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DETERMINATION OF PHYSICAL AND BIOMETRIC PROPERTIES OF ONION BULBS IN RELATION TO DESIGN OF DIGGER CUM WINDROWER

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ABSTRACT
The physical and biometric properties play vital role in design of any soil operating machine. In view of designing the various components of digger-cum-windrower, physical and biometric properties were determined for three varieties of onion bulbs. The critical dimensions, *viz*. equatorial diameter, polar diameter, thickness, geometric mean diameter, arithmetic mean diameter, cross sectional area, shape index, bulk density, true density, weight of bulb, angle of repose were determined. Geometric and arithmetic mean diameters were identical for all three varieties, which could help designing soil separator effectively. The Arka Bhim was observed to be denser than that of two other varieties. The maximum cross sectional area was recorded for both Arka Kalyan and N 53 (1.74 ± 0.05 cm^2 and 1.75 ± 0.07 cm^2) against Arka Bhim (1.50 ± 0.04 cm^2). Highest values of true density and bulk density were recorded for Arka Bhim. Shape index was under 1.5 for all the three varieties and bulb was considered to be nearly spherical. The Arka Bhim with its maximum frictional coefficient experienced less flow behavior. The measured properties as a whole helped optimizing design values of different components and effective fabrication of prototype.

INTRODUCTION

Onion (*Allium Cepa* L.) is an important vegetable crop among the root vegetable crops in all countries. India is the second largest producer of onion after China with the production of 24.4 million tonnes in an area of 1.3 mha during 2018-19. Onion crop has attained major significance of cash crop rather than a vegetable crop as it has high export potential. This is the most unique vegetable consumed by almost sections of society throughout the year. Onion is extensively cultivated in the North-Karnataka districts, *viz*. Gadag, Dharwad, Belgaum, Bagalkot and Vijayapur. The onion root system is fibrous, spreading just beneath the soil surface to a distance of 45 cm (Al-Jamal *et al*., 2001). Onions play a significant role in preventing heart diseases and other ailments (Augusti, 1990).

Of late, farmers cultivate underground vegetable crops over the raised beds in order to save the irrigation water, energy and harvesting of roots with minimum damage. The underground crops, *viz*. potato, onion, turmeric and gingers are the crops which are planted on the raised beds to facilitate healthier root growth, development and better productivity as well. Manual harvesting of root, tuberous and rhizomatous crops is uneconomical, laborious and time consuming one. Harvesting is a labour oriented operation, which accounts to 21.4 per cent of total production cost (Jadhav *et al*., 1995). Timely harvesting is very essential in order to get higher market price and harvesting bulbs with less physical damage. The delay in harvesting may affect the keeping quality of onion bulbs. After maturity, onion bulbs are harvested with tractor operated diggers-cum-harvesters or manually after loosening the soil. Onion diggers are available, however, the dug onions are supposed to be picked by manual labours as the existing diggers leave the onions submerged inside the soil. To avoid onion submerging in soil during digging, there is a need to develop windrower mechanism for digger. Design of any machine or equipment which interacts with soil and crops simultaneously requires the knowledge of physical and biometric dimensions (Somashekar and Nagesha 2010). The physical, frictional, biometric and engineering properties of bulb decides the design values of various functional parts of onion digger-cum-windrower. Availability of these properties is limited for onion bulb and also physical properties of different varieties of onion crop very essential. Some researchers have studied physical, engineering and mechanical properties of onion bulbs from the view point of design of onion diggers. The physical properties of any crop play a key role in designing agricultural processing machinery with higher standards and properly (Tabatabaeefar and Rajabipour, 2005; Karababa, E. 2006). Bahnasawy *et al*. (2004) and Rani *et al*. (2006) studied biometric properties of different cultivars of onion. These properties included shape index, geometric mean diameter, arithmetic mean diameter, frontal surface area, cross sectional area, volume, unit mass, density, angle of repose, rolling angle, crushing load and puncture resistance. Bahnasawy (2007) and Arunkumar *et al*. (2014) also studied some physical and mechanical properties of garlic, *viz*. linear dimensions, shape index and surface area, friction angle, coefficient of static friction etc. for garlic. Abdel-Ghaffar and Hindey (1984) tested Egyptian onion of four different sizes (small, medium, large, and extra-large). They found that the

mean polar diameters were 40.45, 47, 47.94, and 52.40 mm and the mean equatorial diameters were 39.07, 50.03, 56 and 60.40 mm for the same previous order. The mean mass, bulb density and bulk density were 177 g, 0.976 g/cm3, and 0.586 g/cm3, respectively. There was ample demand for growing of cultivars like Arka Kalyan, Arka Bhim and N-53 in North Karnataka and borders districts of Maharashtra. Literature related to the properties, *viz*. Arka Kalyan, Arka Bhim and N-53 is limited. Hence, the study was planned to determine physical, frictional and biometric properties of onion bulbs of Arka Kalyan, Arka Bhim and N-53, in order to attain the design values of different components of digger-cum-windrower.

