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Studies on engineering properties of onion crop for designing an onion stem and root cutter cum sorting machine

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Abstract
The study aimed to determine the physical, mechanical, and biometric properties of onion bulbs to facilitate the design of machinery for post-harvest operations. The engineering properties of the onion crop were measured for 50 randomly selected onions. The variety of onions grown in India needs a comprehensive database of physical, frictional, and textural features for better and more accurate designing of post harvest operations, not withstanding advancements in onion processing and storage. The engineering properties of the crop are important in determining of gap between feeding grooves, cutting force required, capacity of shorter, size of shorter etc. The mean value of polar diameter, equatorial diameter, transverse diameter, mass and D_{gm}, arithmetic mean diameter were found 45.50±2.23 mm, 50.87±3.08 mm, 35.16±2.03 mm, 69.22±8.78 g 43.22±0.85 mm and 43.84±2.29 mm respectively. While the mean value of surface area, frontal surface area and cross sectional area were 6064.66±80.27 mm^2, 1868±193.12 mm^2, 1559.88±160.34 mm^2 respectively. The mean value of sphericity, shape index, aspect ratio, bulk density, true density, porosity and moisture content were found 0.86±0.02, 1.27±0.05 (oval shape), 0.29±0.049, 568.33±2.96,kg/m^3, 933.69±49.39 kg/m^3, 39.29±2.49% and 85.34±0.89% respectively. The mean value of mechanical properties like angle of repose, and coefficient of static friction for different surface like mild steel, galvanized steel, stainless steel and plastic surface were found 43.16^0, 0.36±0.02, 0.32±0.018, 0.23±0.014 and 0.42±0.014 respectively. Cutting force was in the range of 97.13-143.13 N for 200 mm/min speed and 43.42-165.46N for 300 mm/min speed.

Keywords: Onion, physical, frictional, textural, machine

Introduction
The *Alliaceae* plant species known as the onion (*Allium cepa*, L.), which has culinary, food and medicinal uses, which is rich in important vitamins and minerals. Although being seasonal in production, it is always needed. Due to its highly valued flavor, perfume, and unique taste as well as the medicinal properties of its flavor ingredients, it is referred to as the "Queen of the kitchen" (Griffiths *et al.* 2002) [7].

In India onion is grown in three crop seasons – *kharif* (July to August), late *kharif* (October to November), and *rabi* (December to January). About sixty percent of the crop produced annually is produced during the *rabi* season, with the remaining 20% coming from the *kharif* and late *kharif* seasons. After China, India is the world's second-largest producer of onions. With a yield of 16.78 t ha^{-1}, India produces 22.07 MT of onions overall (with a cultivation area of 1.28 Mha). The post-harvest operation in onion includes stem cutting and sorting. The onion stem cutting process is done manually in Chhattisgarh, which is very labour intensive, costly, drudgery prone and time consuming operation.

Materials and Methods
The physical as well as engineering parameters of the onion stems, its bulbs, root system and others are important for designing of onion stem cum root cutter machine. The study is described as below:

Raw material and sample size
Good quality of partial cured onion crop was collected directly from farmer's field of Raipur district of Chhattisgarh for conducting the experiment. The onions were cured for 2 to 3 days after harvesting. The onion bulbs' flavor and keeping quality are improved by the curing process.

For this investigation, fifty onion crops were randomly sampled, and the physical characteristics such as moisture content, different bulb diameters, weight, cutting force, leaf length, and root system length etc. were measured.

Moisture Content (MC)

The oven-drying method determined the moisture content of the onion bulbs and leaves. Onion bulbs were cut in thin slice of 1-2 mm and onion leaves were cut into small pieces of 5 mm length. The samples were weighed and oven dried to constant weight at 60±2° C (ASTM D2216 (1998)). According to AOAC (1970), the desiccator was used to cool down the dried samples before weighing. Using the following formula, the moisture content was determined and given as a percentage. (Gautam *et al*.2021) [6].

$$\text{Moisture content(MC)} = \frac{W_1 - W_2}{W_2} \times 100 \quad (1)$$

Where

MC = percent moisture content(wb);
W_1 = initial weight of sample (g); and
W_2 = final weight of sample (g).

A two pins digital wood moisture meter was used to determination of moisture content of the green leaves in the onion crops as shown in Fig.1. The moisture meter have having 0.5% accuracy which adopt high-precision electron components to test the moisture value digitally.

