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Study of Engineering Properties of N-53 Onion Bulb

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ABSTRACT: Onion is one of the most widely produced vegetables in India. It is very important to know the properties of onion bulb to understand its behavior for design and development of machinery to handle the onion bulb. In this study various engineering properties of onion bulb were studied in prospect to design of onion digger cum separator. Throughout the experiment, an onion bulb of variety N-53 was used. The physical properties were measured namely polar diameter, equatorial diameter, thickness, geometric mean diameter, sphericity, shape index, aspect ratio, surface area, frontal surface area, cross sectional area, mass of onion bulb, bulk density, true density, porosity, moisture content of onion and also mechanical properties like angle of repose and coefficient of static friction were measured. There was linear relationship obtained between geometric mean diameter and mass of onion as the GMD increases the mass of the onion increase. Obtained properties of the onion bulb are helpful to decide the separator arrangement and mechanism of onion digger.

Keywords: Onion bulb, physical properties, mechanical properties and geometric mean diameter.

INTRODUCTION

Onion (*Allium cepa* L.) is a very important and nutritive horticulture produce, it contains vitamins, proteins, carbohydrates, iron, fiber and pungency. It generally used as spices, vegetables and salad in daily life. India is the second largest producer of onion after China, produce about 26.09 million tons from 1.43 million ha area. In Chhattisgarh onion was cultivated in 2019-20 at area about 26.10 thousand hectare with production and productivity about 431.68 thousand metric tonne and 16.54 t/ha (Anonymous, 2015). Based on crop year 2019-20 Raipur, Durg, Raigarh, Kanker and Surajpur are five top onion producer districts in Chhattisgarh (Directorate of Horticulture, C.G.). Given India's diverse agro-climatic conditions, it is possible to cultivate not only a variety of crops, but also distinct types of the same crop. Engineering properties contribute in the design and development of onion digger machine equipment, as well as during onion post-harvest procedures such as grading, sorting, and packaging. The properties of onion bulb were measured by the various researches for various purposes. Physical properties of pelleted and un-pelleted onion seed of Punjab Naroya (PN) variety was determined by Gautam *et al.,* (2016). Dabhi *et al.,* (2017) determined the physical and mechanical properties of the onion crop for the *Talaja* Red variety. Khura *et al.,* (2010) conducted an experiment to investigate the biometric and mechanical parameters of the onion crop which are important to design different components of harvesting machine. Pandiselvam *et al.,* (2013) worked on frictional, mechanical and aerodynamic properties of onion seeds which were needed for design of onion umbels thresher. Similarly properties of onion bulb examine by Priya *et al.,* (2015) for designing of grading, sorting and packaging and compiled a database. With this in mind, the study's major goal was to determine physical and mechanical attributes in order to create a database for the popular onion variety N-53.

MATERIAL AND METHODS

The most popular onion cultivar, N-53, was chosen for experiment. Various physical properties onion bulb were measured in the study by using standard methodology reviewed from the other researchers. The methodology used for observation of onion bulb is described below. Total hundred samples were used to obtain mean value, standard deviation and coefficient of variation of onion bulb during measurement of linear dimensions, geometric mean diameter, arithmetic mean diameter, sphericity, shape Index, aspect ratio, area and mass of the onion bulb.

A. Linear dimensions

The linear dimension polar diameter, equatorial diameter and thickness of onion bulbs were measured for hundred randomly selected onion bulbs with the help of a digital vernier caliper having least count of ± 0.01 mm and the mean value was calculated (Sahay and Singh, 1996). Polar diameter is the distance between the onion bulb crown and the point of root attachment to the bulb (Singhal and Samuel, 2003) as shown in Fig. 1. The equatorial diameter was the maximum width of the onion in a plane perpendicular to the polar diameter, as shown in Fig. 2 and also thickness was measured shown in Fig. 3.

