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# A study of the physical properties of three watermelon seed varieties

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**Watermelon seeds of three major local Iranian varieties, Sarakhsi, Kolaleh and Red, at the moisture content of 4.55, 4.75 & 5.02% (w.b.), were selected to study the physical properties, respectively. Linear dimensions, mean diameters, sphericity, surface area, volume, true and bulk densities, porosity, repose angles and static coefficient of friction of the three varieties' seeds were measured using standard methods. The results showed that the length, width, thickness, arithmetic mean diameter and geometric mean diameter of watermelon seeds varied from 13.45 to 18.97 mm, 8.4 to 10.7 mm, 2.91 to 3.10 mm, 8.256 to 10.894 mm and 6.893 to 8.456 mm, respectively. While The sphericity by Jean & Ball's method, sphericity by the Mohsenin's method, surface area by McCabe et al's method and surface area by Jean & Ball's method, changed from 2.004 to 2.125, 0.446 to 0.513, 149.68 to 225.03 mm2, 128.09 to 198.01 mm2, respectively. The values of the seed volume, true density, bulk density and porosity of watermelon seeds were between 179.53-311.62 mm3, 861.75-866.66 kg/m3, 416.33-527.265 kg/m3 and 39.14-51.68% respectively. The study over the coefficient of friction of watermelon seeds on some materials such as plywood, galvanized metal sheet, glass, fiberglass and rubber showed that the static coefficient of friction varied from 0.26 on glass to 0.676 against rubber. Furthermore, the filling and funneling angles of repose for three watermelon seeds ranged from 27.092 to 32.38, 21.662 to 28.146, respectively. It is concluded that the physical properties of watermelon seeds vary from variety to variety and it is also a function of the seed moisture content, environmental and growth conditions.**

**Key words:** Watermelon seeds; gravimetrical properties; geometrical properties; frictional properties.

## INTRODUCTION

Watermelon is a drought tolerant crop which belongs to the Cucurbitaceae family of flowering plants. It is generally considered to be of the *Citrullus* species and has been referred to as *Citrullus Vulgaris*. It can be placed as "simple multi grains pulp fruits" in the classification of edible fruits which are called "Pepo" fruits (Naseri Pouryazdi & Tehrani Far, 1995). Watermelon is cultivated in a wide range of tropical, semi tropical and rigid regions of the world. It is originally found in Southern Africa, the indigenous people, in their search for water-containing foods, selected varieties with low glycoside content. In ancient times, the watermelon was cultivated in Egypt, from where followed the spread to the Mediterranean areas and in an eastern direction to India. According to Iranian government statistical data of 2003,

vegetable production area is 15024 ha, only in Khorasan province, Iran. It is sown in open field around April and May and harvested in August and September. Of the 50 common varieties of watermelon throughout the world, there are 5 general categories: All sweet, Ice-Box, Seedless, Crimson and Yellow Flesh. In most of the regions around the world, watermelon is cultivated as grain's products.Presently, the seeds are extracted either by manual maceration and washing of decayed fruits in a basket or scooping out pulp from fruit. However, there are special machines which pick up and turn the fruits into pieces or do the same work by tractors sometimes which are moving around or the machines are fixed at the center of the farms and the fruits are transported to them. Watermelon seed has an important role in the people's diet because of its full nutritious particles and it is general and common usage as roasted seeds, seed oil, or medicine for decreasing the blood pressure. The watermelon seed averagely consist of 31.9% protein, 4.4% carbohydrates, 57.1% fat, 8.2% fiber, 6.2% ash, 130 mg calcium, 456 mg
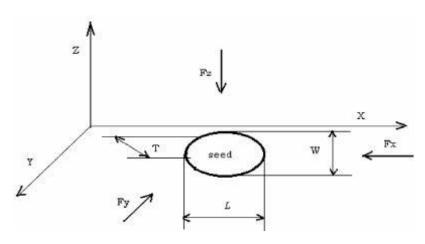
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**Figure 1.** Axes and three major perpendicular dimensions of watermelon seed.

phosphorus, 7.5 mg Iron. Watermelon seeds also contain the necessary amino acids such as Leucine, Isoleucine, Tryptophan and Valine.