Fig 1: Digital wood moisture meter

Physical and physico-chemical properties

Identification and determination of the physical characteristics of onion bulbs, onion leaves, and cured onion crops relevant to the design of the stem and root cutter cum sorting machine. The following characteristics were evaluated: sphericity, linear dimensions, geometric mean diameter, thickness of onion leaves at neck level, and distances of 10 and 20 mm from neck level; also, cured onion crop weight and bulk density of onion bulb were evaluated.

Before measuring the physical properties of the different parts of the onion crop a brief study was conducted on the parts of the onion plants. The pictorial view of the onion plant is given in Fig. 1. Basically onion plants consist of leaves, stem, bulb and root system. The onion bulbs are partially inside the soil at the time of maturity. The green leaves are in a cluster just above the onion bulb. The onion has fibrous roots system which is having superficial root systems spread in multiple directions.

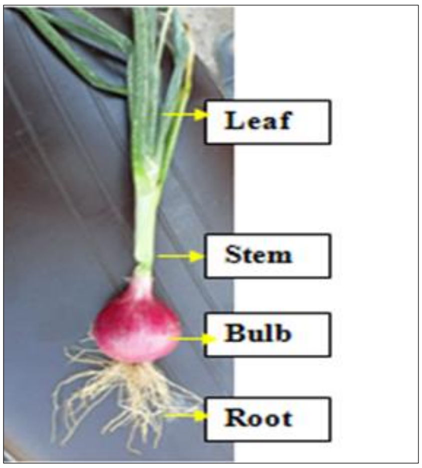

Fig 2: Parts of onion crop

Polar diameter, Equatorial diameter and Transverse diameter

The length of the bulb from its crown to the base, where roots begin to grow, is known as the polar diameter as shown in Fig.3.The equatorial diameter is the extreme breadth of an onion bulb measured perpendicular to the polar diameter both were measured with the help of a digital Vernier Caliper having least count of 0.01 mm. A digital Vernier Caliper was used to measure the transverse diameter (T) of 50 randomly selected onion bulbs.

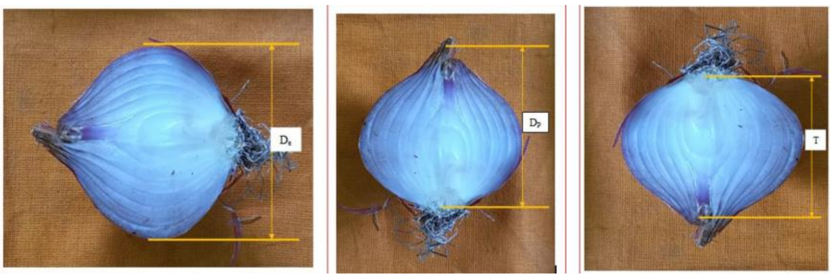

Fig 3: View of Polar diameter(D_p), Equatorial diameter (D_e) and Transverse diameter (T)

Geometric mean diameter (D_{gm})
The following formulas were used to determine the geometric mean diameter (D_{gm}) of an onion bulb (Mohsenin, 1970) [17]:

$$D_{gm} = \left(D_e D_p D_t\right)^{\frac{1}{3}} \quad (1)$$

Arithmetic mean diameter (D_{am})
The arithmetic mean diameter (D_{am}) of onion bulbs were calculated using the following Equations (Bahnasawy *et al.* 2004) [2].

$$D_a = \left(\frac{D_p + D_e + T}{3}\right)$$

Sphericity(S)
The following formula was used to calculate the onion bulb's sphericity (S) (Kaveri and Tirupathi, 2015) [12].

$$S = \frac{(D_e D_p D_t)^{\frac{1}{3}}}{D_e} \quad (4)$$

Shape Index
According to Shoba *et al.* (2017) [20], the shape index was computed using the following formulas to help determine the shape of onion bulbs.

$$\text{Shape Index} = \frac{D_e}{\sqrt{D_p \times T}} \quad (5)$$

Aspect ratio (R_a)
It is also representative of the shape parameter. It is the ratio of width to axial length of the bulb. An aspect ratio is a proportional relationship between an image's width and height. The equation (6) was used to determine the onion bulb's aspect ratio Ra (Abd Alla, 1993) [1].

$$R_a = \frac{D_p}{D_e} \times 100 \quad (6)$$

Shape and shape factor
According to Maw *et al.* (1996) [16] the shape factor is the ratio of the equatorial diameter to the polar diameter. If the shape factor for an onion bulb's various shapes is shape factor > 1, it is considered to be oblate, prolate if the shape factor < 1, and spherical if the shape factor = 1.

