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Determination of Mechanical and Aero-Dynamics Properties of some Legume Crops

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ABSTRACT

The mechanical and aero-dynamic properties such as coefficient of friction, hardness, repose angle, terminal velocity, Reynold's number and drag coefficient for faba bean and lentil seeds were determined at different levels of seed moisture contents while shear force and shear stress of faba bean seeds on both lateral and longitudinal direction were also determined at different levels of seed moisture contents. The obtained results showed that, coefficient of friction changed with type of friction surface and seed moisture contents where it was increased with the increasing of seed moisture contents. Meanwhile for faba bean and lentil seeds, stainless steel surface recorded the lowest values of friction coefficient whereas the rubber surface recorded the highest values. As well, the repose angle increased with the increasing of seed moisture contents. However, hardness, shear force, shear stress decreased with the increasing of seed moisture contents. For aero-dynamic properties both of terminal velocity and Reynold's number of studied crops increased linearly with the increasing of seed moisture contents. While, drag coefficient decreased by increasing the terminal velocity. Mathematical relationships were developed for the studied crops to relate the obtained values of all mechanical and aero-dynamic properties with the changes in seed moisture contents.

INTRODUCTION

Knowledge of the coefficient of friction is necessary in designing equipment for solid flow and storage structures. The coefficient of static friction is the ratio of force required to start sliding the sample over a surface divided by the normal force, i.e. the weight of the object. Bahnasawy, (2007)

Emesu & Phumuza, (2014) mentioned that, the angle of repose is an important parameter for calculation of grain discharge rates from storage vessels which influence the design of seed containers and other storage structures and accessories.

Khanbarad, *et. al.,* (2014) stated that, the hardness of pigeon pea grain decreased from 484.22 to 10.27 N as an increase in moisture content from 6.2 to 30.2 % (w.b.). Where, the greater forces were necessary to rupture the grains with lower moisture level.

Isik & Izli, (2016) found that, the rupture force for yellow lentil seeds decreased from 22.5 to 16.2 N when the moisture content levels increased from 15.6 to 22.5% (d.b.). Also they stated that, "the terminal velocity increased linearly from 1.5 to 2.09 m/s after increasing in the moisture content for yellow lentil seeds. The reason of this increase is the increase in the seed mass per unit frontal area that faces the stream of air".

Marimuthu, *et. al.,* (2013) mentioned that, the coefficient of static friction plays an important role in transports of goods and storages facilities. Also, the rubber surface has a higher static coefficient of friction, followed by stainless steel, plywood, galvanised iron, aluminium and glass surfaces. All the static coefficients of friction increased linearly when the moisture content increased from 11.02 to 24.5% (d.b).

Wandkar *et. al.,* (2012) stated that, the repose angle is the properties of the bulk material which indicates the cohesion among the individual grains. The higher the cohesion, the higher the angle of repose. Also, they found that, the increase in moisture content from 7.37 to 15.80% (d.b.) increased it linearly from 26.35 to 30.96 ^{o}.

Aerodynamic properties of solid materials have been applied to separate and convey grains and seeds during operations of post-harvest. Also, they are needful in the suitable design of separating and cleaning equipment because of dependence of particles behavior in an air stream during pneumatic conveying and separation on their aerodynamic properties. Likewise, knowledge of aerodynamic properties of particles is requisite to set the range of air velocities for grain separation from foreign materials when an air stream is used for separating a product. (Shahbazi, 2015).

El Fawal, *et. al.,* (2009) showed a variation in terminal velocity for the varieties of the same crop due to the variation in particle mass, air and particle densities. Hence, the difference in terminal velocity offers the possibility of separating such materials from each other in an air stream and it can be utilized in designing air screen, threshing, cleaning and grading equipment.

Nalladurai, *et. al.,* (2003) stated that, "the Reynold's number is needful in hydraulic and pneumatic handling of grains, and in accounting thermal diffusivity in drying and heat transfer rates".

Shahbazi, (2015) showed that, there was a significant difference between the drag coefficients of mung bean seeds at different moisture content. However, the drag coefficients were not affected significantly by mung bean seeds grade. Also, the results showed that the drag coefficient of mung bean seeds decreased as moisture content increased.

Dilmac *et. al.,* (2016) reported that, the value of drag coefficients for faba bean seeds were 1.02 and 0.88 at moisture content of 11.4% and 25.8% (w.b.), respectively.

The objective of this study was to investigate moisture-dependent mechanical and aero-dynamic properties, namely, coefficient of friction, hardness, penetration depth, shear force and stress, repose angle, terminal velocity, Reynold's number and drag coefficients for faba bean and lentil seeds at different levels of seeds moisture content.

MATERIALS AND METHODS

1. Materials:

The current study was devoted to specific types of legumes, namely faba bean variety Giza 716 and lentils variety Giza 370. These varieties were obtained from the Agricultural Research Center (ARC). While, the green beans were bought at farm land in Damietta City, Egypt. The samples were selected and cleaned manually. It was ensured that the grains were free of dirt, broken one and other foreign materials. The initial moisture content of samples was determined by oven drying at 105°C for 72h and 103°C for 72h for faba bean and lentil, respectively according to (ASAE, 2000c) and (ASAE, 1993).

