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National Academy of Agricultural Science (NAAS) Rating : 3.03

Physical and Mechanical Properties of Onion Sets (*Allium Cepa, L.*)

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ABSTRACT: *Physical and engineering properties of agricultural products are important parameters to determine the proper standards in design and development of sowing, planting, harvesting, grading, conveying, processing and packaging systems. The physical and engineering properties of onion sets (aggregatum type onion- known as sambar onion) were determined to design and develop a tractor operated onion set planter. The onion sets were graded into four grades based on weight (grade I: 2-3 g, grade II: 3-4 g, grade III: 4-5 g and grade IV: 5-6 g). The planter related physical properties of onion sets namely length, thickness, width, geometric mean diameter, sphericity, shape, projected area, thousand seed onion weight, bulk density and true density and mechanical properties viz., angle of repose and co-efficient of friction were determined for all the four grades. The length, width and thickness were 28.85 ± 0.57, 17.15 ± 0.35 and 12.95 ± 0.28 mm for grade – I onion sets (2-3 g weight), 27.55 ± 0.7, 19.65 ± 0.50, 16.05 ± 0.49 mm for grade – II onion sets (3-4 g weight), 28.10 ± 0.68, 21.75± 0.42, 17.40 ± 0.39 mm for grade – III onion sets (4-5 g weight), 30.10 ± 0.64, 29.05 ± 0.47, and 23.15 ± 0.36 mm for grade – IV onion sets (5-6 g weight), respectively. The geometric mean diameter of onion sets were 18.030 ± 0.176, 20.286 ± 0.182, 21.746 ± 0.265 and 23.663 ± 0.205 mm for the grades I, II, III and IV respectively. The sphericity of onion sets was 0.703 ± 0.012, 0.746 ± 0.014, 0.782 ± 0.015 and 0.788 ± 0.013 for the grades I, II, III and IV respectively. The shape index for onion sets were 1.713 ± 0.044, 1.571 ± 0.045, 1.466 ± 0.043 and 1.441 ± 0.035 for the grades I, II, III and IV respectively. The smaller size of onion sets (I and II grade onion sets) had oval shape and the bigger size onion sets (III and IV grade onion sets) had spherical shape. The projected area for onion sets were 2.62 ± 0.138, 3.34 ± 0.268, 4.46 ± 0.217 and 5.05 ± 0.230 cm^2 for the grades I, II, III and IV respectively. The big size onion sets i.e grade IV (5-6 g weight) had the highest one thousand onion set weight (5.485 ± 0.416 kg) followed by grade II (4-5 g weight: 4.397 ± 0.064 kg), grade III (3-4 g weight : 3.418 ± 0.22 kg) and grade IV (2-3 g weight : 2.479 ± 0.170 kg). The bulk density of onion sets were 524 ± 12.778 kg/m^3, 476 ± 13.781 kg/m^3, 429 ± 20.080 kg/m^3 and 387 ± 6.913 kg/m^3 for the grades I, II, III and IV respectively. The true density was highest for the grade – I onion sets (958.833 ± 64.931 kg/m^3) followed by grade – II (942.041 ± 20.908 kg/m^3), grade – III (939.887 ± 14.988 kg/m^3) and grade IV (933.809 ± 39.094 kg/m^3). The grade I (2-3 g weight) and grade II (3-4 g weight) onion sets had same angle of repose of 37.784 ± 0.701 degree and the grades III (4-5 g weight) and IV (5-6 g weight) had the same angle of repose of 36.922 ± 1.391 degree. The coefficient of friction had a higher value on wooden surface (0.469 ± 0.013) followed by mild steel surface (0.451 ± 0.036), galvanised iron surface (0.423 ± 0.024), aluminium surface (0.405 ± 0.011) and stainless steel surface (0.318 ± 0.018) for grade I (2-3 g weight) onion set. The same trend was observed for all the other three grades i.e., grade II, grade III and grade IV onion sets.*

Keywords: *engineering properties, onion planter, onion sets, physical properties,*