Surface Area (S_a)
The total area over the outside of an onion after the roots and tops have been removed is known as its surface area. The calculated surface area of an onion bulb is computed with the Equation (Bhansaway *et al.* 2004) [2].

$$S_a = \pi \times {D_{gm}}^2 \quad (7)$$

Frontal Surface Area (Afs)
When a solid object is cut by an intersecting plane, it is represented as follows. The equation was used to calculate the onion bulb's frontal surface area. (Bahnasawy *et al.*, 2004, Kaveri and Thirupathi, 2015) [2, 12].

$$A_{fs} = \frac{\pi}{4} D_e D_p \quad (8)$$

Cross Sectional Area (A_{cs})
A plane was used to cut the object transversely at right angles to its longest axis, making the object's cross-sectional area. The equation was used to determine the sample's cross-sectional area (Bhansaway *et al.*, 2004) [2].

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

Neck diameter
Using Vernier calipers (LC 0.01 mm) partially above the bulb's top, the thickness of the neck was measured. It was measured from a sample size of N=20, just after the harvesting of crop.

Weight of onion bulb with stem (W)
The samples (N =20) were randomly selected and measured by a weighing machine to calculate the average weight of the trunk. Average weight (W) was calculated as followed.

$$W = \frac{\sum_{i=1}^{n} W}{n} \quad (10)$$

Where,
W =Weight of samples, mm;
i = Number of sample; and
i = 1, 2, 3… n.

Bulk density
The bulk density is defined as the ratio of the bulb's total weight to the box's volume (Gautam *et al.*, 2021) [6]. Using the following formula, the bulk density of the onion bulbs was determined.

$$\gamma = \frac{W}{V} \quad (11)$$

Where,
γ - The bulk density, kg/m^3;
W - Weight of the onion bulbs, kg; and
V - Volume of box, m^3.

True density (ρt)
The true density (ρt) is defined as the ratio of an onion bulb sample's mass to the solid volume the sample occupies. The true density was then calculated using the Equation.

$$\rho t = \frac{M}{V} \quad (12)$$

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

Porosity
The ratio of the onion bulb's bulk volume to its internal pore volume is known as the bulk sample's porosity. According to Equation (Mohsenin, 1970) [17], it was computed as the ratio of the difference between the true density and bulk density to the true density.

$$P = 1 - \frac{\rho_b}{\rho_t} \times 100 \quad (13)$$

Where,
P = Porosity of onion bulb, %;
ρ_t = True density, kg/m ^{3}; and
ρ_b = Bulk density, kg/m ^{3}.

Mechanical Properties
The following mechanical properties of onion bulbs, onion leaves and cured onion crop were determined as it was required to design the feeding and collecting chutes of onion stem and root with grader.

Angle of repose
The angle that results from the base and slope of a cone formed when granular material falls freely vertically to a horizontal plane is known as the angle of repose. To determine the cured onion crop's angle of repose.

$$\theta = \tan^{-1}\left(H/_{l}\right) \quad (14)$$

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

Co-efficient of static friction
Using the inclined plane method, the onion bulbs' coefficient of static friction (µs) was determined. The test surfaces used were ply wood, mild steel, stainless steel, aluminium and galvanized iron. The Co-efficient of static friction was then calculated using the Equation (15) (Mohsenin, 1970) [17].

$$\text{Co} - \text{efficient of static friction}(\mu_s) = tan\theta \quad (15)$$

Where,
θ = Angle of inclination of material surface, degree.

Shear force required to cut the onion stem
The shear strength is an important parameter to determine cutting strength required for cutting the stem of cured onion crop. Using a texture analyzer (Model number: TA-HDI, Stable Micro Systems, United Kingdom), the shear strength of an onion was measured. A cutting probe that was fixed to the lower end of the load cell served as the texture analyzer. At the base of the texture analyzer, which is fixed, is a base plate with a slot in it. The base plate had the onion bulb with leaves arranged horizontally. leaving a neck that was 22 mm thick so that the cut point was on the slot. 500 kg of vertical loading was applied through the load cell at a 0.2 mm/sec test speed. The compression force was measured while maintaining a 4 mm rupture distance. The crop sample was cut at the neck once the apparatus was adjusted. Peak force was calculated using a computer that was connected to the texture analyzer. It was a five-time experiment for the onion and highest value was calculated.

