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Studies on Engineering Properties of Onion bulbs Cv. N-2-4-1

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Abstract

Onion (*Allium cepa* L.) is an economically important vegetable often used as a spice and medical properties contains many essential vitamins and minerals which are necessary for the human diet. Despite the achievements in onion processing and storage, the versatility of onions grown in India desperately requires clear database of physical, frictional and textural properties for better and precise designing of post harvest operations like grading, sorting and packaging. The popular onion variety in Maharashtra, India is N-2-4-1was selected for the study. Physical, chemical, frictional, thermal and textural properties of onion bulbs measured and calculated. The physical properties such as polar diameter (Dp), equatorial diameter (De), thickness (T), geometric mean diameter (Dgm), arithmetic mean diameter (Dam), shape index, sphericity, bulk density, true density, porosity, volume, surface area, eccentricity, projected area, dry matter, colour L*, colour a* and colour b* values were ranged from 44.56 to 70.36mm, 42.78 to 68.25 mm, 38.46 to 63.13 mm, 41.93 to 66.85 mm, 42.00 to 66.90 mm, 1.0 to 1.14, 0.89 to 0.97, 547.48 to 597.54 kg m^{-3}, 798.26 to 899.72kg m^{-3}, 30.9 to 33.58, 6.42 to 7.91 mm^3, 2157.62 to 2947.21 mm^2, 0.02 to 0.06, 539.40 to 736.8 mm^2, 12.08 to 12.12%, 59.26 to 60.66, 15.89 to 16.21 and 8.53 to 9.89, respectively. The chemical properties such as moisture content, carbohydrate content, ash content, protein content, fat content, inhibition DPPH, anthocynin content, reducing sugars, pH, total soluble soilids, pyruvic acid, ascorbic acid, total phenol and total flavonoids were ranged from 82.60 to 83.20%, 8.92 to 9.32%, 3.1 to 3.3%, 4.11 to 4.2%, 0.15 to 0.18%, 57.27 to 57.42%, 8.20 to 8.50 mg 100^{-1} g, 3.40 to 3.60 g 100^{-1} g, 5.82 to 5.85, 15 to 16°Brix, 14.11 to 14.14 µmole g^{-1}, 17.41 to 18.56 mg 100^{-1} g, 53.24 to 54.84 mg GAE 100^{-1} g and 24.95 to 25.11 mg CE 100^{-1} g, respectively. The thermal property such as thermal conductivity was 0.51 W mK^{-1} and specific heat was ranged from 3.73 to 3.74 kJ kgK^{-1}. The frictional properties such as coefficient of static friction and angle of repose (ϕ) were ranged from 0.45 to 0.47 and 36.45 to 37.97o, respectively. The textural property i.e. firmness was ranged from 8.94 to 9.87 N.

Key words : Onion, N-2-4-1, Physical, Chemical, Frictional, Thermal and Textural properties.

The onion (*Allium cepa* L.) is a prominent agricultural commodity with a long history of medicine usage. It is a staple crop that has been grown and consumed for thousands of years (Sharma et al., 2020). It is one of the most important vegetable crops consumed on a daily basis in India. It is the second most frequently cultivated vegetable bulb crop after tomato and it is familiar to most cultures and consumed worldwide. Onion belongs to the family Amaryllidaceae. Its origins can be traced back to Central Asia and Mediterranean region, where it was an important food source for ancient civilizations such as the Egyptians and the Greeks. Onions are easy to grow and are widely cultivated in many part of the world, including Europe, Asia and the Americans (Tripathi and Lawande, 2016). It is a major source of income for farmers (Sivashankar et al., 2023). They are prized for their unique flavour, which is a result of the sulphur compounds present in the plant (Konduru and Rains, 2015). The plant grows from and underground bulb, which is composed of layers that store nutrients (Lim et al., 2021).Onions are also a key ingredient in a variety of sauces, stews and soups (Sami et al.,2021). They are also a great addition to salads, burgers and sandwiches and can be pickled for added flavour (Berno et al., 2014).

