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Determination of Physical and Mechanical Properties of Garlic Cloves to Develop Cup Type Metering Mechanism for Battery Operated Garlic Clove Planter

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ABSTRACT

This study was conducted to investigate the physical and mechanical properties of garlic cloves (*Allium sativum* L.). Garlic variety of G-282 was selected for the study to develop cup type clove metering mechanism for battery operated garlic clove planter. Knowledge of physical properties of garlic clove are very important for development of machinery. Hence, study was conducted to determine physical properties of garlic variety of G-282. The average length, width, thickness, geometric and arithmetic mean diameter of garlic cloves were 27.80, 12.73, 9.45, 14.96 mm and 16.66 mm^2, respectively. The average of the bulk density, sphericity, aspect ratio and surface area of garlic cloves were 481.74 kg/m^3, 0.52, 0.46 and 702.71 mm^2, respectively. The average moisture content (wb), angle of repose and coefficient of static friction were 49.03%, 41.37° and 0.32, respectively. These physical and mechanical properties of garlic are very essential for designing a garlic clove metering mechanism as well as garlic planter.

Keywords Garlic clove, Metering mechanism, Physical properties of garlic clove.

INTRODUCTION

Garlic (*Allium sativum* L.) is belongs to the Liliaceae family, widely used as food spice across the world. For many centuries various species of garlic have been used as vegetables and spices, and also as traditional medicines for the curing of various types of diseases. Recently, a lot of researches have going-on by many plant physiologists and chemists to ascertain the possibilities of medical applications of garlic plant because of its strong flavors, culinary and medicinal properties (Hacıseferoğulları *et al.* 2005). Garlic is planted by propagated vegetative with garlic cloves because it does not have any seeds. Yield, yield components and quality of garlic are affected by planting methods, cloves rates and sizes. The major problem associated with planting garlic, is the high cost in payment for employment of manpower to plant by hand. The capacity of man power is very low about 0.05 ha/man/day, and the cost for manpower planting is 11.9% of total cost of production. Masoumi *et al.* (2006) compared some physical properties of two common types of Iranian garlic cloves (white and

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pink). Results of their study showed that at different moisture range from 34.9% to 56.7% wb, the bulk density, true density and porosity of cloves were significantly affected by moisture content ($p < 0.01$). They concluded that the type of garlic had a highly significant effect on the true density and ($p<0.01$), as well as significant effect on the bulk density ($p < 0.05$). They also established the relationship between volume and dimensions of cloves using regression analysis. In a study an innovatively designed tractor-mounted, triple unit ground-wheel driven, row crop precision mechanical planter capable of planting three rows of garlic (*Allium sativum* L.) cloves on raised bed was designed, fabricated and tested by Bakhtiari and Loghavi (2009). Rathina Kumari *et al.* (2015) were conducted a study to determine physical, mechanical and aerodynamic properties of garlic bulb and cloves 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% 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 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% 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. Therefore, with respect to the statement above and due to lack of basic engineering properties for design and development of new methods and planters for sowing garlic cloves, in this study the physical properties of garlic cloves were measured, then the most suitable clove metering mechanism for planting garlic cloves was designed and developed.

MATERIALS AND METHODS

Selection of crop variety

The garlic variety of G-282 (Yamuna Safed-3) was selected for the study, which is mostly cultivated by the farmers of Rajasthan state. The garlic was randomly obtained from the bulk samples from KVK Anta, Baran and cloves separated from garlic manually and removed all foreign matter such as dust, dirt, stones, chaff and damage cloves. Before the experiments were conducted, the required quantity of the samples were placed in the laboratory for 2 hrs and allowed to equilibrate to ambient conditions. The physical properties of garlic cloves viz., average dimensions, geometric mean diameter (D_g), arithmetic mean diameter (D_a), aspect ratio (R_a), sphericity (φ), surface area (A_s) and bulk density (ρ_b) and mechanical properties such as the angle of repose and coefficient of static friction of garlic cloves were measured with known moisture content.

Physical properties of garlic cloves of variety G-282

Principle dimension of garlic cloves

The principal dimensions (L: Length, W: Width and T: Thickness) of hundred garlic cloves per replication with known moisture content were determined using a vernier digital caliper with an accuracy of 0.02 mm as shown in Fig.1.