Result and Discussion
Three diameters: transverse (Thickness), polar (Dp), and equatorial (De).
Using 50 samples, the onion bulb's polar diameter, equatorial diameter (De), and transverse diameter were measured. The polar diameter (Dp) of the selected onion bulbs are ranged in between 28.95 mm to 62.00 mm. The size and shape of the bulb is the main reason for the variation. The observed mean polar diameter was 45.50±2.23 mm, with corresponding SD and CV (%) of 7.84 and 17.24, respectively. The equatorial diameter of the bulbs onion ranged in between 19.82 mm to 72.56 mm. the mean equatorial diameter was 50.87±3.08 mm, with SD and CV (%) of approximately 10.82 and 21.28, respectively, The bulb ranged between 17.70 to 51.33 mm. and the onion bulb's mean transverse diameter measured 35.16±2.03 mm, with corresponding SD and CV of 7.15 and 20.32 mm, respectively. The data was used to design the spacing between feeding slot of cutter with brush unit and grading unit. Similar types of finding were also recorded by Khura *et al.* (2010) [13], Gautam *et al.* (2016) [6]. Dabhi *et al.* (2017) [3] determined the polar diameter of the onion crop for the different variety of onion. The data found is near to the other authors.

Bulb mass of onions
To compute bulk density, true density, and facing mass according to machine components, it is essential to determine the mass of the onion bulb. Average mass of onion bulb was determined to be 69.22±8.78 g, with a standard deviation and coefficient of variation of around 30.88 and 44.62, respectively given in (Table 1).

Variation between weights in relation to the different diameters
Variation between weights in relation to polar diameter, Equatorial diameter (D_e) and Transverse diameter (Thickness) of onion is depicted in Fig.4, 5, and 6.
A linier trend was observed with respect to all three diameters on the weight. As the diameter increased the weight of the onion also observed to be increase with a linear relation as given in Equations.

$$W = 3.227\ D_p - 77.61\ (R^2 = 0.671) \quad (16)$$

$$W = 2.774\ D_e - 72.99\ (R^2 = 0.768) \quad (17)$$

$$W = 0.175\ T - 23.02\ (R^2 = 0.574) \quad (18)$$

The coefficient of determination is observed to be 0.671. It is also observed from the data that most of the onions have in the range of 40 to 60 mm polar diameter. It is very helpful for designing of the sorter. Hence, the sorter is divided into three groups i.e. less than 40, 40 to 60 and more than 60 mm. Transverse diameter (T) is very useful for designing of gap between the slots so that it could hold the onion and automatically slide down towards the cutter bar. Pavani *et al.* (2017) [18] reported similar findings in their studies for the Bhima super variety. Similar findings were also observed in another investigation on red, white, and yellow onion bulbs.

Geometric mean diameter (D_{gm}), Arithmetic mean diameter (D_{am}) and Sphericity(S)
The onion bulb's overall diameter is determined by its geometric mean diameter. The diameter was in the range of 22.02 to 59.79 mm. The onion bulb's geometric mean diameter was determined to be 43.22±0.85 mm, with corresponding SD and CV (%) values of 8.04 and 18.59 mm, as shown in Table 1. The arithmetic mean diameter of selected onion bulb ranged between 22.66 to 60.43 mm and the onion bulb's arithmetic mean diameter was measured to be 43.84±2.29 mm, with corresponding SV and CV (%) of 8.07 and 18.40., respectively.

Onion bulb sphericity was observed at 0.86±0.02, with corresponding SD and CV (%) of about 0.08 and 9.53, respectively. The data obtained were analysed and the variation is depicted in Table 1. Forecast volume is correlated with the independent values of onion bulb sphericity (Griffiths and Smith, 1964) [8].