INTRODUCTION

Onion, *Allium cepa*, L., is one of the most important vegetables in all countries. India has the second largest area under onion production of about 10.52 lakh ha. and production of about 168.13 lakh tonnes (NHB, 2013). Twenty percent of India's production is being exported to different parts of world. *Allium cepa* is cultivated mainly as a biennial. Jones and Mann (1963) classifies *Allium cepa* into four group for the use of horticulturists as (a) Common onion group (*Allium cepa* L. Var. Cepa; *Allium cepa* L. ssp. Cepa, and ssp. Australe Trofim): Bulbs are large, normally single. Plants produce from seeds or from seed grown sets. The majority of cultivars grown for dry bulbs belong to this group. This is the most important group of trade grown all over the world, (b) Aggregatum group or Shallots (*Allium ascalonicum auct*. Non strand; *Allium cepa* L. ssp orientale kazak): Bulbs are smaller than

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common onions and several to many form an aggregated cluster. Reproduction is almost exclusively vegetative via daughter bulbs. Occasionally scapes are developed and in some types, seed production is possible and (c) Ever-Ready onion (*Allium cepa* L. var. *Perutile strearn*): Bulbs are narrow with shorter flower stalks and smaller umber. Bulbs or leaves can be gathered at all times of the year. It is used mainly as salad onion. This group is again sub-divided into potato or multiplier onion and shallots. (i) Potato or multiplier onion: The bulbs divide into between 3 and 20 bulb sets that are wider than they are long. They are covered by outer dry skins and (ii) Shallot: Shallots form cultures of narrow, separate bulbs. The leaves and flowers are usually smaller than common onion. Shallots are suitable for high latitude and short season regions.

Aggregatum group onions are mainly grown in Tamil Nadu State of South India due to the food custom in Tamil Nadu and also to have an early crop. The planting system for aggregatum group onion is planting sets. Sets are onions that are planted from seed last year. Sets are available from onion traders and markets. Few farmers sometimes store the current season harvested onions for next season for seed onion set purpose. Onion sets that are firm and marble size but have not sprouted are used as planting material.

Physical characteristics of agricultural products are the most important parameters to determine the proper standards of design of cultivation, grading, conveying, processing and packaging systems (Tabatabaeefar and Rajabipour, 2005).

Bahnasawy *et al*., (2004) studied the physical and mechanical properties to form an important database for three of the most popular cultivars (Giza 6 (white), Beheri (red) and Giza 20 (yellow)) of onion in Egypt. These properties included linear dimensions, shape index, geometric mean diameter (D_{gm}), arithmetic mean diameter(D_{am}), frontal surface area(A_{fs}), cross sectional of area(A_{sc}), volume, mass, density, static friction coefficient, rolling angle, crushing load and puncture resistance.

The main objective of this study was to determine the physical properties of onion set viz., length, thickness, width, geometric mean diameter, shape index, projected area, hundred onion set weight, bulk density, and true density and mechanical properties of onion set viz., angle of repose and co efficient of friction. The knowledge of these properties will be useful in development of machinery for onion cultivation and processing.

EXPERIMENTAL PROCEDURES

The planting material for multiplier onion are small size bulbs which are called as "onion sets". The freshly harvested onions are generally stored for planting material purpose for next season. In general, they are stored upto a period of four months (Sumanaratne and Palipane, 2002). During the planting season, the onions are cleaned and made into single sets from the aggregatum. At this stage, each individual onion set weighs upto 10 g. A local cultivar of onion sets (Variety: Thoraiyur) were procured from commercial onion traders and was used for this study. The onions were cleaned, separated into single sets and graded. The graded onion sets categories of 2-3 g, 3-4 g, 4-5 g and 5-6 g were used for all the experimental purpose during this study (Fig. 1).

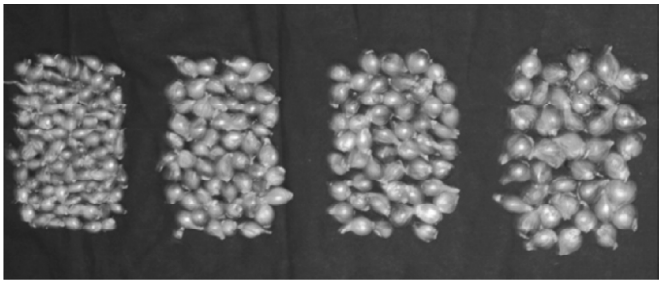

Figure 1: Graded onion sets

Apparatus and procedure

Sample size

In this study, a random sample of 100 onion sets from each grade were selected for measuring the physical properties (Maw *et al*., 1996).