In year 2023, the total world onion production was 2310.8 lakh MT. The area covered by onion in India was 15.43 lakh hectare with 254.73 lakh MT production and 16.51 MT/ha productivity. The area covered by onion in Maharashtra was 6.61 lakh hectare and production was about 89.05 lakh MT and productivity was 13.47 MT ha^{-1}. Most of the onion produced in India comes from the state of Maharashtra, Madhya Pradesh, Rajasthan, Gujarat and Bihar (Anonymous, 2024).

Onion is an incredibly versatile and beneficial vegetable with both nutritional and medicinal properties (Sami et al., 2021). It is rich in vitamins, minerals, potassium, folic acid and other beneficent compounds. It contains a variety of vitamins, including vitamins A, B and C as well as minerals such as phosphorus, calcium, magnesium and sulphur. Onions are also a rich source of dietary fiber, which helps keep the digestive system healthy and are full of antioxidants which can help protect the body from the damage caused by free radicals. They also content iron and have a high protein quality, ratio of mg amino acid/ g protein. Onions are low in sodium and contain no fat. They are low in calories with only 30 cal per serving, yet add abundant flavour to a wide variety of foods (Shukla et al., 2019, Miladi et al., 2020 and Thakre et al.,2023). Therefore, to develop appropriate processing technologies, comprehensive engineering properties of onion must be studied.

Material and methods

The present study was conducted at the Department of Agricultural Process Engineering and Technology, Dr. Annasaheb Shinde College of Agricultural Engineering and Technology, MPKV, Rahuri during year 2023-2025.

1 Physical Properties

The physical properties of onions such as size, shape, mass, volume, bulk density, true density, porosity, shape index, volume, surface area and projected area were measured by using standard methods as described below.

Average size : A vernier caliper having a least count of 0.01 mm was used to measure the dimensions *viz*., length, width and thickness of the onions (Fig.1) A total of 50 onion bulbs were chosen to analyze their physical properties (Mohsenin, 1986).

The geometric mean diameter was calculated from the equation

$$D_{gm} = (D_p\, D_e\, T)^{1/3} \qquad \text{...(1)}$$

where, D_{gm} - Geometric mean diameter, mm, D_p - Polar diameter (largest intercept length) of onions, mm. The polar diameter is defined as the distance between the crowns of the bulb to the bottom part of the bulb from where roots germinate, D_e - Equatorial diameter (width) of onions, mm. The equatorial diameter is the extreme breadth of an onion bulb measured perpendicular to the polar diameter and T = Thickness of onions, mm. The thickness of an onion bulb measured perpendicular to the polar diameter and equatorial diameter.

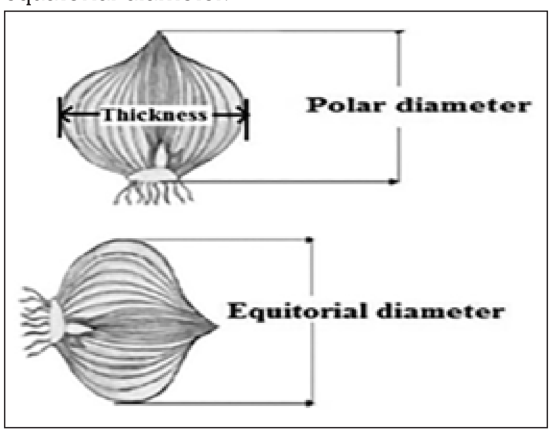

Fig. 1. Diameters of onion

The arithmetic mean diameter (Dam) was the sum of all the three linear dimensions namely length, width and thickness of the sample divided by the total number of linear dimensions (Mohsenin, 1986 and Kakade et al., 2025).

$$Dam = \frac{(Dp + De + T)}{3} \quad ...(2)$$

Shape Index : Shape index was used to evaluate the shape of onion bulbs and it was calculate according to the following equation (AbdAlla, 1993).

