onwood,0.52 on mild steel and 0.48 on stainless steel. Aswathy variety of ginger having 88.96 mm,53.84 mm, 20.92 mm, 44.02 mm, 0.50, 6240.2 cm^2, 25 cm^3, 0.38 g/cm^3, 74.53 %, 36.87° andobtained values of the coefficient of friction was 0.60 on wood, 0.58 on mild steel and 0.50 onstainless steel. Chithra variety of ginger having 81.2 mm, 55.32 mm, 18.64 mm, 41.88 mm,0.52, 5571 cm^2, 0.43 g/cm^3, 40 cm^3, 72.45 %, 36.54° and obtained values of the coefficient offrictionwas0.54onwood,0.51onmildsteel,0.46onstainlesssteel.Karthikavarietyofgingerhaving 85.08 mm, 49.8 mm, 17.2 mm, 38.96 mm, 0.48, 5078 cm^2, 20 cm^3, 0.38 g/cm^3, 38.24°,andcoefficientoffrictionwere0.59onwood,0.53onstainlesssteeland0.45onstainlesssteelrespectively.Allthephysicalpropertiesmeasuredandshowedwhichistypicaloftheresearch.

Keywords: Geometric mean, Sphericity, Surface area, bulk density, bulk volume, Moisturecontentand angle of repose

1. Introduction

India, often referred to as the "Land of Spices," cultivates ginger (Zingiber officinaleRoscoe) in both irrigated and rain-fed regions. This tropical plant thrives even in subtropicalclimates 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 ofdishes. Renowned as the oldest cultivated rhizome, it is treasured as a spice, acclaimed for itsuniquepungent and fierytasteattributedto its oilycomponent, 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 thelargestproducer,consumerandexporterofthesearomatictreasures.Notably,Indiacontributesasubstantial30.27%totheglobalgingerproduction.Asof2020-21,gingercultivationcoveredan expanse of 175,764 hectares, yielding a total of 1.86 MT. In the state of kerala, ginger iscultivatedacrossapproximately2,752ha,withaproductivityrateofabout19.99tonsperhainthesame period.

Ginger, a perennial plant grown yearly for its use as a spice, thrives in warm and humidclimates. Its cultivation spans from coastal plains to altitudes of 1500 meters above sea level,eitherinareaswithsubstantialrainfall(150-300cm/year)orwithaccesstoirrigation.Idealsoiltypes for ginger include sandy or clayey loam, red loam, or laterite loam, all of which boasteffective drainage and humus content. Propagation of ginger is achieved vegetatively throughits 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 themwith soil using hands. These seed pieces, derived from parent seeds, typically measure 3-5 cminlengthandweigharound15-20grams(with15gramsbeingoptimal),containingatleastoneor two buds. For optimal planting, a seed rate of approximately 1500-2000 kg per hectare isrecommended.Thespacingstrategyforgingerplantinginvolvesmaintaining25-45cmdistances between rows and 20-25 cm gaps between individual ginger plants, as stipulated byKAU'sguidelines in 2016.

In recent times, spice crops have gained higher market value in comparison to otherhorticulturalcrops.Thesearomatictreasurespresentlucrativeopportunitiestoenhancefarmers' income, even in arid regions. The current research places focus on ginger due to its elevatedunit productivity and the immense potential it holds for value addition. Achieving greaterproductivityhingesonthetimelyexecutionoffarmtasks.Toensurethis,theemploymentof appropriate farm machinery becomes pivotal. However, the availability of labor in rural areashasbeen diminished dueto migration.

Consequently,thedevelopmentofsuitablemachinerybecomesimperativetonotonlyboostthe productivity of ginger cultivation but also mechanize farm operations. This aspect washighlighted by Kandiannan*et al*. (2008). The research delves into four ginger varieties areathira, aswathy, chitra, and Kartika. Pertaining to their engineer-related physical, mechanical,electrical, and thermal properties. These properties serve as essential insights for engineersdesigning machinery tailored for biomaterial processing. Among these attributes, the physicalproperty takes precedence as it forms the initial consideration in designing cup feed-typemetering mechanisms. Drawing a parallel, Jayan and Kumar (2004) previously devised aplanter based on the physical properties of specific seeds. This underscores the significance ofunderstandingthematerialpropertiestoengineerefficientandeffectiveagriculturalmachinery.

