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Physico-chemical and mechanical properties of Shallot onion for designing of processing equipment and packaging

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Abstract

Aggregatum onion (*Allium cepa* L. var. *aggregatum*.) is used as seasoning material for preparation of food. In south Indian cuisine, it is primarily renowned for its pungency and used in various dishes. By secondary processing different product could be prepared from peeled onion are flakes, powder and paste. Now a days the demand for Ready to cook (RTC) products are high in the market. In order to understand product behaviour during design of processing equipment, grading, packaging, and storage for peeled onion. The physico-chemical and mechanical properties are important. These properties were measured as per the standard procedures. The true density and bulk density of aggregatum peeled onion were 989kg/m³ and 378 kg/m³ respectively. The coefficient of static friction, crushing load and penetration load were also measured. The average crushing load and penetration load of fresh peeled onion were recorded as 107.35 and 8.69 N respectively. The moisture content and shape of aggregatum peeled onion was measured as 83.23% (w.b) and spherical in shape. The TSS of fresh peeled onion was found 14.45 ± 2.47° Brix. The pH, acidity were also measured. The ascorbic content, total phenolic and antioxidant activity DPPH % were found as 16.44 ± 0.28 mg/100gm, 1295 µg GAE/g FW and 67.5% respectively.

Keywords: Peeled onion, physico-chemical properties, ascorbic acid, antioxidant activity, total phenol

1. Introduction

Small onion CO4 (*Allium Cepa* var. *aggregatum*) also known as multiplier, shallot or aggregatum onion. It gives the human diet substantial nutritional value and has medicinal properties. The volatile compound present in onion known as allyl-propyl disulphide is eaten primarily because of its distinctive taste or its capacity to enhance the flavor of other foods. The small onion is used for food, spices, and curry seasoning (Anand, Venkatachalapathy *et al.* 2020) [2]. It is also used for cooking, frying and pickling (Saraswathi, Sathiyamurthy *et al.* 2017) [18]. In India onion is covering 10% out of total vegetable area. In year 2015-16 the onion export from India was reported 203 lakh tones. It occupies 10.5% of total vegetable production (Shoba, Rajeshwari *et al.* 2017) [20]. In India Maharashtra (28.9%) has more production followed by Karnataka (22.4%), Gujrat (10.4%), Madhya Pradesh (6.5%), Andra Pradesh (4.9%), Rajasthan (2.7%) and Haryana (2.6%) (Kaveri and Thirupathi 2015) [11].

Small onion CO4 variety is only cultivated in southern state of India Tamil Nadu, Karnataka and Andhra Pradesh. The primary processing of unpeeled multiplier onions requires washing, grading, storage, etc. Aggregatum onions when peeled can be further processed to make various products by secondary processing, such as paste, flakes, powder, etc. (Kaveri and Thirupathi 2015) [11]. In the present study the physical properties measurement, such as size, shape, volume, surface area, density, sphericity and porosity, contributes to the design of graders, sorters, handling and storage structures. The mechanical and frictional properties includes crushing, compression and penetration strength and coefficient of static friction. Chemical properties includes moisture, TSS, pH, acidity, colour, ascorbic acid, total phenolic content and antioxidant activity gives idea about its chemical constituents present in it. Thus the above characteristics are necessary during design of processing equipment, packaging, storage study and to know the chemical composition of aggregatum peeled onion.

Thus the experiment was planned to study physico-chemical and mechanical properties of fresh peeled aggregatum onion.

2 Materials and Methods

2.1 Raw Material

The shallot onion CO4 variety (Fig.1) was developed by TNAU, Coimbatore. It is spherical in shape and red in colour. It has high yielding variety 19 t/ha with crop period of 65 days. This variety is mainly cultivated in Tamil Nadu state followed by Andhra Pradesh and Karnataka in India. The small onions are used for study have been purchased from local market of Thanjavur, Tamil Nadu. The fresh aggregatum onion were peeled by using peeling machine (Developed by IIFPT). The peeled onion (Fig.2) were used for estimating physico-chemical properties as per the standard procedure.



Fig 1: CO4 Variety of Small Onion



Fig 2: Peeled Shallot CO4 Onion

2.2 Physical Properties of Aggregatum Peeled Onion

The physical properties of aggregatum peeled onion such as linear dimensions, true density, bulk density, Sphericity, shape index, coefficient of static friction, crushing and penetration load has been calculated as per the procedure given below.