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

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

Sphericity : 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 Tirupati,2015 and Kakade et al., 2025).

$$\text{Shericity} = (D_p D_e T)^{(1/3)} / D_p \quad ...(4)$$

Bulk density : Bulk density of onion was defined as the ratio of weight to volume. Bulk density of onion was calculated by placing the sample of onion bulbs in a square box of 200 x 200 x 200 mm. The sample placed in the box was then weighed by using electronic balance with least count of 0.001g. Bulk density was calculated by using the following equation (Ghaffari et al.,2013 and Thakre et al., 2023).

$$\text{Bulk density (kg m}^{-3}\text{)} = \frac{\text{(Weight of bulb (kg)}}{\text{(Volume of box (m}^3\text{)}} \quad ...(5)$$

True density : The true density was 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 (C7H8) displacement method in order to avoid water absorption by the sample. The true density was calculated using following equation.(Ghaffari et al., 2013)

$$\text{True density (kg m}^{-3}\text{)} = \frac{\text{Mass (kg)}}{\text{(Volume (m}^3\text{)}} \quad ...(6)$$

Porosity : Porosity of the onion bulb sample was the ratio of the volume of internal pores within the onion bulb to its bulk volume. It was estimated using the true and bulk density values. The porosity was calculated using following equation (Mohsenin, 1970).

$$\text{Porosity (\%)} = 1 - \frac{\text{Bulk density}}{\text{True density}} \times 100 \quad ...(7)$$

Volume and surface area : The volume and surface area of an onion was determined on the basis of shape. The shape was approximated by one of the following geometric shapes (Mohsenin, 1970).

As per prolate spheroid shape, volume and surface area of the onion was calculated by using the following equation (Mohsenin, 1970).

$$V = 4/3 (\pi ab^2) \quad ...(8)$$

Surface area was defined as the total area over the outside of the onion bulb. Surface area of the onion bulb was calculated by using the following equation.

$$S = 2\pi b^2 + 2\pi(ab/e) \sin^{-1} e \quad ...(9)$$

where, V - Volume, cm^3, S - Surface area, cm^2, a - Major axes of the ellipse of rotation, cm, b - Minor axes of the ellipse of rotation, cm and *e*- Eccentricity

$$e = [1 - (b/a)^2]^{(1/2)} \quad ...(10)$$

Projected Area : The projected area of onion was calculated by one fourth of the surface area. Based on the convex body, V is the volume and S is the surface area of that convex body (Polya and Szezo, 1951).

Projected area = 1/4 x Surface area ...(11)

Colour : The colour of onion was analyzed with a Premier colour scan instrument (Make : BYK Gardner Instruments, Germany). The colour was expressed in dimensions of L*, a*,b* values (Kakade et al., 2023a).

Dry matter : Bulbs was randomly selected from each treatment and cut into small pieces with the help of stainless steel knife. A known weight of the sample was dried in hot air oven at 60°C temperature till a constant weight was obtained. The per cent dry matter was calculated by the following formula (Eriballo et al., 2022).

$$\text{Dry matter (\%)} = \frac{\text{Dry weight}}{\text{Fresh weight}} \times 100 \quad ...(12)$$

2. Chemical Properties

Moisture content (%) : The moisture content was calculated using the formula (Ambrose et al., 2020; Thakre et al.,2023 and Kakade et al., 2023b).

$$M_{wb}(\%) = (W1 - W2) / W1 \times 100 \quad ...(13)$$

where, M_{wb} = Moisture content, per cent wet basis, W1 = Initial weight of the sample, g and W2= Final weight of the sample, g

Total soluble solids (TSS, %) : The total soluble solids of juice were determined by using digital Hand Refractometer (PR-100) having 0 to 32°Brix range.

Carbohydrate : The carbohydrate content of a fruit and vegetables was determined by calculating the per cent remaining after all the other components have been measured (Gennaro et al., 2009).

Carbohydrate (%) = 100 – (% moisture content + fat + % protein + % ash) ...(14)

Determination of Ash Content : Ash is an inorganic residue remaining after the material has been completely burnt at a temperature of 550 oC in a muffle furnace. The % ash content in the onion sample was calculated as as per AOAC,1990:

$$\text{Ash (\%)} = \frac{\text{Weight of ash}}{\text{Weight of sample taken}} \times 100 \quad ...(15)$$

Determination of Crude Proteins : The powdered onion sample was tested for crude proteins content according to the Kjeldahl's method as described in AOAC, 1990.

Determination of crude Fat : The crude fat in the powdered sample was determined using Soxhlet extraction for 24 hour as described in AACC, 2000.