2. MaterialsandMethods

Sampling Process: Fresh ginger rhizomes were obtained from KAU Nursery for the study.Theserhizomeswerecarefullycleansedbyhandtoeliminateanyextraneouselements,includin g dirt, stone fragments, and damaged rhizomes. Subsequently, the measurement ofphysical properties was conducted at the Food Processing Laboratory of Kelappaji College ofAgricultural Engineering and Technology in Tavanur. Each rhizome was assigned a distinctlabel as illustrated in Figure 1, facilitating precise sample identification. Notably, the researchencompassedatotal of four ginger varieties.

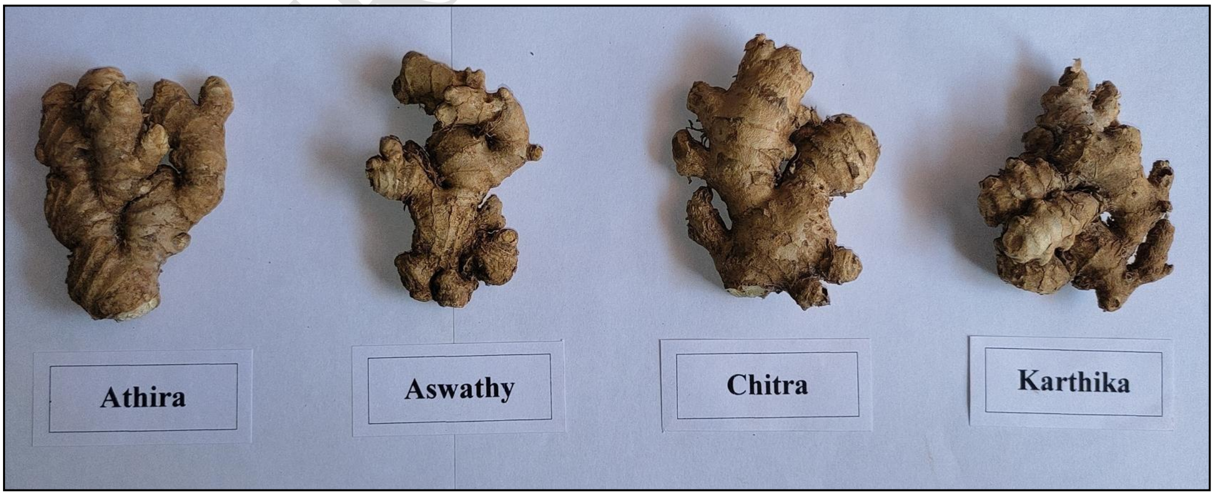
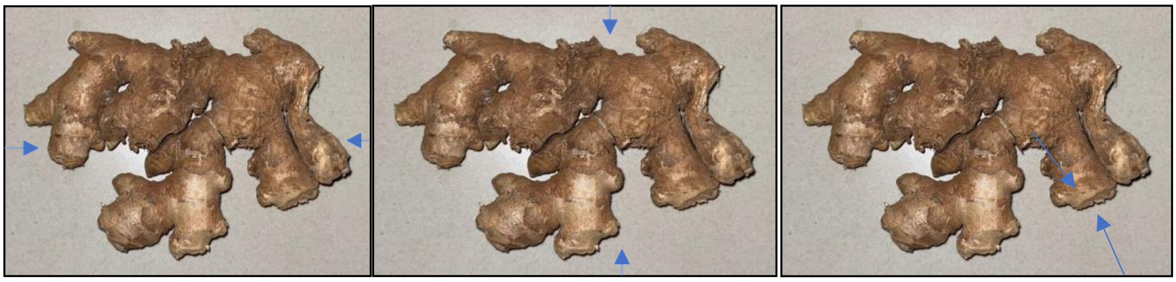


Fig.1.Typesgingervarieties



(x) (y) (z)

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

Moisture Content Determination: The moisture content of the ginger rhizomes wasobtainedaccordingtoASAEStandardS358.2(1983).Thesamplewasdriedinanelectricovenatatemperatureof105°Cfor24hoursandweighedusingaweighingbalanceatevery6hoursinterval to obtain four different levels of moisture content. The moisture content of the sampleinpercent dry basis wascalculated using Equation1.

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

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)$W_f$is theFinalMass of therhizomes after ovendrying (in grams).

Physicalproperties:

i. Determinationsofaxialdimensions

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

ii. Determinationofgeometricmean

Thegeometricmean wascalculated usingEquation2 describedbyMohsenin(1986)

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

Where:GmistheGeometricMean,

xistheMajorDiameterof therhizome,

yis theIntermediateDiameteroftherhizomes,

zis theMinor Diameterof therhizomes (allin mm)

iii. Determinationofsphericity

Sphericity Value Significance: A material's sphericity value indicates its proximity to aspherical shape. This attribute bears significance in the formulation of agricultural equipmentlikehoppersanddehullingmechanisms.Furthermore,itgovernsamaterial'sinclinationto rollwhenpositionedinaspecificorientation.Toassessthesphericityofgingerrhizomes,Equation3,a s outlined by Mohsenin (1986), was employed.