To obtain the desired moisture levels for the studied, samples all seeds were conditioned by adding a calculated amount of water to the moisture conditioning apparatus based on Equation (3.1) (Sacilik, et. al., 2003)

$$Q = \frac{W_i\,(M_f - M_i)}{100 - M_f} \quad \text{.............................} \quad (1)$$

Where: **Q: mass of water to be added, g; W_i: Initial mass of the sample, g; M_i: Initial moisture content of the sample, % (d.b.) and M_f: Final (desired) moisture content of the sample, % (d.b.)**

2. METHODS

Mechanical properties:

Coefficient of friction

The device shown in fig. (1) was used to measure the coefficient of friction for both types of seeds which consists of:

1) The surface which the material was placed on for testing the coefficient of friction.
2) The surface was moved at an angle ranging from 0: 90° with an electric motor (Dc motor) with a reduction gearbox from 1:100.
3) The circuit of (H Bridge) which directed the engine to the right and left to raise or lower the surface.
4) The Arduino circuit (Genuino uno) with 6 input analog and 13 digitals.
5) The Module of HX711 with 24 bits analog to digital conver.
6) Apiece of Mechatronic (Mbu 6050) which consists of:

a) Gyroscope meter. b) Accelerometer meter.
c) Parameter. d) Tilet meter. e) Temperature meter.

7) Power supply for converting from (220-volt Ac) to (12-volt Dc).
8) Laptop (LENOVO ideapad 110) with the Arduino 1.6.10 software which was connected to device to read the friction angle every 1/10 sec and the corresponding weight of drop sample with lifting slowly.

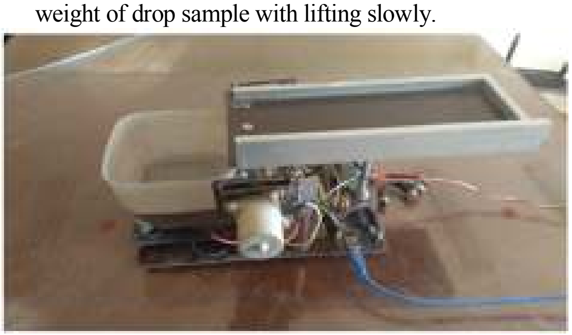

Fig. 1. Apparatus for measuring the angle of friction

The measuring procedure depends on opening the Arduino board of measurement with clicking the upload button and then opening the serial monitor to show the resulted sketch and using the electronic balance for the device to weight the sample of seeds (200g). After that, the seeds should be put on the lifting surface. Then, pressing the lifting switch to gradually rise the surface of seeds. So, the sample will be slide and received on the falling seeds container. As well, the process of calibration depends on stopping the lift motor automatically when about 50-75% of the tested sample is failed down in the seed receiver. The average of 10 readings of the friction angle was used for calculating the coefficient of friction using the following equation:

$$C.F = \tan\theta \text{ , decimal} \quad \text{.............................} \quad (2)$$

Where: **C.F: coefficient of friction; θ: friction angle, degree.**

Seed hardness and shear force device:

The hardness and shear force of seeds were measured by using the apparatus as shown in fig. (2) model (FGC-50) with accuracy (± 0.2% of maximum load + ½ digit at 23°c).

For measuring seeds hardness, penetration and shear force, the meter was set on the maximum reading position then pressing the seed by the flat end for hardness, tapered edge for penetration and sharp end for shear force in both lateral and longitudinal directions.

Fig. 2. Apparatus used for measuring seeds hardness & shear force

Repose angle apparatus

The apparatus was used for measuring the repose angle of seeds which was designed by (Matouk, *et. al.,* 2006 b). The apparatus consists of a wooden box with inner dimensions of 18 x 18 x 20 cm, three transparent plastic sides (left, right and front sides), where the front side is sliding up and down. Wooden parallelogram with a base fixed on the protractor was used to measure the angle between the base and the inclined of the formed cone due to a free side fall of the seeds.

Aero-dynamic properties:

Terminal velocity apparatus

The terminal velocity for seeds was determined by using the apparatus designed by (Matouk, *et. al.,* 2005) as shown in fig. (3). The specifications of the apparatus are shown in table (1).

Fig. 3.Terminal velocity apparatus

Table 1. Specifications of the apparatus used for measuring the terminal velocity:

Apparatus parts	Specifications
Dimensions	1 × 0.85 m (Length × Height)
Accuracy	0.01 m/s
Maximum air velocity	25 m/s
Materials of tubes	PVC and transparent glass
centrifugal fan	Made in Spanish, AC current, 220 V, 50 HZ, 2800 rmp, 0.25 kW
Electric inverter	Made in Japan 1.5 kW, current HZ control

Terminal velocity for each studied crop was measured as follows: First, the instrument was calibrated by relating of the electric current frequency and air velocity passing through a transparent tube with data analysis to reach a direct relationship between the air velocity and the current frequency by usng inverter. This relationship was then used to measure different air velocities within the transparent tube during the experimental work without using the probe of air velocity meter which may obstruct the seeds flow inside the tube during the measurements. The calibration curve for the apparatus is shown in fig. (4).

