Engineering Properties of Cured Small and Bellary Onions

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Abstract- Onion (Allium cepa L. & Allium cepavaraggregatum) is one of the oldest bulb crops, known to mankind and consumed worldwide. It is one of the most important commercial vegetable crops grown in India. 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 sample size taken is 50 bulbs under each grades and the measured properties include equatorial diameter, polar diameter, neck diameter, geometric mean diameter (D_{gm}), arithmetic mean diameter (D_{am}), frontal face area (A_{fs}), cross-sectional area, mass, volume, density, co-efficient of friction, cutting strength and brix. Small onions and Bellary onions though differ in physiology; the shape index of bulbs are spherical in nature. The density of both the onions ranged from 0.95±0.09 to 1.05±0.07 g/cm^3. Bellary onions weigh at least 108.47±21.14 to 129.52±33.65 g whereas small onions contain 8-10 number of bulbs per clump with mass of around 75 g. the Geometric mean diameter (D_{gm}) are 2.51±0.42 to 6.20±0.28 cm, Arithmetic mean diameter (D_{am}) ranged from 2.54±0.429 to 6.25±0.27 cm, frontal surface area (A_{fs}) ranged from 6.15±1.886 to 32.693±2.734 cm^2, cross sectional area (A_{cs}) from 5.21±1.60 to 30.74±2.70 cm^2. Though the values of are close to each other the geometric mean gives a normalized mean for the study. The cutting strength of small onions and Bellary onions are 62.71±15.187 and 129.52±33.65 N. Co-efficient of friction ranged from 0.25±0.05 to 0.27±0.06 and total soluble solids of small onions is 15˚Brix which gives promising storage attributes in comparison to 12˚Brix in Bellary onions. The redness value of the onions is not significantly different for both ranged between 12.24±2.40 to 14084±1.43.

Keywords- Onion, engineering properties, cutting load, co-efficient of friction

1 INTRODUCTION

Onion (*Allium cepa L.*) is one of the oldest crop, known to mankind and consumed worldwide. It is one of the most important commercial vegetable crop grown in India and believed to be originated in Central Asia. It is valued for its distinct pungent flavour and is an essential ingredient for cuisine of many regions. Onions is the queen of kitchen (Selvaraj, 1976).

India ranks second in the production of onions next to china. It contributes about 19.25% of world total world production (FAO, 2012). The compound annual growth rate of production area, is steadily increasing from 1974-75 to 2011-2012 by 3.36 per cent to 5.95 percent, production by 4.94 per cent, to 7.07 percent and productivity by 0.51 to 3.4 per cent respectively. According to FAO-2011 statistics, productivity of country is 14.35 T/ha which is at least 5 times less compared to Republic of Korea (66.16 T/ha), about 4 times less than USA (56.13 T/ha), Spain (55.21 T/ha), Netherland (51.64 T/ha) and Myanmar (46.64 T/ha) (Chengappae *et al.*, 2012).

Onion is cultivated throughout India; during 2012-2013 the era of cultivation is 0.992 million hectares with production of 16.65 million metric tonnes. Maharashtra's standalone contribution is 32.26% in total production and the rest by Karnataka, Gujarat and Madhya Pradesh in India (NHRDF, 2012). Given that India is bestowed with varied agro-climatic conditions it is not only possible to grow different crops but also it supports different varieties of the same crop. Engineering properties aid in design and development of equipment's for use during the post-harvest operations of onion like grading, sorting or packaging. Keeping this in view, the main objective of the study was to determine physical, mechanical and textural properties to form a database for the popular onion varieties Nasik Bellary and CO3 multiplier.

2 MATERIALS AND METHODS

2.1 Materials

Bellary onions (Allium cepa L.) are purchased from the onion commission mundy, Trichy and multiplier CO.3 (Allium cepavaraggregatum) from Perambalur farms, Perambalur.

2.2 Grading

Onions must be from the cultivar of Allium cepa and shall possess general features like intact sound bulbs, devoid of diseases or rotting symptoms, clean and free from visible foreign matters, free from frost damage, sufficiently dry without hollow or tough stems, free from pest, pest damage and abnormal external moisture and also devoid of any foreign smell or taste. Nasik bellary onions of size above 6 cm falls under extra big and less than 2 cm to be graded as small. For small onions in the range of 2.5 – 3.5 cm is considered medium and below 2.5 cm is graded as small.

