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Engineering Properties of the PanchaGanga Royal Pink Onion

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Abstract

Onion, a highly prolific vegetable in India, holds a pivotal position in the agricultural landscape. Understanding the properties of onion bulbs is imperative as it underpins the design and development of machinery tailored for their efficient handling. This study was conducted to explore a spectrum of engineering properties related to onion bulbs.The engineering qualities of the Pancha Ganga Royal Pink Onion bulb were examined using standard methods. The geometric characteristics were mostly linear, with polar diameter of 57.09±0.78 mm and equatorial diameter of 54.01±1.01 mm. Geometric mean diameter varied from 33.26 to 57.00 mm, averaging 47.35±4.98 mm, whereas arithmetic mean diameter was 48.63±4.76 mm, spanning 33.27 to 58.29 mm. The surface area ranged from 3474.06 to 10202.54 mm^2, average 7111.02±1414.18 mm^2, and the frontal area was 905.61 to 2240.23 mm^2, averaging 1559.90±285.10 mm2. The average onion bulb mass was 97.34±12.87 g, with a standard deviation of 10.76 g. Sphericity averaged 0.83±0.04, indicating a spherical form, whereas the shape index was 1.31±0.08. Aspect ratio varied somewhat with onion size and shape, averaging 0.95±0.008. As bulb size rose, PanchaGanga Royal Pink Onion bulk density decreased. The average bulk densities for small, medium, and big bulbs were 564, 552, and 531 kg m^{-3}, respectively. The toluene displacement technique yielded a true density of 834.29±23.54 kg m^{-3}. Onion bulb porosity was 29.98±3.49%, with a standard deviation of 3.67. The average coefficient of friction on different surfaces was 0.27±0.019, 0.36±0.015, 0.54±0.019, and 0.40±0.009 for glass, plywood, rubber, and MS sheet. The angle of repose for these materials was 41, 21, 25, and 28, respectively.

Key words : Onion, Physical, Bulk density, True density, Co-efficient of friction, Angle of repose etc.

The onion (*Allium cepa*) is an enduring agricultural mainstay cultivated and enjoyed for millennia (Kakade *et al*., 2023).This versatile crop plays a pivotal role in the livelihoods of farmers, serving as a significant income source (Sivashankar *et al*., 2023). Its historical roots can be traced to Central Asia and the Mediterranean, where it held a vital place in the diets of ancient civilizations like the Egyptians and Greeks (Tripathi and Lawande, 2016).Onion is an incredibly versatile and beneficial vegetable with both nutritional and medicinal properties (Kakade *et al*., 2023). Onions boast a wealth of essential nutrients, comprising a spectrum of vitamins like A, B, and C, alongside vital minerals like phosphorus, potassium, calcium, magnesium, and sulfur. Furthermore, they are abundant in dietary fiber, promoting digestive wellness, and are teeming with antioxidants, serving as a defense against the harmful effects of free radicals (Miladi Lari *et al*., 2020).

In 2021, global onion production reached 206.51 million metric tons, with China as the top producer at 34.8 million metric tons, followed closely by India at 31.2 million metric tons(Anonymous, 2022). India is the second-largest onion producer, with key production regions including Maharashtra, Gujarat, Uttar Pradesh, Odisha, Karnataka, Tamil Nadu, Madhya Pradesh, Andhra Pradesh, and Bihar. In India, onion cultivation covered 19.1 million hectares in 2021, yielding 16.3 metric tons per hectare (Anonymous, 2021). Maharashtra leads the way with 20% of the area and 25% of the production, contributing significantly to India's total output (Bhardwaj, 2020). In 2020-2021, Maharashtra alone accounted for 32.6% of India's onion production, with 471.66 thousand hectares and 8047.08 thousand metric tonnes produced (Anonymous, 2022).

