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Studies on Properties of Multiplier CO 4 Onion Bulb (*Allium cepa* L.var*. aggregatum.* Don.)

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The properties of multiplier onion bulbs were studied for design of equipment for processing, sorting, transportation and heat transfer processes (heating and cooling). The equatorial diameter, polar diameter, thickness, geometric mean diameter (D_{gm}), arithmetic mean diameter (D_{am}) frontal surface area ($A_{f.s}$) and cross sectional areas ($A_{s.c}$) of the fresh and three months stored Co-4 cultivar were determined. Spherical shapes of bulbs were indicated by values of shape index and sphericity. Surface area ranged from 14.04 ± 6.93 cm_2 for fresh onion and 11.18 ± 2.40 cm_2 for three months stored onion. The roundness values were 0.87 ± 0.04 and 0.84 ± 0.08 for fresh and stored samples respectively. Mass, volume, true density, bulk density and porosity were also determined. The emptying angle of repose for fresh and three months stored onion bulbs was higher than the filling angle of repose. The coefficient of friction was high in rubber surface and lowest in polished wooden card board surface.

Key words: Multiplier onion, Geometrical properties, Physical properties, Frictional properties

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 10% of total vegetable area and is highly valued. The production of onion in the country is 7.52 million MT accounting for 8.9% 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% 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% 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. (www.agritech. tnau.ac.in, 2013)

Geometrical properties like size, shape, and surface area are essential for analysis of the behavior of the product during processing or in the design of any equipment for processing and storage. Knowledge of physical properties like mass, volume, bulk density, true density and porosity is essential for handling of material for filling in bags and storage. Frictional properties such as coefficient of the friction and angle of repose are used to understand the ease with which the given material moves over a given surface. The objective of the current study was to determine the different properties of the fresh and stored multiplier (small size) onion bulbs. The data is required for studying the behavior of the product during the post harvest operations such as curing, transportation, sorting, grading, packaging and storage processes. Geometrical, physical, mechanical, textural and thermal properties are used to compile a data base for the CO 4 variety.

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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.

Moisture content

Onions were peeled manually by removing the skin and the first layer, and then sliced with 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).

$$M_{wb} = \frac{W_1 - W_2}{W_1} \times 10 \quad \text{_____ (1)}$$

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

Linear dimensions

The polar diameter (D_p - distance between the onion crown and the point of root attachment to the onion), equatorial diameter (D_e - maximum width of the onion in a plane perpendicular to the polar diameter), and thickness (T) of the fresh and stored onion bulbs were measured with a digital vernier caliper (Mitayo Instrument, Japan) with the least count of 0.01 mm. The geometric mean diameter (D_{gm}), arithmetic mean diameter (D_{am}), volume, frontal surface ($A_{f.s}$) and cross-sectional of areas ($A_{c.s}$) of the fresh and three months stored onion bulbs were calculated using the following relationships given by Bahnasawy *et al.,*(2004*)* as follows:

Geometric mean diameter (D_{gm})

$$D_{gm} = \left(D_e D_p T\right)^{0.333}, \text{cm} \quad \text{_____ (2)}$$

Arithmetic mean diameter (D_{am})

$$D_{am} = \frac{De + Dp + T}{3}\ \text{cm} \quad \text{____ (3)}$$

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

$$A_{f.s} = \frac{\pi}{8} E P, \text{cm}^2 \quad \text{____ (4)}$$

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

$$A_{c.s} = \frac{\pi}{4} \frac{(D_e + Dp + T)^2}{9}, \text{cm}^2 \quad \text{____ (5)}$$

Shape index

Shape index is used to evaluate the shape of onion bulbs and is calculated according to the following equation (Bahnasawy *et al.,* 2004)

$$\text{Shape index} = \frac{De}{\sqrt{Dp * T}} \quad \text{____ (6)}$$

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

Roundness

The shape of the fresh and three months stored onion bulbs may be expressed as roundness. Roundness measures the sharpness of the corners of the onion. This 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 circles were determined. The roundness was calculated by using the following formula.

$$r = \frac{A_p}{A_c} \quad \text{____ (7)}$$

where,

r - Roundness, decimal

A_p - largest projected area of onion bulbs in a particular position, cm^2

A_c - area of the smallest circumscribing circle, cm^2

Surface area

Surface area is defined as the total area of the onion with the roots and tops removed. The surface area is measured by wrapping aluminum foil around the bulb and then cutting the foil away with scissors into thin strips sufficient to lay the foil flat. A planimeter was used to measure the area of the foil which represents the surface area of the onion. (Maw *et al.*, 1996 and Bahnasawy *et al.,* 2004).

