Available online at www.elixirpublishers.com (Elixir International Journal)

Agriculture

Elixir Agriculture 74 (2014) 27127-27130

ISSN: 2229-712X

Some Physical and Engineering Properties of Persian Shallot (*Allium hirtifolium* Boiss.)

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ARTICLE INFO

Article history:

Received: 26 July 2014;

Received in revised form:

21 August 2014;

Accepted: 20 September 2014;

Keywords

Mechanical properties,

Moisture content,

Persian shallot,

Physical properties.

ABSTRACT

Persian shallot grows as a wild plant in some mountains of Iran. Persian shallot, a bulb producing plant from Alliaceae, is a wildly growing plant collected for its bulbs. Bulbs of Persian shallot, called "Mooseer" in Farsi, are oval, white skinned, usually of one and rarely of two main bulbs and are completely different from common shallot (Allium ascalonicum). In this study, various physical properties of Persian shallot were determined at a moisture content of 68.62% w.b. The equatorial diameters, polar diameters, shape index, volume and density were 36.647 $\pm$3.30 mm, 33.242 $\pm$ 3.47 mm, 1.0898 $\pm$ 0.07, 3.5106 $\pm$ 0.961 cm^3 and 5211.292 $\pm$ 1108.463 $Kg.m^{-3}$, respectively. The static coefficient of friction was obtained on the plywood surface followed by the glass and the galvanized iron sheet surfaces. The shear strength increased with an increase in loading rate. Linear model for describing the mass of Persian shallot, by applying dimensional characteristics and volume was investigated. The results showed that mass modeling of Persian shallot based on oblate spheroid shaped volume (V_{osp}) and geometric mean diameter (D_{gm}) are the most appropriate models, respectively.

Introduction

Persian shallot (*Allium hirtifolium*), sometimesmistakenly named *Allium ascalonium*(common shallot), called as ''Mooseer'' in Iran belongs to Alliaceae family and is one of the important edible alliums in Iran. It is native and endemic of Iran and grows as a wild plant across the Zagross Mountains at high elevations of different provincesfrom Northwestern to Southern of Iran (Sanandaj, Kangavar,Siakhdarengoon, Sahneh, Ashtian, Dashtearzhan,Koohrang, Sepidan, Divandareh, Boroujerd, Khomein, Yasuj, Nahavand, Khansar, Harsin, Arak, Doshmanziare andKoohmaresorkhi) with the climate of very cold to moderate cold (Ghahreman, 1984). Since Persian shallot grows as a wild plant only in some mountains of Iran, very little information is available about different aspects of this species (Ebrahimi et al., 2009). It is different from common shallot (*Allium ascalonicum L.*) for many characteristics. Bulbs of common shallot are pear-shaped, reddish-brown skinned and clustered at the base of the plant and its clusters may contain as many as 15 bulbs (Rubatzky and Yamaguchi, 1997). The storage tissue of Persian shallot is bulb like, yellow, oval, white skinned and usually consists of a single main bulb or rarely of two bulbs. Persian shallot is originated from cold mountains of Iran, but common shallot is originated from warm regions of west Asia (Salunkhe and Kadam, 1998). Persian shallot is a nutritive plant with special taste and its dried bulb slices are used as an additive to yogurt and also pickling mixtures. It has crucial medicinal effects; aqueous extract of Persian shallot has shown antibacterial effects (Ashrafi et al., 2004).

Physical and engineering properties are important in many problems associated with the design of machines and the analysis of the behaviour of the product during agricultural process operations such as handling, planting, harvesting, threshing, cleaning, sorting and drying. The solutions to problems of these processes involve knowledge of the physical and engineering properties (Irtwange, 2000).

Some of these physical and engineering properties are size, shape, mass, volume, hardness, angle of repose, bulk density, true density and coefficient of static friction. Bulk and true densities are essential in knowing the weight of the crop per unit volume and useful in handling operations. Angle of repose has practical applications in design of products handling systems, though not a measure of flowability of solids, it is useful in the determination of the contour of pile when free flowing bulk solids are discharged through a vertical or horizontal opening. Weightand volume are useful in mathematical and computer modelling of handling and processing operations where the behaviour of the bulk system is predicted from the microscopic behavior. Also volume of solids must be known for accurate modeling of heat and mass transfer during cooling and drying. Coefficient and angle of internal frictionhave applications in problems of flow of bulk granular materials especially in calculating hopper sidewall slope angle and the magnitude of the frictional forces that agricultural products applied on machinery components or storage structures. The shape of some fruits is important in determining their suitability for processing as well as their retail value (Bahnasawy et al., 2004).

