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Some Phesoengineering Properties of Okra Seeds Determination

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ABSTRACT

Due to the lack of information about the engineering properties of okra seeds in Egypt. Some physical, mechanical and aerodynamic characteristics of okra seeds were studied to set a database for properties related to grading, separating, handling, cleaning, storage and other future processing units. The study of experiments conducted on okra seeds at 6.31 % moisture content dry basis. The study revealed that the average value of length, width, thickness, geometrical and arithmetic mean diameters, volume, sphericity, coefficient of contact surface and surface area of okra seed were 5.85, 4.40, 4.04, 4.68, 4.75 mm, 56.12 mm^3, 80.43%, 30.77% and 69.77 mm^2, respectively. While; the mean value of bulk and true densities, individual seed mass, one thousand seed, porosity and projected area were 0.633g/cm^3, 0.898g/cm^3, 0.067 g, 61.27 g, 33.81 % and 22.46 mm^2, respectively. The study also revealed that the average value of repose angle was 29.15°. While; the lowest values of static friction coefficient for okra seeds were on stainless steel sheet followed by galvanized iron, plywood and the highest on rubber were 0.271, 0.328, 0.402 and 0.466, respectively. The study also concluded that the rupture force and deformation ratio of okra seeds were 82.89 N and 4.33 %. The mean values of terminal velocity and coefficient of drag were 8.40 m/s and 0.70, respectively. Also; the mean value of Reynolds number was 2621 therefore; the pattern of air flow is in the range of transitional flow.

Keywords: okra, physical, mechanical and aerodynamic properties.

INTRODUCTION

Okra is one of the most important vegetable crops in Egypt and all over the world. In Egypt the total cultivated area of okra crop is about 10.4 thousand feddan, produced about 52 thousand Mg (FAO, 2017). These green pods are the important constituents of diet in developing countries. Its major nutrients are 2.2 % protein, 9.7 % carbohydrate and 1.0 % fiber; it is also a rich source of vitamin C, calcium and iron content (Saifullah and Rabbani, 2009).

Sahoo and Srivastva (2002) reported that the physical properties of okra seeds were evaluated as a function of moisture content. They found that the average value of length, width and thickness of seed ranged from 5.92 to 7.30; 4.71 to 5.40 and 4.59 to 5.36 mm as the moisture content increased from 8.16 to 87.57% d.b, respectively. While; the mean value of bulk density, true density and porosity decreased from 0.592 to 0.558 g/cm^3; 1.107 to 0.986 g/cm^3 and 46.34 to 43.20%, respectively at the previous moisture contents.

Kumar *et al.* (2018) examined some physical properties of okra seeds. They concluded that the mean length, width, thickness, geometrical diameter, sphericity, porosity and sphersccal were 5.73 mm; 4.83 mm; 4.49 mm; 4.98 mm; 87.9%; 49.1%, and 78.2%, respectively: They also found that the bulk and true densities were 0.54 and 1.07 g/cm^3 respectively.

Mohsenin (1986) mentioned that the physical properties of agricultural material such as; shape and size, volume, density, porosity and surface area are important and essential engineering data in many problems associated with machines design or behavior analysis of the agricultural products in different processes. The angle of repose affects the design of mass flow structures. In drying and aeration systems for seeds (Ismail *et al.*, 2009), bulk density and porosity play a significant role as these properties control the amount of hindrance caused by airflow (Zewdu and Solomon, 2006).

The object of this study was to investigate some engineering properties of okra seed which affect designing and developing of precision planting, separation, handling system, threshing and storage machines.

MATERIALS AND METHODS

The samples of okra seeds were brought from Gharbia Governorate, Egypt, during the harvest season of 2019. The sample seeds were cleaned from foreign material, damaged seeds and impurities by manually. The seeds were stored in a burlap sacks inside a ventilated storage room. The experimental part of the present study was carried out in the Agricultural Products Process Engineering Laboratory at Faculty of Agricultural Engineering, Al-Azhar University, Cairo, Egypt.

Physical properties of okra seeds

Moisture content

The moisture content of the seed sample was determined by drying to constant mass. Five samples of seeds taken in aluminum boxes were weighted and placed in hot air oven at 105°C according to (AOAC, 2005). The moisture content of the seeds was found to be 6.31 ± 0.41 % dry basis.

Axial dimensions of okra seeds

To determine the average size of the seeds, 100 seeds were randomly picked and the three linear dimensions namely, length "L", width "W" and thickness "T" were measured using a digital caliper with accuracy 0.01mm.