The physical properties of watermelon seeds vary with the cultivars. In order to optimize various factors, threshing efficiency, pneumatic conveying and storage of watermelon seeds, better understanding of the physical properties are also essential. Some physical properties length, width, thickness, geometric mean diameter, sphericity, mass, volume, bulk density, true density, porosity and static coefficient of friction of squash seeds at 6.4% moisture content were evaluated by Paksoy & Aydin (2004). Joshi, Das & Mukherjee (1993) studied the average length, width, thickness, unit mass, bulk density, true density, porosity, the static coefficient of friction and angle of repose of pumpkin seeds and kernels at 4%. Makanjuola (1972) determined the size and shape of the seeds of two melon varieties and correlated the dimensions of the seeds and kernels.

The objective of this study was to investigate several physical properties of three watermelon seed varieties (Sarakhsi, Kolaleh and Red, which are major commercial Iranian watermelon varieties) and compared in terms of linear dimensions, volume, sphericity, surface area, true and bulk densities, porosity, repose angle, static coefficient of friction of seeds. All the properties of watermelon seeds that provide useful data to engineers in the design of processing machines were generally found to be statistically different in the three watermelon seeds varieties. These differences could be attributed to the individual characteristics of these varieties and environmental and growth conditions.

5.02% (d.b.), respectively were used in this study. The seeds were

**MATERIALS AND METHODS**

**Sample preparation**

Watermelon seeds of three varieties of watermelon seeds namely Sarakhsi, Kolaleh and Red at the moisture contents of 4.55, 4.75 &

manually cleaned to remove all foreign matter such as dust, dirt, stones, chaff, immature and broken seeds. The initial moisture content of the seeds was determined by a standard oven method (AOAC (2002).

**Dimensions, mean diameters, surface area and sphericity**

To determine the average size of the seed, a sample of 100 seeds was randomly selected and their three principle axis for each watermelon variety which was studied. As shown in Figure 1, measurement of the three major perpendicular dimensions length (L, mm), width (W, mm) and thickness (T, mm) were carried out with a micrometer to an accuracy of 0.001 mm. The measuring dimensions included as major, intermediate and minor diameters, respectively. The major diameter is the highest dimension of the biggest surface of the seed. The minor diameter is also the shortest dimension of the smallest surface of the seed and the intermediate diameter is the shortest dimension of the biggest surface of the seed (Figure 1). The arithmetic mean diameter (De, mm) and the geometric mean diameter (Dg, mm) of the seeds were calculated using the following relationships, respectively (Mohsenin, 1970):

$$D_a = \frac{L + W + T}{3} \qquad (1)$$

$$Dg = (LWT)^{1/3} \qquad (2)$$

$$\phi = \frac{(LWT)^{1/3}}{L} \qquad (3)$$

The sphericity ( , %) of watermelon seeds was obtained using the formula given by Mohsenin (1970) and Jean & Ball (1997) as follow:

$$\phi = \frac{B(2L - B)^{1/3}}{L} \qquad 4)$$

Where, B=(WT)$^{0.5}$.

The Surface area (S, mm$^2$) of seeds was calculated using the two following equations (Jean & Ball, 1997; McCabe et al., 1986):

$$S = \frac{\pi B L^2}{2L-B} \qquad (5)$$

$$S = \pi D_g{}^2 \qquad (6)$$

**Volume, true density, bulk density and porosity**

The seed volume and their true density were determined using the liquid displacement method (Mohsenin, 1970). Toluene (C7H8) was used in place of water, because it is absorbed by seeds to a lesser extent. Also, its surface tension is low, so that it fills even shallow dips in a seed and its dissolution power is low (Ögüt, 1998; Sitkei, 1986). A standard pycnometric method was used to determine the volume of weighed samples at different moisture levels. Five replicates were conducted for each watermelon variety. The volume (V, in m3) calculated by the following relationship (Mohsenin, 1970):

$$V = \frac{M_{td}}{\rho_{tol.}} = \frac{(M_t - M_p) - (M_{pts} - M_{ps})}{\rho_{tol.}}$$