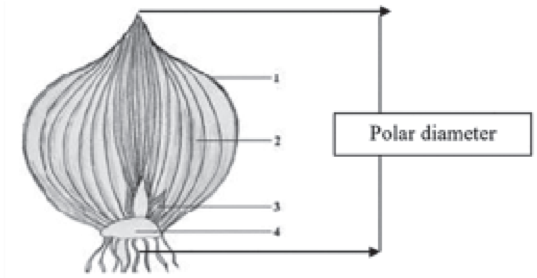
India holds the title of the world's largest onion exporter, consistently leading in recent years. In 2019, India exported 6.40 million metric tons of onions, which increased slightly from 6.01 million metric tons in 2020 (Anonymous, 2021). Key export destinations include Bangladesh, Sri Lanka, Nepal, Malaysia, and the United Arab Emirates. In contrast, India imports onions from Egypt, Iran, Turkey, China, and the Netherlands. Import volumes for 2021 reached an estimated 0.46 million metric tons, up from 0.32 million metric tons in 2020 (Anonymous, 2022).

Onions possess a diverse range of physical and mechanical characteristics that play a crucial role in their use within the culinary realm and food processing sector(Tripathi & Lawande, 2019). Engineers and culinary scientists are collaborating to develop novel methodologies and technologies for efficiently managing, processing, and preserving onions, while ensuring the maintenance of their optimal quality and flavor (Gautam *et al.*, 2021) and (Shelke *et al.*, 2023). Engineering properties of onions are crucial for both storage and the design of specialized machines(Dabhi & Patel, 2017). When storing onions, understanding their properties such as moisture content, density, and porosity helps in optimizing storage conditions, reducing spoilage, and preserving quality (Priya *et al.*, 2014). In machine design, these properties inform the development of equipment for sorting, packaging, and processing onions efficiently. The knowledge of onion size, shape, and firmness is vital in designing equipment like sorters and peelers, while data on moisture content and flow behavior aids in designing machinery for handling onions in bulk(Bisen *et al.*, 2022). Ultimately, these engineering properties ensure efficient handling and preservation of onions throughout the supply chain(Lawande, 2012) and (Shelke *et al.*, 2023).In this regard, the studies main aim was to determine the physical and mechanical properties to create a database of the popular onion variety PanchaGanga Royal Pink.

Material and Methods

The most well-known onion, the PanchaGanga Royal Pink, was selected for the study. The study examined many objective characteristics of onion bulbs in accordance with established protocols (Kad *et al.*, 2021). The method used to observe onion bulbs is described below. The moisture content value was 88.23±0.47.The linear dimensions, average geometric diameters, average arithmetic diameters, sphericity, shape index, aspect ratios, surface area,coefficient of friction and angle of repose and mass of 100 randomly selected onion bulbs were measured. Mean values, standard deviations, and variation coefficients were calculated.

Linear dimensions : The dimensions of polar diameter, equatorial diameter, and thickness of one hundred randomly chosen onion bulbs were measured using a digital vernier caliper with a precision of ± 0.01 mm, and the resulting measurements were used to calculate the mean value (Sahay and Singh, 2014). The polar diameter represents the measurement from the crown of the onion bulb to the point where the root is attached to the bulb (Singhal & Samuel, 2003)as shown in Fig. 1. The equatorial diameter, as depicted in Fig. 1., corresponds to the onion's widest dimension in a plane perpendicular to the polar diameter.



1 - thin, dry, brown outer scale leaves, 2 - thick, white inner scale leaves, 3 - bulbil bud, 4 - basal plate with roots

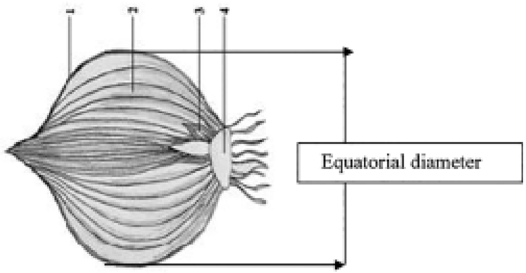


Fig. 1. Polar diameter and Equatorial diameter

Moisture Content : To determine the moisture content (Shelke *et al.*, 2022), the onion bulbs were cut in thin slice of 1-2 mm, weighed and oven dried to constant weight at 60±2°C (Shelke *et al.*, 2019).