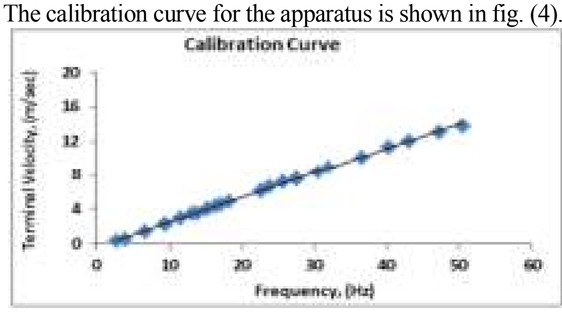

Fig. 4. Calibration curve for the terminal velocity apparatus

Then, selecting a specific number of seeds in ten replicates at different levels of seeds moisture content and put them on the plastic net of the transparent tube. The blower was turned on and the inverter frequency was gradually increased until the floating air suspends the particle in the vertical active part of the transparent tube. When approaching a relatively steady seeds suspension condition, the suspended seeds were counted and the frequency of the inverter current was recorded. With increasing the inverter frequency gradually, the suspended seeds flow out the transparent tube and with additional increase of the inverter frequency other seeds start to suspend. The terminal velocity could be measured using the following relationship. Lately, the average terminal velocity could be measured at each level of moisture content.

$$V_t = 0.2901\,f - 0.3709 \quad \text{(3)}$$

Where: V_t: seeds terminal velocity, (m/s);
f: inverter current frequency (Hz)

Reynold's Number

Reynold's number of seeds was calculated by using the following equation:

$$Re = \frac{\rho_f\,V_t\,D_g}{\mu},\ \text{dimensionless} \quad \text{(4)}$$

The geometric mean diameter of faba bean and lentil seeds (D_g) was also calculated using the following equations, respectively:

$$D_g = (LWT_h)^{1/3},\ mm \quad \text{(5)}$$

$$D_g = (D^2T_h)^{1/3},\ mm \quad \text{(6)}$$

Where:

ρ_f: mass density of the air 1.191 kg/m^3;
V_t: terminal velocity, (m/s)
μ: air viscosity at room temp., (18.5×10^{-6}) N.sec/m^2
L: Seeds length, (m); W = Seeds Width, (m);
T_h: Seeds thickness, (m) D: diameter of lentil seeds, (m)

Drag Coefficient

Terminal velocity was used to calculate the drag coefficient, as follow: (Mohsenin, 1986)

$$V_t = \sqrt{\frac{2mg\,(\rho_p - \rho_f)}{\rho_p\,\rho_f\,A_p\,C_d}},\ m/s \quad \text{(7)}$$

$$C_d = \frac{2mg\,(\rho_p - \rho_f)}{\rho_p\,\rho_f\,A_p\,V_t^2},\ \text{decimal} \quad \text{(8)}$$

Where:

m: mass of the seeds, kg;
g: acceleration due to gravity 9.81 (m/s^2)
ρ_p: mass density of the seeds, (kg/m^3);
ρ_f: mass density of the air 1.191 kg/m^3
A_p: Projection area of the particle, (m^2);
V_t: terminal velocity, (m/s)
C_d: overall drag coefficient

RESULTS AND DISCUSSION

1. Mechanical properties:

A- Coefficient of friction

Fig. (5) illustrate the change in friction coefficient with the change in seeds moisture at different tested surfaces.

For faba bean seeds, the stainless-steel sheet recorded the lowest values of friction coefficient which increased from 0.107 to 0.212 when the moisture content was increased from 11.74 to 79.43 %, but the rubber sheet recorded the highest values of friction coefficient which increased from 0.342 to 0.45 with the increase in moisture content from 11.74 to 79.43 %.

Also, for lentil seeds the stainless-steel sheet showed the lowest values of friction coefficient which increased from 0.107 to 0.183 when the moisture content increased from 12.18 to 22.33 %, But the rubber sheet was recorded the highest values of friction coefficient which increased from 0.229 to 0.328 with the increase in the moisture content 12.18 to 22.33 %.

The increase in friction coefficient with the increase in moisture content may be due to an increase in the strength of cohesion between the wet seeds and the structural surface, where the surface becomes more viscous with the increase of moisture content. This order has been reported for soybean (Wandkar, *et. al.,* 2012); faba bean seeds (Shoughy and Amer, 2006).

A simple linear regression analyses was applied to relate the change in coefficient of friction with the change in seeds moisture content for both studied crops. The obtained regression equation was in the form of:

$$C.F. = g' + h'(M.C) \quad \text{(9)}$$

Where:

C.f.: Coffecient of friction; M.C: Moisture content, % (w.b.); g′ and h′: Constances.

