Physical properties of three Iranian onion varieties

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ABSTRACT: Onion with food and medical properties contains many essential vitamins and mineral which are necessary for the human health. Due to lack of information about the physical properties of onion in Iran, this crop is sold with lower quality. In this research, some physical properties of three Iranian varieties of onion were studied. True density, coefficient of friction, rolling angle, dimensions and shape index were measured. Polar diameter (a) range is from 46.93 mm to 59.82 mm and equatorial diameter (c) is from 46.63 mm to 59.82 mm. The average of 1.004±0.023, 1.001±0.027 and 1.099±0.119 shape index was estimated for red Azarshahr, white Kashan and yellow Isfahan varieties, respectively. It showed that those three cultivars are spherical in shape. The coefficient of static friction on plywood, galvanized, rubber and PVC surfaces were about 0.243 to 0.821, 0.195 to 0.916, 0.852 to 1.186 and 0.909 to 1.250 respectively. The rolling angle was obtained from 11.13 to 15.87 degrees. The results showed that frictional surface have no effects of rolling angle.

Keywords: Onions; Physical properties; Coefficient of static friction; Rolling angle

INTRODUCTION

Onion, Allium cepa, L., of the Alliaceae family with food and medical properties contains many essential vitamins and mineral materials. Based on the previous studies, onion consumption is estimated to be in the range of 8 to 12 kg per each person in Iran while it’s more in urban areas (Rezaei et al, 2010). Onion cultivation was about 50 thousand hectares in the 2008-2009 crop years, while 98.89 percent of it was irrigating land and the rest dry and it is predicted that these lands produce 1.85 million tons of onion. The most area of onion cultivation belonged to the Hormozgan. The East Azerbaijan, Fars, Isfahan, KhorasaneRazavi, Khuzestan and Zanjan are in the second to seventh position. (Agriculture statistic, first volume of crop, 2008-2009 crop year)

Due to lack of information about the physical properties of onion in Iran, this crop is sold with lower quality. So in the case of quality and quantity preservation of onion, its physical properties determination is essential for designing and improvement of harvest and postharvest equipment’s. Physical properties such as length, width, thickness, volume, weight, static coefficient of friction and rolling angle of the crop are used in the following cases: 1. designing of sorting and grading machines, 2. Prediction of chemical material consumption, 3. Describing heat and mass transferand 4. Reduce damage in handling. Also in some fruits and vegetables the shape is important to determine which of these are better, retail or processing.

Recently, there have been many studies on the physical and mechanical properties of fruits such as apple CV. ‘Golab’ (Meisami et al 2009), apricot pit (Fathollahzadeh et al 2009), olive (Kilickan and Guner 2008) and onion (Bahnasawy et al 2004). Abhayawick et al examined some physical properties of three onion varieties affected by the moisture content. These properties included three types of physical properties, thermal (conductivity, specific heat capacity, and diffusivity), structural (density and porosity) and dielectric (relative permittivity and loss factor) properties. Abdel-Ghaffar and Hindey tested four sizes (small, medium, large, and extra-large) of an Egyptian onion (Abo-Fatla variety). They found that the mean polar diameters were 40.45, 47.00, 47.94, and 52.40 mm and the mean equatorial diameters were 39.07, 50.03, 56.00, and 60.40 mm for the same previous order. The mean mass, bulb density and bulk density were 177 gr., 0.976 gr/cm³ and 0.586 gr/cm³, respectively. Eweida et al reported that the
Mean equatorial and polar diameters of onion bulbs were 74 and 52 mm, respectively for an Egyptian onion cultivar (Giza 6 Mohassan) and the mean volume was 187.6 cm$^3$. They also reported that the degree of onion hardness (resistance to penetration) was 86.7 DN (Durometer Number) at harvest. Bulb hardness decreased gradually with storage period, to be 82.2, 77.9 and 72.4 DN at 2, 4, and 6 months of storage periods, respectively.

**MATERIALS AND METHODS**

Three of the most important onions of Iran contain Azarshahr red onion, Kashan white onion and Isfahan yellow onion purchased from fruits and vegetables market. Initial moisture content of onions was determined by oven using standard methods (ASAE 1998). Moisture content for Isfahan yellow, Kashan white, and Azarshahr red onions were 88.13, 88.37 and 86.91 respectively.