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Average diameters and volume

Geometric mean diameter (D_g), arithmetic mean diameter (D_a) and volume (V) of okra seeds calculated using the following equations, according to, (El Raie *et al.*, 1996) and (Ismail *et al.*, 2009)

$$\mathbf{D_g = (LWT)^{1/3} \quad mm \ldots\ldots\ldots (1)}$$

$$\mathbf{D_a = \frac{L + W + T}{3} \quad mm \ldots\ldots\ldots (2)}$$

$$\mathbf{V = \frac{\pi}{6}[LWT] \quad mm \ldots\ldots\ldots (3)}$$

Sphericity

The sphericity percent of seeds (∅) was calculated from the following equation (Mohsenin, 1986):

$$\emptyset = \frac{\mathbf{(LWT)^{1/3}}}{\mathbf{L}} \times \mathbf{100} \quad \% \ldots\ldots\ldots (\mathbf{4})$$

Coefficient of contact surface

Coefficient of contact surface (C.C) was calculated for seeds according to (Abd Alla *et al*. 1995) from the following equation:

$$\mathbf{C.C = \frac{A_f - A_t}{A_f} \times 100} \quad \% \ldots\ldots\ldots (\mathbf{5})$$

Where:

A_f: Flat area surface= $\frac{\pi}{4}(LW)$; and

A_t: Transverse area surface = $\frac{\pi}{4}(WT)$.

Surface area

The surface area of seed (A_s) is depended on values of geometric mean diameter (D_g) was calculated using the following formula (Adejumo *et al.* 2015).

$$\mathbf{A_s = \pi D_g^2 \quad mm^2 \ldots\ldots\ldots (6)}$$

Bulk and true densities of seeds

Bulk density of the seeds is used for seed storage structures designs. It was measured using a graduated flask having a volume of 25 cm^3. The graduated flask was filled with okra seeds without compaction and then its mass was measured. The bulk density "ρ_b" (g/cm^3) was calculated as follows:

$$\boldsymbol{\rho_b = \frac{M_s}{V_s}} \ldots\ldots\ldots\ldots\ldots (\mathbf{7})$$

Where:

M_s: Mass of sample, (g); and V_s: Volume of bulk sample, (cm^3).

The true density was determined using a toluene (C_7H_8) displacement method with a known mass of seeds. The true density"ρ_t" (g/cm^3) was calculated using the following equation according to, (Mohsenin, 1986).

$$\boldsymbol{\rho_t = \frac{M}{V_t}} \ldots\ldots\ldots\ldots (\mathbf{8})$$

Where:

M: Mass of sample, (g); and V_t: Displaced volume of toluene, (cm^3).

The test was repeated ten times, and the average bulk and true densities of the okra seeds were reported.

Mass of seeds

The mass of single seed (M_i) was determined by randomly selecting one hundred seed of okra and then weighing them one by one. A precision weighing balance having least count of 0.001 g was used. To determine the thousand seed mass of 300 seed were randomly selected and weighed, then divided to three groups, each group contains one hundred seed. The mass of thousand seed (M_t) "g" was calculated from the following equation:

$$\mathbf{M_t = 100\ seed\ mass \times 10} \ldots\ldots\ldots (\mathbf{9})$$

Projected area

To determine the projected area of okra seeds (A_p), fifty seeds were randomly selected from okra seeds and then scanned using a scanner to capture the image of seeds at natural flat position, then; the pictures of seeds were exported to SolidWorks, program to calculate the projected area of okra seeds, according to (Badr and Darwish, 2018).

Porosity

The porosity of okra seeds (ε) is depended on values of bulk and true densities using the following equation according to, (Mohsenin, 1986).

$$\boldsymbol{\varepsilon = \left(1 - \frac{\rho_b}{\rho_t}\right) \times 100} \ldots\ldots\ldots\ldots (\mathbf{10})$$

Static friction coefficient

Static friction coefficient of seeds (μ) was determined on four different materials namely; plywood (P_w), galvanized iron (G_i), rubber (R_b) and stainless steel (Ss). In order to determine coefficient of friction a sample was put on the surface with adjustable slope. When a sample started to move, the tangent of the slope angle calculate (β, degree). The procedure was repeated ten times and the static friction coefficient for each replicate was calculated using equation (11).

