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RESEARCH ARTICLE

STUDIES ON GEOMETRICAL AND PHYSICAL PROPERTIES OF CO 4 ONION BULB (*ALLIUM CEPA LVAR. AGGREGATUM DON.)*

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ABSTRACT

Geometrical and physical properties of aggregatum onion bulbs were studied were studied for design of equipment for processing, sorting, transportation and heat transfer processes. The equatorial diameter, polar diameter, thickness, D_{gm}, D_{am}, $A_{f.s}$ and $A_{s.c}$ of the fresh and three months stored CO 4 cultivar were determined. Surface area ranged between 7.0 to 30.5 cm^2 for fresh onion and three months stored onions. Spherical shapes of bulbs were indicated by values of shape index and sphericity. The roundness values were 0.87 ± 0.04 and 0.84 ±0.08 for fresh and stored onion samples respectively. Mass, volume, true density and bulk density were decreased whereas the porosity was increased from the fresh and three months stored onion bulbs. Geometrical and physical properties of the CO 4 onion varieties are the essential parameters for all the properties such as mechanical properties, thermal properties and quality analysis. This data could be used for designing of processing equipments, storage structures and transport.

INTRODUCTION

Onion is one of the most important vegetable crops in world.In India, onion is the fourth most important commercial vegetable crop covering an area of 5.93 lakh hectares which is 10per cent of total vegetable area and is highly valued. The production of onion in the country is 7.52 million MT accounting for 8.9 per cent of the total vegetable production. The total onion export from India was 1.66 million MT worth Rs. 2319.43 crores during the year 2009-10. It occupies around 10.5 per cent of vegetable production in our country. Maharashtra (28.9 %) has the highest production of onion in India followed by Karnataka (22.4 %), Gujarat (10.4 %), Madhya Pradesh (6.5 %), Andhra Pradesh (4.9%), Rajasthan (2.7%) and Haryana (2.6 %).

Small onions are also known as shallots, multiplier or aggregatum onion. This onion is produced only in southern states of India viz., Tamil Nadu, Andhra Pradesh and Karnataka. More than 80 per cent of 3.2 lakh tonnes of onion produced in Tamilnadu from an area of 0.30 lakh ha during 2008-09 constituted of small onion (agritech. 2013).

Geometrical properties like size, shape, and area of the onion surface are essential for analysis of the behavior of the product during processing or during design of any equipment for processing and storage. The objective of the current study was to determine the different geometrical properties of the fresh and stored aggregatum onion bulbs (small size).The data is required for the studying behavior of the product during the post harvest operations such as curing, transportation, sorting, grading, packaging and storage processes. Geometrical properties were used to compile a data base for the CO 4 variety.

MATERIALS AND METHODS

CO 4 was developed and released by the Tamil Nadu Agricultural University, Coimbatore. It is composed of 3-4 bulbs of onion joined together. It is red in colour and spherical in shape. It is a high yielding variety with recorded productivity of 20 tonnes/ha and with a crop duration of 65 days. This variety is cultivated in major onion producing States viz., Karnataka, Tamil Nadu and Andhra Pradesh of India. Freshly harvested and three months stored CO 4 bulbs were brought from farmer's field. Shoot and root were removed and bulbs were separated from the multiplier (bunch) for estimating the properties.

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Moisture content is the basic parameter for all the properties studies of onion bulb. The initial and final moisture content was studied before studied the all properties of onion bulbs.

Moisture content

Onions were peeled manually by removing the skin and the first layer, and sliced using a kitchen scale food processor. The slices, 1 mm thick, were then placed on perforated metal trays, and dried in a ventilated hot air oven at 55 °C till a constant weight was obtained [Abhayawick *et al*, 2002]. The observations were recorded and weighed on an electronic balance to a precision of 0.01 g. The moisture content was calculated using the following equation (AOAC. 1990).

$$M_{wb} = \frac{W_1 - W_2}{W_1} \times 100$$

where,

M_{wb} - Moisture content, per cent wet basis

W_1 - Initial weight of the sample, g

W_2 - Final weight of the sample, g

Geometrical properties

Geometrical properties are size, shape and area of the onion surface. The importance of these parameters is associated with the design of a particular machine or analysis of the behavior of the product during a process (Singhal and Samuel, 2003).