Area of onion surface

Surface area (S_a), Frontal surface Areas ($A_{f.s}$) and Cross sectional of areas ($A_{c.s}$) : Surface area refers to the entire outer area of the onion, excluding the roots and tops. Measuring the surface area involves wrapping aluminium foil around the onion bulb and then carefully cutting it into thin strips, ensuring it is ample to lay flat. To determine the surface area of the onion, a planimeter was utilized to measure the area of the foil. This area represents the surface area of the onion under consideration (Bahnasawy, 2007).

The frontal surface area ($A_{f.s}$) of onion bulbs was measured by the given equation using equatorial and polar diameter of the onion (Bahnasawy, 2004).

$$A_{f.s} = \frac{\pi}{4} \text{DeDp}$$

Where, $A_{f.s}$ - frontal surface area, mm^2, De - equatorial diameter of onion,mm, Dp - polar diameter of onion, mm, T - thickness of onion, mm

Geometric Mean Diameter (Dgm) : The geometric mean diameter was calculated from a number of linear dimensions *viz.*, polar diameter (Dp), equatorial diameter (De), and thickness (T) of the sample. It is the cube root of the product of linear dimensions Dp, De and T(Gautam *et al.*, 2021).

$$\text{Dgm} = \sqrt[3]{(\text{DeDpT})}$$

Arithmetic mean diameter (Dam) : The arithmetic mean diameter is calculated by adding up the three linear dimensions: equatorial diameter, polar diameter, and thickness of the sample. This sum is then divided by the total number of linear dimensions measured. These linear dimensions were obtained using digital vernier calipers with a least count of 0.01mm (Bahnasawy *et al.*, 2004).

$$Dam = \frac{\text{De} + \text{Dp} + \text{T}}{3}$$

Aspect ratio (Ra) : The aspect ratio is defined by the ratio of width of the bulb to the length of bulb into 100. Ra of the onion bulb was determined as recommended by using Equation (Abd-Alla, 1993).

$$\text{Ra} = \frac{\text{Dp}}{\text{De}} \times 100$$

Where, Ra = Aspect ratio, %; Dp = Polar diameter, mm; and De = Equatorial diameter, mm.

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 and expressed in percentage (Pavani, 2017)

$$P = 1 - \frac{\rho b}{\rho t} \times 100$$

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

True Density : This ratio represents the mass of the sample relative to its pure volume. To measure the true density, used the water displacement method, which involved placing fifty individual onion bulbs into a 100 ml measuring cylinder filled with water. Before conducting the experiment, the weighed the combined mass of the fifty onion bulbs using an electronic balance. As the onions were added to the water, the resulting rise in water level corresponded to the volume of the onion bulbs. The true density experiment was repeated three times and reported the average value obtained (Gautam *et al*., 2021).

Bulk Density : To determine the bulk density, filled a container with onions and measured its weight. The bulk density was then calculated as the ratio between the mass and the known volume of the container. This experiment was repeated three times for accuracy (Kad *et al*., 2021).

Bulk density = Mass/Volume

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 (Kaveri and Thirupathi, 2015; Sahay and Singh, 1996).

$$\text{Sphericity} = \frac{(\text{Dp. De. T})^{\frac{1}{3}}}{\text{Dp}}$$

Shape index : The shape index of the onion bulb may be defined as the quotient obtained by dividing the equatorial diameter by the square root of the product of the polar diameter and the thickness of the onion bulbs. The shape index assesses the morphology of onion bulbs, and the following equation determines its computation (Bahnasawy, 2004).

$$\text{Shape Index} = \frac{De}{\sqrt{Dp \times T}}$$

The onion bulb is considered an oval if the shape index >1.5, on the other hand, it is considered spherical if the shape index <1.5.