B. Geometric mean diameter (D_g) and Arithmetic mean diameter (D_a)

The geometric mean diameter (D_g) and arithmetic mean diameter (D_a) was calculated by using the following relationship (Mohsenin, 1986) given in Equation 1 and 2.

$$D_g = (D_p D_e T)^{1/3} \quad (1)$$

$$D_a = \frac{(D_p D_e T)}{3} \quad (2)$$

Where, D_p = Polar diameter (largest intercept length), mm; D_e = Equatorial diameter (width), mm; and T = Thickness, mm.

C. Sphericity (ϕ)

Sphericity defines the ratio of the diameter of a sphere of the same volume as that of the particle and the diameter of the smallest circumscribing sphere or generally the largest diameter of the particle (Sahay and Singh, 1996; Kaveri and Tirupathi, 2015).

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

Where, D_p = Polar diameter (largest intercept length), mm; D_e = Equatorial diameter (width), mm; and T = Thickness, mm.

D. Shape index

Shape index was used to evaluate the shape of onion bulbs and it was calculated using the following equation (AbdAlla, 1993).

$$\text{Shape Index} = \frac{D_p}{\sqrt{D_e \times T}} \quad (4)$$

Where, D_p = Polar diameter, mm; D_e= Equatorial diameter, mm; and T = Thickness, mm.

E. Aspect ratio (R_a)

The aspect ratio is defined by the ratio of width of the bulb to the length of bulb into 100. R_a of the onion bulb was determined as recommended by using Equation 5: (AbdAlla, 1993).

$$R_a = \frac{Dp}{De} \times 100 \quad (5)$$

Where, R_a = Aspect ratio, %; D_p = Polar diameter, mm; and D_e = Equatorial diameter, mm.

F. Surface area (S_a), Frontal surface (A_{fs}) and Cross sectional area (A_{cs})

Surface area is defined as the total area over the outside of the onion bulb. Surface area (S_a) of the onion bulb theoretically calculated using the Equation 6 (Bhansaway *et al.*, 2004).

It is the representation of solid object when it cut by an intersecting plane. The frontal surface area (A_{fs}) of onion bulb was determined by following Equation 7.

Cross sectional area (A_{cs}) of the object was made by a plane cutting the object transversely at right angles to the longest axis. The cross sectional area of sample was determined by following Equation 8 (Bhansaway *et al.*, 2004).

$$S = \pi \times D_g^{\,2} \quad (6)$$

$$A_{fs} = \frac{\pi}{4} D_e D_p \quad (7)$$

$$A_{cs} = \frac{\pi}{4} \frac{(D_e + D_p + T)^2}{9} \quad (8)$$

Where, D_g = Geometric mean diameter, mm; D_p = Polar diameter, mm; and D_e = Equatorial diameter, mm.

G. Mass of onion bulb

To obtain the mass, 100 selected samples of onion bulbs were weighed by using electronic balance. To predict the mass and volume of onion bulb based on physical properties linear regression relationship was established by Pearson's correlation attempt (Priya *et al.*, 2015).

H. Bulk density (b_d)

Bulk density of onion was calculated by placing the sample of onion bulbs in a square box of 200 × 200 × 200 mm (Ghaffari *et al.*, 2013; Pavani, 2017). The sample placed in the cylinder was then weighed by using electronic balance with least count of 0.001g. Bulk density was calculated by using the relationship given in Equation 9 and shown in Fig 4.

$$b_d = \frac{\text{weigth of bulb (kg)}}{\text{volume of box (m}^3)} \quad (9)$$

I. True density (ρ_t)

The true density (ρ_t) is defined as the ratio of the mass of a sample of onion bulb to the solid volume occupied by the sample. The true density of the onion bulb was determined by the toluene (C_7H_8) displacement method (Ghaffari *et al.*, 2013) in order to avoid water absorption by the sample shown in Fig 4. The true density was then calculated using the Equation 10:

$$\rho t = \frac{M}{V} \quad (10)$$

Where, M = Mass of the sample, kg; and V = Volume, m^3.

Fig. 1. Polar diameter (D_p).

Fig. 2. Equatorial diameter (D_e).