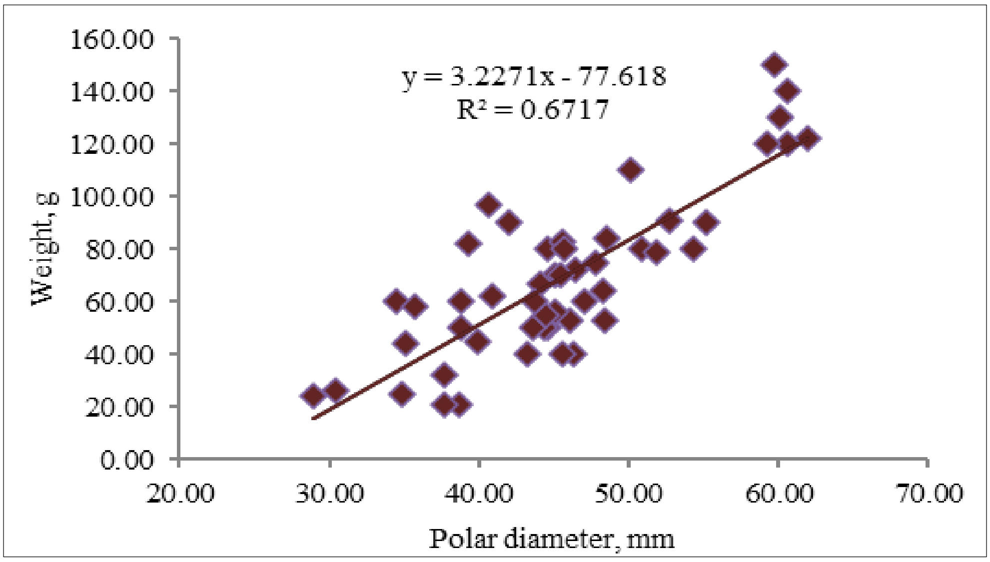

Fig 4: Variation between weight in relation to the polar diameter

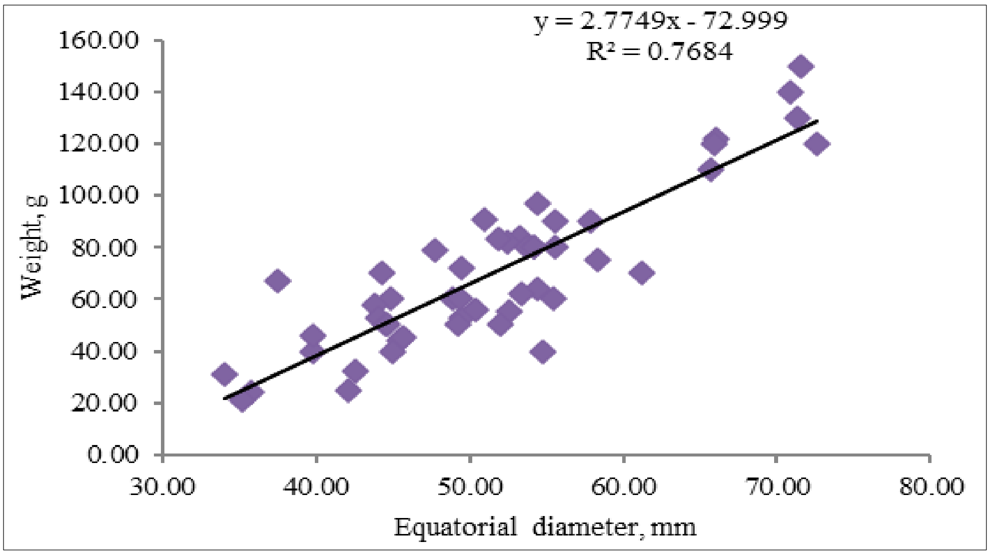

Fig 5: Variation between weight in relation to the equatorial diameter

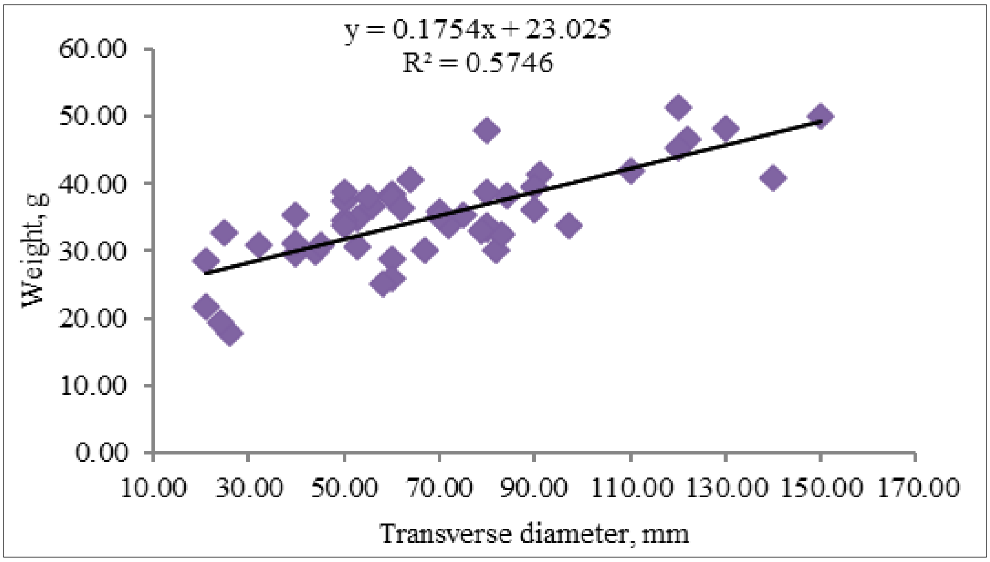

Fig 6: Variation between weight in relation to the transverse diameter

Shape Index (SI), Aspect Ratio (R_a), Surface Area (S_a), Frontal Surface Area (A_{fs}) and Cross Sectional Area (A_{cs})

As shown in Table 1, the shape index was determined to be 1.27±0.05 with an SD and CV (%) about 0.16 and 12.86, respectively. According to Bahnasawy *et al.* (2004) [2], the onion bulb was classified as oval based on the given data, as its shape index was less than 1.5. Similar results were reported by Pavani *et al.* (2017) [18] for the Bhima super variety, about 1.0±0.01. The variation is mainly due to the reason specific and varietal difference.

The average aspect ratio of the onion varied depending on its size and shape; it was found to be 0.74±0.049 mm with SD and CV (%) of 0.174 and 18.92, respectively.