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

Where:ΦistheSphericityindecimalandotherparameters remainasdefinedabove.

iv. Determinationforbulkvolume

The bulkvolumeof the gingerrhizomeswasascertained throughtheapplicationofArchimedes' principle, following the method elucidated by Nelkon (2005). In this approach,the sample was weighed and then submerged within a measuring cylinder, which contained apre-determined volume of water. Subsequently, this immersion resulted in an augmentation(rise)inthewatervolumewithinthecylinder.Thedisparitybetweentheinitialwaterlev elandthenewlyreachedwaterlevelwithinthecylinder representedthebulkvolumeofthe seed.

v. Determinationofbulk density

Thebulkdensityofthegingerrhizomeswasdeterminedastheratioofbulkweightofgingerto thebulk volume.

vi. Determinationofsurfacearea

ThesurfaceareaSinmm^{2}wasestimatedbytherelationshipgivenbyAsoiroandAnthony(2011)as:

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

Where:Gmisthegeometricmeandiameter (mm)

Sis thesurfaceareaof thegingerrhizomes (mm^2)

vii. Determinationofcoefficientoffriction

The static coefficient of friction was evaluatedin relation to three distinct structuralmaterials on a tilting table: stainless steel, plywood, and glass. The ginger rhizomes werepositioned parallel to the direction of movement, and a gradual elevation of the table wasachievedusingascrew mechanism.Asthetablewaselevated,thepointatwhichtherhizomescommenced sliding (known as the angle of inclination) was determined by referencing agraduatedscalepresentonthetiltingtable.Thisprocesswasrepeatedthriceforeachofthe structuralmaterials.Thecoefficientoffrictionwascalculatedasthetangentofthisangleasshownin Equation 5 (Olaoye, 2000; Adejumo, 2003;and Pliestic*et al.*, 2006).

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

Where:μistheStaticCoefficientofFriction(decimal), θistheAngleofInclination(degrees)

viii. Determinationofangleofrepose

To ascertain the angle of repose, a specially designed container constructed without a topor bottom was employed. Crafted from plywood, this container featured a removable frontpanel, adhering to the methodology outlined by Dutta *et al*. (1988) and Olaoye (2000). Thecontainer was loaded with ginger rhizomes and positioned on the ground. Upon promptlyremoving the front panel, the rhizomes woulddescend,naturally adopting their inclinedconfiguration. This parameter carries relevance in the formulation of agricultural equipmentlikehoppersandconveyors.Theangleofreposewasdeducedfromtwokeymeasurements: theheight(h)oftheseeds'freesurfaceandthelength(l)oftheheapformedoutsidethecontainer.These measurementswere utilizedtocomputethe angle of repose usingthe correlationpresentedby Bamgboyeand Adejumo (2009).

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

Where: θ is the Angle of Repose (degrees), h is the Height of the free surface of the rhizomesandl is the Length of theheap formed outside thebox.

3. Resultsanddiscussions

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

a. Moisturecontent

Figure3showstheinteractionbetweenMoisturecontentandgingervarieties.Theaveragemoisturecontentforfourvarietiesofgingerwerecalculatedbasedonthedrybasisasexplainedin above section. The observed values were 71.1%, 74.53%, 72.45% and 76% for Aswathy,Aswathy,ChithraandKarthikavarieties.Karthikavarietyhasmoremoisturecontentcomparedtoother varieties.