Fig. 3. Thikness **(**T**).**

J. Porosity (P)

Porosity of the bulk sample is the ratio of the volume of internal pores within the onion bulb to its bulk volume. It was calculated as the ratio of the difference in the true density and bulk density to the true density as given in Equation 11 and expressed in percentage (Mohsenin, 1970):

$$P = 1 - \frac{\rho b}{\rho t} \times 100 \qquad (11)$$

Where, P = Porosity of onion bulb, %; t = True density, kg/m^3, and ρb = Bulk density, kg/m^3.

Fig. 4. Measuring bulk density of onion bulb.

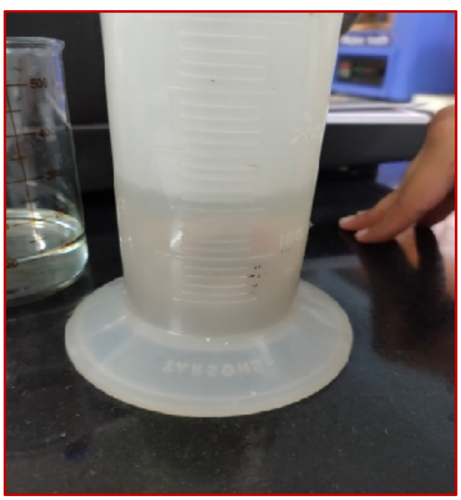

Fig. 5. Measuring true density of onion bulb by using toluene.

K. Moisture content of onion (mc)

Moisture content of the sample was determined by standard air oven method. Test sample was firstly weighted and then kept for 24 hour in hot air electric oven maintained at 105ºC. The sample was drawn from the oven and placed in a desiccator for cooling to ambient temperature. After cooling, the weight of the sample was taken precisely.

The loss in weight was determined and moisture content was calculated using the Equation 12: (Mohsenin, 1986).

$$mc(db) = \frac{w_2 - w_3}{w_3 - w_1} \qquad (12)$$

Where, mc = Moisture content on dry basis, %; w_1 = Weight of container, g; w_2= Sample weight before drying + container weight, g; and w_3= Sample weight after drying + container weight, g.

L. Angle of repose (θ)

Angle of repose is the angle between the base and the slope of the cone formed by vertical fall of granular material on a horizontal surface. The angle of repose of onion sample was calculated by using emptying method. A container having 200 mm length, 200 mm width and 200 mm height was used to determine the angle of repose of onion bulbs. A removable front panel was used to release the material. The samples were filled in the angle of repose instrument by lifting the sliding door of instrument one side of the onions was dropped. The height of remaining sample in the container was measured by scale. The angle of repose was calculated by using the Equation 13 (Rathinakumari and Jesudas 2015).

$$\text{Angle of repose } (\theta) = \tan^{-1}\frac{H}{L} \qquad (13)$$

Where, θ = Angle of repose, degree; H = Height of the remaining sample, mm; and L = Length of sample, mm.

M. Coefficient of static friction

Angle of rolling resistance of onion bulb was measured on mild steel surface by inclined plane method (Khura *et al*., 2011; Ghaffari *et al*., 2013). The onion bulb was kept horizontal on the plate of the instrument and the slope was gradually increased. The angle at which impending slip occurred was measured. The value of coefficient of static friction was used to decide the inclination of rods of soil separator and calculated by using Equation 14:

$$\text{Coefficient of static friction} = \tan ø \qquad (14)$$

Where, ø = Angle of rolling resistance.

Four different materials *viz.* glass, steel, rubber and plywood surfaces were selected the experiment. The experiment was replicated twenty times and the mean value of ø for onion bulb was determined for calculation of coefficient of static friction.

RESULTS AND DISCUSSION

A. Linear dimensions

Polar diameter, equatorial diameter and thickness of the onion bulb were measured by taking 100 samples. Polar diameter was varied as per shape and size of the onion and average was observed to be 51.60±1.16 mm with SD and CV(%) about 5.90 and 11.43, respectively.