Geometric mean diameter

The geometric mean diameter (D_g) of the garlic cloves was calculated using equation 1 (Bakhtiari and Ahmad 2015).

$$D_g = \sqrt[3]{LWT} \qquad \ldots(1)$$

Where,

L= Length of individual clove, mm

W= Width of individual clove, mm

T= Thickness of individual clove, mm

Fig. 1. Measurement of dimensions of garlic clove by using vernier caliper.

Arithmetic mean diameter

The arithmetic mean diameter (Da) of the cloves was calculated using equation 2 (Bakhtiari and Ahmad, 2015).

$$D_a = \frac{L+W+T}{3} \quad \ldots(2)$$

Where,
Da= Arithmetic mean diameter

L= Length of individual clove, mm

W= Width of individual clove, mm

T= Thickness of individual clove, mm

Aspect ratio

The aspect ratio (R_a) of cloves was calculated using equation 3 (Bakhtiari and Ahmad 2015).

$$R_a = \frac{W}{L} \quad (3)$$

Where,

Ra = Aspect ratio

W= Width of individual clove, mm

L= Length of individual clove, mm

Sphericity

The sphericity (φ) of the cloves was calculated using equation 4 (Bakhtiari and Ahmad 2015).

$$\varphi = \frac{D_g}{L} = \frac{\sqrt[3]{LWT}}{L} \quad \ldots(4)$$

Where,

φ = Sphericity

L = Average length of cloves, mm

W = Average width of cloves, mm

T = Average thickness of cloves, mm

Moisture content

The moisture content of the cloves was determined by oven dry method. Three samples of 100 g each were taken and kept in the oven at 105°C temperature for 24 hrs. Thereafter, samples were taken out and their weights were recorded by electronic balance. The moisture content was determined by the following relationship.

$$\text{Moisture content, \%} = \frac{W_1 - W_2}{W_2} \quad \text{---(5)}$$

Where,

W_1 = Weight of sample before drying, g

W_2 = Weight of sample after drying, g

Bulk density

The bulk density (ρb) of the cloves was determined using the standard test weight procedure reported by

Fig. 2. Determination of bulk density by using measuring cylinder.

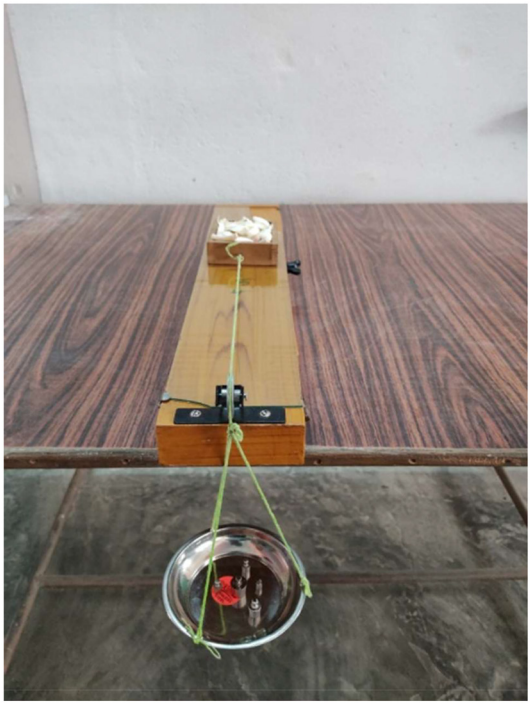

Fig. 3. Determination of coefficient of static friction.

Bakhtiari and Ahmad (2015) by filling a container of 18 cm height and 9.5 cm diameter with the garlic cloves from a height of 14.2 cm from the top surface of the container at a constant rate and then weighing the cloves as shown in Fig. 2 (equation 6).

$$\rho_b = \frac{M_S}{V_C} \qquad \text{---(6)}$$

Where,
ρb = Bulk density, kg/m^3
M_S = Total mass of the cloves in the container, kg
V_C = Volume of the container, m^3

