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Connection of the Radish Seed's Physical Characteristics with the Bottom Holes Design of the Seeder Device

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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, seeds 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, seeds 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 mm^2, 0.67 ±0.02g/cm^3, and 1.265 ±0.16g/cm^3, 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 Çarman (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, Baümler *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 Özarslan, 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 ±0.01mm.
- The seed sphericity ϕ was calculated by Mohsenin (1986) and Ismail *et al.* (2014) equation

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

- 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):

$$Dg = (L.W.T)^{1/3}, \quad mm$$

$$Da = \frac{L+W+T}{3}, \quad mm$$

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

$$As = 2\,\pi\,(L.W), \quad mm\text{^}2$$

- The bulk of seeds 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; Öğüt, 1998; Yalçın and Özarslan, 2004).
- The porosity determines based on the Mohsenin (1986) equation as following;

$$\rho_f = (1 - \rho_b / \rho_t)$$

Where: ρ_f: the porosity, ρ_b is the bulk density of seeds, g/cm^3 and ρ_t 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):

$$Dc = d\,(K * Dg), \quad mm$$

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:

$$Ac = \pi/2 * (Dc)^2 \quad mm\text{^}2$$

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

RESULTS AND DISCUSSION

Elementary values of radish seeds physical properties

Table (1) presented that the average for each of thickness, width and length 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%.

Table 1. Physical measurement of the radish:

Physical measurement	Average	Max.	Min.	S.D	C.V (%)
length (L, mm)	3.38	3.58	3.19	±0.126	3.38
width (W, mm)	2.55	2.82	2.31	±0.160	6.30
thickness (T, mm)	2.32	2.58	2.01	±0.169	7.32
Seed sphericity ϕ	0.80	0.87	0.74	±0.03	3.89
Geometric mean diameter, mm	2.71	2.92	2.49	±0.11	4.22
Arithmetic mean diameter, mm	2.75	2.95	2.53	±0.11	3.94
Seeds surface area, mm^2	54.10	60.78	47.02	±4.17	7.70
Bulk density, g/cm^3	0.67	0.71	0.64	±0.02	2.98
True density, g/cm^3	1.265	1.33	1.20	±0.16	12.6

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 %.

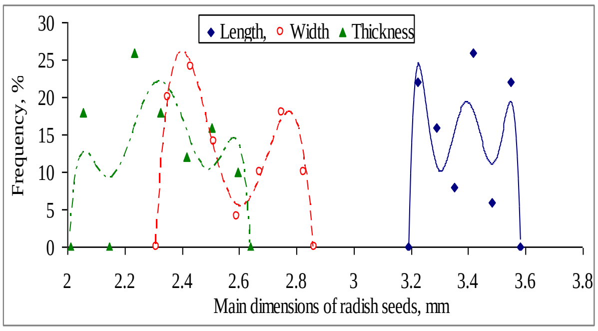

Fig. 1. Frequency of the main dimensions of radish seeds

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).

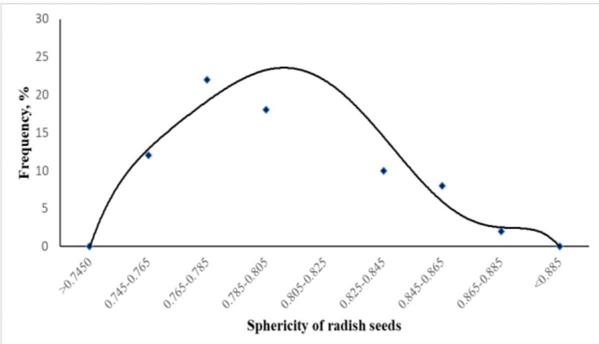

Fig. 2. The radish sphericity frequency

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 mm^2 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 mm^2, and from 53.27 to 55.35 mm^2 it was 16 % (Figure 4).

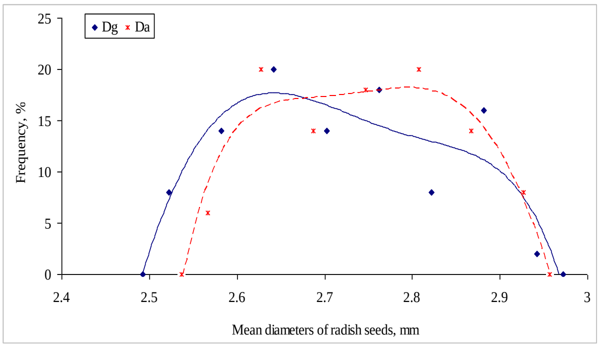

Fig. 3. Radish geometric and arithmetic mean diameter frequency

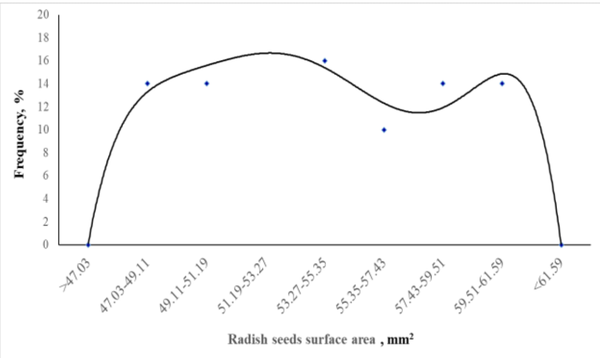

Fig. 4. Radish seeds surface area frequency

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:

$$\phi = -0.155\,L + 0.097\,W + 0.79\,T \qquad (R^2 = 0.99)$$
$$Dg = 0.264\,L + 0.346\,W + 0.384\,T \qquad (R^2 = 1.00)$$
$$Da = 0.333\,L + 0.333\,W + 0.333\,T \qquad (R^2 = 1.00)$$
$$As = 15.73\,L + 21.45\,W - 0.06\,T \qquad (R^2 = 0.99)$$

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.