The % fat in the sample was calculated using the formula:

$$\text{Fat (\%)} = \frac{\text{Weight of fat}}{\text{Weight of sample taken}} \times 100 \quad ...(16)$$

Pyruvic acid : Pyruvic acid of onion bulbs was determined according to the modified method described by Anthon and Barrett (2003).

Ascorbic acid : Ascorbic acid content was estimated titrimetrically using 2, 6–dichlorophenol indophenols dye as per the Association of Official Agricultural Chemists (AOAC, 1990) procedure. (Shelke et al., 2020).

Total Phenol : The total phenol analysis was performed using a slightly modified technique. The onions total phenolic content was calculated as gallic acid equivalent per 100 g fresh weight (GAE 100^{-1} g FW) (Singleton and Rossi 1965 and Marinova et al., 2005).

Total flavonoids : The total flavonoids content of the onion sample was determined using aluminium chloride colorimetric methodology established by Zhishen et al., (1999). Catechin equivalent per 100 g fresh weight (CE 100^{-1} g FW) was used to calculate the total flavonoid content.

Antioxidant or scavenging activity : The antioxidant activity of the bulb after ozone exposure was determined by evaluating the free radical – scavenging effect on the 2, 2- diphenyl-picrylhydrazyl (DPPH) radical. The DPPH free radical- scavenging assay was performed by the method described by (Alothman et al., 2010). The percentage of inhibition of the DPPH radical was calculated as

$$\% \text{ inhibition of DPPH} = \frac{Ac-As}{Ac} \times 100 \quad ...(17)$$

where, Ac -Absorbance of control and As -Absorbance of sample

Anthocyanin content : The pH differential methodology reported by Shehata et al.,(2020) with minor changes was used to measure anthocyanin content. The following formula was used to quantify the anthocyanin pigment content (as cyaniding-3- glucoside equivalent).

Anthocyanin content (mg 100^{-1} g) = (A x MW x DF x 103) / (ε x 1) ...(18)

where, A-Absorbance difference i.e ., (A_{520} nm - A_{700nm}), pH - 1.0 - (A_{520nm} - A_{700nm}) pH4.5, MW - The relative molecular mass of cyaniding-3- glucoside, DF-Dilution factor and ε - 26,000 molar extinction coefficient (L mol^{-1} cm) for cyaniding -3-glucoside.

Reducing sugars : Reducing sugars % was calculated by using the following equation (FSSAI, 2015).

Reducing sugars (%) = (Diulution x Factor of Fehling (in g) x 100) / (Weight of sample x Titre value) ...(19)

pH : The sample of 5g was measured and 45 mL of distilled water was added to the sample and homogenized for one minute. The solution was maintained at room temperature for 1 hour and the pH of the supernatant was measured using a pH meter. The electrode of the pH meter was directly dipped into the onion samples. Then on the screen of the pH meter, the pH of the sample was observed and recorded.

3. Frictional Properties

Coefficient of Static Friction : Angle of rolling resistance of onion bulb was measured on mild steel surface by inclined plane method. The value of coefficient of static friction was calculated by using following equation (Khura et al., 2011; Ghaffari et al., 2013).

Coefficient of static friction (CoF)=tan θ ...(20)

where, θ = Angle of rolling resistance.

Angle of repose : 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 (Rathinakumari and Jesudas, 2015).

The angle of repose was calculated by using the equation,

Angle of repose (θ) = tan - (H/L) ...(21)

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

4. Thermal Properties

Thermal properties varied linearly with moisture content and calculated as follows.

Thermal Conductivity : Thermal conductivity is defined as ability to conduct heat i.e. the amount of heat that passes through a unit of time when there is a temperature gradient. With the help of mass fraction of carbohydrates, proteins, fat, ash and water; thermal conductivity was calculated by using following equation (Abhayawick et al., 2002).

$$k= 0.25 X_c + 0.155 X_p + 0.16 X_f + 0.135 X_a + 0.58 X_w \quad ...(22)$$

where, X_c, X_p, X_f, X_a and X_w are the mass fraction of carbohydrates, proteins, fat , ash and water, respectively and k, the thermal conductivity (W/mK).