Size

Size includes the following properties: equatorial diameter, polar diameter, thickness, geometric mean diameter and arithmetic mean diameter,

Linear dimensions

The linear dimensions of onion bulbs include the polar diameter (D_p), equatorial diameter (D_e) and thickness (T) of onion bulbs from CO 4 cultivars. These bulbs were measured with 0.01mm least count of digital vernier calipers (Make: Mitu Toyo, Japan).

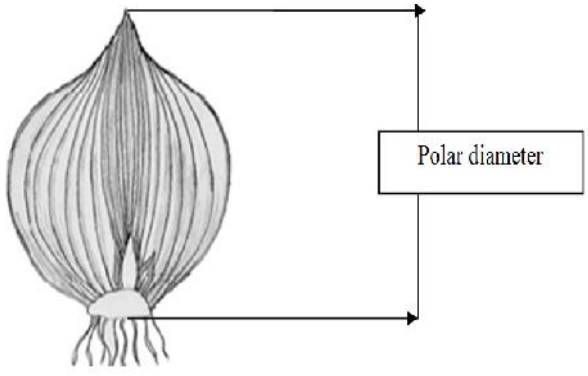

Fig 1 Position of polar diameter of onion bulb

Polar Diameter (D_p)

Polar diameter is the distance between the onion crown and the point of root attachment to the onion. The polar diameter was measured by digital vernier calipers of 0.01 mm least count (Bahnasawy *et al*, 2004).

Equatorial diameter (D_e)

Equatorial diameter is the maximum width of the onion in a plane perpendicular to the polar diameter. The equatorial diameter was measured by digital vernier calipers of 0.01 mm least count (Bahnasawy *et al*, 2004).

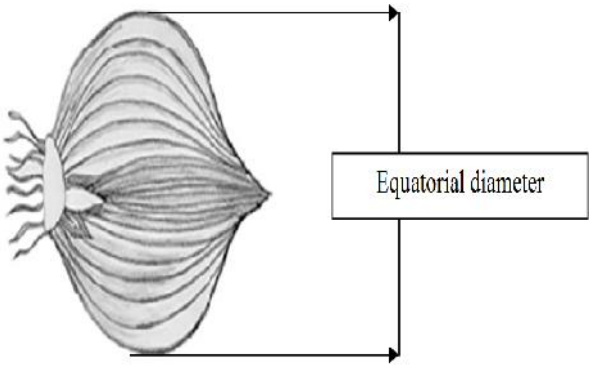

Fig 2 Position of Equatorial diameter of onion bulb

Thickness (T)

It is measured as the dimension between equatorial and polar diameter surfaces of onion bulbs which is smaller than other two dimensions.

The geometric mean diameter (D_{gm}) and arithmetic mean diameter (D_{am}) of the fresh and three months stored onionbulbs were calculated using the following relationships.

Geometric mean diameter (D_{gm})

The geometric mean diameter was calculated from a number of linear dimensions viz., polar diameter (D_p), equatorial diameter (D_e), and thickness (T) of the sample. It is the cube root of the product of linear dimensions D_p, D_e and T.

$$D_{gm} = \sqrt[3]{(De\ Dp T)}$$

Where,

D_{gm} - geometrical mean diameter, cm
D_e - equatorial diameter of onion, cm
D_p - polar diameter of onion, cm
T - thickness of onion, cm

Arithmetic mean diameter (D_{am})

Arithmetic mean diameter is the sum of all the three linear dimensions namely equatorial diameter, polar diameter and thickness of the sample divided by the total number of linear dimensions. The linear dimensions were measured using digital vernier calipers of 0.01mm least count (Bahnasawy *et al*, 2004).

$$D_{am} = \frac{D_e + D_p + T}{3}$$

Where,

D_{am} – arithmetic mean diameter, cm
D_e - equatorial diameter of onion, cm
D_p - polar diameter of onion, cm
T - thickness of onion, cm

Area of onion surface

Area of the onion surface can findout through the frontal surface area, cross sectional area and total surface areaof the fresh and three months stored onionbulbs were calculated (Bahnasawy *et al*, 2004).

Frontal surface ($A_{f.s}$)

Frontal surface area is defined as the representation of a solid object as it would appear if cut by an intersecting plane, so that the internal structure is displayed.