The bulk density from Table (1), resulted it was ranged between 0.64 to 0.71 with average value of 0.67 g/cm^3, 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), Saçılık *et al.* (2003) and Cetin *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 are1.3 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 mm^2, 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 mm^2 and the lowest values were 2.28, 27.77 and 60.46 mm^2, 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 mm^2 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 mm^2, and the lowest values were recorded at 1.31, 27.77 and 60.46 mm^2, respectively.

Table 2. Hydraulic diameter and surface area:

Physical properties	Average	Max.	Min.	SD	CV (%)
With coefficient =1.3					
Dc1 of 5 mm	1.478	1.76	1.21	±0.15	10.06
Dc2 of 8 mm	4.478	4.76	4.21	±0.15	3.32
Dc3 of 10 mm	6.478	6.76	6.21	±0.15	2.30
Ac1 of 5 mm	3.464	4.87	2.28	±0.69	19.94
Ac2 of 8 mm	31.518	35.58	27.77	±2.09	6.63
Ac3 of 10 mm	65.921	71.57	60.46	±3.02	4.59
With coefficient =1.4					
Dc1 of 5 mm	1.207	1.51	0.91	±0.16	13.27
Dc2 of 8 mm	4.207	4.76	4.21	±0.15	3.32
Dc3 of 10 mm	6.207	6.76	6.21	±0.15	2.30
Ac1 of 5 mm	2.327	3.58	1.31	±0.61	26.12
Ac2 of 8 mm	27.829	35.58	27.77	±2.09	6.63
Ac3 of 10 mm	60.531	71.57	60.46	±3.02	4.59

Fig. (5) shows the multi relationship among the bottom hole diameters of the feeding device, its hydraulic diameter, and its hydraulic surface hole 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 mm^2, respectively. Increasing the bottom hole diameter from 5.0 to 8.0 mm, the hydraulic diameters and the hydraulic service area increased by about 3.0 and 1.92 times, respectively.

Meanwhile, by increasing the bottom hole diameter to 10 mm, the average was 6.478mm with 65.921mm^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 hole bottom is 4.478 mm or 4.2 mm at hole coefficient K of 1.3 and 1.4, respectively.

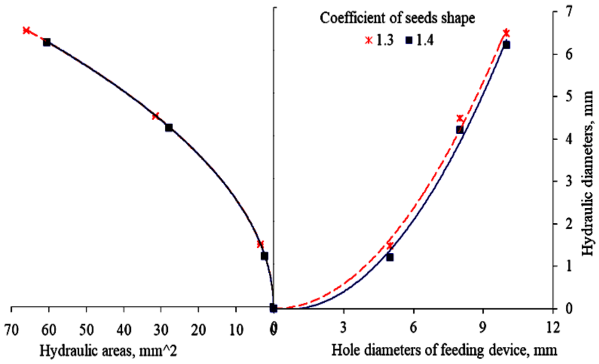

Fig. 5. The relation among bottom hole diameters, hydraulic diameter, and hydraulic surface under coefficient K of 1.3 and 1.4.

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 mm^2, 0.67 g/cm^3, and 1.265 g/ cm^3. 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.

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ربط الخصائص الفيزيائية لبذور الفجل بتصميم الفتحات السفلية لآلة البذر

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[2] قسم بحوث نظم ميكنة العمليات الزراعية- معهد بحوث الهندسة الزراعية- مركز البحوث الزراعية.

الملخص

تم تحديد الخصائص الفيزيائية المختلفة لبذور الفجل لاستخدامها في تصميم وتطوير آلة الزراعة عند محتوى رطوبة بنسبة 9.5٪ على أساس جاف. تم تحديد الأبعاد الرئيسية (الطول والعرض والسمك) ، متوسط القطر الهندسي ، متوسط القطر الحسابي ، مساحة السطح ، الكثافة الظاهرية، الكثافة الحقيقية كمعاملات فيزيائية والمساحة وانسبة الكروية. أظهرت النتائج أن متوسط الخواص الفيزيائية لبذور الفجل ، الأبعاد الرئيسية (الطول والعرض والسمك)، كروية، متوسط القطر الهندسي ، متوسط القطر الحسابي ، مساحة السطح ، الكثافة الظاهرية والحقيقية كانت 3.38 مم ، 2.56 مم ، 2.32 مم ، 0.79 ، 2.69 مم ، 2.76 مم ، 54.63 مم ^{2} ، 0.67 جم / سم ^{3} و 1.265 جم / سم ^{3}. أظهر تحليل الانحدار أن كروية البذور، ومتوسط القطر الهندسى والحسابى يعتمدوا بعلاقات معنوية على كلاً من طول وعرض وسمك البذرة. كان أكبر قطر ومساحة هيدروليكية للبذور متساوى باستخدام معاملى 1.3، 1.4، وذلك عند فتحة خروج البذرة 10 مم، يليه عند فتحة خروج بذور 8 مم، وذلك بمعامل اختلاف (4.56، 6.63 %) على التوالى، بمقارنة القطر والمساحة الهيدروليكية مع القطر الهندسى ومساحة سطح البذور وجد أن القطر والمساحة الهيدروليكية للبذور عند الفتحة 10 مم أكبر من القطر الهندسى.