2.3 Linear dimensions

There are two categories of onion bulb diameter polar diameter and equatorial diameter measured using vernier callipers. Polar diameter is the distance between the polar crowns and the point of root attachment to the onion. Equatorial diameter is the maximum width of an onion in a plane perpendicular to the polar diameter. The equatorial diameter (D_e), polar diameter (D_p) and thickness (T) of each bulbs from each variety was measured with a calliper reading to 0.01 mm accuracy. The geometric mean diameter (D_{gm}), arithmetic mean diameter (D_{am}), volume, frontal surface (A_{fs}) and cross sectional areas (A_{cs}) of the bulbs were calculated using the following relationships given by Mohsenin (1970), as follows:

Geometric mean diameter = $\sqrt[3]{(DeDpT)}$cm

Arithmetic mean diameter = $\frac{(De + Dp + T)}{3}$ cm

Frontal surface area = $\frac{\pi DeDp}{4}$ cm^2

Cross sectional area = $\frac{\pi(De + Dp + T)}{36}$cm^2

2.3.1 Shape index

Shape index is used to evaluate the shape of the onion bulbs and it is calculated according to the following (AbdAlla, 1993) equation

Shape index = $\frac{De}{\sqrt{Dp * T}}$

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

2.3.2 Surface area

Surface area is defined as the total area over the outside of the onions with the roots and tops removed. The surface area is measured by wrapping aluminium foil around the onion bulbs and then cutting the foil away with scissors into thin strips sufficient to lay the foil flat. A plainmeter was used to measure the area of the foil which represents the surface area of the onion considered (Maw et al., 1996).

Table 1: Relationship between mean equatorial diameter, polar diameter, shape index, volume and density in 30 numbers of CO13 and Bellary onion bulbs

Variety	Equatorial Diameter a, (cm)	Polar Diameter b, (cm)	Shape index	Volume (cm3)	Density (g/cm3)
CO13 (Multiplier) – Grade Medium					
Mean	2.70	2.82	1.11	5.9	1.04
SD	0.51	0.44	0.08	0.87	0.09
CV%	19.14	15.83	7.72	14.84	9.50
Correlation with volume-v	0.94	0.80	-	1.0	-
CO13 (Multiplier) – Grade Small					
Mean	2.12	2.97	0.89	5	0.95
SD	0.41	0.38	0.07	4.30	0.094
CV%	19.73	13.07	7.99	86.02	9.80
Correlation with volume-v	0.97	0.95	-	1.0	-
Bellary- Grade Large					
Mean	7.20	5.77	1.24	133.33	1.05
SD	0.33	0.34	0.07	25.16	0.07
CV%	4.64	5.89	6.36	18.87	7.16
Correlation with volume-v	0.96	0.88	-	1.0	-
Bellary- Grade Medium					
Mean	5.79	5.53	1.05	92.5	0.99
SD	0.49	0.50	0.11	19.79	0.04
CV%	8.59	9.15	10.80	21.39	4.93
Correlation with volume-v	0.87	0.56	-	1.0	-

Table 2: Relationship between Geometric mean diameter (D_{gm}), Arithmetic mean diameter (D_{am}), frontal surface area (A_{fs}), cross sectional area (A_{cs}), mass and density of the CO13 and Bellary onion bulbs

Variety	Dgm, c (cm)	Dam, d (cm)	Afs, e (cm2)	Acs, f (cm2)	Mass, g (g)
CO13 (Multiplier) – Grade					
Medium					
Mean	2.51	2.54	6.15	5.21	7.81
SD	0.42	0.42	1.88	1.60	3.19
CV%	17.08	16.88	30.67	30.76	40.92
Correlation with mass- g	0.94	0.91	0.93	0.88	1.0
CO13 (Multiplier) – Grade					
Small					
Mean					
SD	2.25	2.32	5.03	4.33	5.84
CV%	0.38	0.36	1.48	1.34	3.19
Correlation with mass- g	16.95	15.91	29.53	31.07	40.92
Bellary- Grade	0.92	0.93	0.93	0.91	1.0
Large					
Mean					
SD					
CV%	6.20	6.25	32.69	30.74	132.41
Correlation with mass- g	0.28	0.27	2.73	2.70	27.00
Bellary- Grade	4.58	4.45	8.36	8.78	20.39
Medium	0.45	0.49	0.49	0.60	1.0
Mean					
SD					
CV%					
Correlation with mass- g	5.60	5.62	25.25	24.97	88.58
	0.41	0.41	3.64	3.76	17.43
	7.46	7.42	14.44	15.09	19.68
	0.77	0.78	0.79	0.48	1.0

2.3.3 Moisture content

The moisture content of randomly selected onion bulbs froma 10 kg sample was determined according to the ASAE standard (1984). Three samples of each variety were randomly selected and weighed on an electronic balance to a precision of 0.001g.