Physical properties

Mass

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

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

From the mass and the true volume of the bulbs, the true density was calculated. Three replications were conducted and the mean value was determined.

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

Bulk density

Bulk density is the ratio of the mass of a sample to the volume it occupied. The volume of the container was found by measuring length, breadth and height for cubical container. Fresh and three months stored onion sample was filled in a steel cubical container of 11.5 cm x 11.5 cm x 11.5 cm dimension and weighed. By measuring the weight of the onion and volume of the container, the bulk density of the onion was calculated.

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

Porosity

The porosity of the fresh and three months stored onion bulbs were computed using the formula given below and expressed in percent (Kaleemullah and Kailappan, 2003).

$$\text{____ (8)} = 1 - \left(\frac{\rho b}{\rho t}\right) \times 100$$

where

[Ù - porosity, %

$ñ_b$ - bulk density, kg m^{-3}

$ñ_t$ - true density, kg m^{-3}

Frictional properties

Angle of rsepose

The emptying angle of repose was determined by filling the onion bulbs in a rectangular container of 25 cm x12.5 cm. After filling the box with the samples, the front panel was removed. This allowed the onion bulbs to flow and form a natural heap. The angle of repose was calculated from the depth of the heap and the width of the box. (Chandrasekar and Viswanathan,1999).

The filling angle of repose (è) was measured by filling a box with the samples and lifting up the box gradually, allowing the sample to accumulate and form a heap on the surface. Then, the angle of repose was calculated from the ratio of the height to the base radius of the heap formed (Maduako and Faborode, 1990).

$$\theta = \tan^{-1} \frac{h}{r} \quad \text{_____ (9)}$$

where

θ – Angle of repose, degree

h – Height of heap, cm

r – Radius of heap, cm

Coefficient of friction

The experimental set up included a frictionless pulley fitted on a frame, a topless and bottomless cylindrical container (94 mm diameter and 98 mm height), loading pan and test surfaces. The bottomless container was placed first on the test surface and filled with known quantity of fresh onion bulbs and weights were added to the loading pan until the container began to slide. The mass of fresh onion bulbs and the added weights represent the normal force and frictional force, respectively. The coefficient of friction was determined for all samples using the formula (Kaleemullah and Kailappan 2003). Observations were taken on six different surfaces viz., galvanished iron surface, stainless steel surface, aluminum surface, mild steel surface, wooden card board and rubber.

$$\mu = \frac{F}{N} \quad \text{___ (10)}$$

where

μ - Coefficient of friction F

- Weight of the onion, kg

N **-** Weight of the force applied, kg

Results and Discussion

All the properties were evaluated at an average 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 properties

The 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 to 1.67 ± 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 18.37 % respectively. The mean value of the equatorial diameter was higher than that of polar diameter. These results are in agreement with the observation of Granex-Grano type sweet onions by Maw *et al.,* (1996).

Geometric mean diameter (D_{gm}), arithmetic mean diameter (D_{am}), frontal surface area ($A_{f.s}$) and cross sectional surface area ($A_{s.c}$) and surface area

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 % respectively. Bahnasawy (2007) conducted a similar study on garlic (small size, < 4 cm) and the average values of D_{gm} and D_{am} were reported to be 2.53 ±0.12 and 2.53 ±0.08 with CV of 19.48 and 10.23 %.

$A_{f.s}$ 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 %. Bahnasawy *et al*.,(2004) studied the $A_{f.s}$ and $A_{s.c}$ for white onion, red onion and yellow onion and the mean values 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. $A_{s.c}$ was more compared with the $A_{f.s}$ of white onion, red onion and yellow onion (bigger size) varieties but in this case of CO 4 onion bulb (smaller size) was vice versa the $A_{f.s}$ was more than the $A_{s.c}$ depends upon the size and verities.

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 variance of 49.36 to 21.43 %. Thus, there was 20.37 per cent reduction of surface area for three months stored onion bulb.