$$\boldsymbol{\mu = \tan\beta} \ldots\ldots\ldots (\mathbf{11})$$

Repose angle

The repose angle (α, degree) is the angle between the base and the slope of cone formed on a free vertical fall of the seed mass to a horizontal plane. The slope of base of the seed flow structures is based on the average angle of repose of seeds to ensure free flow of seeds. The angle of repose of seeds was measured using a hollow cylinder (80 mm diameter "D" and 200 mm height "H") and a wooden table. The cylinder was placed on the wooden table. Then; it was filled with okra seeds. The cylinder was raised slowly allowing the seeds to flow down to form a cone of seeds and then diameter and height of the cone were recorded. Three readings were taken and average was reported. The angle of repose was calculated using the equation:

$$\boldsymbol{\alpha = \tan^{-1}\left[\frac{2H}{D}\right]} \ldots\ldots\ldots (\mathbf{12})$$

Rupture force and deformation ratio

Rupture force (Rf) is implies the partial or complete destruction of seed. The rupture force and deformation ratio of seeds were measured by using a digital Universal Material Tester. Model No: MT 2021, range of the measurement is 0 to 20 kN and its accuracy is 0.1 N. The used sample for measure the rupture force was 25 seed. The deformation ratio (Dr) "%" at rapture point is the longitudinal strain at rupture point and it was calculated by the following equation:

$$\mathbf{D_r = \frac{y}{d} \times 100} \ldots\ldots\ldots\ldots (\mathbf{13})$$

Where:

y: Deformation at rapture point (change in dimension), (mm); and

d: Original dimension of seed, (mm).

Aerodynamic properties of okra seed:

Terminal velocity and drag coefficient

The terminal velocities of okra seeds were measured using the terminal velocity apparatus Fig.1 according to (Awady and El-Sayed, 1994 and Fawal et al. 2008). The apparatus consists of a rectangular tube constructed from transparent (plexi-glass) and connected with the outlet of the electric blower, two sheet screens were fitted at bottom and top of the transparent tube. An air-flow straightener was attached with the lower screen to improve flow uniformity throw the sloping rectangular tube. A choke valve is built as the inlet of blower to control the air flow rate manually.

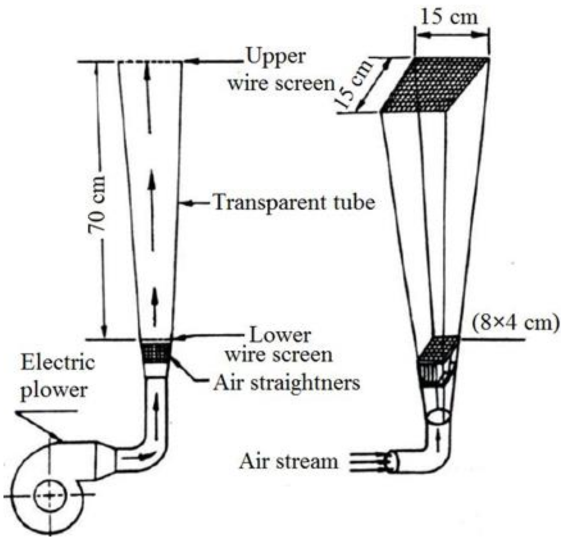

Fig. 1. Terminal air velocity setup(Awady and El-sayed, 1994).

The sample was placed on the lower screen. Terminal velocity can be obtained by measuring the air velocity required to suspend the particles in the vertical air stream (Ismail *et al.*, 2009). Air velocity was measured at the bottom of the tube by an anemometer. The air velocity changes according to changes in the cross-section of the tube. The value of the terminal velocity (V_t) "m/s" was calculated using the following equation:

$$\mathbf{V_t = \frac{Q}{A}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(\mathbf{14})$$

Where:

Q: Air flow rate, (m^3/s); and A: Cross-section area of the tube, (m^2).

When a particle is suspended into a turbulent stream of air, equilibrium is achieved between its weight and the drag force, the drag coefficient of seed was calculated by the following equation according to (Awady and El- sayed, 1994):

$$\mathbf{C_d = \frac{2M.g}{V_t^2 . \rho_a . A_p}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (\mathbf{15})$$

Where:

C_d: Coefficient of drag, (dimensionless); M: Mass of seed, (kg);
g: Acceleration of gravity, (9.81 m/s^2); V_t: Air terminal velocity, (m/s);
ρ_a: Air density (1.2 kg/m^3); and A_p: Projected area of seed, (m^2).

Reynolds number

Reynolds number (R_n) "dimensionless" was calculated by the following equation (Mohsenin, 1986).

$$\mathbf{R_n = \frac{\rho_a . V_t . D_g}{\mu}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (\mathbf{16})$$

Where:

D_g: Geometric mean diameter, (m); and
μ: Dynamic viscosity of air, (18× 10^{-6} kg/m.s).