Specific heat : Specific heat is the amount of heat required to raise the temperature of one unit mass of a substance by one degree Celsius. The specific heat of onion was calculated using the equation (Abhayawick et al., 2002).

$$C_p= 1.547X_c + 1.711 X_p + 1.928X_f + 0.908 X_a + 4.180X_w \quad ...(23)$$

where, Cp is the specific heat capacity (kJ kg^{-1} K)

5. Textural Properties

Firmness of onions : Firmness refers to the resistance of a material or object to deformation, typically measured as the force required achieving a certain amount of compression or penetration. The firmness of onion bulbs was measured using a texture analyzer (Model: TMS-Pro Texture Analyzer, Make : Food Technology Corporation, USA) (Kakade et al., 2023a).

Results and Discussion

The results of the present study entitled "Studies on Engineering Properties of N-2-4-1 Onion bulbs" conducted at the Department of Agricultural Process Engineering, Dr. A.S.College of Agricultural Engineering and Technology, MPKV, Rahuri are present the following headings.

Physical properties : The physical properties of onion bulbs Cv. N-2-4-1 have been measured and recorded in Table1.

The physical properties of the onion bulbs were comprehensively evaluated and are summarized in the table above. The mean polar diameter (D_p), equatorial diameter (D_e), and thickness (T) were recorded as 59.06 mm, 57.22 mm, and 51.93 mm, respectively, indicating a generally uniform shape. The geometric mean diameter (Dgm) and arithmetic mean diameter (Dam) were found to be 55.97 mm and 56.07 mm, respectively, with moderate coefficients of variation (CV), suggesting low variability among samples. The shape index (1.03) and sphericity (0.95) values confirmed the near-spherical shape of the bulbs. 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 forbhima super variety. Similar results were also reported for shape index about 1.22 (Khura et al., 2011) and 1.27 (Kaveri and Thirupathi, 2015).The bulk density and true density averaged 571.56 kg m^{-3} and 840.85 kg m^{-3}, respectively, resulting in a porosity of 31.99%, which implies good airflow potential during storage and drying. Similar results were found for Talaja red onion (Dabhi and Patel, 2017).The mean volume and surface area were 7,120 mm^3 and 2,483.81 mm^2, respectively, supporting their suitability for processing operations. Surface area of the onion bulb was evaluated to know the exposer area of the onion bulb. Additionally, the eccentricity value of 0.04 indicates minimal deviation from a perfect sphere. The average projected area was 620.95 mm^2. The bulbs showed a dry matter content of 12.10%, essential for determining shelf life and

Table 1. Physical properties of N-2-4-1 onion variety

Physical properties	Mean*	Max. value	Min. value	SD	CV (%)
Dp, mm	59.06	70.36	44.56	6.38	10.81
De, mm	57.22	68.25	42.78	6.43	11.23
T, mm	51.93	63.13	38.46	6.43	12.38
Dgm, mm	55.97	66.85	41.93	6.24	11.15
D¬am, mm	56.07	66.90	42.00	6.24	11.14
Shape index	1.03	1.14	1.00	0.03	2.94
Sphericity	0.95	0.97	0.89	0.02	2.11
Bulk density, kg m^{-3}	571.56	597.54	547.48	25.08	4.39
True density, kg m^{-3}	840.85	899.72	798.26	52.65	6.26
Porosity, %	31.99	33.58	30.90	1.41	4.40
Volume, mm^3	7120	7910	6420	0.75	10.50
Surface area, mm^2	2483.81	2947.21	2157.62	412.29	16.60
Eccentricity	0.04	0.06	0.02	0.02	58.18
Projected area, mm^2	620.95	736.80	539.40	103.07	16.60
Dry matter, %	12.10	12.12	12.08	0.02	0.17
Lightness, L*	60.01	60.66	59.26	0.71	1.18
Redness, a*	16.08	16.21	15.89	0.17	1.05
Yellowness, b*	9.28	9.89	8.53	0.69	7.44

*mean of fifty onion bulb samples

processing quality. Color parameters (L*: 60.01, a*: 16.08, b*: 9.28) indicated a uniform and appealing appearance, which is desirable for consumer acceptance. Overall, the low coefficients of variation for most properties suggest a high level of uniformity in the studied onion samples, which is beneficial for post-harvest handling and processing. Similar results were also reported by Pavani et al.,(2017) for bhima super variety. In another study on red, white and yellow onion bulbs also reported similar results (Ghaffari et al., 2013).