The regression parameters(g' and h') are tabulated for both crops as presented in table (2).

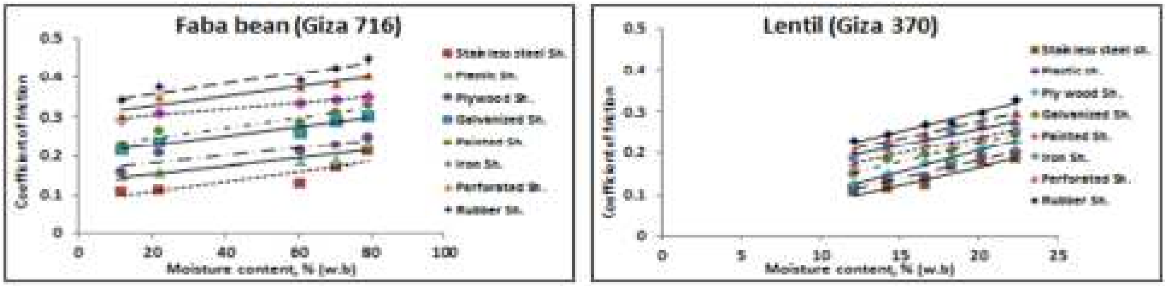

Fig. 5. Effect of moisture content on friction coefficient of faba bean and lentil seeds at different tested surfaces

Table 2. Regression parameters of equation (9) relating the change in friction coefficient to the change in seeds moisture content.

Crop	Tested surfaces	Regression parameters		
		g	h	R^2
Faba bean seeds	Rubber	0.3179	0.0264	0.9912
	Iron Sheet	0.2795	0.0152	0.9667
	Painted Sheet	0.2076	0.0249	0.9868
	Stainless steel	0.0663	0.0264	0.9023
	Galvanized Iron	0.1926	0.0228	0.987
	Ply wood sheet	0.1494	0.02	0.9145
	Plastic Sheet	0.1218	0.02	0.9215
	Perforated Sheet	0.2915	0.0239	0.9271
Lentil seeds	Rubber	0.2091	0.0185	0.9692
	Iron Sheet	0.1791	0.0163	0.9471
	Painted Sheet	0.1639	0.0156	0.9361
	Stainless steel	0.0839	0.0173	0.9345
	Galvanized Iron	0.1383	0.0182	0.9709
	Ply wood sheet	0.1088	0.0202	0.9851
	Plastic Sheet	0.0985	0.0179	0.9562
	Perforated Sheet	0.196	0.017	0.9386

C- Repose angle

As shown in fig. (6), the repose angle for studied crops increased with the increase of moisture content. For faba bean seeds, the angle of repose increased from 18.5° to 32° with the increase of seeds moisture content from 11.72 to 79.43% (w.b.). However, for lentil seeds, the angle of repose was increased from 17.1° to 20.6° when the seeds moisture content increased from 12.18 to 22.33 % (w.b.).

This finding is supported by (Shoughy and Amer, 2006) for faba bean seeds; (Wandkar, *et. al.,* 2012) for soybean. They mentioned that, as the force of solid friction increased, the angle of repose also increased. However, the increment rate is higher for the seeds having lower forces of solid friction at their interface in comparison with those having higher forces.

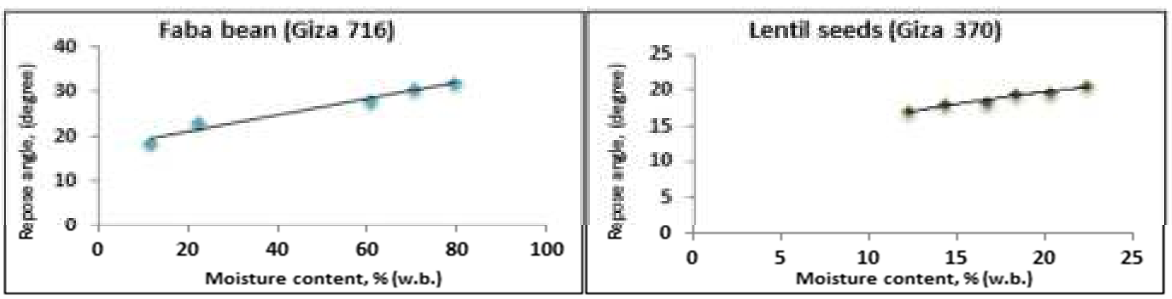

Fig. 6. Effect of moisture content on angle of repose for studied crops

The results of regression analysis illustrate the relationship between the repose angle and seeds moisture content on the form of:

$$R_a = i' + j'(Mc) \quad \text{.......... (10)}$$

Where: **R_a: angle of repose, degree; MC: seeds moisture content % (w.b.); i' and j': Constants.**

The regression parameters for the obtained regression equations were tabulated for both studied crops as presented in Table (3).