2.3.4 Volume and density

The real density of the samples was determined by the water displacement method. Fifteen bulbs of each sample were weighed and each one was dropped, separately into a 1000 ml measuring cylinder filled with distilled water up to ml. The rise in water level indicated the true volume of the bulbs, the real density was calculated. For each case, the determination was replicated four times and the mean was considered (Mohsenin, 1970).

2.4 Mechanical property

2.4.1 Co-efficient of static friction

Co-efficient of static friction is the ratio of the force required to slide the bulb over a surface divide by the normal force pressing the bulb against the surface. The co-efficient of friction was the tangent of the slope angle of the table measured with a protractor (Oje & Ugbor, 1991).

2.5 Textural properties

2.5.1 Cutting strength

Firmness of the vegetable cubes was measured using a texture analyser (Stable Microsystems Texture Analyser) with a TA-42 knife probe with 45 chisel blade. A 50 kg load cell was used for all texture measurements. The pre-test speed was 3.00 mm/s, the test speed was 2.50 mm/s, and the post-test speed was 10.00 mm/s. the cutting of onion is performed both in polar and equatorial axis (Koskiniemi, et al, 2013).2.5.2 Puncture or penetration load

Puncture load is the load required for pushing a probe in a product to a depth that causes irreversible crushing. It was given as an indicator of the mechanical strength of the onion to withstand harvesting and post-harvest handling. A head of a flat-head probe (3.0 mm in diameter) was used to measure the puncture resistance of the onion bulb (Bahnasawy, 2004).

Statistical analysis was carried out according to Frend and Lihell (1981). Multiple linear regression for tables 1, 2 and 3 are done to find the best fit and relation among the measured properties. Mean, standard deviation (SD) and coefficient of variation (CV) are also calculated for Table 1-3. Colorimetric values are analysed for paired t-test.

2.6 Colour measurements

The colour of onions were measured using Hunter Lab Colorimeter. The instrument was calibrated with a white, black and green plate. Colour of onion bulbs was measured in all the axis and average of the value is taken as colour of the bulb.

Table 3: Relationship between cutting strength and penetration force with moisture content, brix and COF of CO13 and Bellary onion bulbs

Variety	Brix (%)	COF	Moisture Content, MC (wb)	Cutting Strength, CS (N)	Penetration Force, PN (N)
CO13 (Multiplier) – Grade Medium					
Mean					
SD	14.39	0.24	83.19	59.34	6.07
CV%	0.56	0.02	1.83	8.38	1.38
Correlation with CS	3.92	0.1	2.19	14.13	22.86
Correlation with PN	-	-	0.99	1	-
CO13 (Multiplier) – Grade Small	-	-	0.99	-	1
Mean					
SD					
CV%	15.37	0.27	84.14	62.68	5.55
Correlation with CS	0.33	0.06	6.33	15.19	1.66
Correlation with PN	2.14	0.23	7.52	24.23	0.29
Bellary- Grade	-	-	0.97	1	-
Large	-	-	0.8	-	1
Mean					
SD					
CV%	11	0.25	83.19	128.22	5.22
Correlation with CS	11.4	0.05	1.82	30.12	0.91
Correlation with PN	12	21.1	2.19	23.49	17.44
Bellary- Grade	-	-	0.98	1	-
Medium	-	-	0.78	-	1
Mean					
SD					
CV%	12.1	0.22	83.69	108.47	6
Correlation with CS	12	0.074	2.44	21.14	1.01
Correlation with PN	12.2	32.63	2.91	19.49	16.85
	-	-	0.89	1	-
	-	-	0.91	-	1

3 RESULTS AND DISCUSSION

3.1 Physical properties

3.1.1 Relationship between equatorial diameter, polar diameter, shape index, volume and density in 30 numbers of CO3 and Bellary onion bulbs Size and shape are inseparable in physical object and both are generally necessary to

describe the irregular shapes of the fruits and vegetables. AbdAlla, 1993found the shape index of onion bulbs using the polar and equatorial diameter. Shape index of the chosen Bellary and CO3 onions irrespective of grades fall in the spherical shape. Volume change is also another important parameter in estimating the shrinking of onions during storage. The predict volume, the independent values of equatorial and polar diameters of onion bulbs are related (Griffith and Smith, 1964). It is found that linear regression with Pearson's correlation attempts to predict the volume ranged between 92-94 per cent for small onion and 82-99 per cent for Bellary onions.