Chemical Properties : The chemical properties of onions Cv. N-2-4-1 were measured and recorded in Table 2.

The mean moisture content was found to be 82.97%, indicating high water content typical of fresh onions. A similar result was reported by Amita et al. (2021), they found the moisture content to be 83.09 ± 0.55%, with a standard deviation of 2.80 and a CV of 0.03%. The average carbohydrate content was 9.12%, contributing significantly to the energy value. The ash content, representing total mineral content, was 3.20%, and the protein content was 4.15%, reflecting the nutritional quality of the bulbs. The fat content was minimal at 0.16%, supporting the classification of onion as a low-fat food. These values are consistent with findings from other studies on onion varieties as reported by Dinkecha, K and M.Muniye (2017). They found the carbohydrates, ash, protein and fat to be 16.77 ± 1.1 to 21.87± 0.4 g/100g, 4.14 ± 0.12 to 8.3 ± 0.14 %, 8.6 ± 0.03 to 10.84 ± 1.23 % and 0.68 ± 0.7 to 0.85 ± 0.12 % respectively. Antioxidant activity measured as DPPH inhibition was high at 57.35%, indicating strong free radical scavenging potential. The bulbs contained 8.33 mg 100^{-1} g of anthocyanin and 3.50 g 100^{-1} g of reducing sugars, contributing to both nutritional and sensory attributes. The pH was slightly acidic at

Table 2. Chemical properties of N-2-4-1 onion variety

Chemical properties	Mean*	Max. value	Min. value	SD	CV (%)
M.C.,%	82.97	83.20	82.60	0.32	0.39
Carbohydrate,%	9.12	9.32	8.92	0.20	2.19
Ash,%	3.20	3.30	3.10	0.10	3.12
Protein,%	4.15	4.20	4.11	0.05	1.09
Fat,%	0.16	0.18	0.15	0.02	9.35
Inhibition DPPH,%	57.35	57.42	57.27	0.08	0.13
Anthocynin, mg 100^{-1} g	8.33	8.50	8.20	0.15	1.83
Reducing Sugars, g 100^{-1} g	3.50	3.60	3.40	0.10	2.86
pH	5.83	5.85	5.82	0.02	0.26
TSS, °Brix	15.60	16.00	15.00	0.53	3.39
Pyruvic acid, µmole g^{-1}	14.13	14.14	14.11	0.02	0.11
Ascorbic acid, mg 100^{-1} g	17.83	18.56	17.41	0.63	3.56
Total Phenol, mgGAE 100^{-1} g	54.11	54.84	53.24	0.81	1.50
Total flavonoids, mgCE 100^{-1} g	25.04	25.11	24.95	0.08	0.32

*mean of fifty onion bulb samples

5.83, suitable for maintaining storage quality. Total soluble solids (TSS) averaged 15.60 °B, suggesting good sweetness and flavor. Pyruvic acid content, which influences pungency, was 14.13 µmole g^{-1}. Additionally, ascorbic acid (vitamin C) was measured at 17.83 mg 100^{-1} g, indicating good antioxidant content. The total phenol and total flavonoid contents were 54.11 mg GAE 100^{-1} g and 25.04 mg CE 100^{-1} g, respectively, further highlighting the onion's health-promoting properties. Similar results were reported by Kakade et al. (2023a) and Kakade et al. (2023b) for onions.

Frictional Properties : Frictional properties *viz*., coefficient of friction and angle of repose of onion Cv. N-2-4-1 are presented in Table 3.

Table 3. Frictional properties of N-2-4-1 onion variety

Frictional properties	Mean*	Max. value	Min. value	SD	CV (%)
Coefficient of static friction, (CoF)	0.46	0.47	0.45	0.01	2.17
Angle of repose (ϕ), °	37.30	37.97	36.45	0.77	2.08

The frictional properties of the onion bulbs were evaluated to understand their behavior during handling and processing. The coefficient of static friction (CoF) was found to have a mean value of 0.46, with minimal variation (CV: 2.17%), indicating a consistent surface interaction with different contact materials. The mean angle of repose was recorded at 37.30°, with a low coefficient of variation (2.08%), suggesting uniform flow characteristics of the bulbs when piled. These results indicate that the onion bulbs possess good flowability and moderate frictional resistance, which are advantageous for designing storage bins, hoppers, and conveying systems, ensuring efficient post-harvest handling and processing operations. Similar results of angle of repose were obtained 43.6±2.904° for Bhima super variety (Pavani et al., 2017).