**Measurement of physical properties**

**Linear dimensions**

Geometrical dimension of onion $a$, $b$ and $c$ in which, $a$ is equatorial diameter (largest diameter perpendicular to the polar diameter), $b$ is thickness (diameter perpendicular to polar diameter) and $c$ is polar diameter (distance between the onion crown and the point of root attachment to the onion). These diameters were measured using a digital caliper with accuracy of 0.01 mm. Geometric mean diameter ($D_{gm}$) and arithmetic mean diameter ($D_{am}$) were calculated from the following equations: (Sirisomboon et al, 2007)

$$D_{gm} = \sqrt[3]{abc}, \text{ mm}$$

$$D_{am} = (a + b + c)/3, \text{ mm}$$

**Shape index (SI)**

Shape index is used to evaluate the shape of onion bulbs and is calculated as following equation:

$$SI = a/\sqrt{bc}$$

If the shape index of onion is greater than 1.5 that onion would be assumed as oval, and in the case of smaller than 1.5 it would be considered as spherical. (Bahnasawy et al, 2004)

**Volume and density**

The true density of the samples was measured using water displacement as following. Twenty samples of each cultivar were selected and each sample was thrown in a 1000 ml scaled container that 500 ml of that were filled with distilled water (Fig. 1). Then volume of onion is determined by measuring the weight of displaced water. Finally true density was determined by dividing mass to volume. (Mohsenin 1978, Maw et al 1995)

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Figure 1. Diagram of volume measurement
Frictional properties

Coefficient of static friction

Coefficient of static friction is the ratio of the force required to slide the onion bulb over a surface divided by the normal force pressing the onion bulb against the surface. Coefficients of friction were determined for onion bulbs on four surfaces: rubber, galvanized iron, plywood and PVC. The material surface was fastened to tilting table. A frame made with a square wooden bar was placed on the surface. The frame was filled with bulbs. The table was tilted slowly until the whole bulb mass was moved. The coefficient of friction was the tangent of the slope angle of the table measured with a protractor (Oje and Ugbor, 1991; Bahnasawy et al, 2004; Yalcin et al, 2007).

For static coefficient of friction, a factorial experiment based on CRD was used in which the first factor was onion varieties (Azarshahr red onion, Kashan white onion and Isfahan yellow onion), the second factor was the type of surface (rubber, galvanized iron, plywood and PVC) and the last factor was the size of onions (small, medium and large (<39 mm (small), from 39 to 51.8 mm (medium) and >51.8 mm (large)).

Rolling angle

To determine the rolling angle, the onion bulb to be tested was kept on the selected surface, in the most stable position to prevent toppling over (top upwards). Then by rotating the handle at minimum speed, the platform was inclined until the onion bulb began to roll. At this position, the turning of the handle was stopped and the angle of inclination of the platform was read. For rolling angle, the mentioned statistical method was used in which the first factor was onion varieties (Azarshahr red onion, Kashan white onion and Isfahan yellow onion) and the second factor was the type of surface (rubber, galvanized iron, plywood and PVC). (Buyanov and Voronyuk, 1985; Nalbandi et al, 2011; Bahnasawy et al, 2004, Goyal et al, 2007)

RESULTS AND DISCUSSION

Physical properties

Table 1 shows the mean values and standard deviation (SD) of dimensions and shape index (SI) of Iranian onion cultivars. According to the values, polar diameter (a) varies from 46.93 mm to 59.82 mm and equatorial diameter (c) is in the range of 46.63 mm to 59.82 mm. For Iranian onions it's obvious that all diameters for yellow Isfahan cultivar have the highest and for red Azarshahr cultivar have the lowest values (Average comparison have done with Duncan test at 1% probability level). The average of 1.004±0.023, 1.001±0.027 and 1.099±0.119 shape index was estimated for red Azarshahr, white Kashan and yellow Isfahan varieties. It indicated that those three cultivars are spherical in shape. Bahnasawy et al obtained that red and yellow Egyptian cultivars are round and white cultivar is elliptic. Onion shape is very important in marketing and designing of sorting systems. Average mass for red, white and yellow varieties obtained about 54.52, 63.59 and 79.45 cm³ for red, white and yellow varieties, respectively.

As it can be seen in Table 2, yellow cultivar has more density than red cultivar but about white onion cultivar, it is in the same class using Duncan average comparison test at 5% probability level. Bahnasawy et al, 2004 reported that density range for the three varieties of Egyptian onion varied from 1.04 to 1.11 (gr/cm³) that is denser than those varieties of onions which were studied in this research.