$V_{L\text{-}SO}$=-4.513 + 8.409a – 3.369b, R^2= 0.921

$V_{M\text{-}SO}$=-6.449 – 4.416a + 9.720b, R^2=0.946

$V_{L\text{-}BO}$=-368.955 + 45.455a + 30.303b, R^2=0.99

$V_{M\text{-}BO}$=128.596 + 25.977a + 12.383b, R^2=0.820

Table 1 shows the mean values of the medium and small sized CO3 multiplier onions, equatorial and polar diameters ranged from 2.120±0.418 and 2.972±0.388 cm and the volume and density ranged from 5.4±0.301 to 5.9±0.875 cm^3; 1.040±0.099 to 0.959±0.094 cm^3 respectively. Bellary onions of grades large and medium ranged from 5.795±0.498 and 7.204±0.344 cm and the volume and density ranged from 92.5±19.790 to 133.33±25.166 cm^3; 0.991±0.048 to 1.057±0.075 cm^3 respectively.

3.1.2 Relationship between Geometric mean diameter (D_{gm}), Arithmetic mean diameter (D_{am}), frontal surface area (A_{fs}), cross sectional area (A_{cs}), mass and density in 30 numbers of CO3 and Bellary onion bulbs Mass of the onion bulbs are an important quality parameter and the surface areas of fruits and vegetables are important in investigations related to spray coverage, removal of residues, respiration rate, reflectance, and colour evaluation, as well as in heat transfer studies in heating and cooling processes (Mohsenin, 1970). Frechette and Zahradnik, 1966 related the weight and surface area of the McIntosh apples and found the correlation coefficient of 97.5 per cent. Baten and Marshall, 1943 developed numerous equations to calculate weight by surface area measurements which is corresponding to specific fruit cultivar of apples, pear and plums. Onion bulb mass is predicted using the multiple linear regression equation involving geometric mean diameter (D_{gm}), arithmetic mean diameter (D_{am}), frontal surface area (A_{fs}) and cross sectional area (A_{cs}). It is found that linear regression with Pearson's correlation attempts to predict the mass ranged between 89-90 per cent for small onion and 78-86 per cent for Bellary onions.

$M_{L\text{-}SO}$=3.373 + 22.334c – 26.485d + 2.913e – 0.105f, R^2=0.891

$M_{M\text{-}SO}$=0.657 + 13.103c – 14.575d + 1.894e – 0.167f, R^2=0.902

$M_{L\text{-}BO}$=-8662.867 + 2800.190c – 443.534e + 156.484f, R^2=0.86

$M_{L\text{-}BO}$=351.426 – 67.308c – 61.469d + 10.838e +7.508f, R^2=0.775

Table 2 shows the geometric mean diameter (D_{gm}) ranged from 2.26±0.384 to 2.51±0.429 cm, arithmetic mean diameter (D_{am}) ranged from 2.32±0.369 to 2.54±0.429 cm, frontal surface area (A_{fs}) ranged from 5.03±1.486 to 6.15±1.886 cm^2, cross sectional area (A_{cs}) from4.33±1.347 to

5.21±1.604 cm^2 and the mass ranged from 6.23±3.196 to 7.81±3.196 g for mediumand small grade CO3 onions. For Bellary onions the geometric mean diameter (D_{gm}) ranged from 5.606±0.418 to 6.205±0.284 cm, arithmetic mean diameter (D_{am}) ranged from 5.624±0.417 to 6.253±0.278 cm, frontal surface area (A_{fs}) ranged from 24.972±3.678 to 32.693±2.734 cm^2, cross sectional area (A_{cs}) ranged from 24.972±3.768 to 30.741±2.700 cm^2 and the mass ranged from 88.588±17.434 to 132.415±27.004 g.