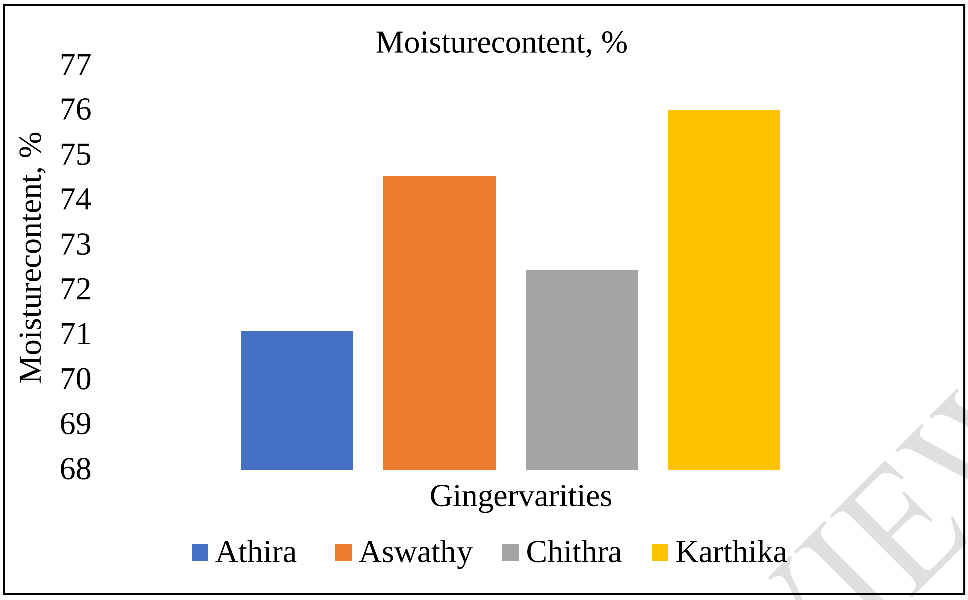


Fig. 3. Effect of ginger varieties on moisture content of the gingerTable1. Summary of theathira variety of ginger

Property	No ofsamples	Range	Meanvalue	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^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. Geometricmean

Figure 4 shows the size of the ginger at each variety decreased as well as increased, thiswas because of the reduced water content in the ginger causes a decrease in the size of theginger, other chemical compounds will increase can affect the size of the ginger. Ginger is aplant that can adapt to temperature differences. So, the shape and size of the ginger rhizomehavevarious sizes becausegingeris a plant that lives in clumps.

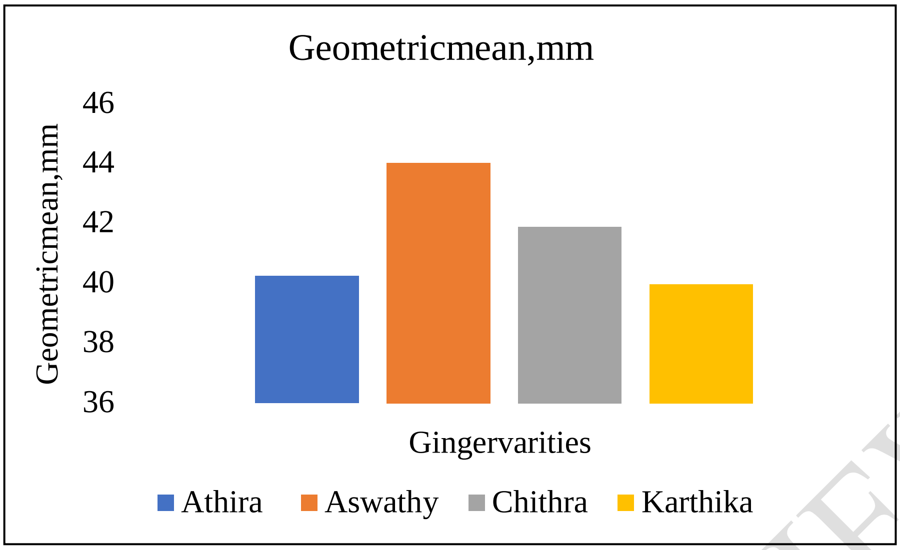


Fig. 4. Effect of ginger varieties on geometric meanTable2. Summary of theaswathyvariety of ginger

Property	No ofsamples	Range	Meanvalue	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^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

c. Sphericity

Figure 5 shows that there is an interaction between ginger varieties on the sphericity ofginger. Where the porosity in influenced by the size of the ginger where in this study athiravarietyofgingercontainshighestsphericityvalue0.59comparetoallothervarieties.Inchithraginger there was an increase in the sphericity value is 0.5 this was because the size value ofchithragingeralsoincreasedsothatthesphericityvaluealsoincreased.Thesphericityvalueofgingerrhizomeisinfluencedbythesizeofthegingerwhichisalsoinfluencedbythe moisture contentofthegingerproduced.Withthistest,itcanbeseenthatthepackagingisinaccordancewith the size and shape of the roundness of ginger in order to maximize the existing gingerstoragespace.Gingerthatispackagedproperlywillbeabletoextenditsshelflifeandmaintainitsquality both physically and nutritionally.