Similar results were also reported by Pavani *et al.*, (2017) for *bhimasuper* variety. In another study on *red*, *white* and *yellow* onion bulbs also reported similar results (Ghaffari *et al*., 2013). The average equatorial diameter of the onion bulb was obtained to be 47.93±1.23 mm with SD and CV(%) about 6.26 and 13.06, respectively. Similar results were also reported by Khura *et al.*, (2011); Ghaffari *et al*., (2013). Thickness of the selected onion samples were also measured and average thickness of the onion bulb was found to be 37.33±0.74 mm with SD and CV(%) about 3.80 and 10.18, respectively.

B. Geometric mean diameter (D_g)

The obtained data of polar diameter, equatorial diameter and thickness were used to determine geometric mean diameter of the onion bulb. It defines the overall diameter of the onion bulb. Geometric mean diameter of the onion bulb was measured to be 45.11±0.85 mm with SD and CV (%) about 4.34 and 9.63, respectively. Similar result obtained by Ghaffari *et al*., (2013); Pavani *et al*., (2017). Geometric mean diameter would be helpful to determine spacing between separator rods of onion separator.

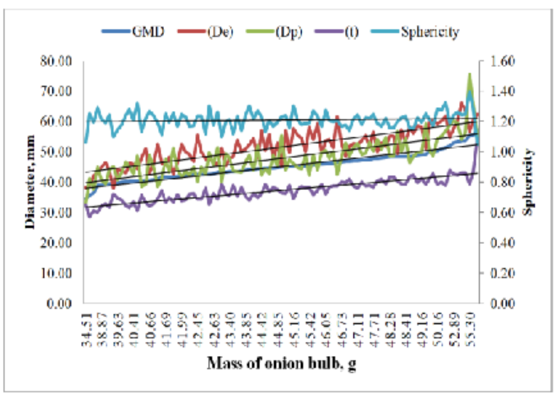

Fig. 6. Physical properties of onion bulb (Geometric mean diameter, equatorial diameter, polar diameter, thickness and shpericity) with mass.

C. Sphericity (Φ), Shape Index (S_i) and Aspect ratio (R_a)

The sphericity was 1.2±0.01 with SD and CV(%) about 0.06 and 4.70, respectively. To find out the shape of the onion bulb sphericity and shape Index were observed. The shape Index was obtained was 1.23±0.02 with SD and CV(%) about 0.12 and 9.46, respectively. Aspect ratio of the onion bulb was measured by taking 100 samples. It was varies with the different shape and size of the onion and average aspect ratio was observed to be 1.09±0.03 mm with SD and CV(%) about 0.14 and 12.85, respectively. Based on obtained data onion bulb was considered spherical because its shape Index was <1.5 (Bahnasawy *et al.*, 2004). Pavani *et al.*, (2017) was reported similar sphericity of about 1.0±0.01 for *bhima super* variety. Similar results were also reported for shape index about 1.22 (Khura *et al.*, 2011) and 1.27 (Kaveri and Thirupathi, 2015).

D. Surface area (S_a), Frontal surface area (A_{fs}) and Cross sectional area (A_{cs})

Surface area of the onion bulb was evaluated to know the exposer area of the onion bulb. Surface area of the onion bulb was measured to be 1965.96±80.27 mm^2 with SD and CV(%) about 409.55 and 20.83, respectively. Frontal surface area of the onion bulb was measured to be 7814.06±319.06 mm^2 with SD and CV(%) about 1627.85 and 20.83, respectively. Cross sectional area of the onion bulb was measured to be 1649.11±63.51 mm^2 with SD and CV(%) about 324.05 and 19.65, respectively.

E. Mass of onion bulb

The mass of the onion bulb is important to calculate bulk density, true density and mass of onion facing by the machine component (like separator) during digging operation. Average mass of onion bulb was measured to be 42.74 ± 1.108 g with SD and CV (%) about 5.52 and 12.92, respectively.