Table 3. Regression parameters of equation (10) relating the change in repose angle to the change in seeds moisture content

Crop	Moisture Content, % (w.b.)	Regression parameters		
		i'	j'	R^2
Faba bean seeds	11.72 – 79.43	17.488	0.1828	0.9707
Lentil seeds	12.18 – 22.33	7.9973	0.3014	0.9598

B- Seed Hardness

As shown in fig. (7), the hardness values of seeds for faba bean decreased from 433.87 to 14.778 N when the moisture content increased from 11.74 to 79.43 % (w.b.).

As well, for lentil seeds, the values of seeds hardness decreased from 193.32 to 79.386 N as the moisture content increased from 12.18 to 22.33 % (w.b.).

These results matching these of Khanbarad, *et. al.,* (2014) for pigeon pea grain and Alibas and Koksal, (2015) for soybean seeds reported a decrease in hardness with increasing seed moisture content.

The lower hardness at higher moisture content might have resulted from the fact that the kernel tended to be very soft in high moisture content.

A simple regression analysis was also proceeded to study the effect of moisture content on seed hardness. The relationship between them could be presented by the following equation:

$$H = k'e^{l'M.C} \quad \text{.......... (11)}$$

Where: **H: Seeds hardness, N; MC: seeds moisture content % (w.b.); k' and l': Constants.**

The regression constants (k' and l′) for the obtained regression equation are tabulated in Table (4).

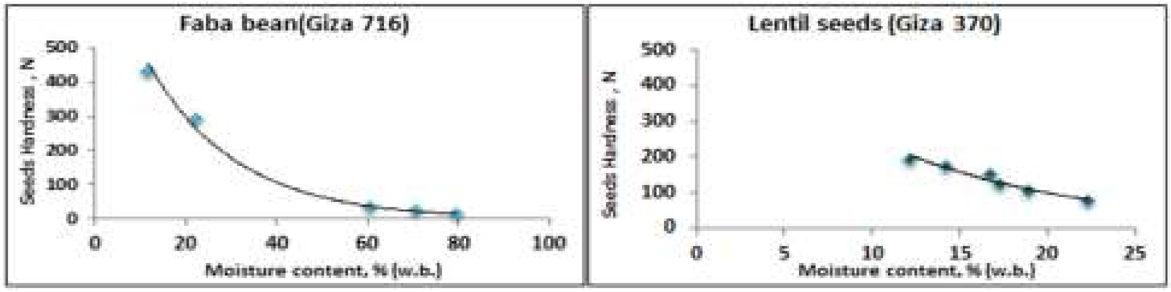

Fig. 7. Effect of moisture content on seeds hardness for the studied crops

Table 4. Regression parameters of equation (11) relating the change in hardness with the change in seeds moisture content

Crop	Moisture Content, % (w.b.)	Regression parameters		
		k'	l'	R^2
Faba bean seeds	11.72 – 79.43	830.62	- 0.051	0.9968
Lentil seeds	12.18 – 22.33	600.59	- 0.088	0.9679

D- Shear force & shear stress

For faba bean seeds, the values of shear force and shear stress on the lateral and longitudinal directions were decreased from 349.09 to 32.985 N, from 289.11 to 31.65 N, from 4.5767 to 0.2954 N/mm^2 and 2.7608 to 0.1917 N/mm^2, respectively, as the moisture content increased from 11.74 to 7943% (w.b.) as shown in fig. (8).

While, the shear force and shear stress for lentil seeds as shown in fig. (9) were decreased from 55.11 to 20.555 N and from 6.8082 N/mm^2 to 2.4195 N/mm^2 with an increase in moisture content from 12.18 to 22.33 % (W.b.).

A polynomial relationship was related the effect of moisture content on seed shear as the following equation:

$$\delta = a'' e^{b'' M.C} \qquad (12)$$

Where:

δ: Seeds shear force and stress, N.
$M.C$: Seeds moisture content % (w.b.).
a'' and b'': Constants.

The regression constants (a'' and b'') for the obtained regression equation are tabulated in Table (5).