2.2.1 Equatorial Diameter (De)

It is the maximum width of the onion in a plane perpendicular to the polar diameter. By using digital vernier caliper of ± 0.01 mm least count the equatorial diameter was measured (Bahnasawy 2007) [4].

2.2.1 Polar Diameter (Dp)

It is the distance between the onion crown and the point of root attachment to the onion. By using digital vernier caliper of ± 0.01 mm least count the equatorial diameter was measured (Bahnasawy 2007) [4].

2.2.3 Thickness (T)

Thickness is measured as the dimension between equatorial and polar diameter of onion bulbs. By using digital vernier caliper of ± 0.01 mm least count the thickness was measured (Kaveri and Thirupathi 2015) [11].

2.2.4 Geometric Mean Diameter (Dgm)

It was calculated by using linear dimensions Polar diameter (Dp), Equatorial diameter (De) and Thickness of onion. It is the cube root of De, Dp and T (Sunil, Venkatachalapathy *et al.* 2016) [22].

$$\text{Geometric mean diameter } (D_{gm}) = (D_p * D_e * T)^{0.333}, \text{ cm} \quad (2.1)$$

Where

D_{gm} - Geometrical mean diameter, cm
 D_p - Polar diameter, cm
 D_e - Equatorial diameter
 T - Thickness, cm

2.2.5 Arithmetic Mean Diameter (Dam)

Arithmetic mean diameter is the sum of three linear dimensions polar diameter, equatorial diameter and thickness of sample divided by the total number of linear dimensions. By using digital vernier caliper of ± 0.01 mm least count, these dimensions were measured (Pandiselvam, Pragalyaashree *et al.* 2014) [16].

$$\text{Arithmetic mean diameter } (D_{am}) = \frac{(D_e + D_p + T)}{3} \text{ cm} \quad \dots(2.2)$$

Where

D_{am} - Arithmetic mean diameter, cm
 D_e - Equatorial diameter, cm
 D_p - Polar diameter, cm
 T - Thickness, cm

2.2.6 Frontal Surface Area (Afs)

The frontal is the representation of solid object as it appears if cut by intersecting plane.

The frontal surface area of peeled onion bulb was calculated by the given relationship (Bahnasawy, El-Haddad *et al.* 2004) [4].

$$\text{Frontal surface area } (A_{fs}) = \frac{\pi}{4} D_e * D_p, \text{ cm}^2 \quad \dots(2.3)$$

Where,

A_{fs} - Frontal surface area, cm^2
 D_e - Equatorial diameter, cm
 D_p - Polar diameter, cm

2.2.7 Cross-Sectional Area (Ac.s)

The cross sectional area refers to area of section made by plane cutting an object transversely at right angles to the longest axis. The ($A_{c.s}$) of peeled onion bulb was calculated by given relationship (Kate, Chakraborty *et al.* 2019) [9].

$$\text{Cross - sectional area } (A_{c.s}) = \frac{\pi (D_e + D_p + T)^2}{9} \text{ cm}^2 \quad \dots(2.4)$$

Where,

$A_{c.s}$ - Cross sectional area, cm^2
 D_e - Equatorial diameter, cm
 D_p - Polar diameter, cm

2.2.8 Shape Index

Shape Index is used to evaluate the shape and it is calculated according to the following equation (Shoba, Rajeshwari *et al.* 2017) [20].

$$\text{Shape index} = \frac{D_e}{\sqrt{D_p * T}} \quad \dots(2.5)$$

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

2.2.9 Sphericity

It is the ratio of root of the product of polar diameter, equatorial diameter, and thickness and equatorial diameter of peeled onion (Kate, Chakraborty *et al.* 2019)^[9].

$$\text{Sphericity} = \frac{(D_p \cdot D_e \cdot T)^{0.333}}{D_e} \quad \dots(2.6)$$

2.2.10 Mass

Individual weight of peeled onion were measured by using digital weighing balance. Randomly 50 aggregatum peeled onions were selected for weight measurement (Kaveri and Thirupathi 2015)^[11].

2.2.11 Volume

The volume of individual peeled onion measured by water displacement method. The rise in water level indicated volume of peeled onion bulb (Kaveri and Thirupathi 2015)^[11].