$$(7)$$

Where, $M_t$ is mass of pycnometer is filled by toluene; $M_p$, mass of pycnometer; $M_{pts}$, mass of pycnometer is filled by toluene & sample; $M_{ps}$, mass of pycnometer & sample and tol, density of toluene. Then, the true density ($\rho_t$ in kgm-3) of watermelon seed obtained by the following equation (Deshpande et al., 1993):

$$\rho_t = \frac{M_{ps} - M_p}{V} \qquad (8)$$

In order to measure the bulk density, a container with known mass and volume was filled with the watermelon seeds to the top. The seeds were poured to the container in excess and with a constant rate from a height of about 150 mm (Singh & Goswami, 1996). Dropping the seeds from a height of 150 mm produces a tapping effect in the container to reproduce the settling effect during storage (Kashaninejad, et al., 2006) After filling the container, excess seeds were removed by passing a flat stick across the top surface using 2 zigzag motions. The seeds were not compacted in any way. The container was weighed using a digital balance (Model GT 2100, Germany) reading to 0.01 g. Bulk density ($\rho_b$) was calculated from the ratio of seed mass in the container ($m_b$) to its volume ($V_b$). The Bulk density was measured with 10 replications for each watermelon variety.

The porosity ($\varepsilon$, %) of bulk seeds was computed from the values of true density and bulk density using the relationship given by Mohsenin (1970) as follows:

$$\varepsilon = 1 - \frac{\rho_b}{\rho_t} \times 100$$

$$(10)$$

**Static coefficient of friction**

The static coefficients of friction for watermelon seed determined with respect to five test surfaces namely plywood, glass, fiber glass, rubber and galvanized metal sheet. A fiberglass box of 150 mm length, 100 mm width and 40 mm height without base and lid was filled with sample and placed on an adjustable tilting plate, faced

with the test surface. The sample container was raised slightly (5–10 mm) so as not to touch the surface. The inclination of the test surface was increased gradually with a screw device until the box just started to slide down and the angle of tilt was read from a graduated scale and the angle of tilt ($\alpha$) was read from a graduated scale. For each replication, the sample in the container was emptied and refilled with a new sample (Joshi et al., 1993; Olajide et al., 2000). The static coefficient of friction ($\mu_s$) was then calculated from the following equation:

$$\mu_s = \tan \qquad (11)$$

**Angles of repose**

The filling angle of repose is the angle with the horizontal at which the material will stand when piled. This was determined by using a topless and bottomless cylinder of 15 cm diameter and 25 cm height. The cylinder was placed at the centre of a raised circular plate having a diameter of 35 cm and was filled with seeds. The cylinder was raised slowly until it formed a cone on a circular plate. The height of the cone was measured and the filling angle of repose ($\theta_f$) was calculated using the following equation:

$$\theta_f = Arc \tan (2H/R) \qquad (12)$$

To determine the funneling angle of repose, a fiberglass box of 20 cm ×20 cm ×20 cm, having a removable front panel was used. The box was filled with the sample, and then the front panel was quickly removed allowing the seeds to follow and assume a natural slope (Joshi, Das, & Mukherjee, 1993). The funneling angle of repose ($\theta_e$) was calculated from the measurement of the depth of the free surface of the sample at the centre.

$$\theta_e = Arc \tan (H / X) \qquad (13)$$

## RESULTS AND DISCUSSION

### Geometrical properties

Experimental data on physical properties of watermelon seeds are given in Table 1. The results showed that the Red variety had the maximum length (8.9 mm), width (10.7mm), arithmetic mean diameter (10.89 mm), geometrical mean diameter (8.756 mm), sphericity by Jean & Ball method (2.125), surface area by McCabe et al. (225.03 m$^2$) and Jean & Ball method (198.01 mm2), among the varieties to it self. While the greatest thickness was obtained for Sarakhsi variety and the highest accounted sphericity by the Mohsenin method was belonged to Kolaleh variety (0.513). The geometric mean diameter of the Red watermelon seeds (10.894 mm) was higher than that of sunflower seeds (5.39 mm). On the other hand, the sphericity of sunflower (57%) was greater than that of seeds of three watermelon varieties, as it can be found from Table 1 (Gupta and Das, 1997). The mean values of length, width, thickness, geometric mean diameter and sphericity reported by Paksoy and Aydin (2004) for squash seeds at 6.4% moisture content were 18.16, 9.80, 2.67, 7.72 mm and 43.0%, respectively. Several physical properties of seeds and kernels at 4% moisture content were evaluated by Joshi (1993)The average length, width and thickness of