RESULTS AND DISCUSSIONS

Physical properties

Based on the experiments conducted in the laboratory for each mentioned property of okra seeds, the results are as follows:

Axial dimensions of okra seeds

The axial dimensions of okra seeds were measured and found that value of average length was 5.85 ± 0.75 mm, varying in range from 4.11 to 7.31 mm, with coefficient of variation as 12.79%. whilst; the mean values of width and thickness were 4.40 ± 0.72 and 4.01 ± 0.59 mm which ranged from 3.08 to 6.38 and 2.89 to 5.76 mm, with coefficient of variation as 16.35% and 14.82%, respectively.

Average diameters

The mean value of geometric mean diameter (D_g) was 4.68 ± 0.58 mm and it varied in range from 3.80 to 6.42 mm, with coefficient of variation as 12.46 %. While; the mean value of arithmetic mean diameter was 4.75 ± 0.57 mm which ranged between 3.81 to 6.46 mm, with coefficient of variation as 12.05%.

Sphericity and volume

The mean sphericity of the seeds was recorded as 80.43 ± 8.21 %, which ranged between 63.55 % and 96.27%, with coefficient of variation as 10.20%. While; the mean value of volume was found to be 56.12 ± 22.69 mm^3 which ranged from 28.63 to 138.70 mm^3, with coefficient of variation as 40.43%.

Surface area and coefficient of contact surface

The average of surface area for okra seeds was found to be 69.77 ± 18.07 mm^2, which ranged from 45.26 to 129.58 mm^2, with coefficient of variation as 25.90%. Meanwhile; the value of coefficient of contact surface for okra seeds ranged from 2.40 to 52.48% with an average value of 30.77 ± 11.03%, with coefficient of variation as 35.85%.

Bulk and true densities of okra seeds

The bulk density of okra seed varied between 0.549 to 0.658 g/cm^3. The average value of bulk density of the seed was 0.633 ± 0.03 g/cm^3. The mean true density of the seed was found to be 0.898 ± 0.08 g/cm^3, which ranged from 0.756 and 0.993 g/cm^3.

Mass of okra seeds

The values of individual seeds masses varied from 0.041 to 0.098 g with an average value of 0.067 ± 0.01g, with coefficient of variation as 18.59%. Whereas; the average mass of one thousand okra seeds varied from 50.73 g to 73.53 g with an average value of 61.27 ± 11.50 g, with coefficient of variation as 18.77%. The mass of the seed plays an important role in cell design of seed metering mechanisms.

Porosity and projected area for okra seeds

The mean values of porosity and projected area for okra seeds were 33.81 ± 2.69 % and 22.46 ± 2.06 mm^2, these values ranged from 30.41 to 37.95% and 18.23 to 27.13 mm^2, with coefficient of variation as 7.96% and 9.17%, respectively.

Mechanical properties

Table 1 indicated that the mean values, standard deviation "SD" and coefficient of variation "CV%" for mechanical properties of okra seeds.

Static friction coefficient

According to Table 1 the lowest values of static friction coefficient were on stainless steel sheet followed by galvanized iron, plywood and the highest on rubber (0.271, 0.328, 0.402 and 0.466), respectively. This is due to the smoother and more polished surface of stainless steel sheet and galvanized iron than the other tested surfaces.

Repose angle

The average value of repose angle was found to be 29.15±1.14° which ranged from 27.47° to 30.54°, as shown in Table 1.

The coefficient of friction and angle of repose are important in designing equipment for solid flow and storage structures.

Rupture force and deformation ratio

The mean values of rupture force (R_f) and deformation ratio (D_r) of okra seeds were found to be 82.89±11.85 and 4.33±0.82% which ranged from 63.42 to 106.15 N and 3.23 to 6.72 % respectively, as shown in Table 1 .This properties is beneficial for extract oil from okra seeds.

Table 1 .Mechanical properties of okra seeds.

Parameter	Symb.	Range Min.	Range Max.	Mean ± SD	CV, (%)
Static friction coefficient	P_w	0.351	0.482	0.402 ± 0.04	9.84
	G_i	0.304	0.354	0.328 ± 0.02	5.51
	R_b	0.432	0.517	0.466 ± 0.03	5.52
	Ss	0.236	0.303	0.271 ± 0.02	8.38
Repose angle, (degree)	α	27.47	30.54	29.15 ± 1.14	3.90
Rupture force, (N)	R_f	63.42	106.15	82.89 ± 11.85	14.29
Deformation ratio, (%)	D_r	3.23	6.72	4.33 ± 0.82	18.95

Terminal velocity and drag coefficient

The values of terminal velocity and coefficient of drag for seeds varied from 7.39 to 9.73 m/s and 0.51 to 0.89 with average values of 8.40 ± 0.57 m/s and 0.70 ± 0.09, with coefficient of variation as 6.78% and 13.16% respectively, These properties can be utilized in designing air screen, threshing, cleaning and grading equipment.

