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Physical and Mechanical Properties of Garlic Bulbs and Cloves (*Allium sativum* L.) Relevant to Development of Garlic Bulb Breaker

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ABSTRACT: *Garlic (*Allium sativum*) is one of the important bulb crops grown and used as a spice in culinary ingredient as it adds to the taste and flavour in a wide range of food preparations. It also has medicinal properties. Garlic cloves are processed in the form of dehydrated products like flakes, powder, pickles paste, canned and bottled. Processed products of garlic are in good demand in local market for defense and fast food industries and also exported to exotic markets to earn valuable foreign exchange. Garlic is propagated by single clove. For these reasons, garlic bulbs are broken and loosened into garlic cloves. Conventionally, garlic cloves are separated by rubbing the bulb between palms, against jute bags or by beating with a wooden stick. As these methods are very laborious and time consuming, machinery are being developed to break the whole garlic into single cloves. Knowledge of physical, mechanical and mechanical properties of garlic bulb and garlic clove are very important for development of machinery. Hence, study was conducted to determine physical, mechanical and aerodynamic properties at 60.92 per cent moisture content on dry basis. These properties namely polar diameter, equatorial diameter, thickness, geometric mean diameter, shape index, weight of garlic bulbs, bulk density, true density, porosity, angle of repose were found to be 61.25±1.43 mm, 43.21±0.83 mm, 36.00±0.85 mm, 45.70±0.86 mm, 0.74±0.01, 3065.59±0.97 g, 453.5±20.7 kg/m^3, 988.08±20.7 kg/m^3, 53.99±2.40 per cent and 54.16±3.85° for garlic bulbs. The co-efficient of static friction on different surfaces of materials like plywood, glass sheet and mild steel sheet for garlic bulbs were found to be 0.454±0.40, 0.321±0.28 and 0.387±0.34. The force required to loosen the garlic cloves from the whole bulb was 40.15±0.1 N. The physical, mechanical and aerodynamic properties of garlic cloves viz., length, width, thickness, geometric mean diameter, sphericity, weight of hundred garlic cloves, bulk density, true density, porosity, and angle of repose were 27.3±1.92 mm, 10.18±0.35 mm, 7.42±0.24 mm, 12.55±0.04 mm, 0.45± 0.001, 181.1±0.2 g, 424.94±7.23 kg/m^3, 1516.22± 23.22 kg/m^3, 59.02±6.09 per cent and 38.40±3.78°. The co-efficient of static friction on different surfaces of materials like plywood, glass sheet and mild steel sheet were found to be 469±0.006, 0.364±0.003 and 0.394±0.004 for garlic cloves. The terminal velocity of garlic cloves, stems and skins were 11± 0.69, 4.26±0.56 and 1.32±0.42 m/s.*

Key words: *Garlic bulbs, Garlic cloves, Mechanical properties, Physical properties,*

INTRODUCTION

Garlic *(Allium sativum* L.,), the spice of human life, is one of the important perennial bulb crops of the lily family (Liliaceae) grown and used widely as a spice or condiment in many parts of the world. It has been cultivated for centuries all over the world on account of its culinary and medicinal properties (Baruchin *et al.*, 2001; Sharma and Prasad, 2001). Garlic bulbs are valued for their flavor and command an extensive commercial importance because of their medicinal value and application in food and pharmaceutical preparations. As a classic ingredient in pickles, chutney, curries powder, curried vegetables, meat preparations etc., garlic has a powerful aroma and pungent taste. The use of garlic as condiment, garlic oil as insecticide, garlic paste as biofungicide, garlic residue with antibacterial properties, garlic as medicine including use for cancer treatment and in human nutrition are well recognized (NHRDF, 2001). Garlic bulbs can be used not only to flavor curries but can be used for drinks and savory deserts. It is also used in processed forms e.g. essential oil, powder, oil macerate, aged extract, paste, pickles etc.