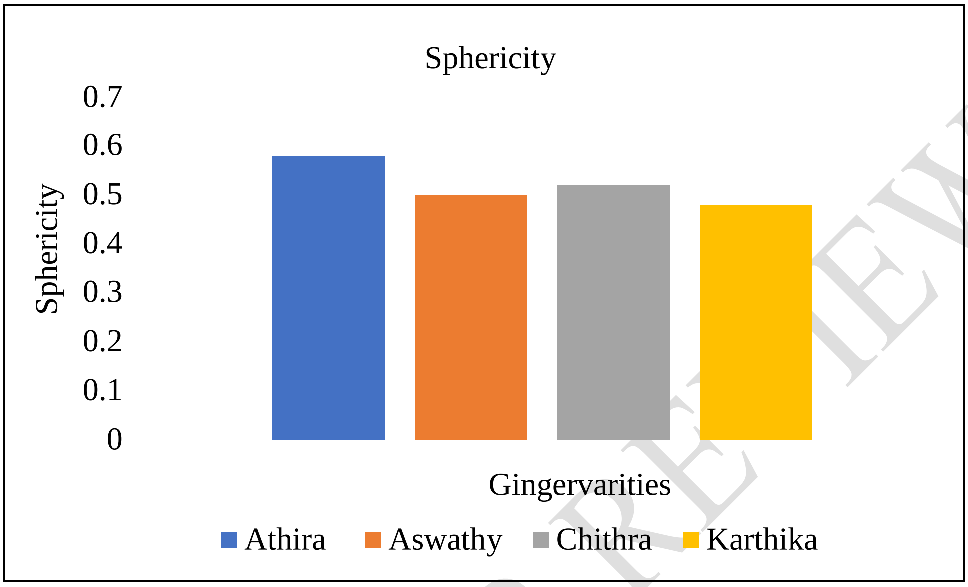


Fig.5.Effectofgingervarietiesonsphericityofginger

d. Bulkvolume

Figure 6 shows that interaction with the different varieties of ginger rhizomes on bulkvolume,itwasobservedthatthebulkvolumeofthechithravarietyisrisesfrom0-40g/cc,thenaswathy,athira,chithravarieties arevariedfrom 0-25 g/cc,0-24 g/ccand 0-20 g/cc.

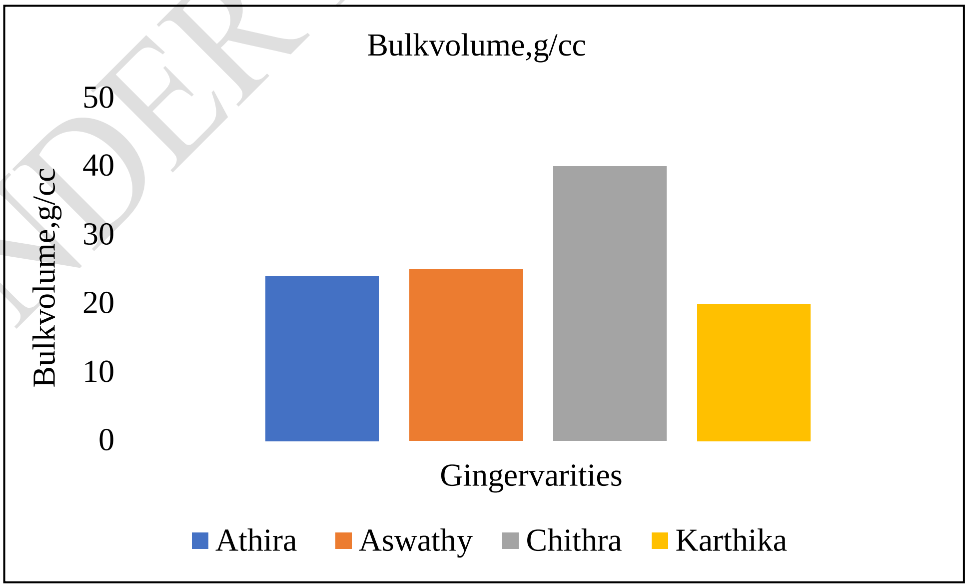


Fig.6.Effectof gingervarietieson bulk volume of theginger

e. **Bulkdensity**

Figure 7 shows the bulk density of ginger increased and decreasedwith differentvarieties of ginger rhizomes. It was observed that maximum bulk density obtained from theathira and chithra varieties is 0.43g/cc and 0.4 g/cc, then the remaining varieties those areaswathy,and karthika.Itcontains 0.38g/cc,and 0.38g/cc.