To determine the onion bulb's exposer area, the surface area was measured. The onion bulb's surface area was measured to be 6064.66±80.27 mm^2, with a 2209.52 SD and 36.43 CV (%).The onion bulb's frontal surface area was obtained as 1868.62±193.12 mm^2 with SD and CV (%) as 679.53 mm^2 and 36.37 mm^2, respectively. The onion bulb's cross sectional area was measured to be 1559.88±160.34 mm^2, with a corresponding SD and CV (%) of about 564.20 and 36.17.

The weight-surface area, frontal surface area, and cross-sectional area relationship is depicted in Equation 19, 20 and 21. It is observed a linear relationship with respect to weight on frontal surface area with R^2 value of 0.78. Similar relationship was also observed by Gautam *et al.* (2021) [6] and Kaveri and Thirupathi (2015) [12] as well as Khura *et al.* (2011) [14].

$$S_a = 19.92\,W + 489.3\ (R^2 = 0.82) \quad (19)$$

$$A_{fs} = 63.27W + 168.5\ (R^2 = 0.782) \quad (20)$$

$$A_{cs} = 16.30W + 431.5\ (R,^2 = 0.80) \quad (21)$$

Where,

S_a = Surface area of the onion bulb, mm^2;

W = Weight of onion bulb, g.