Garlic has higher nutritive value than other bulb crops. It is rich in proteins, phosphorous, potassium,

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calcium, magnesium and carbohydrates. Ascorbic acid content is very high in green garlic. Garlic is processed in the form of dehydrated products like flakes, powder, pickles paste, canned and bottled. Processed products of garlic are in good demand in local market for defense and fast food industries and also exported to exotic markets to earn valuable foreign exchange. Thus, there is a steady demand for garlic not only in India, but also throughout the world. Garlic production might be increased by increasing the area with good variety and changing the existing management practices. Through improved seed production, both yield and quality can be improved, to fetch higher prices in the market. Therefore, there is a need to increase the supply of quality clove to increase the productivity. The garlic is propagated by single clove. Bulbils produced in some varieties are also used as a planting material.

Cloves of 8-10 mm diameter since gives increased yield of better quality bulbs. To design and develop some specific crop production and processing equipments and provide facilities for planting, handling, storing, aeration, drying, bulb breaking, peeling and other unit operations of garlic processing, engineering properties are essential. Therefore, there is a need to determine engineering properties of garlic for promoting better utilization of garlic and its products. In view of this, the present study was undertaken to establish some engineering properties of garlic.

Knowledge of length, width, volume, surface area and weight of the product is necessary to: (a) the design of sorting and grading machines (b) predicting amounts of surface applied chemicals and (c) describing heat and mass transfer during thermal processes and in quantification of bruise, abrasion and damage in handling process. Many researches were carried out on the physical and engineering properties of many agricultural products (Irvine, Jayas, White and Britton, 1992; and El-Raie, Hendawy and Taib,1996, Bahnasawy et al., 2004). The information on size, density and crushing strength are required for the development of grading system for barriers and for the pulpers (Gosh, 1969). The physical and mechanical properties such as size, friction angle, angle of repose, crushing strength and bulk density are important in the design of the handling system and grading (Chandrasekar and Viswanathan, (1999). Abd Alla, Radwan and El-Hanfy (1995) reported that the shape index and coefficient of contact surface had a high significant effect on the rupture force and broken percentage in milling process of rice grains.

Haciseferogullari *et al., (*2004) studied some technological properties of garlic using 10 repetitions at a moisture content of 66.32% (d.b.). They have reported that the mean mass and mass weight of 1000 garlic segment, length of segment, diameter of whole garlic, geometric mean diameter, sphericity, projected area, volume, bulk density, porosity and hardness of segments were measured as 32.81 g, 2383.8 g, 27.24 mm, 46.51 mm, 15.15 mm, 0.559, 4.54 cm^2, 2245.64 mm^3, 478.75 kg/m^3, 54.16% and 13.78 N respectively. Also static and dynamic coefficients of friction for garlic segments were established on a galvanized sheet, iron steel and plywood. These values for static and dynamic coefficients were found as 0.416-0.352, 0.472-0.406 and 0.541-0.481 respectively.

Physical characteristics of agricultural products are the most important parameters to determine the proper standards of design of cultivation, grading, conveying, processing and packaging systems (Tabatabaeefar and Rajabipour, 2005).

Bahnasawy (2007) studied few selected physical, chemical and mechanical properties of the garlic. He reported that the crushing load of the cloves ranged from 55.6 to155 N, depending on the bulb size. The force required for loosening the cloves from the bulb ranged from 110 to 272 N and 101 to 320 N on the horizontal and vertical positions of the bulbs.

Manjunatha. *et al.,* (2008) estimated the physical properties of garlic at 40.50% moisture content on wet basis namely shape by comparison with the standard chart as suggested by Mohension (1986). He found that the terminal velocity, angle of repose, specific gravity, compressive and shear forces of garlic segment increased from 7.18 to 12.24 m/s, 25.53 to 37.50 degree, 0.90 to 0.97, 2.25 to 10.70 kg and 1.75 to 2.83 kg respectively, while bulk density decreased from 483.10 to 449.76 kg/m^3. The static coefficient of friction increased on three surfaces, namely, teak wood (0.46 to 0.53), aluminum (0.38 to 0.48) and mild steel (0.34 to 0.41) with increase in moisture content from 23.05 to 40.50% (w.b.).