**Table 1.** Means and standard errors of the seeds of three watermelon varieties dimensions.[*]

| Variety | Sarakhsy | Kolaleh | Red |
|---|---|---|---|
| Moisture content, % (w.b.) | 4.55 | 5.02 | 4.75 |
| Length, mm | 15.597±1.065 | 13.455± 0.933 | 18.972± 0.956 |
| Width, mm | 9.190± 0.691 | 8.401± 0.633 | 10.72± 0.59 |
| Thickness, mm | 3.107± 0.358 | 2.912± 0.287 | 2.988± 0.315 |
| Arithmetic mean diameter, mm | 9.298± 0.524 | 8.256± 0.487 | 10.894± 0.433 |
| Geometric mean diameter, mm | 7.620± 0.455 | 6.893± 0.398 | 8.456± 0.394 |
| Sphericity, % (Mohsenin, 1970) | 0.49± 0.028 | 0.513± 0.022 | 0.446± 0.02 |
| Sphericity, % (Jain & Ball, 1997) | 2.066± 0.028 | 2.004± 0.039 | 2.125± 0.036 |
| Surface area, $mm^2$ (McCabe et al., 1986) | 182.963±21.765 | 149.684±17.042 | 225.031± 21.035 |
| Surface area, $mm^2$ (Jain & Ball, 1997) | 157.905±18.276 | 128.093±14.537 | 198.012± 17.761 |
| Variety | Sarakhsy | Kolaleh | Red |

* All data are means of 100 replications.

**Table 2.** Means and standard errors of the seeds of three watermelon varieties Gravimetric properties[*]

| Variety | $M_c$, % (w.b.) | Volume ($mm^3$) | True density ($kg/m^3$) | Bulk density ($kg/m^3$) | Porosity (%) |
|---|---|---|---|---|---|
| Sarakhsy | 4.55 | 206.279±16.187 | 861.754±10.417 | 416.333±9.239 | 51.681±1.452 |
| Kolaleh | 5.02 | 179.534±21.307 | 866.669±17.398 | 527.265±4.051 | 39.143±1.246 |
| Red | 4.75 | 311.627±29.885 | 863.036±10.085 | 451.616±4.566 | 47.604±0.755 |

* All data are means of 10 replications.

**Table 3.** Means and standard errors of the seeds of three watermelon varieties Frictional properties[*]

| Variety | $M_c$, % (w.b.) | Static coefficients of friction | | | | | Angle of repose | |
|---|---|---|---|---|---|---|---|---|
| | | Plywood | Galvanized sheet metal | Glass | Rubber | Fiber glass | Filling | Funneling |
| Sarakhsy | 4.55 | 0.56±0.01 | 0.38±0.01 | 0.26±0.01 | 0.66 0.01 | 0.30±0.00 | 30.57±0.28 | 26.12±0.92 |
| Kolaleh | 5.02 | 0.48±0.01 | 0.40±0.01 | 0.31±0.01 | 0.56±0.01 | 0.36±0.00 | 27.09±0.53 | 21.66 0.95 |
| Red | 4.75 | 0.61±0.01 | 0.43±0.01 | 0.26±0.00 | 0.68±0.01 | 0.34±0.00 | 32.38±0.47 | 28.15±0.95 |

* All data are means of five replications.

the pumpkin seeds were obtained 16.91 mm, 8.67 mm and 3.00 mm, respectively (Joshi et al., 1993).