Due to the lack of information about the physical and mechanical properties of Persian shallot, the main objective of this work was to study the physical and mechanical properties to form an important database for Persian shallot. These properties include: linear dimensions, sphericity, geometric mean diameter, arithmetic mean diameter, volume, mass, density, static friction coefficient and the shear strength.

Materials and methods

Persian shallots were collected from their main local growth areas of Lorestan province in Iran. The Persian shallotswere cleaned manually and the foreign matter, such as stones, dirty

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and spoilage fruits were removed.Shallots were peeled manually by removing the skin and the layer.

The initial moisture content of fruits was determined by using a standard method (ASAE, 2003).Physical properties of Persian shallots were determined using 30 repetitions at a moisture content 68.62% w.b. In order to determine the physical properties of Persian shallots, 100 fruits randomly were selected and measuring the three linear dimensions, namely, length, width and thickness were determined using a electronic caliper with areading accuracy of 0.01 mm. One hundred fruits of each sample were picked at random and weighed by means of a digital balance with an accuracy of 0.01 g. Physical properties were determined by following methods:

The following methods were used in the determinationof some physical and engineering properties ofPersian shallot.

Linear dimensions

There are two categories of shallot bulb diameter: polar diameter and equatorial diameter. Polar diameter is the distance between the shallot crown and the point of root attachment to the shallot. Equatorial diameter is the maximum width of the shallot in a plane perpendicular to the polar diameter (Bahnasawy et al., 2004). The equatorial diameter (D_e) in mm, polar diameter (D_p) in mm, and thickness (T) in mm of each one hundred bulbs were measured with a caliper with a reading accuracy of 0.01 mm. The geometric mean diameter (D_{gm}) and arithmetic mean diameter (D_{am}) of the bulbs were calculated using the following relationships given by (Mohsenin, 1986), as follows:

Shape index

$$D_{gm} = (D_e\, D_p\, T)^{1/3} \tag{1}$$

$$D_{am} = \frac{(De + Dp + T)}{3} \tag{2}$$

Shape index is used to evaluate the shape of shallot bulbs and it is calculated according to the following equation (Abd Allah, 1993):

$$Shapeindex = \frac{De}{\sqrt{DpT}} \tag{3}$$

The shallot bulb is considered an oval if the shape index >1.5, on the other hand, it is considered spherical if the shape index <1.5 (Bahnasawy et al., 2004).

Mass, Volume and density

The shallots mass (M) were measured using an electronic balance to an accuracy of 0.01 g. The real density of samples was determined by the water displacement method. One hundred bulbs were placed with a metal sponge sinker into a measuring cylinder containing known water volume such that the bulbs did not float during immersion in water; weight of water displaced by the shallots were recorded. The volume of each bulb was calculated by following equation (Mohsenin, 1986):

$$Actual\ volume = \frac{W}{\gamma} \tag{4}$$

where W in gr and γ in gr/cm^3 were considered as weight of displaced water and weight density of water, respectively.

Coefficient of static friction

Coefficient of static friction is the ratio of the force required to slide the bulb over a surface divided by the normal force pressing the bulb against the surface. Coefficients of friction were determined for shallot bulbs on three surfaces: glass, galvanized iron sheet and plywood. The material surface was fastened to tilting table. A frame made with square metallic bars was placed on the surface. The frame was filled with bulbs. The table was tilted slowly manually until movement of the whole bulb mass. The coefficient of friction was the tangent of the slope angle of the table measured with a protractor (Oje and Ugbor, 1991).