A_{fs} = Frontal surface area of the onion bulb, mm^2; and

A_{cs} = Cross sectional area of the onion bulb, mm^2

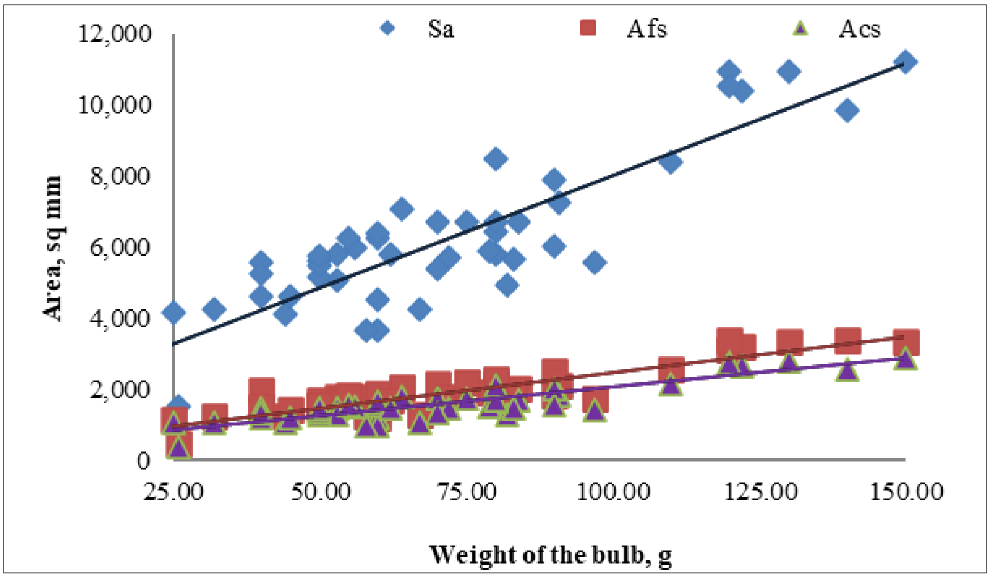

Fig 7: Relationship between surface area, cross sectional area, and frontal surface area based on onion bulb weight

Bulk density, True density, Porosity, and Moisture content

To determine the volume and mass of the material controlled by the sorting, the bulk density of the onion bulb was measured. For the onion bulb, the bulk density was obtained as 568.33±2.96 kg m^{-3} with SD and CV (%) of 10.31 and 0.02, respectively. Using the toluene displacement method, the true density of the bulb of onion was found to be 933.69±49.39 kg m-3, with an SD and CV (%) corresponding to 39.78 and 4.26, respectively. The onion bulb's porosity was found to be 39.29±2.49%, with corresponding SD and CV (%) values of 5.67 and 0.17. The onion bulb's moisture content was determined to be 85.34±0.89 percent, with corresponding SD and CV (%) values of 0.71 and 0.51 as shown in Table 1, Similar findings were reported by Gautam *et al.* (2021) [6] for the N-53 onion bulb and by Dabhi and Patel (2017) [3] for the Talaja red onion.

Angle of repose

The emptying box method was used to measure the angle of repose of onion bulbs. The mean angle of repose was 43.16°, with a standard deviation of 1.10° with CV (%) and V as 2.07 and 0.89, respectively. This data is presented in Table 1. The grooves of the inclination angle were calculated using the angle of repose. It was observed that the inclination angle should always be less than 43.16°. Similar type of observation was observed by (Gautam *et al.*2021) [6] there should never be an inclination greater than approximately 41.35°. For the Bhima super variety, similar results regarding the angle of repose were observed, 43.6±2.904° (Pavani *et al.*2017) [18]. The inclination angle of the sorter was determined by the angle of repose.

Coefficient of static friction

Using the surfaces of various materials, the inclined plate method was utilized to calculate the onion bulb's coefficient of static friction. The sorting slope was chosen based on the onion bulb's coefficient of static friction. Table 1 shows the average coefficient of static friction for mild steel, galvanized iron, stainless steel, and plastic, which are, respectively, 0.36, 0.32, 0.23, and 0.42. According to (Dabhi and Patel, 2017) [3], the Talaja red onion showed a comparable coefficient of friction values of 0.42, 0.39, 0.45, and 0.32 for galvanized iron, mild steel, aluminum, and plywood, respectively.

Table 1: Different engineering properties of onion (N=50)

Properties	Min	Max	Mean	Standard Error	Standard Deviation	Coefficient of variation	Confidence level (95.0%)
D_{gm}	22.02	59.79	43.22	1.14	8.04	18.59	2.28
D_{am}	22.66	60.43	43.84	1.14	8.07	18.4	2.29
S	0.76	1.13	0.86	0.01	0.08	9.53	0.02
SI	0.83	1.52	1.27	0.02	0.16	12.86	0.05
Ra (%)	0.74	1.61	0.92	0.025	0.174	18.92	0.049
S_a(mm^2)	1523.02	11226.77	6064.66	312.47	2209.52	36.43	0.02
A_{fs}(mm^2)	474	3374.97	1868.62	96.1	679.53	36.37	193.12
A_{cs}(mm^2)	403.16	2868.42	1559.88	79.79	564.2	36.17	160.34
Bulk Density (kg/m^{-3})	566.07	572.12	568.66	1.06	2.39	5.69	2.96
True Density (kg/m^{-3})	883.24	992.83	933.69	17.79	39.78	1582.44	49.39
Porosity (%)	35.91	42.89	39.01	1.15	2.58	6.64	3.2
Moisture content (%)	84.37	86	85.34	1.28	0.71	0.51	0.89
Angle of repose, degree	41.4	45.8	43.16	0.39	1.10	2.07	0.89
Coefficient of friction(MS)	0.32	0.37	0.36	0.02	0.02	6.74	0.02
Coefficient of friction (GS)	0.31	0.34	0.32	0.02	0.02	4.99	0.018
Coefficient of friction (SS)	0.22	0.25	0.23	0.01	0.01	4.96	0.014
Coefficient of friction (PS)	0.41	0.44	0.42	0.01	0.01	3.42	0.014

