ABSTRACT

Various physical properties of radish seeds were determined as indicators during the hole design of the seeder bottom. The principal dimensions (thickness, width, and length), geometric mean diameter, arithmetic mean diameter, seed surface area, bulk density, true density, sphericity, and porosity were recognized as physical parameters. The results showed that the average physical properties of radish seeds, principal dimensions, sphericity, geometric mean diameter, arithmetic mean diameter, seed surface area, bulk density, and true density were 2.32±0.126mm, 2.55 ±0.160mm, 3.38±0.169mm, 0.81±0.03, 2.71 ±0.11mm, 2.75±0.11 mm, 54.10 ±4.17 mm², 0.67 ±0.02g/cm³, and 1.265 ±0.16g/cm³, respectively. The regression analysis showed that the spherical seeds, geometric and arithmetic mean diameters were significant relationships on each seed's length, width, and thickness. The largest diameter and hydraulic areas of radish seeds were equal using holing coefficients K of 1.3 and 1.4 at the bottom open hole diameter of 10 mm, followed by 8.0 mm hole diameter with a coefficient of variation of 4.56 and 6.63%, respectively.

Keywords: Radish seed, Holes seeder bottom design, Geometric and Arithmetic mean diameter.

INTRODUCTION

The radish plant (*Raphanus sativus* L.) is considered a vital medicinal plant in worldwide due to its high nutritional value (Liang et al., 2008 and Umar et al., 2019), as it is used in the treatment of many diseases, including jaundice, gallstones, liver diseases, and heart diseases (Curtis, 2003). All the pods of the radish plant are edible, and the leafy parts of the plant are widely used as an alternative to medicines because they contain elements, vitamins, and minerals (Yu et al., 2022). Radish seeds contain 8% protein, 4% fat, 1% carbohydrates, 8% vitamin A, 48% vitamin C, 5% calcium and 5% iron (USDA, 2009).

It is necessary to evaluate principal properties as length, width, thickness, bulk density, and porosity of seeds for industrial use (e.g. plant transplants and harvesters) (Cetin et al., 2010). However, there is a shortage of data on the principal properties of radish seeds and their relationship to the bottom-hole design of the seeder device. The physical properties of radish seeds, like other plants, are significant for designing a handling system, harvesting, transporting, cleaning, separating, packing, storing, and processing types of equipment.

Ismail et al. (1989) and El-Nakib et al. (1996) considered the physical properties are the most significant guide for designing the machinery components of planters and harvesters. Also, many researches have described the seeds physical properties of a number of crops which they worked by Dev et al. (1982) for sorghum, Shepherd and Bhardwaj (1986) for pigeon pea, Ismail (1994) and Carman (1996) for lentil, Suthar and Das (1996) for karingda, Singh and Goswami (1996) and Ismail et al. (2022) for fine seeds as cumin, Gupta and Das (1997) for sunflower, Ogunjimi et al. (2002) for locust, Özarslan (2002) for cotton, Sahoo and Srivastava (2002) for okra, Konak et al. (2002) for chick pea, Vilche et al. (2003) for quinoa, Saçılık et al. (2003) for hemp, Abalone et al. (2004) for amaranth, Baimler et al. (2006) for safflower, Fawal et al. (2008) for sugar beet, Ismail et al. (2009) for caw pea and Matouk, et al. (2018) for some legume.

The principal objective of this study is to identify the relationships between the different physical properties of radishes and the shape of the seeds. The geometrical characteristics of radish seeds and the physical properties such as bulk and true densities, and the seed dimensions were measured and calculated to achieve the above goal.

MATERIALS AND METHODS

The physical properties of radish seeds were identified at Rice Research and Training Center (R.R.T.C.) at Alexandria, Egypt. Before measuring the seeds properties, they were cleaned manually to remove all foreign matter as seed hops, stones, seeds chaff, unripe and fragmented seeds.  

- **Moisture content**: The oven was used for determine the initial moisture content by drying the seeds at 105±1 °C for 24 h. (Cetin, et al., 2010 and Ozarslan, 2002).
- The different physical properties were measured in ways that depend on the simplicity and accuracy of the accepted results, and they were measured the principal dimensions; thickness (T), width (W), and length (L) of radish seeds, taking an average of 50 seeds randomly selected using a digital caliper with accuracy of ±0.01 mm.
- The seed sphericity $\phi$ was calculated by Mohsenin (1986) and Ismail et al. (2014) equation.