Table 1. The mean value and standard deviation of the dimensions and Shape Index

<table>
<thead>
<tr>
<th></th>
<th>a(mm)**</th>
<th>b(mm)**</th>
<th>c(mm)**</th>
<th>D₁(mm)**</th>
<th>D₂(mm)**</th>
<th>SI*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red</td>
<td>46.93±11.70m</td>
<td>46.51±11.93m</td>
<td>46.63±7.47m</td>
<td>45.46±31.24m</td>
<td>45.65±10.68m</td>
<td>1.0036±0.023m</td>
</tr>
<tr>
<td>White</td>
<td>51.16±12.95m</td>
<td>48.10±13.01m</td>
<td>52.92±10.75m</td>
<td>51.52±11.93m</td>
<td>51.66±11.90m</td>
<td>1.001±0.027m</td>
</tr>
<tr>
<td>Yellow</td>
<td>59.52±15.80m</td>
<td>59.65±14.88m</td>
<td>59.82±10.93m</td>
<td>61.61±15.97m</td>
<td>61.71±24.70m</td>
<td>1.095±0.119m</td>
</tr>
</tbody>
</table>

Note: Comparison of average for all columns have been done with Duncan test at **1% and *5% probability level

Table 2. The mean value and standard deviation of the mass (gr), volume (cm³) and density (gr/cm³)

<table>
<thead>
<tr>
<th></th>
<th>Red</th>
<th>White</th>
<th>Yellow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass</td>
<td>54.54±23.16m</td>
<td>63.64±23.53m</td>
<td>79.48±35.30m</td>
</tr>
<tr>
<td>Volume</td>
<td>54.52±23.15m</td>
<td>63.59±23.52m</td>
<td>79.45±35.29m</td>
</tr>
<tr>
<td>Density</td>
<td>1.00052±0.0007m</td>
<td>1.00078±0.0003m</td>
<td>1.00041±0.0004m</td>
</tr>
</tbody>
</table>

Note: Comparison of average for all rows have been done with Duncan test at 5% probability level

Coefficient of static friction

The ANOVA related to coefficient of static friction results are given in Table 3. It showed that the main factors (variety, bulb size and type of frictional surface) also interaction effects between onion varieties on the type
of frictional surface and bulb size was significant. But effect of bulb size on the frictional surface and interaction of variety × bulb size × frictional surface weren’t significant.

Table 3. Summary of ANOVA for Coefficient of static friction and rolling angle

<table>
<thead>
<tr>
<th>S.O.V</th>
<th>DF</th>
<th>SS coefficient of friction</th>
<th>rolling angle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variety (V)</td>
<td>2</td>
<td>6.61</td>
<td>11.26*</td>
</tr>
<tr>
<td>Size (S)</td>
<td>2</td>
<td>1.68</td>
<td>-</td>
</tr>
<tr>
<td>Surface (Su)</td>
<td>3</td>
<td>38.23*</td>
<td>224.86*</td>
</tr>
<tr>
<td>V*S</td>
<td>4</td>
<td>1.26*</td>
<td>-</td>
</tr>
<tr>
<td>V*Su</td>
<td>6</td>
<td>1.90</td>
<td>88.76**</td>
</tr>
<tr>
<td>S*Su</td>
<td>6</td>
<td>0.11 ns</td>
<td>-</td>
</tr>
<tr>
<td>V<em>S</em>Su</td>
<td>12</td>
<td>0.06 ns</td>
<td>-</td>
</tr>
</tbody>
</table>

**Significant difference at 1% probability level, * Significant difference at 5% probability level and ns is no significant.

Figure 2 shows the interaction between variety and frictional surface. According to Fig. 2, white variety had the largest coefficient of static friction and red variety has the lowest value except rubber surface that yellow variety has smaller amount. According to Table 4 and Fig. 2, coefficient of static friction was the lowest on galvanized surface for red variety (0.195) and highest on PVC surface for white variety (1.25). Moreover, Fig. 2 shows the plywood and galvanized surfaces, three varieties are different in 1% probability level but on rubber and PVC surfaces red and yellow varieties aren’t different, however white variety has significant difference in 1% probability level. Bahnasawy et al., 2004 found that coefficient of static friction ranged from 0.67 to 1.34 for three Egyptian onions and from highest to lowest values is on plywood, rubber and galvanized surfaces, respectively. However, galvanized surface have different results of this research and this is perhaps due to the different nature of Iranian and Egyptian onions.