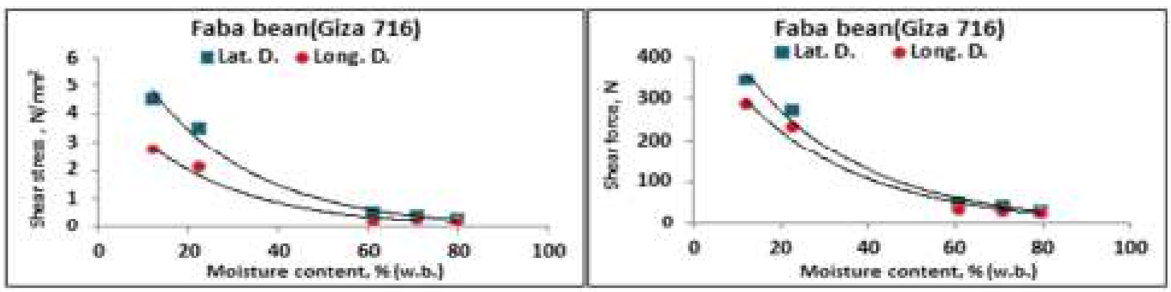

Fig. 8. Effect on moisture content on shear force & stress for faba bean seeds

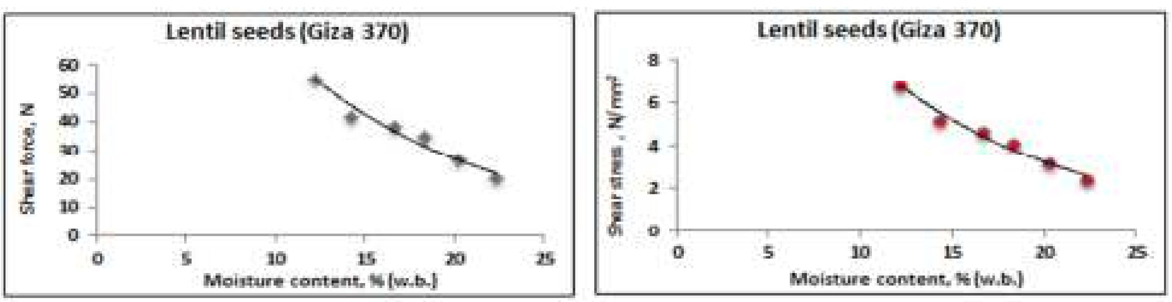

Fig. 9. Effect on moisture content on shear force & stress for lentil seeds

Table 5. Regression parameters of equation (12) relating the change in shear force & stress with the change in seeds moisture content

Crops	Parameters		Regression parameters		
			a''	b''	R^2
Faba bean seeds	Shear force	Lat. D.	561.43	- 0.037	0.9927
		Long. D.	456.7	- 0.036	0.9729
	Shear stress	Lat. D.	7.9922	- 0.042	0.9941
		Long. D.	4.6959	- 0.042	0.9561
Lentil seeds	Shear force		164.83	- 0.09	0.9619
	Shear stress		21.607	- 0.9095	0.9678

1. Aerodynamic properties

a. Terminal velocity

Fig. (10) shows the terminal velocity of the studied crops as a function of seeds moisture content. It can be seen that, terminal velocity of faba bean seeds increased from 8.874 to 10.506 m/sec with the increase in seeds moisture contents from 11.72 to 79.43 % (w.b.).

Also, for lentil seeds, as the moisture content increased from 12.18 to 22.33 % the values of terminal velocity were increased from 6.174 to 6.919 m/sec.

These results matching with those published in literatures for some seeds like Carman, (1996) for lentil seeds, Shahbazi, (2015) for mung bean seeds, Marathe, *et. al.,* (2017) for sesame seeds. The increase in terminal velocity with increasing the moisture content could be attributed to the increase in mass of the individual seed per unit frontal area affected by the air stream.

A mathematical relationship was developed to relate the change in the obtained values of terminal velocity (Vt) with seeds moisture content as shown in the following equation:

$$V_t = c'' + d''(MC) \quad (13)$$

Where: **Vt: Terminal velocity of seeds, m/sec; c″and d″: Constants.**

The regression constants (e' and f') for the obtained regression equation are tabulated in table (6).

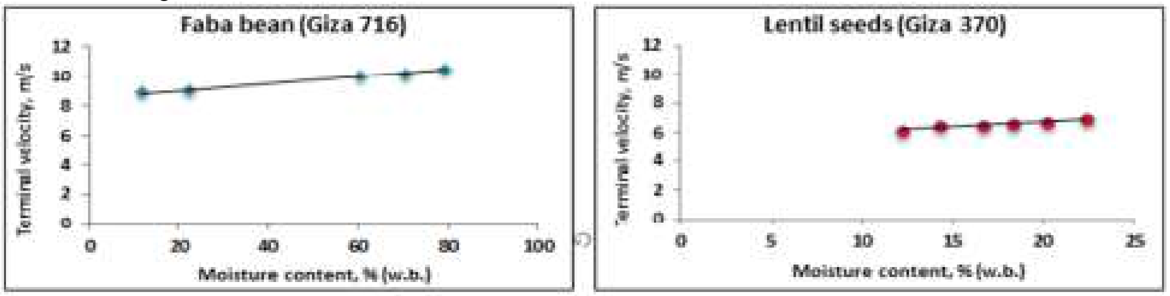

Fig. 10. Effect of moisture content on terminal velocity of studied crops

Table 6. Regression parameters of equation (13) relating the change in seeds moisture content with the seed's terminal velocity.