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 *et al*, 2004).

$$A_{f.s} = \frac{\pi}{4} D_e D_p$$

Where,

$A_{f.s}$ - frontal surface area, cm^2
D_e - equatorial diameter of onion, cm
D_P - polar diameter of onion, cm

Cross sectional of areas ($A_{c.s}$)

Cross sectional area refers to the area of section made by a plane cutting an object transversely at right angles to the longest axis. The cross sectional area of sample was determined by given equation.

$$A_{c.s} = \frac{\pi}{4} \frac{(D_e + D_p + T)^2}{9}$$

Where,

$A_{c.s.}$ – cross sectional area, cm^2
D_e - equatorial diameter of onion, cm
D_p - polar diameter of onion, cm
T - thickness of onion, cm

Total Surface area

Total surface area is defined as the total area over the outside of the onion with the roots and tops removed. The surface area is measured by wrapping aluminum foil around the onion bulb and then cutting the foil away with scissors into thin strips sufficient to lay the foil flat (Maw *et al*, 1996). A Li-COD 3100 leaf area meter was used to measure the area of the foil.

Shape

The shape of individual onion bulbs was expressed in terms of the shape index and roundness.

Shape index

The shape index of the onion bulb is the ratio of the equatorial diameter and root of the product of polar diameter and thickness of onion bulbs. Shape index is used to evaluate the shape of onion bulbs and it is calculated according to the following equation (Bahnasawy *et al*, 2004).

$$\text{Shape index} = \frac{D_e}{\sqrt{D_p \times T}}$$

If the shape index is <1.5, the onion bulb is considered as spherical in shape.

Sphericity

The sphericity of the onion bulb is the ratio of root of the product of equatorial diameter, polar diameter and thickness of onion bulbs and equatorial diameter of onion bulbs (Loghavi *et al*, 2011).

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

Roundness

Roundness measures the sharpness of the corners of the onion. The roundness of onion bulb was calculated by tracing the magnified shadowgraphs on graph sheet with the help of an overhead projector (Kaleemullah and Kailappan, 2003). The projected area, diameters of the largest inscribing and the smallest circumscribing projected views were measured. The roundness was calculated using the following formulae (Mohsenin, 1970).

$$r = \frac{A_p}{A_c}$$

Where,

r = roundness, decimal
A_p = the largest projected area of onion bulbs in a particular position, cm^2
A_c = area of the smallest circumscribing circle, cm^2

Physical properties

Physical properties like bulk density and porosity are important during the handling of material for filling in bags and storage. Bulk density indicates the weight of the substance held in unit volume and variation of densities tends to cause the undesirable stratification as bags or bins are filled. The porous nature of some agricultural materials presents a number of problems in volume and density measurement (Sahay and Singh, 1994).

Mass

The weight of individual onion bulbs were measured randomly selected 100 samples each from fresh and the three months stored onion bulbs by using an electronic balance (Ohaus Corporation, New Jersey, USA) with an accuracy of 0.01 g.

Volume

The volume of fresh and three months stored onion samples were determined by the water displacement method. Twenty five bulbs of each sample were weighed and dropped separately into 100 ml measuring cylinders filled with distilled water up to 50 ml. The rise in water indicated the true volume of the bulbs.

True density

True density was measured by the water displacement method. The mass of fifty numbers of individual onion bulbs were measured in an electronic balance and were dropped into the water in 100 ml measuring cylinder. The rise in water level, which is proportional to the volume of the onion bulbs, was noted. The true density experiment was replicated three times and the average value reported. From the mass and volume of the onion bulbs, true density was calculated.

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

Bulk density

Bulk density was determined by filling the onion bulb in a steel cubical container of a known volume and the content was weighed. The ratio between the mass and volume (10x10x10cm) was calculated as bulk density. The experiment was repeated three times by emptying and filling with new samples each time. The average value of bulk density was reported.

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

Porosity

Porosity is the percentage of volume of voids or pore space to the total volume of bulk onion expressed in per cent of whole mass.

Measurement of porosity for stored onion bulbs

Porosity was measured by the Multivolume Pycnometer (Micromeritics model USA: model 1305). It consists of a chamber to hold the cylindrical size sample cup. The cylindrical sample size cup varies from 0.5 to 150 cm^3. A cylinder filled with helium gas which was connected to the equipment. A regulator was provided to adjust the test sample.
A fill valve was provided to pressurize the sample and a vent valve was provided to release the pressure from the chamber. A knob was provided and it can be adjusted as per requirement for calibrating and testing the samples. A digital indicator was provided to record and display the pressure readings inside the chamber.