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- For the calculation of each of the mean seeds of geometric diameter (Dg, mm) and the arithmetic diameter (Da, mm) of radish seeds, the following equations were used (Seyed and Elnaz, 2006):

\[
Dg = \left( \frac{LW_T}{3} \right)^{1/3}, \quad \text{mm}
\]

\[
Da = \left( \frac{L + W + T}{3} \right)^{1/3}, \quad \text{mm}
\]

- Seeds surface area (As) was calculated using the Mohsenin (1970) equation as following:

\[
As = 2 \pi \left( \frac{L + W}{2} \right)^2, \quad \text{mm}^2
\]

- The bulk density of the radish seed was calculated based on the standard assessment of Singh and Goswami (1996). The following steps are filling a 500 mL vessel with the seed to 150 mm height at a constant rate and then weighing the content.

- The true density determines using a toluene displacement method. The volume of displaced toluene was found by immersing a weighted amount of radish seed in toluene (Singh and Goswami, 1996; Özgüt, 1998; Yalçın and Özarslan, 2004).

- The porosity determines based on the Mohsenin (1986) equation as following:

\[
\rho_r = \left( 1 - \frac{\rho_v}{\rho} \right)
\]

Where: \( \rho_r \) is the true density of seeds g/cm^3 and \( \rho_v \) is the true density of seeds g/cm^3.

- Hydraulic diameter, a number of orifices with holes of different diameters are used for seed flow, the hydraulic diameter is calculated using the following equation (Ismail, 2014):

\[
Dc = d \left( \frac{8K}{Dg} \right), \quad \text{mm}
\]

Where, \( d \) = hole diameter (5, 8 and 10 mm), \( K = \) coefficient used to differ in the circular shape of the seeds, which is equal to 1.3 or 1.4.

- Hydraulic surface area, It was calculating under the different seed flow openings, using the following equation:

\[
Ac = \pi/2 \times (Dc)^2 \quad \text{mm}^2
\]

All the experimental data were statistically analyzed using Microsoft Excel 2010.

RESULTS AND DISCUSSION

Elementary values of radish seeds physical properties

Table (1) presented the average for each of thickness, length and width of radish seeds. There are 3.38, 2.55 and 2.32 mm, respectively. As for the length of the seeds, the highest and lowest length were 3.58 and 3.19 mm, respectively, with coefficient of variation (CV %) of 3.38 %. The normal distribution curve of radish seed length is illustrated in Figure (1). The figure illustrate that the peak frequency of radish length fluctuating from 3.19 to 3.25 mm was about 22%, and from 3.25 to 3.31 mm it was 16%.

As for the seed width, the highest and lowest seed widths were recorded at the values of 2.82 and 2.31 mm, respectively, with CV = 6.30 %. The distribution of radish seed width curve indicated the highest recurrence rate of radish seed width was 24, 20%, respectively as shown in Figure (1). The range of radish seed width at in height frequencies was from 2.31 to 2.47 mm.

Also, the highest and lowest seed thicknesses were recorded at the values of 2.58 and 2.01 mm, respectively (CV = 7.32 %). The frequency of radish seed thickness is illustrated in Figure (1), the highest frequency was 26% ranging from 2.19 to 2.28 mm, and the lowest ranging from 2.01 to 2.1 mm and from 2.28 to 2.37 mm it was 18 %. The importance of these dimensions and other attributes in determining the appropriate aperture sizes needed in the design of agricultural machinery was discussed by Mohsenin (1986), Omobuwajo et al. (2000) and Solomon and Zewdu (2009).

For the average mass of one thousand seeds of radish, the average mass was 10.69 g at moisture content of 9.5 %.

![Fig. 1. Frequency of the main dimensions of radish seeds](image)

Derived values of the radish seeds physical properties

The sphericity of the seeds is calculated, as it depends on the main dimensions of the radish seeds. Table (1) showed the value of the sphericity of the seeds ranged between 0.74 for 0.87 with a coefficient of variation was 3.89 %. Figure (2) shows the distribution relation of radish sphericity. The highest recurrence rate of radish seed sphericity were 22 and 18 %, respectively. The variation of radish sphericity at high frequencies was from 0.805 to 0.825 and from 0.765 to 0.785. This information is significant in designing hoppers and conveying and separating equipment (Omobuwajo et al., 2000).