2.2.12 True Density

The true density of sample was determined by the water displacement method. Fifteen bulbs were weighed and lowered individually into a 100 ml measuring cylinder filled with up to 50 ml of distilled water.

The rise in water level indicated the true volume of the bulbs. The experiment was performed three times and average value reported as true density of peeled onion (Chandrasekar and Viswanathan 1999)^[5].

$$\text{True density (kg/m}^3\text{)} = \frac{\text{weight of onion, (kg)}}{\text{volume of onion, (m}^3\text{)}} \quad \dots(2.7)$$

2.2.13 Bulk Density

The bulk density of onion determine by filling peeled onion bulbs of known volume of metal container (10×10×10 cm) and weighed.

The bulk density of peeled onion calculated by using ratio of mass and volume of peeled onion bulbs. The experiment performed three times by emptying and filling new sample and average value noted (Dhineshkumar, Anandakumar *et al.* 2016)^[7].

$$\text{Bulk density (kg/m}^3\text{)} = \frac{\text{weight of onion, (kg)}}{\text{volume of onion, (m}^3\text{)}} \quad \dots(2.8)$$

2.2.14 Porosity

By using the values of true density and bulk density the porosity of peeled onion was calculated using following relationship (Kate, Chakraborty *et al.* 2019)^[9].

$$\text{Porosity} = \frac{\text{Bulk density} - \text{True density}}{\text{True density}} \times 100 \quad \dots(2.9)$$

2.2.15 Colour value

The colour of peeled small onion measured with the aid of HUNTER COLOUR LAB. It is an indicator for visual appearance of produced. Colour parameters were expressed as L* describing lightness (L* = 100 for white, L* = 0 for black), a* describing intensity in green-red (a* > 0 for red, a* < 0 for green), b* describing intensity in blue – yellow (b* > 0 for yellow, b* < 0 for blue) (Nagamaniammai, Chithra *et al.* 2019)^[15].

2.3 Coefficient of static friction

It is the ratio of the force required to slide the bulb over a surface divided by the normal force pressing the bulb against the surface.

Coefficients of friction were determined for aggregatum peeled onion bulbs on four surfaces: white plywood, mica, rough cardboard and plywood. In the sample holder, the onion bulbs were filled and the weight was applied to the weight pan before the sample holder just began moving, overcoming the surface friction. By using the weight of the peeled onion bulbs (N) and weight in the pan (F) and the coefficient of static friction was calculated using the formula (Kaleemullah and Kailappan 2003)^[8].

$$\mu = \frac{F}{N} \quad \dots(2.10)$$

where,

μ = Coefficient of friction

F = Force of static friction, kg

N = Normal force, kg

2.4 Crushing load

The crushing is the partial or complete destruction of product. It was determined by using Texture Analyzer (Model: TA HD plus). The P/75 (75 mm is diameter of aluminium probe) probe was used for measuring crushing load. This experiment performed three times and average value was noted (Bahnasawy, El-Haddad *et al.* 2004)^[3].

2.5 Puncture or Penetration Load

The force needed to drive a probe into a product to a depth that causes irreversible crushing is the puncture load. It gives an idea about mechanical strength of a commodity. By using Texture Analyzer (Model: TA HD plus) the penetration load was measured.

The P/4 needle probe was used to measure the puncture resistance of the peeled onion bulb. The force required to penetrate the onion was recorded. The experiment performed three times and value noted (Bahnasawy, El-Haddad *et al.* 2004)^[3].

2.6 Bio Chemical Properties Aggregatum peeled onion

The biochemical properties of peeled onion such as moisture content, pH, TSS, titratable acidity, phenols and antioxidants were calculated as per the standard procedure. The details are given below.

2.6.1 Moisture Content

The peeled onion sliced in to 1 mm thick and kept on perforated metal trays and dried at 55°C in hot air oven still constant weight was obtained. The observations recorded and moisture content was determined by given equation (Kaveri and Thirupathi 2015)^[11].

$$\text{Moisture content } M_{w,b} = \frac{W_1 - W_2}{W_1} \times 100 \quad \dots(2.11)$$

Where,

M_{w,b} = Moisture content, percent wet basis

W₁ - Initial weight of the sample, g

W₂ - Final weight of the sample, g

2.6.2 pH, TSS and Titratable acidity

Peeled Onion bulbs (10g) were measured, milled and diluted into 10ml of distilled water then the pH was measured using pH meter (Jenway, model 3510).