MATERIALS AND METHODS

The study was conducted in the food engineering laboratory of College of Horticultural Engineering and Food Technology, UHS Bagalkote, Karnataka during 2019-20. Three varieties of onion extensively grown in different parts of Karnataka state were selected for the study (Fig.1). Ten onion bulbs were randomly chosen from the lot of fresh bulbs for the measuring properties. The physical properties, *viz*. equatorial diameter (De), polar diameter (Dp), thickness(t), geometric mean diameter (Dgm), arithmetic mean diameter (Dam), cross sectional area (Acs), shape index, bulk density, true density, weight of bulb, angle of repose were determined (Fig 2). In order to provide aeration, onion bulbs were stored in jute bag.

Moisture content

The moisture content of freshly harvested onion bulbs were determined by oven method. Bulbs were dried in an air ventilated oven at 105ºC for 48h and the observations related to weights were taken on an electronic balance of precision of 0.01 g. Moisture content was calculated in wet basis. (AOAC, 1990).

Physical, frictional and biometric properties

Twenty onion bulbs were randomly selected from the lot of each variety and their linear dimensions such as polar diameter, equatorial diameter and transverse diameter were measured. The vernier caliper (Mitutoyo 530-312) of ± 0.01 mm accuracy was used for measurement of linear dimensions. Polar diameter (Dp) is the distance between the onion crown and the point of root attachment to the onion bulb (Fig.2). Equatorial diameter (De) is the largest diameter perpendicular to the polar diameter and transverse diameter (Dt) is the smallest diameter perpendicular to polar diameter.

Mean diameters and cross sectional area

The geometric mean diameter (Dgm), arithmetic mean diameter (Dam) and cross sectional area (Acs) of onion bulb were calculated using the following equations;

$$D_{gm} = (De.Dp.Dt)^{1/3} \quad \text{.....(1)}$$

$$D_{am} = \left(\frac{De + Dp + Dt}{3}\right) \quad \text{.....(2)}$$

$$A_{cs} = \frac{\Pi}{4}\left[\left(\frac{De + Dp + Dt}{3}\right)^2\right] \quad \text{.....(3)}$$

Where, De–Equatorial diameter, mm; Dp– Polar diameter, mm; Dt –Transverse diameter, mm

Shape index

Shape index is a measure of the shape of onion bulbs and it is computed according to the following equation:

$$\text{Shape index} = \frac{De}{\sqrt{Dp.Dt}} \quad \text{.....(4)}$$

RESULTS AND DISCUSSION

The properties were determined at moisture content of 80.57 ± 0.95 per cent (wb) for the freshly harvested onion bulbs. The descriptive statistics such as mean, standard deviation and CV were computed for all the properties determined in this study. There were no previous works accomplished related to physical properties of these varieties Arka Kalyan, Arka Bhim and N53.

Shape and size

The linear measurements are very crucial in finalizing the

Table 1: Details of physical and engineering properties measured

Variety	Physical and Engineering properties
Arka kalyana	Equatorial diameter, Polar diameter, Thickness, GMD, AMD, Cross sectional area, Shape index, Bulk density, True density, Weight of bulb, Angle of repose
Arka Bhim	
N-53	

Table 2: Properties of onion bulbs to determine shape index

Variety	Descriptive Statistics	Equatorial diameter (De), cm	Polar d iameter (Dp), cm	Transverse diameter, cm	Shape index
Arka Kalyan	Mean	7.27	6.42	6.21	1.15
	SD	0.33	0.37	0.3	0.07
	CV, %	4.54	5.81	4.77	6.24
Arka Bhim	Mean	6.47	5.49	5.21	1.21
	SD	0.3	0.31	0.29	0.07
	CV, %	4.6	5.61	5.63	5.93
N 53	Mean	7.27	6.47	6.37	1.13
	SD	0.43	0.35	0.22	0.06
	CV, %	5.9	5.43	3.39	5.57