Determination of moisture content

The physical properties of many agricultural products are moisture dependent. Dean and Stark distillation apparatus was used to determine the moisture content of onion set (Osborne and Voogt, 1978).

The moisture content of onion set in percentage was calculated by using the following formula.

$$\text{Percentage of moisture } M_{wb} = \frac{V}{W} \times 100 \qquad \ldots (1)$$

Where,

W - weight of the sample, g

V - volume of water collected, ml

The procedure was replicated five times and the mean moisture content of onion sets was calculated.

Determination of physical properties of onion

The physical properties viz., linear dimensions (length, width and thickness), geometric mean

diameter, shape index, projected area, thousand onion set weight, bulk density and true density were determined.

One thousand onion sets were randomly selected from each graded category and their linear dimensions length (*L*), width (*W*) and thickness (*T*) were measured using digital calliper having an accuracy of 0.01 mm.

Geometric mean diameter (Dg) was found for all the four categories of onion sets using the following formulae (Jain and Bal, 1997; Mohsenin, 1970).

$$Dg = (LWT)^{0.333} \quad \text{... (2)}$$

Shape index was used to evaluate the shape of onion sets for all the four categories of onion sets and it was calculated according to the following equation (Abd Alla, 1993):

$$\text{Shape index} = \frac{L}{\sqrt{WXT}} \quad \text{... (3)}$$

Where,

The onion set would be considered an oval if the shape index >1.5, on the other hand, it would be considered spherical if the shape index <1.5.

Twenty onion sets were randomly selected from each graded category and individually they were placed on a graph sheet and outer line was marked on the graph sheet. The projected area of onion set was determined by counting the number of squares inside the marked line. The onion sets were kept in an orientation that ensured maximum projected area. This procedure was replicated five times for each graded category of onion sets. Thousand onion sets were randomly selected from each graded category and weight was measured with an electronic balance having an sensitivity of 2 g. This procedure was replicated five times for each graded category of onion sets.

The bulk density of onion set was determined by using containers of cubical and cylindrical shape. The onion sets were dropped into the containers from a height of approximately 15 cm. The excess sets were removed by sweeping the top surface of the container and care was taken that the sets were not compressed in any way while sweeping. From the mass and volume the bulk density of the onion sets was calculated.

The onion set's true density was determined by using the liquid displacement method. Toluene (C7H8) was used instead of water because it is absorbed by the onion sets to a lesser extent. Also, its surface tension is low, so that it fills even shallow dips in a segment and its dissolution power is low (Mohsenin, 1970; Singh and Goswami, 1996). Known volume of toluene was taken in a 100 ml measuring cylinder and twenty individual onion sets were weighed and each one was dropped into the measuring cylinder. The rise in toluene level indicated the true volume of the onion sets. From the mass and the true volume of the sets, the real density was calculated. This procedure was replicated five times, was done for all the four categories of onion set grades and the mean was calculated.

Determination of related mechanical properties of onion sets

The mechanical properties of onion sets viz., (i) angle of repose and (ii) coefficient of friction were determined.

A metal container having 125 mm length, 125 mm width and 200 mm height was used to determine the emptying or dynamic angle of repose of onion sets (Plate 3.3).

A removable front panel with 200 mm height and 125 mm width was used to release the material side ways. The container was filled with the onion sets, levelled and then the front panel was quickly slid upwards allowing the onion sets to flow out. The angle of repose was calculated from the measurement of the maximum depth of the free surface of the sample and length of the box.

$$\text{Angle of repose} = \tan^{-1}\frac{\text{Height of sample}}{\text{Length of sample}} \quad \text{... (4)}$$

The procedure was replicated five times with different samples and the mean was calculated.