Shearing strength

The shearing characteristics of shallot were assessed using a shearing test similar to those described by O'Dogherty et al. (1995), Ïnce et al. (2005) and NazariGaledar et al. (2008).The measurements were made using a proprietary tension/ compression testing machine (Instron Universal Testing Machine SMT-5, SANTAM Co., Iran). The shearing strength was measured in double shear using a shear box consisting essentially of two fixed parallel hardenedsteel plates 6 mm apart, between which a third plate can slide freely in a close sliding fit. A series of holes with diameter ranging from 1.5 to 20 mm were drilled through the plates to accommodate internodes of different diameter. Shear force was applied to the shallot specimens by mounting the shear box in the tension/compression testing machine. The applied force was measured by a strain-gauge load cell and a force-time record obtained up to the specimen failure. The shear failure stress (or ultimate shear strength), τ, of the specimen was calculated from (Tavakoli et al., 2009):

$$\tau = \frac{F}{2A} \tag{5}$$

where τis the shear strength (MPa), Fis the shear force at failure (N) and A is the wall area of the specimen at the failure cross-section (mm^2).

Mass modeling of shallot

Linear model for describing the mass of shallot, by applying dimensional characteristics and volume was investigated. In the case of first modeling, mass modeling was accomplished with respect to Polar diameter, Equatorial diameter, geometric diameter and arithmetic diameter. Model obtained with two variables for predicting of shallot mass was:

$$M = D_p\, a + D_e\, b + c \tag{6}$$

In the case of second modeling, to achieve the models which can predict the shallot mass on the basis of volume, three volume values were measured or calculated. At first, actual volume V_m as stated earlier was measured then the shallot shape was assumed as a regularly geometrical shape, oblate spheroid (V_{osp}) and ellipsoid (V_{ellip}) shapes and, thus, their volumes were calculated as:

$$V_{osp} = \left(\frac{4}{3}\right)\pi\left(\frac{De}{2}\right)\left(\frac{Dp}{2}\right)^2 \tag{7}$$

$$V_{ellip} = \left(\frac{4}{3}\right)\pi\left(\frac{De}{2}\right)\left(\frac{De}{2}\right)\left(\frac{T}{2}\right) \tag{8}$$

In this classification, the mass can be estimated as either a function of volume of supposed shapes or the measured actual volume as represented in following expressions:

$$M = V_r\, a + b \tag{9}$$

$$M = V_{osp}\, a + b \tag{10}$$

$$M = V_{ellip}\, a + b \tag{11}$$

The data were analyzed statistically using SPSS 18 software. Packages of statistical programs, available on both main frame and personal computers, can perform such regression analysis. Many spreadsheet programs also can perform multiple regressions. When evaluating the usefulness of such regression analyses, it is necessary to know how well the data fit the model. One measure of the goodness of fit is the value of the coefficient of determination which is usually designated as R2. For regression equations in general, the nearer R2 is to 1.00, the better the fit (Stroshine and Hamann, 1994). If values of kiexactly predict the mass, then R2 would be equal to 1.00. Win-Area-Ut_06 software was used to analyze data and determine regression models between the physical.

Results and discussion

Physical properties

Mean results, range and standard deviation of the size, shape and density characteristics of sorrel seeds are presented in Table 1. These properties include: the equatorial and polar diameters, shape index, geometric mean diameter (D_{gm}), arithmetic mean diameter (D_{am}), mass, volume and density.

Table 1. Some physical properties of shallot

Property	Mean value	Range of values	Standard deviation
Equatorial diameter (mm)	36.647	30.10- 45.00	3.309
Polar diameter (mm)	33.242	27.00- 41.00	3.473
Geometric diameter (mm)	34.508	30.88- 42.80	2.556
Arithmetic diameter (mm)	34.710	31.00- 43.00	2.571
Shape index (%)	1.0898	0.955- 1.238	0.070
Mass (g)	17.825	11.94- 33.47	4.754
Volume (cm^3)	3.5106	2.290- 5.980	0.961
Density (Kg/m^3)	5211.292	3183.070- 7376.404	1108.463

The average of 1.0898 $\pm$ 0.07 shape index was estimated. It indicated that the shallot bulbs are an oval in shape. On the other hand, the shape of the onion bulbs of Giza 6(white onion) can be regarded as an oval according to AbdAlla (1993) and a spherical in shape according to Bahnasawy et al. (2004).

Table 1 shows the mean values and SD of the D_{gm}, D_{am} and mass of the bulbs. They were 34.508 $\pm$ 2.556 mm, 34.710 $\pm$ 2.571 mm and 17.825 $\pm$ 4.754 gr, respectively. Also shows the mean values and SD of the volume and the density of bulbs. The mean volume was 3.5106 $\pm$ 0.961 cm^3 and the average density was 5211.292 $\pm$ 1108.463 $Kg.m^{-3}$. Also 70% of shallot had a diameter between 35 and 45mm, 43.33% of shallot were between 35 and 45mm in length, and 70% of shallot had a mass between 15 and 35 gr.