Thermal Properties : Thermal properties i.e. thermal conductivity and specific heat varied linearly with moisture content and calculated and recorded in Table 4.

The thermal properties of N-2-4-1 onion

Table 4. Thermal properties of N-2-4-1 onion variety

Thermal properties	Mean*	Max. value	Min. value	SD	CV (%)
Thermal Conductivity, W m^{-1} K	0.51	0.51	0.51	0.00	0.20
Specific Heat, kJ kg^{-1} K	3.73	3.74	3.73	0.01	0.15

variety were analyzed to support the design of thermal processing and storage systems. The mean thermal conductivity was observed to be 0.51 W mK^{-1}, with negligible variation (CV: 0.20%), indicating a uniform heat transfer capacity across the samples. The specific heat was measured at an average of 3.73 kJ kg^{-1} K, showing minimal variability (CV: 0.15%). These consistent thermal properties suggest that the N-2-4-1 onion variety has stable and predictable behavior during processes involving heat transfer, such as drying, cooling, and thermal treatments, ultimately ensuring uniform quality and energy efficiency during post-harvest handling and processing. A similar result was reported by Abhayawick et al. (2002).

5. Textural Properties

The firmness of multiplier onion in terms of penetrating force and crushing strength was determined with the help of texture analyser (Table 5).

The textural properties of the N-2-4-1 onion variety were evaluated to assess its mechanical strength and suitability for handling and processing. The mean firmness was recorded as 9.42 N, with a maximum value of 9.87 N and a minimum of 8.94 N, resulting in a low coefficient of variation (4.94%). The high firmness value reflects good structural integrity, which is beneficial for withstanding mechanical stresses during harvesting, transportation, and storage, while also contributing to consumer preference for crispness and freshness. Overall, the uniform firmness of the N-2-4-1 onion variety confirms its suitability for both fresh market and processing applications. Firmness values for onion bulbs typically range from 8 to 12 N, as observed in the research by Ambrose (2020), which examined various onion varieties for their textural properties.

Table 5. Textural properties of N-2-4-1 onion variety

Textural properties	Mean*	Max. value	Min. value	SD	CV (%)
Firmness, N	9.42	9.87	8.94	0.47	4.94

Conclusion

For the N-2-4-1onion variety, the polar diameter, equatorial diameter, thickness, geometric mean and arithmetic mean diameter were calculated as 59.06, 57.22, 51.93, 55.97 and 56.07 mm, respectively. The shape index and sphericity were 1.03 and 0.95, respectively. The average bulk density, true density and porosity were 571.56 kg cm^{-3}, 840.85 kg cm^{-3} and 31.99%., respectively. The average volume, surface area, eccentricity and projected area were 7120 mm^3, 2483.81 mm^2, 0.04 and 620.95 mm^2, respectively. Dry matter content was 12.10%. Colour values i.e. L*, a* and b* were 60.01, 16.08 and 9.28, respectively.

The chemical properties viz., moisture content, carbohydrate, ash, protein, fat, inhibition DPPH, anthocynin content, reducing sugars, pH, TSS, pyruvic acid, ascorbic acid, total phenol and total flavonoids were 82.97%, 9.12%, 3.20%, 4.15%, 0.16%, 57.35%, 8.33 mg 100^{-1} g, 3.50 g 100^{-1} g, 5.83, 15.60°B, 14.13 µmole g^{-1}, 17.83 mg 100^{-1} g, 54.11 mg GAE 100^{-1} g and 25.04 mg CE 100^{-1} g, respectively.

The thermal properties i.e. thermal conductivity and specific heat were 0.51 W m^{-1} K and 3.73 kJ kg^{-1} K, respectively. The coefficient of static friction was 0.46 whereas, angle of repose (ϕ) was 37.30o. The firmness of N-2-4-1onion variety was 9.42 N.

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