![Fig. 2. The radish sphericity frequency](image)

From Table (1) as for the calculated physical properties represented by the mean geometric and arithmetic diameter, the average values ranged from 2.71 and 2.75 mm,
with coefficients of variation (4.22 and 3.94 %) respectively. Figure (3) showed that the highest frequency of mean geometric diameter of radish seeds was ranged from 2.612 to 2.672 mm was 20 %, and from 2.732 to 2.792 mm it was 18 %. Also, Figure (3) showed that the distribution curve of mean arithmetic diameter of radish seed it was the highest ranged from 2.597 to 2.657 and from 2.777 to 2.837 it was 20 %, and from 2.717 to 2.777 mm it was 18 %, respectively.

Also, Table (1) showed that the seed surface area was also calculated, and the values ranged from 47.02 for 60.78 mm² with coefficient of difference 7.7 % at moisture content 9.5 %. The frequency of radish seed surface area was 18% ranging from 51.19 to 53.27 mm², and from 53.27 to 55.35 mm² it was 16 % (Figure 4).

The bulk density from Table (1), resulted it was ranged between 0.64 to 0.71 with average value of 0.67 g/cm³, for CV % of 2.98.

The values of seeds true density ranged in between 1.20 and 1.33 with a coefficient of variation 12.6 %. The seeds true density values of the radish are close to the values obtained by Öğüt (1998), Chowdhury et al. (2001), Baryeh (2002), Özarslan (2002), Saçlık. et al. (2003) and Çetin et al. (2010). The porosity of radish seeds was 0.702 % with moisture content of 9.5 %. Baryeh (2002), Coşkuner & Karababa (2007), Konak et al. (2002), Abalone et al. (2004) and Altuntaş et al. (2005) reported similar results.

**Hydraulic diameter and surface area of the bottom holes seeder device**

The hydraulic diameter (Dc) and hydraulic surface area (Ac) are calculated based on the geometric diameter of the seeds, and the open holes diameters. The calculation was done using two different coefficients (K), which are 1.3 and 1.4 due to the difference in the sphericity of the seeds. Table (2) showed that the average hydraulic diameters for bottom holes 5 (Dc1), 8 (Dc2), and 10 (Dc3) mm were 1.478, 4.478, and 6.478 mm, with a coefficient of variation of 10.06, 3.32, and 2.30 %, respectively.

As for the hydraulic surface area (Ac), from Table (2) it can showed that the average hydraulic surface area for bottom holes 5 (Ac1), 8 (Ac2), and 10 (Ac3) mm were 3.464, 31.518, and 65.921 mm², with a coefficient of variation of 19.94, 6.63 and 4.59 %, respectively. The highest values were recorded at the values of 4.87, 35.58 and 71.57 mm² and the lowest values were 2.28, 27.77 and 60.46 mm², respectively.

With the coefficient K of 1.4, the Table (2) showed that the average hydraulic diameters for bottom holes 5, 8, and 10 mm were 1.207, 4.207 and 6.207 mm, respectively, with coefficient of variation 13.27, 3.32 and 2.30 %, respectively, the highest values were recorded at the values (1.51, 4.76 and 6.76 mm), respectively, and the lowest values were 0.91, 4.21 and 6.21, respectively. For hydraulic surface area, with coefficient K of 1.4, Table (2) showed that the average hydraulic surface area for bottom holes diameter of 5, 8 and 10 mm were 2.327, 27.829 and 60.531 mm² with coefficient of variance of 26.12, 6.63 and 4.59 %, respectively. The highest values recorded at 3.58, 35.58 and 71.57 mm², and the lowest values were recorded at 1.31, 27.77 and 60.46 mm², respectively.

<table>
<thead>
<tr>
<th>Table 2. Hydraulıc diameter and surfacę area:</th>
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<tr>
<td>Physical properties</td>
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<td>With coefficient =1.3</td>
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<td>Dc1 of 5 mm</td>
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<td>Ac2 of 8 mm</td>
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<td>Ac3 of 10 mm</td>
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<td>With coefficient =1.4</td>
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<td>Dc1 of 5 mm</td>
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<td>Dc2 of 8 mm</td>
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<td>Dc3 of 10 mm</td>
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<tr>
<td>Ac1 of 5 mm</td>
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<td>Ac2 of 8 mm</td>
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<td>Ac3 of 10 mm</td>
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</table>

Analysis of variance, using multiple regression analysis, showed the seed dimensions (length, width, and thickness) had a highly significant effect on sphericity, mean each of geometric and arithmetic diameters, and the seed’s surface area. From the analysis of variance, the most appropriate equation for all these calculated physical characteristics was obtained, which is as follows:

\[ {D_g} = 0.155 \times L + 0.097 \times W + 0.79 \times T \] (\[ R^2 = 0.99 \])

\[ {D_a} = 0.264 \times L + 0.346 \times W + 0.384 \times T \] (\[ R^2 = 1.00 \])

\[ {D_s} = 0.333 \times L + 0.333 \times W + 0.333 \times T \] (\[ R^2 = 1.00 \])

\[ A_s = 15.73 \times L + 21.45 \times W - 0.06 \times T \] (\[ R^2 = 0.99 \])

The regression analysis showed that the spherical seeds was directly proportional to both the widest and thickness of the seed, and inversely to the length of the seed, while the average geometric and arithmetic diameter were directly proportional to all dimensions of the seed, while for the seed area it was inversely proportional to the thickness of the seed and directly proportional to both the length and width of the seed.