Figure 2. The effect of cultivar × frictional surface (comparison of average have been done with Duncan test at 5% probability level)

Table 4. Values of coefficient of static friction for three varieties of Iranian onions for three bulb size and four frictional surfaces

<table>
<thead>
<tr>
<th></th>
<th>Red</th>
<th>White</th>
<th>Yellow</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Small</td>
<td>Medium</td>
<td>Large</td>
</tr>
<tr>
<td>Plywood</td>
<td>0.243&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.265&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.279&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Rubber</td>
<td>0.984&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.936&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.915&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>PVC</td>
<td>1.046&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.986&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.909&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>Galvanize</td>
<td>0.195&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.244&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.367&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Note: Comparison of average for all columns have been done with Duncan test at 5% probability level.
According to Table 4 and Fig.3, we can't grade onions in small, medium and large sizes but they can be divided in large and middle sizes on galvanized surface and in small and large sizes on rubber surface while onion size has no effect on coefficient of static friction on PVC surface. Mohsenin revealed that friction force depends on normal load (so crop weight), area of the sliding surfaces (so crop shape), sliding velocity (so surface material) and finally crop nature. So in the case of present study, these results can be due to size and shape of onion or surface materials. For example on PVC surface due to nature of onion, adhesion is more than other surfaces therefore onion's size has no effect on coefficient of static friction. On the other hand adhesion between onion and frictional surface on plywood and galvanized is low, and in this situation, shape and size effects are more effective. Larger onions have higher center of gravity than middle size onions and it causes torque to the front side of onions will slip faster. But smaller samples have different behaviors and based on shape (round or elliptical); their coefficients of static friction are between large and middle size onions. And for the same reason, just like yellow variety onion on PVC frictional surface, onion size is not significant in 5% probability level, but on plywood, galvanized and rubber surfaces, it can be seen that large and middle size onions are not different in 5% probability level. In the case of

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Figure 3. Comparison of average of yellow onion on the frictional surfaces and for three bulb sizes (the tests have been done with Duncan test at 5% probability level)

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Figure 4. Comparison of average of white onion on the frictional surfaces and for three bulb sizes (the tests have been done with Duncan test at 5% probability level)
white variety on plywood, rubber and galvanized surfaces onions can be dividing into two size classes a) Small and b) Large and middle size. Red variety has different apparent properties and shell type comparing with yellow and white varieties and so has different frictional behavior. Considering Fig. 5 and Table 4 it can be seen that red variety can be graded into three sizes mentioned above on PVC surface but on rubber surface it isn’t significant in 5% probability level. Also it has the lowest value on galvanized and plywood surfaces, respectively.

![Figure 5. Comparison of average of red onion on the frictional surfaces and for three bulb sizes (the tests have been done with Duncan test at 5% probability level)](image)

**Rolling angle**

According to Table 3, rolling angle ANOVA shows that frictional surface in 5% probability level is significant but variety and its interaction with frictional surface is not significant. It’s obvious in Table 5 and Fig. 6, the red variety is different from white and yellow varieties on galvanized and plywood surfaces in 5% probability level. Also according to Fig. 6, the lowest amount of rolling angle belongs to red variety on galvanized surface is 11.13° and the highest amount again is for red variety on rubber frictional surface (15.87°). Bahnasawy et al. obtained range of rolling angle for three varieties of onion from 14 to 23 degrees for rubber, plywood and galvanized surfaces. The result that obtained from this study is that the surface has no effect on rolling angle and the cheapest surface can be chosen for conveying. The last result is that it’s not possible to sort onion based on rolling angle.

| Table 5. Values of rolling angle for three varieties of Iranian onions on the four surfaces |
|-------------------------|----------------------|---------------------|---------------------|
|                        | Plywood              | Galvanized          | Rubber              | PVC                  |
| Red                     | 11.89±4.21°          | 11.13±2.98°          | 15.87±6.26°         | 14.80±6.27°          |
| White                   | 13.33±4.02°          | 12.15±4.54°          | 13.58±4.38°         | 13.63±4.97°          |
| Yellow                  | 12.49±4.43°          | 11.72±3.18°          | 14.44±3.37°         | 12.60±3.06°          |

Comparison of average for all rows have been done with Duncan test at 5% probability level

**CONCLUSION**

In the studied cultivars, Yellow variety is the largest cultivar and red variety is the smallest. Average polar diameter, equatorial diameter, geometrical and arithmetic mean diameter for red cultivar onion obtained, 46.93, 46.63, 45.46 and 45.65 mm for White cultivar onion, 51.16, 51.92, 51.52 and 51.66 mm and for Yellow cultivar onion, 59.82, 59.82, 61.61 and 61.71 mm, respectively.

Yellow cultivar is the densest between cultivars and average weight of these cultivars were 54.54, 63.64 and 79.48 gr for red, white and yellow varieties, respectively.

Coefficients of static friction on plywood, galvanized, rubber and PVC surfaces were about 0.243 to 0.821, 0.195 to 0.916, 0.852 to 1.186 and 0.909 to 1.250 respectively.

The result of this study showed that frictional surface has no effect on rolling angle also rolling angle obtained ranges from 11.13 to 15.87 degrees.
Figure 6. Comparison of average of rolling angle on the four surfaces (the tests have been done with Duncan test at 5% probability level)

REFERENCES