Lack of basic engineering properties of this planting material is an identified problem in the development of new methods of sowing of garlic crop, development of new equipment for processing and control strategies for crop storage. So that, the main objective of this work was to study the physical, mechanical and aerodynamic properties of garlic bulbs and cloves. These properties include: linear dimensions, shape index, geometric mean diameter, arithmetic mean diameter, frontal surface area, cross-sectional of area, volume, mass, bulk density, static

friction coefficient, rolling angle, crushing load and force required to loosening the cloves from the whole bulb. The knowledge of these properties will be useful in design and development of machinery agricultural processing.

EXPERIMENTAL PROCEDURE

Good quality garlic bulbs were procured from a local market, Bangalore rural district for conducting the laboratory experiments. Procured garlic bulbs were kept in the trays for free movement of air to avoid the possible moisture migration into the bulbs which leads to spoilage of the bulbs. These garlic bulbs (Fig. 1) were used to determine the physical, mechanical and aerodynamic properties.

Figure 1: Garlic bulbs

PHYSICAL PROPERTIES

Linear dimensions

One hundred garlic bulbs and cloves were randomly picked and their linear dimensions were measured using a digital vernier caliper (Model CD-6BS-Mitutoyo Corporation, Japan) with an accuracy of ± 0.01 mm. In case of garlic bulbs there are two categories of garlic bulb diameter: polar diameter and equatorial diameter. Polar diameter is the distance between the garlic crown and the point of root attachment to the garlic. Equatorial diameter is the maximum width of the garlic in a plane perpendicular to the polar diameter. The equatorial diameter (D_e), polar diameter (D_p) and thickness (T) were measured. In case of garlic cloves the major dimensions length (l), width (b) and thickness (t) were measured (Bahnasawy, 2007; Haydar, 2005).

Geometric mean diameter

The geometric mean diameter (D) of the garlic bulb was calculated by using the following formula.

$$D = (D_e D_p T)^{1/3} \quad \text{... (1)}$$

Where,

D_e - equatorial diameter, mm

D_p - polar diameter, mm

T - thickness, mm

The geometric mean diameter (D) of the garlic cloves was calculated by using the following formula (Mohsenin, 1970).

$$D = (lbt)^{S!} \quad \text{... (2)}$$

Where,

l = length, mm

b = breadth, mm

t = thickness, mm

Shape index

Shape index is used to evaluate the shape of the garlic bulbs and cloves. It is calculated according to the following equation (Abd Alla, 1993):

$$\text{Shape Index} = D_e / \sqrt{D_p * T} \quad \text{... (3)}$$

Where,

D_e = Equatorial diameter, mm

D_p = Polar diameter, mm

T = Thickness, mm

The garlic bulb/clove is considered an oval if the shape index $\wp$1.5, on the other hand, it is considered spherical if the shape index <1.5.

Sphericity

Sphericity (S) of the garlic cloves/clove was calculated by using the following formula (Mohsenin, 1970).

$$S = \frac{(lbt)^{*}}{l} \quad \text{... (4)}$$

Where,

l = length, mm

b = breadth, mm

t = thickness, mm

One hundred garlic bulbs and hundred garlic cloves weight

One hundred garlic bulbs and one hundred garlic cloves were randomly selected and weighed using an electronic balance (Model PS200/2000/C/2 – RADWAG, Poland) with an accuracy of ± 0.001 g. This procedure was repeated for five times.

Bulk Density

The samples of garlic bulbs and cloves were filled into a container of standard size 100 × 100 × 100 mm up to the top level. The excess samples were removed so that the top surface was perfectly level and even. The garlic bulbs and cloves were not compressed in any way. Then the samples in the container were weighed by using an electronic balance (Mohsenin 1970). The bulk density was calculated by using following formula. This procedure was replicated for five times.

$$\text{Bulk density (kg/m}^3\text{)} = \frac{\text{Weight of sample in container (kg)}}{\text{Volume of container (m}^3\text{)}} \quad \text{... (5)}$$