Similarly, total soluble solids present in the onion were determined by using pocket refractometer PAL-1 (ATAGO) with a range of 0-53 °Brix. The crushed juice was put into the refractometer directly and the value showed in the digital display is noted the value in °Brix. (Khatiri, Sheikh *et al.* 2017) [12]. To determine the titratable acidity of peeled onion about 5 gm of sample and 25ml of distilled water were mixed and filtered, 10ml of filtrate and 2.3 drops of phenolphthalein indicator titrated with 0.1N NaOH. The observation were noted and calculated as follows.

$$\text{Total acidity \%} = \frac{0.1 \text{Normality of NaOH} \times \text{Eq.wt of acid} \times \text{titer value}}{10} \times 100 \quad \dots(2.12)$$

2.6.3 Extraction of sample

To determine the total phenolic content and antioxidant activity (DPPH) the extraction method used based on that of (Siddiq, Roidoung *et al.* 2013) [21]. Onions were peeled and cut into slices using manual slicer. For analysis in waring blender, 5 g of onion slices and 40 ml of methanol-80 were added and homogenized. On water-bath shaker the materials were mixed for 1 h and centrifuged at 10000rpm for 10 min. The supernatant was collected and with 10 ml of methanol-80 residue were re-extracted two times and the centrifugation was carried out at 10000rpm for 5min. All collected supernatants were mixed for further analysis of total phenolic content and antioxidant activity.

2.6.4 Total phenolic content

The content of total phenolic was determined by spectrophotometrically using Folin- Ciocalteu reagent at 790 nm. To determine total phenolic the (100µL) ml onion sample extracts was taken in test tube and mixed with 2.9 ml distilled water. The diluted Folin- Ciocalteu reagent (0.5ml) was added in test tube. The samples were mixed properly and kept for 15 min at room temperature.

The 2 ml of 20% aqueous solution of sodium carbonate was added to test tube. The reaction mixture was incubated for 90 min at room temperature. The absorbance was measured using UV-1700 against blank at 790 nm. The total phenolic content were determined using standard gallic acid curve. The total phenolic is equivalent to gallic acid (µg GAE/g FW) (Sharma, Assefa *et al.* 2014) [19].

2.6.5 Antioxidant activity by DPPH

The antioxidant activity of extracted onion sample taken for total phenolic content was measured using DPPH (2,2-diphenyl-1-picrylhydrazyl) describe by (Mlcek, Valsikova *et al.* 2015) [13].

To prepare DPPH solution 24 mg of DPPH added into 100 ml of method. By adding 10 ml of stock solution and 45 ml of methanol, a working solution was prepared. Onion extract 150 µL were mixed with 2850 µL of DPPH solution, and the mixture kept in dark for 1h.

The absorbance was measured using methanol without DPPH as the blank at 515 nm (UV-1700). The antioxidant activity (DPPH) was calculated by using given formula.

$$\text{DPPH Radical scavenging activity \%} = \frac{(AO - A1) \times 100}{AO} \quad \dots(2.13)$$

Where

AO = is the absorbance of control

A1 = is the absorbance of sample.

2.6.6 Ascorbic acid

Ascorbic acid content determined by procedure given by (Sadasivam 1996) [17]. The sample was prepared using using 4% oxalic acid and 5 gm of peeled onion extracted then made it up to 100 ml and centrifuged. By using micropipette 5 ml working standard was taken in conical flask, added 10 ml of 4% of oxalic acid and titrate against dye (v1 ml). The endpoint was appearing pink colour and persist for few minutes. The quantity of dye absorbed was equal to that of ascorbic acid. Similarly, for a sample 10 ml of 4% of oxalic acid was added in 5 ml of extract and titrate against dye (V2 ml). The experiment was replicate three times and titre value has noted. The content of ascorbic mg/100 gm was calculated using given formula.

$$\text{Ascorbic acid mg/100g} = \frac{0.5}{v1} \times \frac{v2}{5} \times \frac{100}{\text{wt of sample}} \times 100 \dots(2.14)$$