Onion bulbs were placed in the sample cup and it was closed with the lid. The pressure reading was brought to zero by calibrating the instrument. Fill valve was opened and kept at a moderate level for allowing the helium gas to flow through the chamber. Vent valve kept closed to avoid any pressure leakage. The peak pressure (P_1) and after expansion (P_2) were noted. Vent valve was opened to release the pressure and the sample was taken out. The ratio between the pressure drop [Peak pressure (P_1) – Expansion pressure (P_2)] to the expansion pressure (P_2). The following formula was used for calculating the porosity of sample.

$$\varepsilon(\%) = \frac{P_1 - P_2}{P_2} \times 100$$

Where,

P_1 - peak pressure, kg/cm^2

P_2 - expansion pressure, kg/cm^2

ε - porosity (%)

RESULTS AND DISCUSSION

All the properties were assessed at anaverage moisture content of 83.45±1.10 per cent (wb) for the fresh onion bulbs and 81.82 ±1.01 per cent (wb) for the three months stored onion.

Geometrical properties

Size

Equatorial diameter, polar diameter and thickness

Table 1 shows the mean values, SD and CV of the equatorial diameter, polar diameter and thickness bulb of the CO 4 cultivar. The measurements were made separately for fresh and three months stored bulbs. Results show that the average equatorial diameter, polar diameter and thickness ranged from 2.64 ± 0.52 to 2.25 ±0.38, 2.13 ± 0.41 to1.67±0.29, 2.07 ± 0.39 to 1.61±0.30 cm with the coefficient of variance (CV) of 19.68 to 17.09, 19.38 to 17.53 and 18.78 to 18.37per cent respectively. The mean value of the equatorial diameter was higher than that of polar diameter. These results were similar to the Granex-Grano type sweet onions size (Maw *et al*, 1996).

Table 1 Size of fresh and three months stored CO 4 cultivar

Sl. No	Particulars	Fresh onion			Stored onion		
		Mean	SD	CV (%)	Mean	SD	CV (%)
1	Equatorial diameter (cm)	2.64	0.52	19.68	2.25	0.38	17.09
2	Polar diameter (cm)	2.13	0.41	19.38	1.67	0.29	17.53
3	Thickness (cm)	2.07	0.39	18.78	1.61	0.30	18.37
4	Geometric mean diameter (cm)	2.25	0.40	17.97	1.82	0.31	16.96
5	Arithmetic mean diameter (cm)	2.28	0.41	17.92	1.84	0.31	16.84

Geometric mean diameter (D_{gm}) and arithmetic mean diameter (D_{am}),

Table 1 shows the values of D_{gm} and D_{am} were 2.25±0.40 to 1.82±0.31 and 2.28±0.41 to 1.84 ±0.31 cm, with the coefficient of variance of 17.97 to 16.96 and 17.92 to 16.84 %.Similar studies were conducted on garlic (small size, < 4 cm) and the average values of D_{gm} and D_{am} were 2.53 ±0.12 and 2.53 ±0.08 with CV of 19.48 and 10.23 per cent (Bahnasawy *et al*, 2004).

Table 2 Area of the fresh and three months stored CO 4 cultivar

Sl.No	Particulars	Fresh onion			Stored onion		
		Mean	SD	CV (%)	Mean	SD	CV (%)
1	Frontal surface area (cm^2)	45.23	15.95	35.27	30.18	9.70	32.15
2	Cross sectional area (cm^2)	42.04	14.77	35.14	27.42	8.94	32.62
3	Total Surface area (cm^2)	14.04	6.93	49.36	11.18	2.40	21.43

Table 3 Shape of the fresh and three months stored CO 4 cultivar

Sl. No	Particulars	Fresh onion			Stored onion		
		Mean	SD	CV (%)	Mean	SD	CV (%)
1	Shape index	1.27	0.19	14.75	1.38	0.13	9.59
2	Sphericity	0.84	0.08	10.07	0.79	0.05	6.54
3	Roundness	0.87	0.04	4.04	0.84	0.08	9.10

Table 4 Physical properties of fresh and three months stored CO 4 onion bulbs

Particulars	Initially stored onion			After three months Stored onion		
	Mean	SD	CV (%)	Mean	SD	CV (%)
Mass (g)	6.83	2.87	42.03	5.19	1.21	23.24
Volume (cm^3)	7.19	2.83	39.37	5.97	2.12	35.51
True density (g/cm^3)	0.970	0.08	8.68	0.930	0.10	10.57
Bulk density (kg/m^3)	547.48	26.30	4.80	408.53	8.86	2.17
Porosity (%)	42.34	4.40	10.38	74.37	2.69	3.62