Reynolds number

The results showed that the mean value of Reynolds number was 2621 ± 178 ranging from 2306 to 3036 with coefficient of variation as 6.78%. The results showed that the pattern of air flow is in the range of transitional flow.

CONCLUSION

The study of experiments conducted on okra seeds at 6.31 % moisture content dry basis revealed the following conclusions:

- -The average values of length, width, thickness, geometrical and arithmetic mean diameter were 5.85, 4.40, 4.04, 4.68 and 4.75 mm, respectively. Also; the average values of volume, sphericity, coefficient of contact surface and surface area were 56.12 mm^3, 80.43%, 30.77% and 69.77 mm^2, respectively.
- -The mean value of bulk and true densities of okra seeds were 0.633 and 0.898 g/cm^3, respectively. In addition to that the average values of individual seed mass and one thousand seed were 0.067 and 61.27 g, respectively. Also; the mean values of porosity and projected area were 33.81 % and 22.46 mm^2, respectively.
- -The average value of repose angle was 29.15°. While; the lowest values of static friction coefficient for okra seeds were on stainless steel followed by galvanized iron, plywood and the highest on rubber were 0.271, 0.328, 0.402 and 0.466 respectively. The study also concluded that the rupture force and deformation ratio of seeds was 82.89 N and 4.33%.
- -The mean values of terminal velocity and coefficient of drag were 8.40 m/s and 0.70 respectively. While; the mean value of Reynolds number was 2621 so; the pattern of air flow is in the range of transitional flow.

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بعض الخصائص الفيزوهندسية لبذور البامية

علوان على درويش و عاطف موسى إبراهيم موسى

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تعتبر محاصيل الخضر من المحاصيل الاقتصادية الهامة والتي تنافس الكثير من المحاصيل الحقلية حيث تعد من مصادر الدخل السريع للمزارع المصري. ومنها محصول البامية والتي انتشرت زراعته في مصر، وذلك بغرض التغذية المباشرة على القرون أو إنتاج البذور لإستخلاص الزيت والذى يستخدم فى مستحضرات التجميل وغيرها. وكان تصنيع الآلات الزراعية وخاصة آلات الزراعة والات استخلاص الزيوت يحتاج إلى توفير البيانات عن الخصائص الهندسية للبذور لكي تساعد في تصميم أجزاء الآلة. ولتحقيق هذا الهدف تم دراسة الخواص الطبيعية والميكانيكية والأيروديناميكية المتعلقة ببذور البامية وذلك عند محتوي رطوبي 6,31 ٪ على أساس جاف. ويمكن تلخيص النتائج كما يلى: متوسط كل من الطول، العرض، السمك، القطر الهندسي، القطر الحسابي، الحجم، والكروية، معامل التلامس السطحى والمساحة السطحية لبذور البامية 5,85 ، 4,40 , 4,01 ، 4,68 ، 4,75 مم ، 56,12 مم³، 80,43 % ، 30,77 % و 69,77 مم² على التوالي. متوسط كل من الكثافة الظاهرية، الكثافة الحقيقية، كتلة البذرة الواحدة، كتلة الألف بذرة، المسامية والمساحة المسقطة لبذور البامية 0,633، 0,898 جرام/سم³، 0,067 ، 61,27 جرام ، 33,81% ، 22,46 مم² على التوالي. وجد أن أقل قيمة لمعامل الإحتكاك الإستاتيكي لبذور البامية كانت 0,271 لسطح الإستانلس ستيل (صلب مقوم للصدأ) يليها سطح الصاج المجلفن 0,328 وسطح الخشب 0,466 بينما كانت أعلى قيمة 0,466 لسطح الجلد. كما وجد أيضاً أن متوسط كلاً من زاوية الراحة للبذور وكذلك القوة اللازمة لكسر البذرة ونسبة تشوة للبذور 29,15° و 82,89 نيوتن و 4,33% على التوالي. متوسط السرعة الحرجة ومعامل الجرف كانت 8,40 م/ث و 0,70 على التوالى، بينما وجد أن متوسط رقم رينولد 2621 وبالتالى تقع فى نطاق سريان الهواء الإنتقالى.