3 Result and Discussion

3.1 Physical Properties of Peeled Shallot Onion

The values for equatorial diameter, polar diameter and thickness of fresh peeled onion is given in Table. 1. From the table it is observed that the average values of equatorial diameter, polar diameter, and thickness of small peeled onion were 2.48±0.20, 1.81 ± 0.13 and 1.53±0.13cm respectively. The result showed that equatorial diameter value was higher than that of polar diameter. The similar results were found for Talaja Red Onion (Dabhi and Patel 2017) [6]. The arithmetic mean diameter (D_{am}) and geometric mean diameter (D_{gm}) of peeled onion were 1.94±0.10 and 1.90 ± 0.11 cm respectively. (Muhammad, Isiaka *et al.* 2015) [14] has reported that the groundnut pods for three varieties Manipinter, Local I and Local II the D_{gm} and D_{am} values were 16.28, 16.5 cm, 15.73 and 17.80, 17.90 and 17.30 cm respectively.

The values of cross-sectional surface area and frontal surface area of fresh aggregatum peeled onion were, 29.84±0.34, 35.44 ± 0.40 cm² respectively. Similar study conducted for CO4 fresh

and stored onion bulb and the values of frontal surface area and cross-sectional area were 4.23 ± 15.95, 42.04 ± 14.77cm² and 30.18 ± 9.70, 27.42 ± 8.94 cm² respectively (Kaveri and Thirupathi 2015) [11]. The shape index of peeled onion was 1.49 ± 0.15. The shape index values showed the aggregatum onion were spherical in shape.

The shape index of small garlic was estimated to be 1.36 ± 0.32 (Bahnasawy 2007) [4]. Similarly, the sphericity of fresh peeled onion found 0.76±0.05 with coefficient of variance of 7.05 percent.

The average values of true density bulk, density and porosity of peeled onion were measured as, 989±0.09 kg/m³, 378 ± 0.02 kg/m³ and 61.32±5.27% respectively. The similar result for bulk density for Talaja red onion was found as 552 kg/m³ (Dabhi and Patel 2017) [6].

The true density of CO4 variety fresh and stored onion bulb were measured as 970 and 930 kg/m³ respectively (Kaveri and Thirupathi 2015) [11]. The colour values (L*, a* and b*) of fresh peeled onion were found L*(37.01 ± 0.13), a*(10.39 ± 0.16) and b*(5.41 ± 1.08) respectively. Similarly the colour values of peeled shallot were reported as 54.34, 17.26 and 5.46 by (Nagamaniammai, Chithra *et al.* 2019) [15].

Table 1: Physical Properties of Fresh Peeled Small Shallot Onion

Sr. No	Parameters	Mean	CV %
1	Equatorial diameter(cm)	2.48±0.20	8.03
2	Polar diameter(cm)	1.81±0.13	7.26
3	Thickness(cm)	1.53±0.13	9.01
4	Arithmetic mean diameter (cm)	1.94±0.10	5.64
5	Geometrical mean diameter(cm)	1.90±0.11	5.84
6	Cross sectional are(cm ²)	29.84±0.34	11.50
7	Frontal Surface area (cm ²)	35.44±0.40	11.46
8	Shape Index	1.49±0.15	10.44
9	Sphericity	0.76±0.05	7.05
10	Mass (g)	5.13±0.59	11.58
11	Volume (cm ³)	6.07±0.64	10.54
12	True density (kg/m ³)	989±0.09	9.36
13	Bulk density (kg/m ³)	378±0.02	6.90
14	Porosity %	61.32±5.27	8.60
15	L*	37.01±5.13	13.87
16	a*	10.39±0.16	1.63
17	b*	5.41±1.08	19.97

3.2 Frictional Properties of Peeled Shallot Onion

The coefficient of static friction is an important parameter to measure level of frictional characteristics of peeled onion. The coefficient of static friction were measured with different surfaces such as mica, plywood, metal (SS) and rough cardboard also the values are shown in Figure 3.

The coefficient of static friction were found 0.54±0.03, 0.58±0.01, 0.63±0.02, 0.64±0.03 respectively. From the table it is noticed that the value of coefficient of static friction recorded on the rough cardboard has more values than other materials which may be due to roughness of surfaces and moisture.

Similar study conducted for Talaja red onion the coefficient of friction for different surfaces GI, mild steel, aluminium and plywood were 0.42, 0.39, 0.45 and 0.32 respectively (Dabhi and Patel 2017) [6].