MS= Mild steel, SS = Stainless steel,GS= Galvanized steel, PS= Plastic surface

Shear force required to cut the onion stem

Using UTM, an experiment was carried out to determine the force required for cutting the onion leaves from the bulbs, as indicated in Table 2. The measure of cutting force required to cut the onion's leaves ranged between 97.13-140.13 N for 200 mm/min speed and 43.42–165.46 N for 300 mm/min speed respectively; For a neck diameter of 10 mm, the lowest cutting force was required, and for a neck diameter of 20 mm, the highest cutting force. As the speed increased, the cutting energy and compression load decreased and as the neck diameter increased, they increased (Figure 4.13). Because the cutting force and cutting energy decreased with an increase in loading rate, the loading rate may be the reason of this. Similar results were also observed for the saffron flower by Hassan-Beygi *et al.* (2010) [9]; the maize stalk by Igathinathane *et al.* (2010) [11]; the pigeon pea stems by Dange *et al.* (2011) [4]; the lirium stalk by Heidari *et al.* (2012) [10]; the rice stem by Esgici *et al.* (2018) [5]; and the paddy stem by Pekitkan *et al.* (2020) [19].

Table 2: Cutting force required to cut onion leaves from the bulb

Sample	Speed (mm/min)	Neck dia. (mm)	Cutting force (N)	Cutting energy (mJ)
1	200	10	97.13	225.34
2	200	15	118.63	282.34
3	200	20	140.13	341.92
1	300	10	43.4	140.18
2	300	15	105.46	340.64
3	300	20	165.46	534.44

Table 3: Significance of engineering properties of onions as a crop to develop various components of onion stem and root cutting cum sorting machine.

Properties	Parts	Description
Polar dia. (D_P) Equatorial dia.(D_e) Transverse dia.(T) Geometric mean diameter.	Sorter, grading unit and cutting brush unit	The data was used to design the spacing between feeding slot of cutter. Brush unit and grading unit. This is also required to decide the spacing of the guide rod
Mass		Utilized to determine the mass, bulk density, and true density of the onion face that the machine component is facing.
Bulk density	Capacity of grader/sorter	measured to determine the mass and volume of the material under control by grader/sorter
Angle of repose	Sorting unit	Used to determine the inclination angle of the sorter
Coefficient of static friction	Slope of sorting unit	Used to select the slope of the sorting unit
Cutting force	Cutting unit, power unit	Calculate the force required for cutting the onion leaves from the bulbs.

Conclusion

- The engineering properties of onion crop play important function in determining of gap between feeding slot, cutting force required, capacity of sorter, size of shorter etc.
- The mean value of polar diameter(D_P), equatorial diameter(D_e), transverse diameter(T), mass, D_{gm}, and D_{am} were found 45.50±2.23 mm, 50.87±3.08 mm, 35.16±2.03 mm, 69.22±8.78 g, 43.22±0.85 mm and 43.84±2.29 mm respectively. While the mean value of surface area(S_a), frontal surface area(A_{fs}) and cross sectional area(A_{cs}) were 6064.66±80.27 mm^2, 1868±193.12 mm^2, 1559.88±160.34 mm^2 respectively.
- The mean value of sphericity, shape index, aspect ratio, bulk density, true density, porosity and moisture content were found 0.86±0.02, 1.27±0.05 (oval shape), 0.29±0.049, 568.33±2.96,kg/m^3, 933.69±49.39 kg/m^3, 39.29±2.49% and 85.34±0.89% respectively.
- The average value of mechanical properties like angle of repose was found 43.16^0 and coefficient of static friction for different surface like mild steel, galvanized steel, stainless steel and plastic surface were found 0.36±0.02, 0.32±0.018, 0.23±0.014 and 0.42±0.014 respectively. Cutting force was in the range of 97.13-143.13 N for 200 mm/min speed and 43.42-165.46N for 300 mm/min speed.

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