Angle of repose

The angle of repose can be measured by measuring the height and diameter of the heap formed by the seeds (Mohsenin 1986). The apparatus was a 30 × 30 cm rectangular platform with an opening at its center mounted with a circular plate of 10 cm diameter. Beneath the platform, a funnel larger than the circular plate was installed at the same axis. A hollow rectangular block of 30 × 30 × 30 cm was placed over the rectangular platform and seeds are filled into it with a sliding door at bottom of the funnel kept closed. Height of the heap formed over the circular plate by opening the sliding door was noted using an optical scale. The angle of repose of seeds was calculated using the following expression (equation 7).

$$\theta = tan^{-1}\frac{h}{r} \qquad \text{------ (7)}$$

Where,
θ = Angle of repose, º
h = Height of heap, cm
r = Radius of a circular plate, cm

Coefficient of static friction

The box of size 95 × 78 × 25 mm was joined with a rope passing over a pulley and other end was attached to pan. The weights were added into pan until the box started to slide. The weights to slide empty and filled box were noted. The set up to determining the static friction for garlic cloves is shown in Fig. 3. The

Table 1. Linear dimensions of garlic clove variety of G-282.

	L, mm	W, mm	T, mm	Dg, mm	Da, mm^2
Average	27.80	12.73	9.45	14.96	16.66
Max	32.87	17.69	12.9	19.58	21.16
Min	21.36	9.38	5.08	10.06	11.94
SD	2.72	1.49	1.47	1.24	1.27
CV%	9.80	11.68	15.55	8.30	7.64

experiments were repeated three times and average coefficient was calculated for different materials. The following equation 8 was used to calculate coefficient of static friction (Kachru *et al.*1994).

$$\mu = \frac{W_2 - W_2}{W} \quad \text{----- (8)}$$

Where,

μ = Coefficient of internal seed friction

W_1 = Weight needed to slide empty box, g

W_2 = Weight needed to slide filled box, g

W = Weight of the material in the box, g

RESULTS AND DISCUSSION

Moisture content of garlic cloves

The average moisture content of the clove was determined as discussed in section 2.2.2. The average moisture content of garlic clove variety of G-282 was found to be 49.03%.

Physical properties of garlic cloves

Linear dimensions of clove

It is observed from Table 1 that the average length, width and thickness of cloves of variety G-282 with standard deviation (SD) were 27.8 ± 2.72, 12.73 ± 1.49 and 9.45 ± 1.47 mm, respectively. The average geometric mean diameter and arithmetic mean diameter with standard deviation were 14.96 ± 1.24 mm and 16.66 ± 1.27 mm^2, respectively. Corresponding coefficient of variation (CV) for average length, width, thickness, geometric mean diameter and arithmetic mean diameter were 9.80, 11.68, 15.55, 8.30 and 7.64%, respectively. Similar results also reported by Rathinakumari *et al.* (2015). These linear dimensions of cloves were considered for designing the cup size of clove metering mechanism.

Table 2. Sphericity, aspect ratio and surface area of garlic clove variety of G-282.

	Sphericity	Aspect ratio	Surface area, mm^2
Average	0.52	0.46	702.71
Max	0.67	0.54	1204.44
Min	0.41	0.44	317.88
SD	0.05	0.06	117.26
CV%	9.31	13.72	16.69

Sphericity, aspect ratio and surface area of garlic clove variety of G-282

The average value of sphericity for garlic cloves of variety of G-282 was determined to define the curvature of the cup to hold the clove before dropping into the seed tube. The sphericity was found from length, width and thickness of respective cloves. The shape of the cloves following the sphericity indicates that the garlic clove was peculiar. Sphericity affects the smoothness of flow. Round seeds ensure the free flowing on seed tubes by intermittent rolling whereas, Oval seeds also possess good rolling action but not as good as round seeds. Sphericity also influences the loading of a cup in the clove metering mechanism.

Table 2 shows the average value of sphericity for G-282 variety with corresponding standard deviation was found to be 0.52±0.05 and CV was 9.31 %. The obtained value of sphericity was similar to that value reported by Rathinakumari *et al.* (2015).

The average value of the aspect ratio of garlic cloves of variety of G-282 was found to be 0.46±0.06 with the corresponding CV was 13.72 %. This aspect ratio value is very useful in designing hopper of sowing and planting machines. Similar results were found by Bakhtiari and Ahmad (2005) i.e. aspect ratio of garlic cloves ranges from 0.67 to 0.69 for Iranian garlic.