The experimental apparatus for the determination of coefficient of static friction was, a tube container filled with known quantity of onion sets and the tube was connected by a string running over a frictionless pulley to a loading pan. Weights were added to the pan until the tube began to slide. The weight of the onion sets and the added weights comprise the normal force *N* and friction force *F*, respectively. The coefficient of static friction, μ was calculated as the ratio

$$\mu = \frac{F}{N} \quad \text{... (5)}$$

The experiment was carried out using test surfaces of aluminium, wooden surface(ply wood), stainless steel, mild steel and galvanised iron with five replications. For each replication, the sample in the tube container was emptied and refilled with a different sample. The experiment was conducted for all the four categories of onion sets to determine coefficient of friction.

RESULTS AND DISCUSSIONS

Moisture content

As the properties of agricultural products are moisture dependent, the moisture content of onion set was determined and was found as 74.600 ± 2.368 per cent.

Physical properties of onion sets

Linear dimensions of onion sets

Length, width, thickness, geometric mean diameter, shape index, projected area, thousand onion set weight, bulk density, and true density of onion sets for all the four grades results are given in Table 1. The frequency distributions of length, width and thickness of onion sets for all the four grades are given in Figs. 2, 3, 4 and 5 respectively. It was observed that in case of grade I onion sets (2-3 g weight), 99 per cent of onion sets had length between 20 and 35 mm, 87 per cent of onion sets had width between 15 and 20 mm and 91 per cent of onion sets had thickness between 10 and 15 mm (Fig.2). In case of grade II onion sets (3-4 g weight), 97 per cent of onion sets had length between 20 and 35 mm, 99 per cent of onion sets had width between 15 and 25 mm and 98 per cent of onion sets had thickness between 10 and 20 mm (Fig. 3). Fig. 4 showed that in case of grade III onion sets (4-5 g weight), 98 per cent of onion sets had length between 20 and 35 mm, 97 per cent of onion sets had width between 15 and 25 mm and 95 per cent onion sets had thickness between 10 and 20 mm. In case of grade IV onion sets (5-6 g weight), 91 per cent onion sets had length between 25 and 35 mm, 99 per cent onion had width between 25 and 35 mm and 99 per cent of onion sets had thickness between 20 and 30 mm (Fig. 5).

Table 1
Dimensional properties of onion sets for four grades

	Grades			
Physical attributes	*Grade I (2-3 g)*	*Grade II (3-4 g)*	*Grade III (4-5 g)*	*Grade IV (5-6 g)*
Length, mm	25.85 ± 0.57	27.55 ± 0.73	28.10 ± 0.68	30.10 ± 0.64
Width, mm	17.15 ± 0.35	19.65 ± 0.15	21.75 ± 0.42	29.05 ± 0.47
Thickness, mm	12.95 ± 0.28	16.05 ± 0.49	17.40 ± 0.39	23.15 ± 0.36
Geometric mean diameter, mm	18.030 ± 0.176	20.286 ± 0.182	21.746 ± 0.265	23.663 ± 0.205
Sphericity	0.703 ± 0.012	0.746 ± 0.014	0.782 ± 0.015	0.788 ± 0.013
Shape index	1.713 ± 0.044	1.571 ± 0.045	1.466 ± 0.043	1.441 ± 0.035
Projected area, cm^2	2.62 ± 0.138	3.34 ± 0.268	4.46 ± 0.217	5.05 ± 0.230
Thousand onion sets weight, (kg)	2.479 ± 0.170	3.418 ± 0.221	4.397 ± 0.064	5.485 ± 0.416
Bulk density, (kg/m^3)	524 ± 12.778	476 ± 13.781	429 ± 20.080	387 ± 6.913
True density, (kg/m^3)	958.833 ± 64.931	942.041 ± 20.908	939.887 ± 14.988	933.809 ± 39.094