Co-efficient of Friction and Angle of Repose

The coefficient of friction is a measure of the force needed to move an onion bulb across a surface, divided by the downward force pressing the bulb onto the surface. To find this coefficient, tested different surfaces like Galvanized Iron sheet, Mild Steel sheet, Aluminium sheet, and plywood. Each surface was securely attached to a tilting table. A frame constructed from square wooden bars was positioned on the surface and filled with onion bulbs. The table was then manually tilted gradually until the entire mass of bulbs began to move. The coefficient of friction was calculated as the tangent of the slope angle of the table, which measured using a protractor. The angle of repose for PanchaGanga Royal Pink onion bulbs was determined as per the procedure describedby (Pavani, 2017).

Results and Discussion

Linear dimensions : Polar diameter, equatorial diameter and thickness of theonion bulb were measured by taking 100samples. Polardiameter was varied as per shape and size of the onionand average was observed to be 57.09±0.78 mm with SD about 7.48. This finding aligns with results reported by Pavani *et al*. (2017) for the Bhima super variety, as well as with another study involving red, white, and yellow onion bulbs, as reported by Ghaffari *et al*. (2013). The average equatorialdiameter of the onion bulb was obtained to be 54.01±1.01 mm with SD about 7.49. Similar results were reported by (Khura *et al*., 2011), Ghaffari *et al*., (2013), and Dabhi and Patel (2017), with mean equatorial and polar diameters ranging from 55.80±10.49 to 44.72±7.40 mm.Thickness of the selected onion samples were alsomeasured and average thickness of the onion bulb wasfound to be 34.77±0.45 mm with SD about 4.09.

Geometrical Mean Diameter (Dgm), Arithmetic MeanDiameter (Dam), Surface Area (As), frontal surface area and Massof Onion : The geometrical mean diameter, arithmetic mean diameter,cross sectional area and unit mass of onion was measured for100 randomly selected onion bulbs. The geometrical meandiameter of onion bulbs was varied from 33.26 to 57.00 mmwith a mean value of 47.35 ± 4.98 mm and arithmetic meandiameter was varied from 33.27 to 58.29 mm with a meanvalue of 48.63 ± 4.76 mm.Similar result obtained by Ghaffari *et al*., (2013) andPavani, (2017). Geometric meandiameter would be helpful to determine spacingbetween separator rods of onion separator.The value of surface area wasvaried from 3474.06 to 10202.54 mm2 with a mean value of 7111.02 ±1414.18 mm2. The value of frontal surface area wasvaried from 905.61 to 2240.23 mm2 with a mean value of 1559.90 ±285.10 mm2. The mass of the onion bulb is important to calculatebulk density, true density and mass of onion facing bythe machine component (like separator) during diggingoperation. Average mass of onion bulb was measured tobe 97.34 ± 12.87 g with SD about 10.76.

Sphericity (Φ), Shape Index (Si) and Aspect ratio (Ra) : The sphericity was 0.83±0.04 with SD about0.04. To find out the shape of theonion bulb sphericity and shape Index were observed.The shape Index was obtained was 1.31±0.08 with SDabout 0.08. Aspectratio of the onion bulb was measured by taking 100samples. It was varies with the different shape and sizeof the onion and average aspect ratio was observed tobe 0.95±0.008 mm with SD about 0.008. Based on obtained data onion bulbwas 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 forbhima super variety. Similar results were also reportedfor shape index about 1.22 (Khura *et al*., 2011) and 1.27(Kaveri and Thirupathi, 2015).

Bulk density : Onion bulb bulk density was determined using the methods outlined in section 2.9. With 83.87 percent moisture content (w.b.), the bulk density of onion bulbs of three distinct sizes-small, medium, and large-was found for the PanchaGanga royal pink variety.the size of the onion bulb increased; its bulk density decreased. This trend paralleled findings in studies on various sizes of grains within the same variety. The increase in onion bulb size led to a higher bulk porosity, ultimately causing a reduction in bulk density (Gajjar *et al*., 2019). The mean bulk density values for small (below 40 mm), medium (40-60 mm), and large (above 60 mm) onion bulbs were determined to be 564 kg m^3, 552 kg m^3, and 531 kg m^3, respectively. In contrast, Akbari, (1997) reported a bulk density of 677 kg m^3 for the Talaja Local White variety of onion. This variation could be attributed to differences in onion varieties.