Table 3 : Physical and engineering properties of onion bulbs

Variety	Descriptive Statistics	GMD (Dgm), cm	AMD (Dam), cm	CS area (Acs), cm2	Mass of bulb (g)
Arka Kalyan	Mean	6.61	6.63	1.74	157.9
	SD	0.18	0.18	0.05	6.01
	CV, %	2.68	2.67	2.67	3.81
Arka Bhim	Mean	5.68	5.72	1.5	131.6
	SD	0.16	0.16	0.04	6.42
	CV, %	2.82	2.85	2.85	4.87
N 53	Mean	6.67	6.7	1.75	168
	SD	0.27	0.27	0.07	7.39
	CV, %	4.02	4.06	4.06	4.4

Figure 1: Overview of different varieties of onion bulbs selected for the study

Table 4: Bulk density and true density of onion bulbs

Variety	Descriptive Statistics	Bulk Density , gcc-1	True density, gcc-1
Arka Kalyan	Mean	0.66	1.01
	SD	0.02	0.08
	CV, %	3.47	7.65
Arka Bhim	Mean	0.67	0.98
	SD	0.03	0.04
	CV, %	5.1	3.88
N 53	Mean	0.71	0.92
	SD	0.05	0.03
	CV, %	6.45	3.37

Table 5 : Coefficient of static friction of onion bulbs for different surfaces

Surface	Coefficient of static friction		
	Arka Kalyan	Arka Bhim	N-53
GI Sheet	0.31	0.33	0.27
Mild steel sheet	0.34	0.29	0.31
Plastic sheet	0.22	0.3	0.29
Plywood	0.27	0.32	0.27

dimensions of length and widths of blade and soil separators. The descriptive statistics of various properties determined for three varieties of onion bulbs were computed (Table 2). The mean values of equatorial, polar and transverse diameter were 7.27 ± 0.33, 6.42 ± 0.37 and 6.21 ± 0.30 for Arka Kalyan; 6.47 ± 0.30, 5.49 ± 0.31 and 5.21 ± 0.29 for Arka Bhim and 7.27 ± 0.43, 6.47 ± 0.35 and 6.37 ± 0.22 for N 53. The coefficients of variation for equatorial, polar and transverse diameter were below 10 per cent under all varieties. The Arka Kalyan and N 53 were recorded higher values as that of Arka Bhim. Shape index was 1.15 ± 0.07 for Arka Kalyan; 1.21 ± 0.07 for Arka Bhim and 1.13 ± 0.06 for N53. From the observations, it was conceptualized that onion bulbs are spherical in shape. There were no similar studies which compared the physical properties of these varieties of onion. However, with respect to shape, similar results were observed by Bahnasawy *et al*. (2004).

The geometric mean diameter (Dgm) and arithmetic mean diameters (Dam) for all varieties were indifferent. Mean values of Dgm and Dam were 6.61 ± 0.18 cm and 6.63 ± 0.18 cm for Arka Kalyan; 5.68 ± 0.16 cm and 5.72 ± 0.16 cm for Arka Bhim and 6.67 ± 0.27 cm and 6.70 ± 0.27 cm for N 53(Table 3). The CV values of Dgm and Dam were below 10 per cent for all the varieties. The cross sectional area was 1.74 ± 0.05 cm2 for Arka Kalyan, 1.50 ± 0.04 cm2for Arka Bhim and 1.75 ± 0.07 for N 53. Marginally, the higher cross sectional area was recorded for Arka Kalyan and N 53 (1.74 ± 0.05 cm2 and 1.75 ± 0.07 cm2) as compared to Arka Bhim (1.50 ± 0.04 cm2). The average mass of bulbs for three varieties Arka Kalyan, Arka Bhim and N 53 were to the tune of 90 ± 6.01g, 131.60 ± 6.42g and 168 ± 7.39 g, respectively. Higher mass of bulb was obtained under cultivar N 53 followed by Arka Kalyan and Arka Bhim. The lower CV (less than 5 per cent) values were observed for both mass of bulb and cross sectional area. There were no similar studies which compared the physical properties of these varieties of onion. However, the geometric dimensions of onion bulbs in general were in agreement with the results of Bahnasawy *et al*. (2004).