True density

The true density of garlic bulb and cloves were measured by using liquid displacement method. Toluene (C_7H_8) was used instead of water because it was absorbed by the sample to a lesser extent (Mohsenin, 1970; Sitkei, 1976; Singh & Goswami, 1996). Three hundred ml of toluene was taken in a 500 ml measuring jar. Twenty numbers of garlic bulbs were weighed individually and were dropped one by one into the jar. The change in the level of toluene in the jar was recorded. In case of cloves fifteen ml of toluene was taken in 25 ml measuring jar. Twenty numbers of garlic cloves were weighed individually and were dropped one by one into the jar. The change in the level of toluene in the jar was recorded. The true densities of the samples were calculated using the formula. This procedure was repeated for five times.

$$\text{True volume of bulb/clove (ml)} = \left\{\text{Final toluene level in measuring jar}\right\} - \left\{\text{Initial toluene level in measuring jar}\right\} \quad \text{... (6)}$$

$$\text{True density (kg/m}^3\text{)} = \frac{\text{Weight of bulb/clove}}{\text{True volume of bulb/clove}} \quad \text{... (7)}$$

Porosity

The porosity is also known as the packing factor and it was determined from bulk density and true density of sample. The porosity was calculated by using the following expression (Mohsenin, 1970).

$$\text{Porosity (\%)} = \frac{\text{True density} - \text{Bulk density}}{\text{True density}} \times 100 \quad \text{... (8)}$$

MECHANICAL PROPERTIES

Angle of repose

The angle of repose is the angle between the base and the slope of the cone formed on a free vertical fall of the granular material to a horizontal plane. The dynamic angle of repose of garlic bulb and cloves were measured by the 'emptying method'. A metal container having 125 mm length, 125 mm width and 200 mm height was used to determine the dynamic angle of repose of garlic bulbs /cloves. A removable front panel with 200 mm height and 125 mm width was used to release the material sideways. The container was filled with the garlic sets leveled and then the front panel was quickly slide upwards allowing the garlic bulbs/cloves to flow out. The angle of repose was calculated from the movement of the maximum depth of the free surface of the sample and length of the box. The procedure was replicated five times with different samples and the mean was calculated.

$$\text{Angle of repose } (\theta) = \tan^{-1}\frac{H}{L} \quad \text{... (9)}$$

Where,

θ - Angle of repose, ^{o}

H - Height of the sample, m

L - Length of sample, mm

Co-efficient of static friction

The coefficient of static friction (μ_s) of garlic bulb and cloves were determined by inclined plane method. The test surfaces used were plywood, mild steel and glass. The samples were placed on the test surface at the top edge. The inclined surface was tilted until the samples begin to move leaving an inclined surface. The angle of inclination with the horizontal was measured by a scale provided and taken as an angle of internal friction and tangent of the angle was taken as co-efficient of friction between surface and sample (Mohsenin, 1970).

$$\mu_s = \tan\theta \quad (10)$$

Where,

μ_s – Co-efficient of static friction,

θ - Angle of inclination of material surface, ^{o}

Force required for loosening the cloves form the whole garlic bulb

The force required for loosening the cloves form the whole garlic bulb was determined by using the texture analyzer instrument. Individual garlic bulbs were placed on the flat stationery lower platform and load was applied by a moving upper head until the garlic cloves got loosened from the bulb. Then the load was recorded. The procedure was repeated for ten times.

AERODYNAMIC PROPERTIES

Terminal velocity

Terminal velocities of garlic clove, stem and skin were measured by using an air column system. For each experiment, a sample was dropped into the air stream from the top of the air column, up from which air was blown to suspend the material in the air stream. The air velocities near the location of the garlic clove, stem and skin suspension were measured by a hot wire anemometer having a least count of 0.01 m/s. The procedure was repeated for five times.

RESULTS AND DISCUSSION

Physical properties

Polar diameter, equatorial diameter and geometric mean diameter

Table 1 shows the mean values (mean±SD) values, SEM and 98% confidential limit of the Polar diameter, equatorial diameter and geometric mean diameter of the garlic bulbs. The average polar diameter, equatorial diameter and geometric mean diameter of the garlic bulbs were found to be 61.25±1.431mm, 43.21±0.8345 mm and 45.697±0.8561 mm.

Length, width and thickness of garlic cloves

Table 1 shows the mean values (mean±SD) values, SEM and 98% confidential limit of the length, width and thickness of the garlic cloves. The average length, width and thickness of the garlic cloves were found to be 27.3±1.92 mm, 10.18±0.352 mm and 7.42±0.235 mm.