Table 3. Bulk density of garlic clove variety of G-282.

	Average	Max	Min	SD	CV%
Value	481.74	484.65	478.32	2.27	0.47

The average value of the surface area was found to be 702.71±117.26 mm^2 and corresponding CV was 16.69%. Bakhtiari and Ahmad (2005) reported the surface area of Iranian garlic clove was 1875.06 mm^2, which was higher value than the obtained results this may be due to variation in size of garlic variety.

Bulk density

The bulk density of the clove was determined as discussed in section 2.2.3. Table 3 shows the average bulk density of garlic clove variety of G-282 was found to be 481.74±2.7 kg/m^3, whereas corresponding CV was 0.47 %. The similar results were reported by Bakhtiari and Ahmad (2005) and Rathinakumari *et al.* (2015). By considering these bulk density values of garlic cloves the capacity of clove hopper was designed.

Mechanical properties of garlic cloves

Angle of repose of garlic clove variety of G-282

The angle of repose was measured as explained in section 2.2.4 and computed. Table 4 shows the average angle of repose was found to be 41.37±1.48° and corresponding CV was 3.58%. Rathinakumari *et al.* (2015) were also reported the angle of repose of garlic clove was 38.40±3.78°, which was nearer the obtained value. For the free movement of the cloves from hopper to the metering device the inclination in the side of hopper was kept and it was greater than the maximum values of angle of repose.

Coefficient of static friction

The coefficient of static friction for garlic clove variety of G-282 was measured against four different surfaces i.e. MS sheet, GI sheet, plywood and acrylic at moisture content of 49.03% (wb) and depicted in Table 5.

Table 4. Angle of repose of garlic clove variety of G-282.

	Average	Max	Min	SD	CV%
Value	41.37°	43.50°	39.00°	1.48	3.58

Table 5. Coefficient of statistic friction of garlic variety of G-282.

	MS sheet	GI sheet	Plywood	Acrylic
Average	0.32	0.38	0.44	0.20
Max	0.35	0.41	0.48	0.23
Min	0.29	0.36	0.40	0.17
SD	0.02	0.02	0.02	0.02
CV%	6.01	4.36	5.25	9.74

Table 3 clearly shows that the average value of coefficient of friction for garlic clove variety of G-282 on MS sheet, GI sheet, plywood and acrylic surface were 0.32±0.02, 0.38 ±0.02, 0.44 ±0.02 and 0.20 ±0.02, respectively. The values of coefficient of friction was within range as reported by Rathinakumari *et al.* (2015). Therefore, MS sheet material was used in developing the hopper of the planter.

CONCLUSION

The average moisture content of the garlic clove variety of G-282 was found to be 49.03%. The average principal dimensions viz. length, width and thickness of garlic cloves with standard deviation were 27.8 ± 2.72, 12.73 ± 1.49 and 9.45 ± 1.47 mm, respectively. The average geometric mean diameter and arithmetic mean diameter with standard deviation were 14.96 ± 1.24 mm and 16.66 ± 1.27 mm^2, respectively. Corresponding coefficient of variation (CV) for average length, width, thickness, geometric mean diameter and arithmetic mean diameter were 9.80, 11.68, 15.55, 8.30 and 7.64%, respectively. The average value of sphericity with corresponding standard deviation was found to be 0.52±0.05 and CV was 9.31%. The average value of the aspect ratio of garlic cloves was found to be 0.46±0.06 with the corresponding CV was 13.72 %. This aspect ratio value is very useful in designing hopper of sowing and planting machines. The average value of the surface area was found to be 702.71±117.26 mm^2 and corresponding CV was 16.69 %. The average bulk density of garlic cloves was found to be 481.74±2.7 kg/m^3, whereas corresponding CV was 0.47%. The average angle of

repose was found to be 41.37±1.48° and corresponding CV was 3.58%. The coefficient of static friction for garlic cloves was measured against four different surfaces i.e. MS sheet, GI sheet, plywood and acrylic at moisture content of 49.03% (wb) and the average value of coefficient of friction for garlic cloves on MS sheet, GI sheet, plywood and acrylic surface were found to be 0.32 ±0.02, 0.38 ±0.02, 0.44 ±0.02 and 0.20 ±0.02, respectively.

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