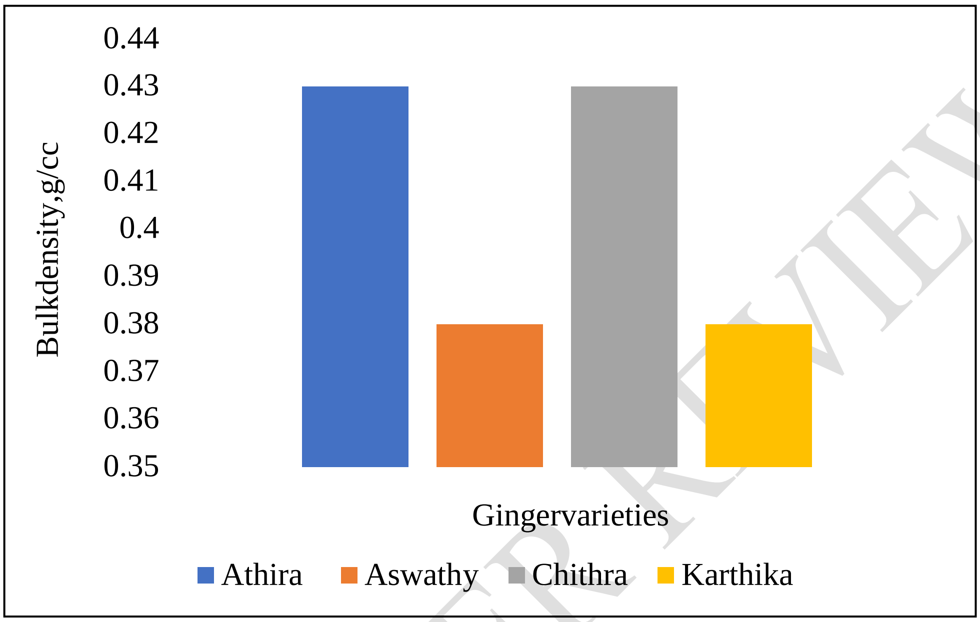


Fig. 7Effect of the ginger varieties on bulk densityTable3. Summary of thechithravariety of ginger

Property	Noof samples	Range	Meanvalue	Standard deviation
Majordiameter (mm)	25	48 -100	81.2	13.5
Intermediate diameter(mm)	25	40 -72	55.3	8.5
Minordiameter (mm)	25	14 -23	18.6	2.3
Geometricmean (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
Bulkvolume (cm^3)	25	15 -40	40	8.2

f. Surfacearea

Figure 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 areadecreased and the value of the surface area increased in aswathy variety of ginger as well asvalueofsurfaceareaincreasedanddecreasedinothertwovarietiesofginger,wherethefactorinfluenced this was the water content in ginger.Stating the value of a small ginger size, thevalue of the surface area of ginger will also be small. Because of the water content in gingergreatly affects the size of the ginger, so it can also affect the surface area of the ginger. Gingerrhizome when viewed physically the size of ginger from each harvest age does not show asignificant difference, it's just that there is compaction of ginger due to reduced water contentsothatincreasingthechemicalcontentofgingercanalsoaffectthesurfaceareavalueofginger. Other factors that can affect the surface area are the terrain where ginger is planted, soilconditions, weather conditions, rainfall climate, harvest age and varieties of ginger tubers thatgreatlyaffect thegrowthof ginger.