Table 1
Physical and mechanical properties of garlic bulbs and cloves

	Garlic bulb			*Garlic clove*		
Property	*Mean*	*Standard error of mean*	*95 per cent confidence limit*	*Mean*	*Standard error of mean*	*95 per cent confidence limit*
Moisture content (d. b)	60.92	0.65	60.92 ± 1.28	59.36	0.68	59.36 ± 1.33
Polar diameter/Length, mm	61.25	0.73	61.25 ± 1.43	27.3	0.98	27.3 ± 1.92
Equatorial diameter/Width, mm	43.21	0.42	43.21 ± 0.83	10.18	0.18	10.18 ± 0.35
Thickness, mm	41.21	0.43	41.21 ± 0.85	7.42	0.12	7.42 ± 0.23
Geometric mean diameter, mm	45.69	0.43	45.69 ± 0.85	12.55	0.01	12.55 ± 0.03
Sphericity/Shape index	0.74	0.01	0.74 ± 0.01	0.45	0.01	0.45 ± 0.001
Weight, g	3065.59	0.49	3065.59 ± 0.97	181.1	0.03	181.1 ± 0.2
Bulk density, kg/m^3	453.5	10.56	453.50 ± 20.7	424.94	3.69	424.94 ± 7.23
True density, kg/m^3	988.08	10.56	988.08 ± 20.7	1516.22	11.84	1516.22 ± 23.22
Porosity, %	53.99	1.22	53.99 ± 2.40	59.02	3.11	59.02 ± 6.09
Angle of repose, degree	54.16	1.96	54.16 ± 3.84	38.40	1.93	38.402 ± 3.78

Table 2
Co-efficient of static friction of garlic bulbs and cloves

	Bulb			*Clove*		
Friction surface	*Mean*	*Standard error mean*	*95 per cent confidence limit*	*Mean*	*Standard error of mean*	*95 per cent confidence limit*
Ply wood	0.45	0.20	0.45 ± 0.39	0.46	0.003	0.46 ± 0.005
Glass	0.32	0.14	0.32 ± 0.28	0.36	0.001	0.36 ± 0.002
Mild steel sheet	0.38	0.17	0.38 ± 0.33	0.39	0.002	0.39 ± 0.004

Table 3
Mechanical property of garlic bulb

Property	*Mean (N)*	*Standard error of mean*	*95per cent confidence limit*
Force required to loosen the garlic cloves from whole bulb	40.70	1.56	40.70 ± 3.05

Table 4
Terminal velocities of garlic cloves, stems and skins

Type of material	*Mean (m/s)*	*Standard error of mean*	*95per cent confidence limit*
Cloves	11.00	0.35	11 ± 0.69
Stems	4.26	0.28	4.26 ± 0.56
Skins	1.32	0.21	1.32 ± 0.41

Shape index/sphericity, weight, bulk density, true density and porosity

Table 1 shows the mean values (mean±SD) values, SEM and 98% confidential limit of the shape index/ sphericity, weight, bulk density, true density and porosity of the garlic bulb and garlic cloves. The shape index, weight of hundred garlic bulb, bulk density, true density and porosity of the garlic bulb were found to be 0.74±0.0123, 3065.59±0.9 g, 453.5±20.7 kg/m^3, 988.08±20.7 kg/m^3 and 53.99±2.402. The sphericity, weight of hundred garlic cloves, bulk density, true density and porosity of the garlic cloves were found to be 0.45±0.001, 181.1±0.2 g, 424.94±7.23 kg/m^3, 1516.22±23.22 kg/m^3 and 59.02±6.09.