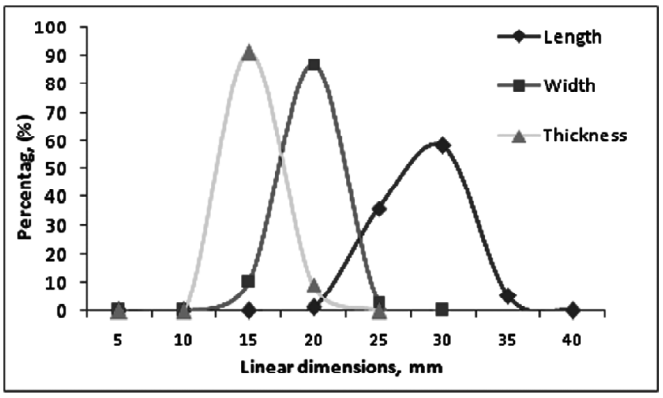

Figure 2: Frequency distribution curves length, width and thichness of linear dimensions of onion sets for gradre 2-3 g

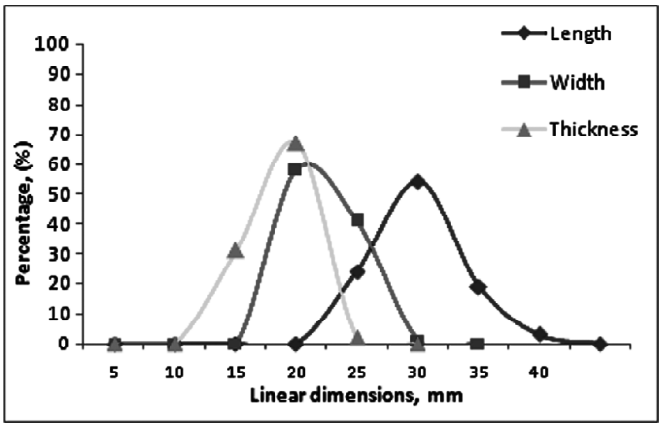

Figure 3: Frequency distribution curves length, width and thichness of linear dimensions of onion sets for gradre 3-4 g

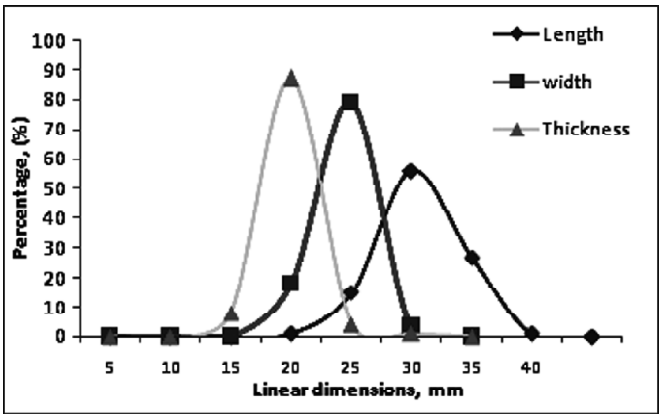

Figure 4: Frequency distribution curves length, width and thichness of linear dimensions of onion sets for gradre 4-5 g

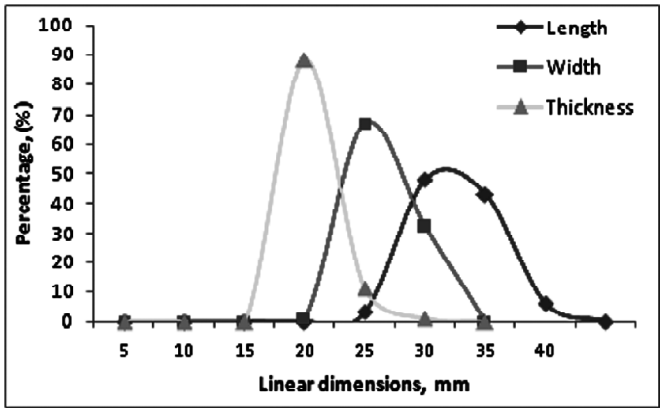

Figure 5: Frequency distribution curves length, width and thichness of linear dimensions of onion sets for gradre 5-6 g

It was observed that range for length remained same (20 - 35 mm) for all the four grades of onion sets except for the grade IV (25 - 35 mm). However, the range for width and thickness was varying and increasing when grade size increased. The ranges of width were 15-20 mm, 15 - 25 mm, 15 - 25 mm, and 25 - 35 for onion sets grades of grade I, grade II, grade III and grade IV respectively, The ranges of thickness were 10 - 15 mm, 10 - 20 mm, 10 -20 mm and 20 - 30 mm for onion sets grades of grade I, grade II, grade III and grade IV respectively.