Table 1. Geometrical properties of fresh and three months stored CO 4 cultivar

Particulars	Fresh onion			Stored onion		
	Mean	SD	CV (%)	Mean	SD	CV (%)
Equatorial diameter (cm)	2.64	0.52	19.68	2.25	0.38	17.09
Polar diameter (cm)	2.13	0.41	19.38	1.67	0.29	17.53
Thickness (cm)	2.07	0.39	18.78	1.61	0.30	18.37
Geometric mean diameter (cm)	2.25	0.40	17.97	1.82	0.31	16.96
Arithmetic mean diameter (cm)	2.28	0.41	17.92	1.84	0.31	16.84
Frontal surface area (cm_2)	45.23	15.95	35.27	30.18	9.70	32.15
Cross sectional area (cm_2)	42.04	14.77	35.14	27.42	8.94	32.62
Surface area (cm_2)	14.04	6.93	49.36	11.18	2.40	21.43
Shape						
Shape index	1.27	0.19	14.75	1.38	0.13	9.59
Sphericity	0.84	0.08	10.07	0.79	0.05	6.54
Roundness	0.87	0.04	4.04	0.84	0.08	9.10

Shape index, sphericity and roundness

The average of shape index value 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 to 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.

Table 2. Physical properties of the fresh and three months stored CO 4 cultivar

Particulars	Fresh onion			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)	0.97	0.08	8.68	0.93	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

Physical properties

Mass, volume, true density, bulk density and porosity

Table 2 shows the average values, SD, CV of the CO 4 cultivar. 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, 0.970 ± 0.08 0.930 ± 010 g/cm_3, 547.48 ± 0.026 to 408.53 ± 8.86 kg/m_3 and 42.34 ± 4.40 to 74.37 ± 2.69 % with the CV of 42.03 to 23.24, 39.37 to 35.51, 8.68 to 10.57, 4.80 to 2.17 and 10.38 to 3.62 % respectively. Jarolmasjed *et al* ., (2012) revealed the same results of mean bulk density (540 kg/m_3) for Lorestan Black Fig fruit.

Table 3. Frictional properties of the fresh and three months stored CO 4 cultivar

Particulars	Fresh onion			Stored onion		
	Mean	SD	CV (%)	Mean	SD	CV (%)
Angle of repose						
Filling angle of repose	24.36	2.58	10.58	14.76	0.88	5.97
Emptying angle of repose	37.36	3.41	9.13	41.83	2.45	5.86
Coefficient of friction						
Galvanized iron sheet	0.57	0.08	13.22	0.52	0.05	8.67
Stainless steel sheet	0.52	0.08	16.12	0.44	0.10	22.74
Aluminum sheet	0.51	0.04	7.66	0.46	0.04	7.97
Mild Steel sheet	0.56	0.02	4.03	0.41	0.04	10.37
Polished wooden card board	0.50	0.04	8.93	0.39	0.05	13.12
Rubber	0.72	0.04	5.51	0.58	0.04	6.41

The similar result of porosity was observed by Kaleemullah and Kailappan (2006) for the chillies around 44.37% at the moisture content of 329.44 % db (77% wb).

Frictional properties

Angle of repose and coefficient of friction

Table 3 shows the average value, SD, CV of frictional properties of CO 4 onion cultivar. The filling and emptying angle of repose of the fresh and three months stored onion bulbs were 24.36 (24°21'36'') ± 2.58 to 14.76 ± 0.88 (14° 45' 36'') and 37.36 ± 3.41 (37°21'36'') to 41.83 ± 2.45 (41°49'48'') degree with CV value of 10.58 to 5.97 and 9.13 to 5.86 %. Thus, there was a reduction of the 39.41 per cent in filling angle of the three months stored onion. But, there was a increase of the 11.96 per cent of the emptying angle of repose. The emptying angle of repose was

higher than the filling angle of repose. These results are in agreement with the observation recorded for coffee parchment by Chandrasekar and Viswanathan (1999).

The coefficient of friction of fresh and three month stored CO 4 was 0.57± 0.08 to 0.52 ± 0.05, 0.52 ± 0.08 to 0.44 ± 0.10, 0.51 ± 0.04 to 0.46 ± 0.04, 0.56 ± 0.02 to 0.41 ± 0.04, 0.50 ± 0.04 to 0.39 ± 0.05 and 0.72 ± 0.04 to 0.58 ± 0.04 with the CV value 13.22 to 8.67, 16.12 to 22.74, 7.66 to 7.97, 4.03 to 10.37, 8.93 to 13.12 and 5.51 to 6.41% for the galvanized iron surface, stainless steel surface, aluminum surface, mild steel surface, polished wooden card board surface and rubber surface respectively. The coefficient of friction was high in rubber surface and lowest in polished wooden card board surface. For *jatropha curcas* seeds at 9% moisture content for all sizes, the coefficient of friction was high on the rubber surface compared to plywood, aluminium, stainless steel surfaces as observed by Karaj *et al.,* (2008).