F. Bulk and true density

Bulk density of the onion bulb was measured to identify the volume and mass of the material controlled by separator. Bulk density of the onion bulb was measured by using metallic box of dimension 200×200×200 mm. Bulk density of the onion bulb was obtained 597.54±13.52 kg/m^3 with SD and CV(%) about 30.86 and 0.05, respectively. The true density of the onion bulb was determined about 899.72 ± 29.80 kg/m^3 by toluene displacement method with SD and CV(%) about 67.99 and 0.08, respectively. Similar results were found for *Talaja red* onion (Dabhi and Patel, 2017).

G. Porosity and Moisture content

Porosity of the onion bulb was determined about 33.27±2.49% by toluene displacement method with SD and CV (%) about 5.67 and 0.17, respectively. Oven drying method was used to determine the moisture content of the onion bulb on wet basis. Moisture content of the onion bulb was obtained 83.09±0.55% with SD and CV(%) about 2.80 and 0.03, respectively.

H. Relationship between equatorial diameter (D_e), polar diameter (D_p) and volume of the onion bulb (V_o)

To predict the volume of the onion bulb based on equatorial diameter and polar diameter of onion bulb, Pearson's correlation attempted and a relationship was achieved on given in equation 15. In a physical object, size and shape are closely linked, and both are required to represent the irregular shape of fruits and vegetables. The shape index of onion bulbs was discovered by AbdAlla (1993) using the polar and equatorial diameters. In predicting the shrinkage of onions during storage, volume change is also a significant metric. The independent values of the polar and equatorial diameters of onions bulbs are related to forecast volume (Griffiths and Smith, 1964).

$$V_o = 0.47D_p + 0.45D \text{ , } R^2=0.99 \quad (15)$$

I. Relationship between geometric mean diameter, surface area and mass of onion bulb (M_o)

To predict the mass of the onion bulb based on geometric mean diameter and surface area of onion bulb, Pearson's correlation attempted and relationship was achieved on given in equation 16. In studies including spray coverage, residue removal, respiration rate, light reflection, and colour, the mass of onions bulbs is an essential quality metric, and the surface areas of fruits and vegetables are also important (Mohsenin, 1970).

$$M_o = 0.82D_g + 0.0029S_a, \; R^2 = 0.99 \qquad (16)$$

J. Angle of repose and Coefficient of static friction

Angle of repose was measured by emptying box method. Angle of repose of the onion bulb was obtained 41.35°±0.79° with SD and CV(%) about 1.79 and 0.04, respectively It was observed the inclination should be always lesser than around 41.35°. Similar results of angle of repose was obtained 43.6±2.904° for *Bhima super* variety (Pavani *et al*., 2017).

Inclined plate method was used to determine the coefficient of static friction of onion bulb by using different material's surface. Average coefficient of static friction of the onion bulb in various material surfaces was obtained to be 0.38±0.020, 0.40±0.018, 0.46±0.014 and 0.38±0.014 for glass, steel, rubber and plywood surfaces, respectively. Similar results of coefficient of friction for galvanized iron, mild steel, aluminum and plywood was found 0.42, 0.39, 0.45 and 0.32 respectively of *Talaja red* onion (Dabhi and Patel, 2017).

CONCLUSION

The engineering properties of onion bulb (N-53 variety) were measured by standard methodology. The geometric properties of onion bulb mainly depend on the linear dimension (equatorial diameter, polar diameter and thickness). The average angle of repose of the onion bulb was found 41.35±0.79°, and coefficient of static friction for steel material was determined 0.40±0.018. The sphericity and shape index of onion bulb were 1.2±0.01 and 1.23±0.02, respectively. The shape of onion bulb was observed spherical. The relationship was determined to predict the volume and mass of onion with R^2 = 0.99 for both the equations. These measured parameters would be helpful to design the various components of onion digger like conveyor, separator and other handling machinery. The geometric mean diameter of the onion bulb would be helpful to decide spacing between two rods of separator, whereas the bulk density and true density of onion bulb were helpful to decide the handled dugout material during separation.

Conflict of Interest. None.

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