Area of onion surface

Frontal surface area ($A_{f.s}$) and cross sectional surface area ($A_{s.c}$)

$A_{f.s}$ and $A_{s.c}$ were 45.23 ± 15.95 to 30.18 ± 9.70 and 42.04 ± 14.77 to 27.42 cm^2 with the value of CV 35 to 32 per cent (Table 2). Similar studies were carried out for on white onion, red onion and yellow onion and the mean values of $A_{f.s}$ and $A_{c.s}$ were 26.9 ±8.64 and 26.68 ±9.35, 28.8 ± 11.09 and 29.52 ±12.46 and 23.33 ±4.66 and 23.96 ± 4.95 cm^2 respectively (Bahnasawy *et al*, 2004).

Total surface area

Total surface area ranged from 7.0 to 30.50 cm^2 for fresh onion and 7.5 to 16 cm^2 for three months stored onion. The mean values were 14.04 ± 6.93 to 11.18 ± 2.40 cm^2 with coefficient of varianceof 49.36 21.43 per cent (Table 2).

Shape

Shape index, sphericity and roundness

Table 3 shows the average value of shape index was 1.27 ± 0.19 for fresh and 1.38 ±0.13 for three months stored onion bulbs. It can be deduced from the shape index that the bulbs are spherical in shape. This value is agreement with the average shape index of small size garlic which was estimated to be 1.36±0.32 (Bahnasawy, 2007). Sphericity was estimated as 0.84±0.08 to 0.79±0.05 with the value of CV of 10.07 6.54 per cent. Roundness was 0.87±0.04 to 0.84 ± 0.08 with the CV of 4.04 – 9.10 per cent. CO 4 varieties were some of the onion bulbs spherical in shape and some of the onion bulbs were roundness in shape.

Physical properties

The average value of mass, volume, true density, bulk density and porosity of the fresh and three months stored onion bulbs are given in Table.4.

True density

Table.4 shows the average value of fresh and three months stored onion bulbs were 0.970±0.08 to 0.930±010 g/cm^3 respectively. This similar results were to that the average value of true density of Giza 6 (white), Beheri (red) and Giza 20 (yellow) onion cultivars were 1.09 ± 012 g/cm^3, 1.11 ± 0.15 g/cm^3 and 1.04 ± 0.09 g/cm^3 respectively (Bahnasawy *et al*, 2004).

Bulk density

The average value of the fresh and three months stored onion bulbs were 547.48 ± 26.30 to 408.53 ± 8.86 kg /m^3 respectively (Table.4). The similar results revealed for the Lorestan Black Fig fruit average bulk density was 540 kg/m^3 (Jarolmasjed *et al*, 2012).

Porosity

Table.4 shows the average value of fresh and three months stored onion bulbs were 42.34 ± 4.40 to 74.37 ± 2.69 per cent respectively. Porosity increased by 75.65 per cent porosity for three months stored onion bulb. This may be due to the reduction of moisture content based on weight loss from fresh onion bulb to three months stored onion bulb owing to this changing the shape index and the porosity may also increased.

CONCLUSION

A complete set of geometrical properties and physical properties were obtained for the fresh and three months stored multiplier onion bulbs. The following conclusionswere made.
All the properties were assessed at an average moisture content of 83.45±1.1 per cent (wb) for the fresh onion bulbs and 81.82 ±1.01 per cent (wb) for the three months stored onion. The equatorial diameter, polar diameter and thickness weredetermined. Spherical shapes of bulbs were indicated by values of shape index and sphericity. The roundness values were 0.87±0.04 and

0.84±0.08 with the CV of 4.04 and 9.10 per cent respectively. Surface area range was more for fresh sample than the three months stored onion. Mass, volume, true density, bulk density and porosity of the fresh and three months stored onion bulbs were 6.83±2.87 to 5.19±1.21g, 7.19±2.83 to 5.97 ± 2.12 cm^3, 970 ± 0.08 to 930 ± 010 kg/m^3 and 547.48 ± 26.30 to 408.53 ± 8.86 kg $/m^3$ and 42.34 ± 4.40 to 74.37 ± 2.69 per cent respectively.

It was also observed that storage of the bulbs resulted in reduction of values of most the geometrical properties. Mass, volume, true density and bulk density were decreased whereas the porosity was increased from the fresh and three months stored onion bulbs. The observations of the study are a database for the CO 4 bulbs. The data could be used for designing processing equipments, storage structures and transport.

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