3.2 Textural properties

3.2.1 Relationship between cutting strength and penetration force with moisture content, brix, COF of CO13 and Bellary onion bulbs

Moisture content of onions decreases from the core to the outermost layer. CO3 and Bellary onions papery layer, first layer and core moisture ranges from 0.17 to 0.10, 8 to 25, 83 to 89 per cent wb respectively. The onion requires higher cuttingstrength for low core moisture onions and vice versa. The relation of cutting and moisture content are

$CS_{L\text{-}SO}$=438.569 – 4.558MC, R^2=0.984

$CS_{M\text{-}SO}$=258.808 – 2.331MC, R^2=0.944

$CS_{L\text{-}BO}$=1650.158 – 18.390MC, R^2=0.976

$CS_{L\text{-}BO}$=760.559 – 7.792MC, R^2=0.809

It is found that linear regression with Pearson's correlations to predict he cutting strength (CS) ranged between 94-98 per cent for small onion and 97-80 per cent for Bellary onions. The TSS of the small onions are about 14-15% and cutting strength ranged from 62.716±15.187 to 50.101±9.683 N. Bellary onion TSS ranged between 11-12% and cutting strength ranged from 108.478±21.145 to 129.526±33.653 N. Penetration strength of onions shows inverse relation with the cutting strength. The probe (P/2N) needle used for penetration is exposed to very small surface area of onions and thus it takes lesser force to penetrate than the cutting probe. The relation of penetration and penetration strength are

$PN_{L\text{-}SO}$=1498.043 – 16.465MC, R^2=0.995

$PN_{M\text{-}SO}$=15.981 – 0.115MC, R^2=0.805

$PN_{L\text{-}BO}$=23.060 – 0.214MC, R^2=0.614

$PN_{L\text{-}BO}$=37.871 – 0.381MC, R^2=0.844

It is found that linear regression with Pearson's correlation attempts to predict he penetration strength (PN) ranged between 80-99 per cent for small onion and 61-84 per cent for Bellary onions. The penetration strength of small and Bellary onions ranged between 5.2±0.91 to 6.07±1.38 N respectively.

Table 4: Colour values of CO13 and Bellary onion bulbs

Variety	L*	a*	b*	C	H	ΔL	Δa*	Δb*	ΔE
CO13 (Multiplier) - Grade Medium									
Mean	37.05	11.99	8.14	14.49	34.2				
SD	6	1.05	4.3	3.14	12.43				
CV (%)	16.2	8.79	52.78	21.67	36.34				
CO13 (Multiplier) - Grade Small						-1.59	2.43	1.33	6.86
Mean	35.47	14.42	9.48	17.32	33.56				
SD	2.78	1.64	0.98	1.05	5.29				
CV (%)	7.83	11.39	10.31	6.05	15.75				
ΔC	-	-	-	2.83	-				
ΔH	-	-	-	-	0.64				
Bellary - Grade Large									
Mean	27.74	12.93	8.26	14.81	29.94				
SD	7.56	3.35	3.7	4.44	13.03				
CV (%)	27.24	25.9	44.84	30.02	43.52				
Bellary - Grade Medium						4.32	0.61	0.92	10.31
Mean	23.42	12.33	7.34	32.38	32.38				
SD	5.81	2.28	2.78	15.72	15.72				
CV (%)	24.82	18.47	37.87	48.56	48.56				
ΔC	-	-	-	-	-				
ΔH	-	-	-	2.44	2.44				

L*- Lightness; a*- redness to greenness; b*- yellowness to blueness; C- Chrome value; H- Hue angle; Δa*- difference in redness/greenness; Δb*- difference in yellowness/blueness; ΔL- difference in lightness; ΔC- difference in Chrome value
ΔH- difference in Hue angle; ΔE- Total colour difference

3.3 Colorimetric properties

Table 4 shows the total colour difference (ΔE) for CO3 and Bellary onion bulbs to be 6.68 to 10.31. Artes et al. (2000a) used ΔE to follow colour changes during de-greening of citrus. The disadvantages with ΔE is that they give no indication of the direction of the colour change. The value of H represents the angle of hue. The positive Δa* and Δb* values represent the first quadrant in standard colour chart. The hue angle of the small and Bellary onions ranged between 29.94±13.03 to 34.20±12.43 respectively. These values corresponds to red colour, while the positive chrome (ΔC) values indicates the brighter red colour of onions.

T-test for colour of onions is performed to know that the colour changes in grades are significant or not. Small and medium grade onions have higher colour value than large and the changes are significant whereas in Bellary onions the colour change in grade large and medium are not significant.

4 CONCLUSION

Onion polar and equatorial diameter are the important factors in developing the prediction model for volume and mass of bulbs. The TSS of the small onions ranged from 14-15˚Brix has more potential for storage than that of the Bellary onions which has only 11-12˚Brix. Moisture of the onions plays important role in determining the cutting and penetration strength. Linear regression of the variable moisture and cutting/penetration strength is satisfactorily correlated. The cutting strength of the onion is in inverse relationship with penetration strength of the onions. Colorimetric values onions suggest that they fall in the bright red region of standard chart.

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