True density : The true density of the onionbulb was determined about 834.29 ± 23.54 kg m^3 bytoluene displacement method with SD about 54.78. Similar results werefound for Talaja red onion (Dabhi and Patel, 2017).

Porosity : Porosity of the onion bulb was determined about 29.98±3.49% by toluene displacement method with SD about 3.67. Similar results werefound for Talaja red onion (Dabhi and Patel, 2017) and (Gautam *et al.*, 2021).

Coefficient of friction and angle of repose : The coefficient of friction and angle of repose are theimportant parameters to measure the level of frictioncharacteristics. Hence, these parameters were determinedunder gravity flow for different surfaces such as glass, plywood surfaces, rubber and MS sheet. Average coefficient offriction of the onion bulb in various materialsurfaces was obtained to be 0.27±0.019, 0.36±0.015,0.54±0.019 and 0.40±0.009 for glass, plywoodsurfaces,rubber and MS sheet, respectively. Similar results ofcoefficient of friction for galvanized iron, mild steel,aluminum and plywood was found 0.42, 0.39, 0.45 and0.32 respectively of Talaja red onion (Dabhi and Patel,2017) and 0.38±0.020, 0.40±0.018,0.46±0.014 and 0.38±0.014 was found for glass, steel, rubber andplywood surfaces, respectively of N-53 onion bulbs (Gautam *et al.*, 2021). Also, the angle of repose for glass, plywood, rubber and MS sheet was found 41, 21, 25 and 28, respectively.Similar results ofangle of repose were obtained 43.6±2.904° for Bhimasuper variety (Pavani *et al.*, 2017) and the angle of repose for galvanized iron,mild steel, aluminum and plywood was found 23, 21, 24 and17, respectively (Dabhi and Patel, 2017).

Conclusion

The engineering properties of the PanchaGanga Royal Pink Onion bulb were analyzed using standard methods. Geometric features predominantly relied on linear dimensions, including polar diameter, which averaged 57.09±0.78 mm, and equatorial diameter, which averaged 54.01±1.01 mm. The geometric mean diameter spanned 33.26 to 57.00 mm, averaging 47.35±4.98 mm, while the arithmetic mean diameter ranged from 33.27 to 58.29 mm, averaging 48.63±4.76 mm. Surface area varied from 3474.06 to 10202.54 mm^2, averaging 7111.02±1414.18 mm^2, with frontal surface area ranging from 905.61 to 2240.23 mm^2 and averaging 1559.90±285.10 mm^2.Onion bulb mass averaged 97.34±12.87 g, with a standard deviation of around 10.76. Sphericity was approximately 0.83±0.04, suggesting a generally spherical shape, while the shape index averaged 1.31±0.08. The aspect ratio exhibited slight variation with onion size and shape, averaging 0.95±0.008.Bulk density was assessed across different sizes (small, medium, large) of the PanchaGanga Royal Pink Onion, revealing a decrease as bulb size increased. Average bulk densities were 564 kg m^{-3}, 552 kg m^{-3}, and 531 kg m^{-3} for small, medium, and large bulbs, respectively. True density, determined via the toluene displacement method, was approximately 834.29±23.54 kg m^{-3}. Onion bulb porosity was measured at 29.98±3.49% with a standard deviation of roughly 3.67.Furthermore, the average coefficient of friction on various material surfaces was 0.27±0.019, 0.36±0.015, 0.54±0.019, and 0.40±0.009 for glass, plywood, rubber, and MS sheet, respectively. The angle of repose for these materials was 41, 21, 25, and 28, respectively.

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