## Gravimetric properties

Data on some Gravimetric properties of watermelon seeds are shown in Table 2. The results of experiments over mentioned varieties includes that the Red variety seeds had the highest volume (311.627 $mm^3$) Kollaleh variety seeds had the greatest bulk density (527.265 $kg/m^3$) and true density (866.669 $kg/m^3$). However, the maximum porosity was belonged to the Sarakhsi variety seeds (51.681).

The Estimated volume of watermelon seeds was obtained lower than the kernel of pumpkin seeds and squash seeds. The bulk density, true density and porosity of squash seeds reported 350 kg/m3, 450 kg/m3 and 22.2%, respectively, which these values were lower than the watermelon seeds (Paksoy & Aydin, 2004).

However, true density and porosity of pumpkin seeds obtained 1179 $kg/m^3$ and 65.73%, respectively, which were higher than the values for watermelon seeds (Joshi et al, 1993).

## Frictional properties

The results over the frictional coefficient of watermelon seeds on some materials made of plywood, glass, fiber glass, rubber and galvanized sheet metal surfaces

showed that at studied moisture contents, the static coefficients of friction were greatest for seed against rubber and least for glass, with plywood in between (Table 3). The friction coefficient of Red variety seeds was ranged from 0.26 to 0.68, Sarakhsi was between 0.26-0.66 and Kolale was about 0.306 to 0.558. When compared with other seeds, the coefficient of friction for watermelon seeds was higher than that of values reported for lentil seed, sunflower seed, pumpkin seed, white lupine, squash seeds (Carman, 1996; Gupta & Das, 1997; Joshi et al, 1993; Ogut, 1998; Paksoy & Aydin, 2004). The static coefficient of friction of squash seeds fluctuated from 0.18 to 0.64 over the surfaces of different materials (Paksoy & Aydin, 2004). In the moisture of 4% (d.b.), the static coefficient of friction was 0.41 for pumpkin seed and 0.34 for its kernel over different material surfaces (Joshi et al, 1993). The static coefficient of friction of Karingda seeds against surfaces of three structural materials was ranged from 0.91 to 0.34 with plywood, 0.80 to 0.29 with mild steel and 0.67 to 0.23 with galvanized iron (Suthar & Das, 1996).

As it can be found from Table 3, the values of the filling and funneling angles of repose for watermelon seeds ranged between 27.09-32.38° and 21.66-28.15°, respectively. The highest value of repose angles was obtained for Red variety, whereas the Kolaleh seeds had the lowest values. The mean values of angle of repose for watermelon seeds was lower than the pumpkin's seeds and kernels, and squash seeds (Joshi et al., 1993; Paksoy & Aydin, 2004). However, the angle of repose for watermelon seeds was higher than values reported for Locust Bean Seed (Olajide and Ade-Omowaye, 1997).

## Conclusion

In this paper, some physical properties of watermelon seed including linear dimensions, volume, sphericity, surface area, true and bulk densities, porosity, repose angle, static coefficient of friction investigated as a function of moisture content and variety. These characteristics are necessary in order to the designing of equipments and machines for the transporting, sorting, handling, processing, drying, and storing watermelon seeds. The following are concluded from this investigation into the physical properties of watermelon seeds:

The physical properties of watermelon seeds vary from variety to variety and it is also a function of the seed moisture content.

Red variety had more Length (18.972 mm) and width (10.72 mm) than other varieties, while the thickness of seeds was the greatest for Sarakhsy variety (3.107 mm). Kolaleh variety had more true density (866.669 kg/m$^3$) and bulk density, (527.265 kg/m$^3$) than other watermelon seed varieties. Furthermore, Sarakhsy seeds had less true density among the varieties.

The funneling angle of repose of seeds was the greatest for red (28.15±0.95) and the least for kolaleh (21.66±0.95).

The filling angle of repose observed higher than funneling angle of repose for all varieties at those moisture contents.

The static coefficient of friction value for red watermelon seeds on Plywood, Galvanized sheet metal and rubber surfaces was the greatest.

These findings and the lack of other published intensive work on the physical properties of common watermelon seed varieties in Iran underline the need for more research on this important edible seed in order to achieve a complete profile of physical properties of common Iranian watermelon seeds

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