**Fig. 3. Radish geometric and arithmetic mean diameter frequency**

**Fig. 4. Radish seeds surface area frequency**
Fig. (5) shows the multi relationship among the bottom hole diameters of the feeding device, its hydraulic diameter, and its hydraulic surface area under coefficient K of 1.3 and 1.4. Distribution curves of the hydraulic diameter and hydraulic surface area under bottom hole diameters for feeding devices of 5 mm are 1.478 mm, and 3.464 mm²/2, respectively. Increasing the bottom hole diameter from 5.0 to 8.0 mm, the hydraulic diameters and the hydraulic surface area increased by about 3.0 and 1.92 times, respectively.

Meanwhile, by increasing the bottom hole diameter to 10 mm, the average was 6.478 mm with 65.921 mm²/2 for a coefficient K of 1.3. Also, the results indicated that at seeds arithmetic mean diameter of 2.75 ±0.11 mm, the most suitable hydraulic diameter of the bottom hole is 4.478 mm or 4.2 mm at hole coefficient K of 1.3 and 1.4, respectively.

**CONCLUSION**

The mean physical properties of the radish seed, main dimensions (L, W, and T), sphericity, geometric mean diameter, arithmetic mean diameter, surface area, bulk, and true densities were 3.38 mm, 2.55 mm, 2.32 mm, 0.81, 2.71 mm, 2.75 mm, 54.10 mm², 0.67 g/cm³, and 1.265 g/cm³. The regression analysis showed that the spherical seeds were directly proportional to both seed width and thickness and inversely to the seeds length. But the average geometric and arithmetic diameters were directly proportional to all seeds dimensions. The seeds surface area was inversely proportional to the seed thickness and directly proportional to each seed length and width. The largest seed diameter and hydraulic area were equal using coefficients K of 1.3 and 1.4, respectively at the open hole of 10 mm, followed by the open hole of 8 mm, with a coefficient of difference of 4.56 and 6.63%, respectively. At comparing the diameter and hydraulic area with the geometric diameter and seeds’ surface area, the seed’s hole diameter and its hydraulic surface area are higher than the geometric diameter.

**REFERENCES**


الخصائص الفيزيائية لبذور الفجل

لطفية (الطول والعرض والسمك) ، الحجم (الطول والعرض والسمك) ، مساحة السطح ، الكثافة الظاهرية، وانسبة الكروية. أظهرت النتائج أن متوسط الخصائص الفيزيائية لبذور الفجل، كان أكبر القطر والمساحة الهيدروليكية للبذور متساوية باستخدام معامل الاختلاف (الطول والعرض والسمك) في المجموعة. تشير النتائج إلى أن كروية البذور większa، وانسبة الكروية (الطول والعرض والسمك) ترتبط بالخصائص الفيزيائية لبذور الفجل، مما يساعد في تصميم الفتحات السفلية لآلة البذر.

الملخص

تم تحديد الخصائص الفيزيائية المختلفة لبذور الفجل لاستخدامها في تصميم وتطوير آلة الزراعة عند مستوى رطوبة بنسبة 9.5% على أساس جاف. تم تحديد الأبعاد الرئيسية (الطول والعرض والسمك) ، متوسط قطر البذور، وانسبة الكروية، وانسبة التفريز، والكثافة الظاهرية، والمساحة (الطول والعرض والسمك) في مجموعة متنوعة من البذور. أظهرت النتائج أن متوسط الخصائص الفيزيائية لبذور الفجل كان أكبر القطر والمساحة الهيدروليكية للبذور متساوية باستخدام معامل الاختلاف (الطول والعرض والسمك) في المجموعة. تشير النتائج إلى أن كروية البذور وانسبة الكروية (الطول والعرض والسمك) ترتبط بالخصائص الفيزيائية لبذور الفجل، مما يساعد في تصميم الفتحات السفلية لآلة البذر.