It was also observed that the first three grades of onion sets had same lower levels of range i.e., 20 mm, 15 mm and 10 mm for length, width and thickness respectively, whereas the lower level of range for grade IV was high i.e., 25 mm, 25 mm and 20 mm for length, width and thickness respectively.

The geometric mean diameter and shape index for all the four grades of onion sets were established and are presented in Table 1. The geometric mean diameter of onion sets were observed as 18.030 ± 0.176 mm, 20.286 ± 0.182 mm, 21.746 ± 0.265 mm and 23.663 ± 0.205 mm for the grades I, II, III and IV respectively and it was also observed that the geometric mean diameter increased as the grade size increased. It is clear that onion sets of grades I, II and III have closer range of size with geometric mean diameter of 20±2 mm and hence can be expected to have less variation in behaviour.

The shape index for onion sets were 1.713 ± 0.044, 1.571 ± 0.045, 1.466 ± 0.043 and 1.441 ± 0.035 for the grades I, II, III and IV respectively. It was observed that the smaller size of onion sets (I and II grade onion sets) had oval shape as the shape index was >1.5 and the bigger size onion sets (III and IV grade onion sets) had spherical shape as the shape index was <1.5. These results had agreement with the study conducted by Abd Alla (1993). He studied the shape index of three varieties of onions and concluded that onion varieties Beheri and Giza 20 were spherical in shape and the bulbs of onion variety Giza 6 had oval shape.

The shape index for onion sets were 1.713 ± 0.044, 1.571 ± 0.045, 1.466 ± 0.043 and 1.441 ± 0.035 for the grades I, II, III and IV respectively. It was observed that the smaller size of onion sets (I and II grade onion sets) had oval shape as the shape index was >1.5 and the bigger size onion sets (III and IV grade onion sets) had spherical shape as the shape index was <1.5. These results had agreement with the study conducted by Abd Alla (1993). He studied the shape index of three varieties of onions and concluded that onion varieties Beheri and Giza 20 were spherical in shape and the bulbs of onion variety Giza 6 had oval shape.

The projected area for onion sets were 2.62 ± 0.138 cm^2, 3.34 ± 0.268 cm^2, 4.46 ± 0.217 cm^2 and 5.05 ± 0.230 cm^2 for the grades I, II, III and IV respectively. It was observed that when the size of onion sets increased the projected area increased. The thousand onion set weight was determined for all the four grades of onion sets and the results are presented in Table 1. The big size onion sets i.e grade IV (5-6 g weight) had the highest one thousand onion set weight (5.485 ± 0.416 kg) followed by grade II (4-5 g weight : 4.397 ± 0.064 kg), grade III (3-4 g weight : 3.418 ± 0.22 kg) and grade IV (2-3 g weight : 2.479 ± 0.170 kg).

The bulk density of onion sets were 524 ± 12.778 kg/m^3, 476 ± 13.781 kg/m^3, 429 ± 20.080 kg/m^3 and 387 ± 6.913 kg/m^3 for the grades I, II, III and IV respectively. It was observed that when the size of onion sets increased, the bulk density decreased. This is with behaviour of granular material. The true density was highest for the grade - I onion sets (958.833±64.931 kg/m^3) followed by grade - II (942.041 ± 20.908 kg/m^3), grade - III (939.887 ± 14.988 kg/m^3) and grade IV (933.809 ± 39.094 kg/m^3).

Mechanical properties of onion sets

The angle of repose for all the four grades of onion sets are presented in Table 2. It was observed that the grade I (2-3 g weight) and grade II (3-4 g weight) onion sets had same angle of repose of 37.784±0.701 degree and the grades III (4-5 g weight) and IV (5-6 g weight) had the same angle of repose of 36.922±1.391 degree.