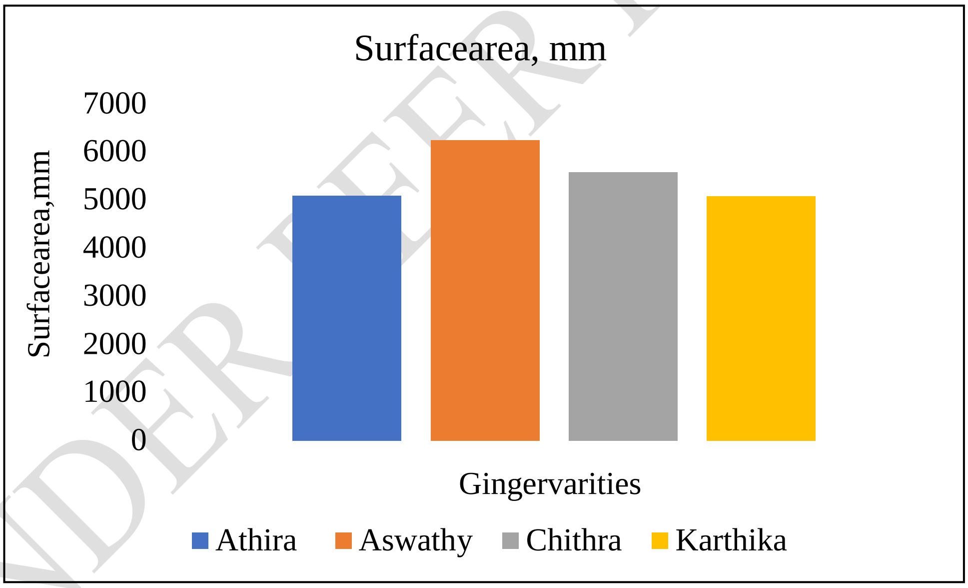


Fig.8Effectofginger varieties onsurfaceareaoftheginger

Table4.Summaryofthekarthikavarietyofginger

Property	No ofsamples	Range	Meanvalue	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^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

g. Coefficientoffriction

Figure 9 shows the interaction between the ginger varieties and coefficient of friction.the coefficientof friction ofrhizomes isrequired in the design of silos and hopper forprocessing 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 varietyofgingerandtheobservedvalueis0.6,leastvalueobtainedonstainlesssteelinkarthikavariety gingerand the observedvalue is 0.45.

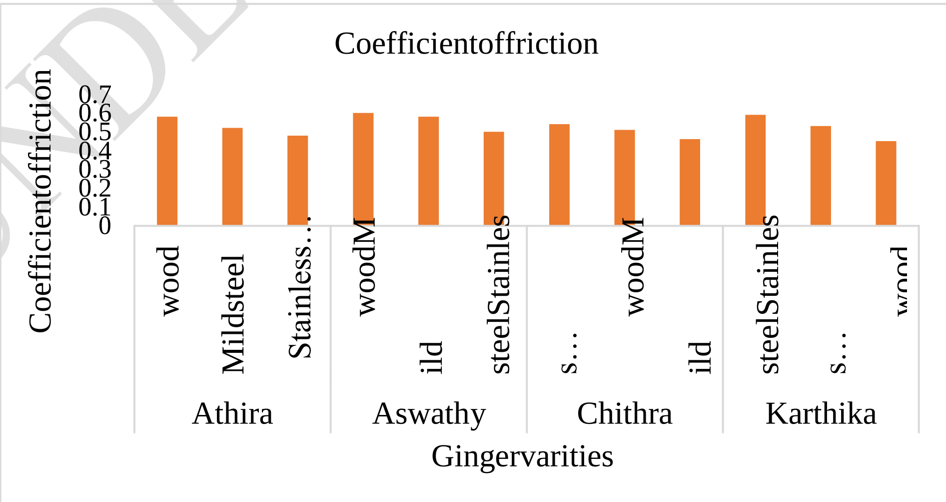


Fig.9.Effectofgingervarietiesoncoefficientoffriction

h. Angleofrepose

Figure 10 shows the interaction between the ginger varieties and angle of repose. Angleofreposedeterminedatdifferentvarietiesthoseareathira,aswathy,chithraandkarthika,thoseobtained values ranging from 34^0, 36.5^0, 37^0 and 38^0. This increasing trend of angle of reposewith moisture content occurs in different varieties of ginger, because surface layer of moisturesurroundingtheparticleholdtheaggregateofgraintogetherbythesurfacetension(Pradhan*et al.*, 2008) and it implies that friction increases on the surface of the rhizomes as water contentincreases, thereby making the seeds less able to flow on one another. The experimental valueswereseen to be higher than that of oil beanseed (Ojeand Ugbor, 1991).