MECHANICAL PROPERTIES

Angle of repose, Coefficient of contact surfaces and force required loosening the cloves from the whole bulb

Table 1 shows the mean, SEM and 98% confidential limit angle of repose and coefficient of contact surface of garlic bulbs and garlic cloves. The angle of repose of garlic bulbs and garlic cloves were found to be 54.16 ± 3.85°-and 38.40 ± 3.78° respectively. The co-efficient of static friction on different surfaces of materials like plywood, glass sheet and mild steel sheet were found to be 0.454 ± 0.40, 0.321 ± 0.28 and 0.387 ± 0.34 for garlic bulbs, 0.469 ± 0.006, 0.364 ± 0.003 and 0.394 ± 0.004 for garlic cloves respectively (Table 2). The force required to loosen the garlic cloves from the whole bulb was found to be 4.15 ±0.1 kg/cm^2 (Table 3). The terminal velocity of garlic clove, stem and skin fraction were found to be 11.00 m/s, 4.26 m/s and 1.32 m/s respectively (Table 4)

CONCLUSIONS

This work focuses on some physical, mechanical and aerodynamic properties of the garlic bulbs and cloves which will be useful for design and development of planting, grading, garlic bulb breaking, garlic clove peeling and any other handling and processing machinery for garlic. The following conclusions were drawn:

(1) The average polar diameter, equatorial diameter and geometric mean diameter of the garlic bulbs were found to be 61.25±1.431mm, 43.21±0.8345 mm and 45.697±0.8561 mm.

(2) The average length, width and thickness of the garlic cloves were found to be 27.3±1.92 mm, 10.18±0.352 mm and 7.42±0.235 mm.

(3) The shape index, weight of hundred garlic bulb, bulk density, true density and porosity of the garlic bulb were found to be 0.74±0.0123, 3065.59±0.9 g, 453.5±20.7 kg/m^3, 988.08±20.7 kg/m^3 and 53.99±2.402.

(4) The sphericity, weight of hundred garlic cloves, bulk density, true density and porosity of the garlic cloves were found to be 0.45±0.001, 181.1±0.2 g, 424.94±7.23 kg/m^3, 1516.22±23.22 kg/m^3 and 59.02±6.09

(5) The angle of repose of garlic bulbs and garlic cloves were found to be 54.16±3.85°-and 38.40±3.78° respectively.

(6) The co-efficient of static friction on different surfaces of materials like plywood, glass sheet and mild steel sheet were found to be 0.454±0.40, 0.321±0.28 and 0.387±0.34 for garlic bulbs, 0.469±0.006, 0.364±0.003 and 0.394±0.004 for garlic cloves, (Table 5) respectively.

(7) The force required to loosen the garlic cloves from the whole bulb was found to be 4.15±0.1 kg/cm^2.

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REFERENCES

Abdullah M. H. R. O., Ching P. E., and Lim T. H., (2011), Some physical properties of *parkia speciosa* seeds, *International Conference on Food Engineering and Biotechnology, IPCBEE* (9).

Aydin C., (2003), Physical properties of almond nut and kernel, *Journal of Food Engineering*, **60**: 315-320.

Bahnasawy A. H., (2007), Studies on some physical and mechanical properties of garlic, *International Journal of Food Engineering*., **3**(6):1-18.

Bahnasawy A. H., El-haddad Z. A., El-ansary M. Y., and Sorour H. M., (2004), Physical and mechanical properties of some Egyptian onion cultivars, *Journal of Food Engineering*, **62**: 255-261.

Davies R. M., (2009), Some physical properties of groundnut grains, *Research Journal of Applied Sciences*, *Engineering and Technology*, **1**(2): 10-13.

Haciseferogullari H., Musa ozcan, Fikret dimir, and Sedat Cahsir, (2004), Some nutritional and technological properties of garlic, *Journal of Food Engineering*, **68**: 463 -469.

Kushwaha H. L., Srivastava A. P., and Harpal Singh, (2007), a study on physical properties of okra pod and seed, *Journal of Agricultural Engineering*, **44** (1).

Manjunatha M., Samuel D. V. K., and Jha S. K., (2008), Studies on some engineering properties of garlic (*Allium sativum*), *Journal of Agricultural Engineering*, **45**(2): 18-23.

Masoumi A. A., Rajabipoor A., Tabil L., and Akram A. A., (2006), Studies on physical attributes of a garlic, *Journal of Agricultural Science Techno*logy, **8**: 15-23.

Tabatabaeefar A., and A. Rajabipour, (2005), Modeling the mass of apples by geometrical attributes, Scientia Horticulturae, **105**: 373-382.