The coefficient of friction for onion sets on an aluminium, a wooden, a stainless steel, a mild steel and a galvanised iron surface were observed and are presented in Table 2. It was observed that the coefficient of friction had a higher value on wooden surface (0.469

Table 2
Mechanical attributes of onion sets for four grades

Mechanical attributes	*Grades*			
	Grade I (2-3 g)	*Grade II (3-4 g)*	*Grade III (4-5 g)*	*Grade IV (5-6 g)*
Angle of repose (degree)	37.784 ± 0.701	37.784 ± 0.701	36.922 ± 1.391	36.922 ± 1.391
Coefficient of friction				
(a) Aluminium	0.405 ± 0.011	0.465 ± 0.023	0.396±0.004	0.315 ± 0.010
(b) Wooden surface	0.469 ± 0.013	0.524 ± 0.029	0.536±0.006	0.506 ± 0.007
(c) Stainless steel	0.318 ± 0.018	0.345 ± 0.005	0.287±0.006	0.275 ± 0.012
(d) Mild steel	0.451 ± 0.036	0.506 ± 0.008	0.510±0.008	0.497 ± 0.006
(e) Galvanised iron	0.423 ± 0.024	0.496 ± 0.007	0.415±0.010	0.460 ± 0.007

± 0.013) followed by mild steel surface (0.451 ± 0.036), galvanised iron surface (0.423 ± 0.024), aluminium surface (0.405 ± 0.011) and stainless steel surface (0.318 ± 0.018) for grade I (2-3 g weight). The same trend was observed for all the other three grades i.e., grade II, grade III and grade IV. This trend of these results were in agreement with that obtained by Bahnasawy *et al*., (2004) and Helmy (1995).

CONCLUSIONS

(i) The physical properties of onion sets namely length, width, thickness, geometric mean diameter, shape index, projected area, thousand onion set weight, bulk density and true density were determined for all the four grades.

a. The range for length remained same (20 - 35 mm) for all the four grades of onion sets except for the grade IV (25 - 35 mm). The range for width and thickness was varying and increasing when grade size increased. The ranges of width were 15-20 mm, 15 - 25 mm, 15 - 25 mm, and 25 - 35 mm for onion sets grades of grade I, grade II, grade III and grade IV respectively, The ranges of thickness were 10 - 15 mm, 10 - 20 mm, 10 -20 mm and 20 - 30 mm for onion sets grades of grade I, grade II, grade III and grade IV respectively.

b. The first three grades of onion sets had same lower range of 20 mm, 15 mm and 10 mm for length, width and thickness respectively and lower ranges for grade IV were 25 mm, 25 mm and 20 mm for length, width and thickness respectively.

c. The geometric mean diameter of onion sets were 18.030 ± 0.176, 20.286 ± 0.182, 21.746 ± 0.265 and 23.663 ± 0.205 mm for the grades I, II, III and IV respectively. The smaller size of onion sets (I and II grade onion sets) had oval shape and the bigger size onion sets (III and IV grade onion sets) had spherical shape. The projected area for onion sets were 2.62 ± 0.138, 3.34 ± 0.268, 4.46 ± 0.217 and 5.05 ± 0.230 cm2 for the grades I, II, III and IV respectively.

d. One thousand onion set weight for grade I, II, III and IV were 2.479 ± 0.170, 3.418 ± 0.22, 4.397 ± 0.064 and 5.485 ± 0.416 kg respectively.

e. The bulk density of onion sets were 524 ± 12.778 kg/m^3, 476 ± 13.781 kg/m^3, 429 ± 20.080 kg/m^3 and 387 ± 6.913 kg/m^3 for the grades I, II, III and IV respectively.

f. The true densities were for the grade - I, II, III and IV onion sets were 958.833±64.931 kg/m^3, 942.041 ± 20.908 kg/m^3, 939.887 ± 14.988 kg/m^3 and 933.809 ± 39.094 kg/m^3.

(ii) The angle of repose for grade I (2-3 g weight) and grade II (3-4 g weight) onion sets had same angle of repose of 37.784 ± 0.701 degree and the grades III (4-5 g weight) and IV (5-6 g weight) had the same angle of repose of 36.922 ± 1.391 degree.

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