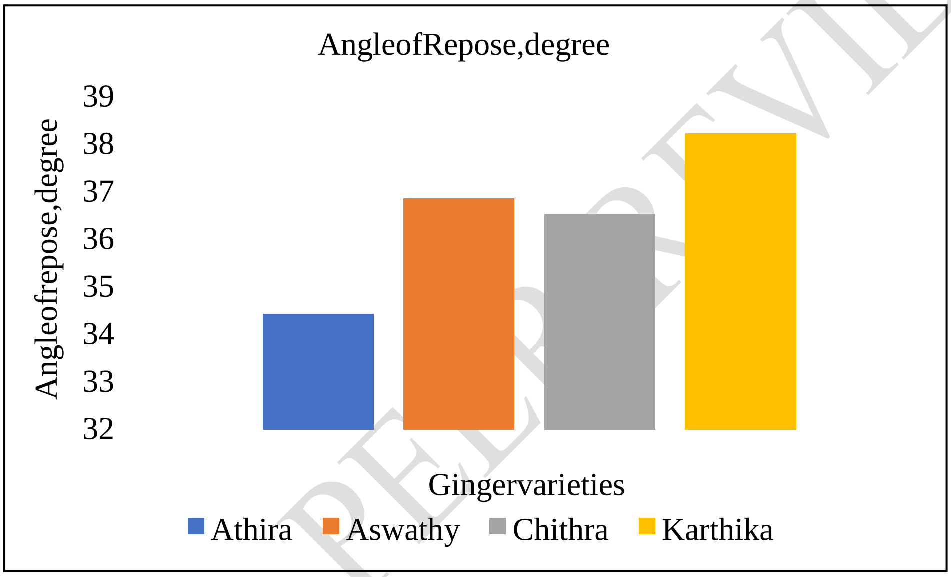


Fig.10 effectofginger varieties on angleofrepose

4. Conclusion

Thestudyexaminedvariousphysicalattributesofdifferentgingervarieties,includingtheiraxial dimensions(length,width,andthickness),geometricmean,sphericity,bulkdensity,bulkvolume,surfacearea,angleofrepose,andcoefficientoffriction.Thesepropertiesplayacrucialrole 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,ascommonlyobservedinbiomaterials.Basedontheresearchfindings,thefollowingconclusionsweredrawn.

1. Physical properties of seeds are determined as a function of different ginger varietiesvariedsignificantly withgingervarieties.

2. The axial dimensions, geometric mean diameter, angle of repose, surface area, bulkdensity, coefficient of friction, sphericity showed an ascending and descending orderwithdifferentvarietiesofginger.Thesepropertieswouldprovideimportantandessentialdata for efficient design process.
3. The coefficient of friction varies from one variety to another variety of ginger and theobserved values for athira variety were 0.58, 0.52, and 0.48 for wood, mild steel andstainless-steelsurfacematerials.Theobservedvaluesforaswathy,chithraandkarthikawere 0.6, 0.58, 0.5; 0.54, 0.51, 0.46 and 0.59, 0.53, 0.45 for wood, mild steel and stainlesssteel surfacematerials.

5. REFERENCES

Adejumo,O.I.(2003).PhysicalPropertiesofNeemSeeds.LandzunJournalofEngineeringandAppropriateTechnology, 1(2), 68-77

Asoiro, F. U. and Anthony, O. A. (2011). Determination of some Physical Properties ofAfrican Yam Beans. The Pacific Journal of Science and Technology, Volume 12:Number1.Also available onlinehttp://www.akamaiuniversity.us/PJST.htm

Bamgboye, A.I,. and Adejumo, O.I,. (2009). Physical Properties of Roselle (Hibiscussabdariffa)Seed.AgriculturalEngineeringInternational:theCIGREjournal. Manuscript1154. Vol.XI

Dutta, S.K., Nema, V.K, and Bhardwaji, R.K. (1998). Physical properties of Sainfoin(Onobrychis sativa Lam.), Grasspea (Lathyrus sativus L.) and Bitter Vetch (Viciaervilia)Seeds. Journal ofApplied Science, 6(6): 1373-1379

Jayan,P.R.andKumar,V.J.F.(2004).PlanterdesigninrelationtothePhysicalPropertiesofseeds. Journal of Tropical Agriculture. 42(1-2): 69-71.

Kandiannan, K., Sasikumar, B., Thankamani, Suseela Bhai, R., Santhosh, C. K., Eapen, J.,Devasahayam. S., and John Zachariah, T. (2008). Turmeric (Extension Pamphlet).Indian Institute ofSpiceResearch. Calicut.

Mohsenin, N. N. (1986). Engineering Properties of Plants and Animal Materials. GordonandBreach Sciencepublishers, New York, London. 2nd Edition.

Nelkon,M.(2005).PrinciplesofPhysicsforSeniorSecondarySchools.6thEd.,HeinemannLondon, London.

Olaoye, J. O. (2000). Some Physical Properties of Castor Nut Relevant to the Design ofProcessing Equipment. Journal of Agricultural Engineering Research. Vol. 77(1),113-118

Oje, K. and Ugbor, E. C. (1991). Some Physical Properties of Oil bean Seeds. Journal ofAgriculturalEngineeringResearch.Vol. 50: 305-313

Pradhan, R. C., S. N. Naik, N. Bhatnagar and S.K. Swain (2008). Moisture-dependentphysical properties of Karanja (Pongamia pinnata) kernel. Ind. Crops.Products.,28(2):155-161