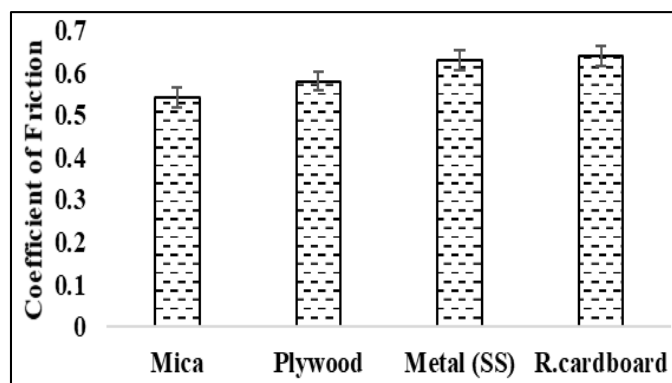


Fig 3: Coefficient of Friction of Fresh Peeled Small Onion with Different Surfaces

3.3 Mechanical Properties of Peeled Shallot Onion

The mechanical properties such as crushing load and pertetration load was calculated and the values are presented in Table 2. The values of crushing load and penetration load of fresh peeled onion as 107.35±20.28 and 8.69±1.31 N respectively. The crushing load was found high due to make 50 percent damage in the peeled onion.

Similar study was conducted for three Egyptian varieties of onion, the crushing load for Giza 6, Beheri, Giza 20 values were 443.30 ± 3.10, 341.40 ± 4.57, 400 N and Penetration load 26.90 ± 0.49, 26.10 ± 0.47 and 27.60 ± 0.40 N respectively (Bahnasawy, El-Haddad *et al.* 2004) [3].

Table 2: Crushing load and Penetration Load of Fresh Peeled Small Onion

Sr. No	Parameters	Mean	CV%
1	Crushing load (N)	107.35±20.28	18.89
2	Penetration load (N)	4.35±0.81	18.67

3.4 Bio Chemical Properties of Peeled Shallot onion

The major biochemical properties such as moisture content, TSS, pH, Acidity, Ascorbic acid, colour value, total phenolic content and antioxidant activity of the fresh peeled onion measured and the values are given in Table 3. The moisture content of aggregatum peeled onion was found as 83.23 ± 1.39% (w.b). The average values of TSS and Ascorbic acid of fresh peeled onion were found 14.45 ± 2.47° Brix and 16.44 mg/100gm respectively. Similarly, the TSS and ascorbic acid of CO5 onion were 16.70°Brix and 12.77 mg/100gm (Acharya, Sharma *et al.* 2015) [1]. The average value of pH of fresh peeled was found 5.86 ± 0.25. The average values titratable acidity were found 0.18 ± 0.007%. (Nagamaniammai, Chithra *et al.* 2019) [15] has reported the titratable acidity of peeled shallot onion is 0.11 ± 0.003. The average value of total phenol and antioxidant activity (DPPH) were found 1295 ± 77.18 (ug GAE /g FW) and 76.85% DPPH. The average value of total phenolic and antioxidant activity (DPPH) of onion grown by different cultivars in India were 42 to 140 mg/ 100gm and 18 to 84% DPPH reported by (Kaur, Joshi *et al.* 2009) [10].

Table 3: Bio Chemical properties of Fresh Peeled Small Onion

Sr. No	Parameters	Mean	CV%
1	Moisture content %	83.23±1.39	1.67
2	TSS Brix	14.45±2.47	17.12
3	pH	5.86±0.25	4.28
4	Acidity %	0.18±0.007	3.82
5	Ascorbic acid mg/100gm	16.44±0.28	1.72
6	Total phenol (µg GAE/g FW)	1295±77.18	6.00
7	Antioxidant (DPPH %)	67.5±2.05	3.05

4. Conclusion

The physico-chemical properties, frictional properties and mechanical properties of fresh peeled onion were measured at the moisture content of 83.23 percent. The equatorial diameter of small peeled onion was greater than polar diameter. The shape index and sphericity showed that peeled onion were in spherical shape. The crushing load was high for

peeled onion compared with penetration load. Similarly the bulk density of small onion was found less compared with true density. The static coefficient of friction value was found high for rough cardboard followed by metal, plywood and mica. These data could be supportive for design of processing equipment, packaging, storage vessels. The biochemical composition TSS, pH, acidity ascorbic acid, total phenolic and antioxidant activity (DPPH) of fresh peeled small onion support the food process industry for secondary and tertiary processing.

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