Crop	Moisture Content, % (w.b.)	Regression parameters		
		c″	d″	R^2
Faba bean seeds	11.72 – 79.43	8.5278	0.0241	0.9911
Lentil seeds	12.18 – 22.33	5.4161	0.0672	0.9603

b. Reynold's Number

Reynold's number was calculated as a function of the change in terminal velocity at different levels of moisture content. As shown in fig. (11), Reynold's number of faba bean and lentil seeds increased from 6074.66 to 8662.336 and from 1425.19 to 1631.83 when the moisture content increased from 11.72 to 79.43 % and from 12.18 to 22.33 %, respectively.

Similar results were also reported by Matouk, *et. al.,* (2005) for rice, corn, wheat and barley. Also, Shahbazi, (2015) for

A simple linear regression analyses was applied to relate the change in Reynold's number with the change in seeds moisture content for both studied crops. The obtained regression equation was in the form of:

$$R_{No} = i' + j'(V_t) \quad (14)$$

Where: **R_{No}: Reynold's number; e" and f": Constants.**

The regression constants (i' and j') are tabulated in table (7).

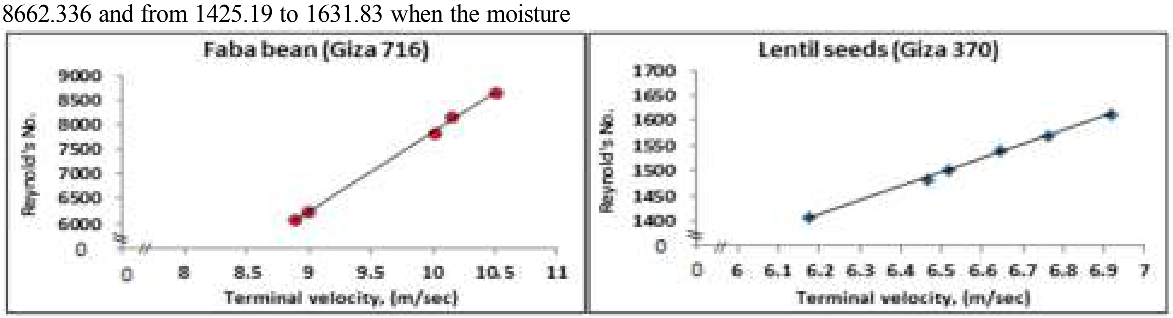

Fig. 11. Effect of terminal velocity on Reynold's No. of faba bean and lentil seeds

Table 7. Regression parameters of equation (14) relating the change in seeds terminal velocity with Renold's number.

Crop	Moisture Content, % (w.b.)	Regression parameters		
		e″	f″	R^2
Faba bean seeds	11.72 – 79.43	- 8139.1	1600.4	0.9993
Lentil seeds	12.18 – 22.33	- 306.56	277.37	0.9983

c. Drag Coefficient

As shown in fig. (12), the drag coefficient (D_r) of faba bean and lentil seeds decreased from 1.51967 to 1.30779 and from 0.87983 to 0.75153 with the increase in seeds terminal velocity from 8.874 to 10.506 and from 6.174 to 6.919 m/sec, respectively.

Similar results were also reported by several researchers for other seeds like Shahbazi, (2015) for mung bean seeds, Marathe, *et. al.,* (2017) for sesame seeds.

A simple linear regression analyses was proceeded to relate the affected of terminal velocity and drag coefficient. The acquired regression equation was in the form of:

$$D_r = g'' + h''(V_t) \quad (15)$$

Where: **D_r: Drag coefficient; g" and h": Constants.**

The regression constants (g' and h') are tabulated in table (8).

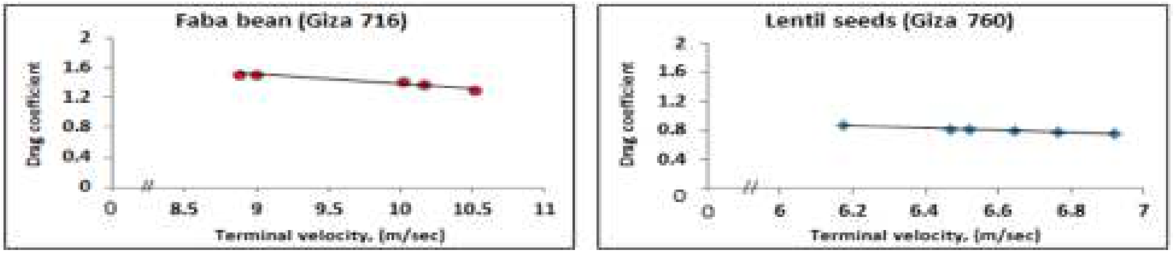

Fig. 12. Effect of terminal velocity on drag coefficient of faba bean and lentil seeds

Table 8. Regression parameters of equation (15) relating the change in the drag coefficient seeds with terminal velocity

Crop	Moisture Content, % (w.b.)	Regression parameters		
		g	h	R^2
Faba bean seeds	11.72 – 79.43	2.6002	- 0.121	0.9596
Lentil seeds	12.18 – 22.33	1.9116	- 0.1687	0.9629

CONCLUSION

1- The values of friction coefficient increased with the increase in the moisture content of the seeds. The obtained values were varied with the changing the surface of the friction and the roughness of the outer shell of seeds and its moisture content.