Conclusion

The following conclusions were made from the study of geometrical, physical and frictional properties of fresh and three months stored multiplier onion. The properties of all the values were evaluated at an average moisture content of 83.45 ± 1.1 % (wb) for the fresh onion bulbs and 81.82 ±1.01 % (wb) for the three months stored onion. The equatorial diameter, polar diameter and thickness were determined. 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 % respectively. Surface area ranged from 14.04 ± 6.93 cm_2 for fresh onion and 11.18 ± 2.40 cm_2 for three months stored onion. Thus, there was 20.37 per cent reduction of surface area for three months stored onion bulb.

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 % respectively. Porosity increased by 75.65 per cent porosity for three months stored onion bulb. Similarly, the decrease in the mass, volume, true density, and bulk density of three months stored onion was 24.01, 16.97, 4.12 and 25.38 per cent respectively. This may be due to the reduction of moisture content based on weight loss from fresh onion bulb (85 wb %) to three months stored onion bulb (81.82 wb %) due to this changing the shape index and porosity may also increased

The emptying angle of repose was higher (37°21'36'' and 14° 45' 36'') than the filling angle of repose (24°21'36'' and 41°49'48'') for fresh and three months stored onion bulbs. Thus, there was a reduction of the 39.41 per cent in filling angle of the three months stored onion. But, there was a increase of the 11.96 per cent of the emptying angle of repose.

The coefficient of friction was high (0.72 ± 0.04 to 0.58 ± 0.04) in rubber surface and lowest (0.50 ± 0.04 to 0.39 ± 0.05) in polished wooden card board surface for the fresh and three months stored onion bulbs. This complete set of data for the CO 4 onion bulb could be used for designing processing equipments, storage structures and transport. It was also observed that storage of the bulbs resulted in reduction of values most of the geometrical, physical and frictional properties. Deviation from this trend was observed in filling angle of repose and porosity, which increased with storage. 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.

References

Abhayawick, L. Laguerre, J.C, Tauzin, V and Duquenoy. A. 2002. Physical properties of three onion varieties as affected by the moisture content. *Journal of Food Engineering*, **55**: 253–262.

AOAC. 1990. Fruits and fruit products. In: *Official Methods of Analysis of the Association of Official Analytical Chemists*. Vol. II. Arlington, Virginia (USA), 910-928.

Bahnasawy, A. H. 2007. Some Physical and Mechanical Properties of Garlic. *International Journal of Food Engineering*, **3** : 1556-3758.

Bahnasawy, A. H,. El-Haddad, Z.A, El-Ansary, M.Y. and Sorour, H.M. 2004. Physical and mechanical properties of some Egyptian onion cultivars. *Journal of Food Engineering*, **62**: 255–261.

Chandrasekar,V and Visvanathan, R.1999. Physical and thermal properties of coffee. *Journal of Agricultural Engineering Research,***73** : 227-234.

Jarolmasjed, S, Nahandi, F. Z, Karami, M and Asl, A. K. 2012. Determining some physical and mechanical properties of Lorestan Black Fig fruit. *International conference of Agricultural Engineering, Spain.*

Kaleemullah, S and R.Kailappan. 2003. Geometric and Morphometric Properties of Chillies. *International Journal of food properties*, **6** : 481- 498.

Kaleemullah, S. and Kailappan, R. 2006. Modelling of thin-layer drying kinetics of red chillies. *Journal of Food Engineering,* **76**: 531–537.

Karaj, Shkelqim, Huaitalla, Mendozaa. R, Müller and Joachima. 2008. Physical, mechanical and chemical properties of Jatropha curcas L. seeds and kernels. *Tropentag - Conference on International Agricultural Research for Development, Stuttgart-Hohenheim.*

Maw, B. W, Hung, Y. C, Tollner, E. W, Smittle, D. A. and Mullinix, B. G. 1996. Physical and mechanical properties of fresh and stored sweet onions. *Transaction of ASAE*, **39**: 633–637.

Maduako, J.N. and Faborode. M.O. 1990. Some physical properties of cocoa pods in relation to primary processing. *IJE Journal of Technology*, **2**: 1–7.

www.agritech.tnau.ac.in (2013)

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