Table 2. Static Coefficient of friction of shallot

Surface	Mean value	Range of values	Standard deviation
Plywood	0.859	0.809- 0.900	0.026
Glass	0.539	0.509- 0.577	0.026
Galvanized iron sheet	0.849	0.839- 0.869	0.010

Table 2 shows the mean values of static friction of shallot bulbs on three surfaces (plywood, glass and galvanized iron sheet). They were 0.859 $\pm$0.026, 0.539$\pm$0.026, 0.849$\pm$0.010, respectively. The results show that the highest coefficient of friction was obtained by the plywood followed by galvanized iron sheet and glass surface for shallot bulbs. This trend of these results is in agreement with that obtained by Hacıseferoğulları (2005) for garlic and Saif and Bahnasawy (2002) for onion.

Mechanical properties

The variance analysis of the data indicated that the loading rate created a significant effect on the shear strength. The values of shear strength are presented in Table 3.

Table 3. Tensile stress of shallot(MPa)

Velocity	Mean value	Range of values	Standard Deviation
10 ($mm.s^{-1}$)	0.337	0.101- 0.391	0.097
20($mm.s^{-1}$)	0.345	0.293- 0.420	0.045
30($mm.s^{-1}$)	0.351	0.295- 0.408	0.039

The average shear strength was obtained as 0.337 MPa varying from 0.101 to 0.391 MPa, while the loading rate was 10 $mm.s^{-1}$, 0.345 MPa varying from 0.293 to 0.420 MPa, while the loading rate was 20 $mm.s^{-1}$ and 0.351 MPa varying from 0.295 to 0.408 MPa at the loading rate equal 30 $mm.s^{-1}$.It is observed that the shear strength increased significantly with an increase in the loading rate. This effect of loading rate was also reported by El Hag et al. (1971) for cotton stalk and Tavakoli et al. (2009) for barley straw. As the rate of deformation increased, the maximum force of rupture increased.

Mass modeling

Some linear regression models based on the selected independent variables have been represented in Table 4. Among these models, models 3, 4 and 7 had R^2 values standard and were the best models. Among models 1, 2, 5 and 6, model 5 where two dimensions were considered had the highest R^2 value. Models were respectively:

$$M= 1.037\, D_e- 20.222 \quad (12)$$
$$M= 0.958\, D_p- 14.036 \quad (13)$$
$$M= 1.668\, D_g- 39.739 \quad (14)$$
$$M= 1.656\, D_a- 39.650 \quad (15)$$
$$M= 0.642\, D_p+ 0.731\, D_e- 30.317 \quad (16)$$
$$M= 3230211.740\, V_r + 6.485 \quad (17)$$
$$M= 724246.550\, V_{osp}+ 0.444 \quad (18)$$
$$M= 100946.355\, V_{ellip}- 0.024 \quad (19)$$

Table 4. Shallot mass models based on selected in dipendent variables

No.	Models	R^2
1	$M= D_e\, a + b$	0.522
2	$M= D_p\, a + b$	0.490
3	$M= D_g\, a + b$	0.804
4	$M= D_a\, a + b$	0.802
5	$M= D_p\, a + D_e\, b + c$	0.696
6	$M= V_r\, a + b$	0.427
7	$M= V_{osp}\, a + b$	0.810
8	$M= V_{ellip}\, a + b$	0.726

Conclusions

Themean equatorial and polar diameters were 36.647 $\pm$3.31 mm, 33.242 $\pm$ 3.47 mm.

The geometric mean diameter (D_{gm}) ranged from 30.88 to 42.80 mm, the arithmetic mean diameter (D_{am}) ranged from 31.00 to 43.00 mm.

The volume ranged from 2.29 to 5.98 cm^3.

The density ranged from 3183.07 to 7376.40 $Kg.m^{-3}$.

The coefficient of friction ranged from 0.509 to 0.9. The highest coefficient of friction was offered by plywood surf ace followed by galvanized iron sheet and the glass surfaces.

Shear strength increased with an increase in loading rate.

The recommended equation to calculate shallot mass were based on oblate spheroid shaped volume.

Mass model No 3 from economic standpoint is recommended.

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