Bulk density and true density

The bulk and true densities are most important functional properties essential for the design of width of windrowing mechanism. In general, Arka Bhim was denser than other two varieties. However, the higher values of density were obtained for cultivars N 53 and Arka Bhim than Arka Kalyan. The bulk

Table 6 : Design values of different components of digger-cum-separator

S No.	Property	Design values	Dimensions of components to be designed
1	De	6.47±0.35 cm	Length, width and thickness of blade, soil separator
2	Dp	5.49±0.34 cm	
3	T	5.21±0.27 cm	
4	Dgm	5.68±0.20 cm	Shape of blade and length of soil separator
5	Dam	5.72±0.20 cm	
6	Acs	1.75±0.05 cm2	
7	SI	1.21±0.07	Soil separator slits/grooves
8	BD	0.71±0.03gcc-1	Width of blade
9	TD	1.01±0.05gcc-1	
10	W	168±6.61g	Length of soil separator
11	AR	21±0.15°	Digger blade angle and separator angle

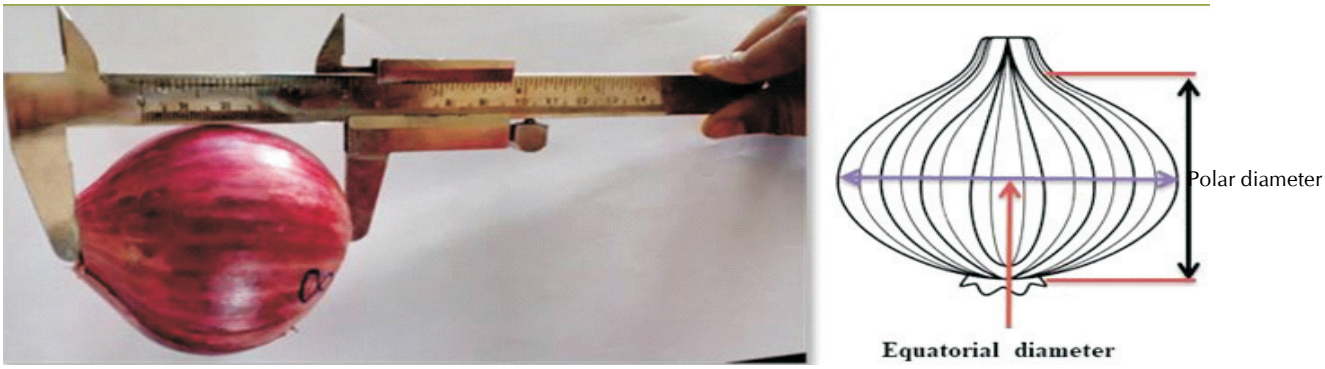

Figure 2: Measurement of polar diameter and conceptual view

density of 0.66±0.02 g/cc, 0.67±0.03 g/cc and 0.71±0.05 g/cc was recorded under Arka Kalyan, Arka Bhim and N 53, respectively. The true density was 1.01±0.08 g/cc, 0.98±0.04 g/cc and 0.92±0.03 g/cc for Arka Kalyan, Arka Bhim and N 53, respectively. In general, the results were in accordance with the findings of Bahnasawy *et al*. (2004).

Frictional property

The coefficient of friction is the important parameter to measure the level of friction characteristics. Hence, coefficient of friction was measured for different metal surfaces in order to finalize the material of fabrication for blade and soil separator. The Arka Bhim recorded highest coefficient for GI sheet (0.33) followed by plywood (0.32), plastic sheet (0.30) and mild steel sheet (0.29).

The cultivar N 53 had highest coefficient of friction in mild steel sheet (0.31) subsequent to plastic sheet (0.29) whereas; identical results were acquired for GI sheet and Plywood (0.27).. The maximum value was obtained for the frictional surface of mild steel sheet (0.34) followed by GI sheet (0.31), plywood (0.27) and plastic sheet (0.22) for the variety Arka Kalyan (Table 5). There was marginal variation in the values of friction coefficient of bulbs of all varieties and the results were in accordance with Savitha and Naik (2011). This difference was due to variations in the unit weight of bulb and volume. In general, the results were in accordance with the findings of Bahnasawy *et al*. (2004).

Based on the measured properties of onion bulbs, the design values were finalized by considering the deviations (SD) in the values for the design of various components of digger cum separator (Shiddanagouda Yadachi *et al*., 2013). The design values were in accordance with the relevant measured properties of bulbs. The 3-D pro-e designing of various components was accomplished as per the design values of different components. The blade dimensions such as inclination, thickness and width were critical in attaining the good performance of digger-cum separator. All the linear dimensions were helpful for the design of blade and length of soil separators (Table 6).

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