2- The values of the seeds repose angle increased by increasing the moisture content. The measured values of the repose angle increased from 18.5° to 32° and from 17.1° to 20.6° for faba bean and lentil seeds, respectively.

3- The values of hardness decreased with the increase of seeds moisture content. Where, the recorded values for faba bean seeds decreased from 433.87 to 14.778. While the values for lentil seeds decreased from 193.32 to 79.386 N.

4- Both shear force and shear stress decreased with the increase in the moisture content. The shear force and stress values of faba bean seeds decreased from 349.09 to 32.985 N and from 4.5767 to 0.2954 N/mm^2 at the lateral direction and decreased from 289.11 to 31.65 N and from 2.7608 to 0.1917 N/mm^2 at the longitudinal direction. Likewise, for lentil seeds, the shear force and stress values decreased from 55.11 to 20.555 N and from 6.8082 to 2.419 N/mm^2, respectively.

5- Terminal velocity increased linearly by increasing the seeds moisture content. The values of terminal velocity increased from 8.874 to 10.506 m/s and from 6.174 to 6.645 m/s for faba bean and lentil seeds, respectively.

6- Reynold's Number increased by increasing seeds moisture content. The values of Reynold's No. increased from 6074.66 to 8662.336 and from 1407.47 to 1611.54 for faba beans and lentil seeds respectively.

7- Drag coefficient decreased with increase in terminal velocity of seeds. The values decreased from 1.5197 to 1.3078 and from 0.87983 to 0.75153 for faba bean and lentil seeds, respectively.

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تقدير الخصائص الميكانيكية والإيروديناميكية لبعض المحاصيل البقولية

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تم تعيين كل من الخصائص الميكانيكية والايروديناميكية المتمثلة في معامل الاحتكاك والصلابة وقوى القص وإجهاد القص وزاوية المكوث وكذلك السرعة الحرجة ورقم رينولد ومعامل الجرف لكلاً من الفول البلدي صنف جيزة 716 والعدس صنف جيزة 370 عند مستويات مختلفة من المحتوى الرطوبي بينما تم تعيين قوى وإجهادات القص (في اتجاه المحور الطولي والمحور العرضي) لبذور الفول البلدي. ولقد أوضحت النتائج أن قيم زاوية المكوث للبذور موضع الدراسة قد زادت لكلاً من الفول البلدي والعدس من (18.5 : 32 ^{o}) و من (17.1 : 20.6 ^{o}) على الترتيب بزيادة المحتوى الرطوبي للبذور من (11.72 : 79.43 %) ومن (12.18 : 22.33 %) على أساس رطب. في حين انخفضت قيم الصلابة لكلاً من الفول البلدي والعدس من (433.87 : 14.778 نيوتن) ومن (193.32 : 79.386 نيوتن) على الترتيب وكذلك انخفضت قوى القص لكلاً من الفول البلدي على المحور العرضي والطولي والعدس من (349.09 : 32.985 نيوتن) ومن (289.11 : 31.65 نيوتن) ومن (55.11 : 20.555 نيوتن) وكذلك انخفض إجهاد القص لكلاً من الفول البلدي على المحور العرضي والطولي والعدس من (4.5767 : 0.2954 نيوتن/م^2) ومن (2.7608 : 0.1917 نيوتن/م^2) ومن (6.8082 : 2.419 نيوتن/م^2). كما أوضحت النتائج أن هناك تأثير واضح لكل من المحتوى الرطوبي للبذور ونوع سطح الاحتكاك المستخدم على قيم معامل الاحتكاك حيث زادت قيم معامل الاحتكاك خطياً مع زيادة المحتوى الرطوبي للبذور في حين كانت أقل قيم معامل الاحتكاك عند استخدام سطح الاستانل ستل لكلاً من الفول البلدي والعدس (0.107 : 0.212) ومن (0.107 : 0.183) بينما كانت أعلى قيم معامل الاحتكاك عند استخدام سطح المطاط (0.342 : 0.45) ومن (0.229 : 0.328) على الترتيب. أيضاً زادت قيم السرعة الحرجة من (8.874 : 10.506 م/ث) ومن (6.174 : 6.645 م/ث) وكذلك رقم رينولد من (6074.66 : 8662.336) ومن (1407.47 : 1611.54) لكلاً من بذور الفول البلدي والعدس على الترتيب خطياً بزيادة المحتوى الرطوبي للبذور. في حين انخفضت قيم معامل الجرف من (1.5197 : 1.3078) ومن (0.87983 : 0.75153) لكلاً من الفول البلدي والعدس على الترتيب خطياً بزيادة قيم السرعة الحرجة. تم أيضاً تطوير بعض العلاقات الرياضية والتي تصف طبيعة التغير في قيم الخصائص الميكانيكية والايروديناميكية المختلفة تبعاً للتغير في المحتوى الرطوبي للمحاصيل موضع الدراسة.