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Determination of Physical Properties of some Legume Crops

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ABSTRACT

Physical properties such as principal dimensions, surface area, projected area, volume, mass of 1000 seeds, true and bulk densities and porosity for faba bean and lentil seeds were measured and calculated at different levels of seed moisture contents. The obtained results showed that, the principal dimensions, geometric and arithmetic diameter, surface area, actual and calculated volume, sphericity, mass of 1000 seed and porosity of faba bean (pods and seeds) and lentil seeds generally increased linearly with the increasing of moisture content. For faba bean pods and seeds, shape parameters (flakiness ratio Fr and elongation ratio Er) increased with the increase of moisture content but aspect ratios R_1 (W/L), R_2 (L/T_h) and R_3 (W/T_h) of faba bean pods and seeds decreased with the increasing of moisture content. The values of projected area for faba bean and lentil seeds were also increased with the increase of moisture content. On the other hand, the results also showed that, both of bulk and true densities decreased by increasing the moisture content. Mathematical relationships were also developed relating the obtained values of all physical properties with the change in seed moisture contents.

INTRODUCTION

Legume grains are very important in the diets of human being throughout the world. They are important source of proteins, carbohydrates and minerals .They are the sources of bioactive compounds (Liny *et. al.,* 2013). On the other hand, its self-sufficiency rate reduced from 92.21% in 1997 to 26% in 2011 for faba beans and from 16.64% in 1993 to about 1.62% in 2005 for lentils. (Central Agency for Public Mobilization and Statistics, 2012)

Recently, strengthen support for takeing advantages of the modern biotechnology would be of major importance for Egypt to attain self-sufficiency of faba bean crop since it considers the first legume crop in Egypt with a cultivated area of 102 thousand hectares with an annual production of 357 thousand tones. As well, lentil (Lens culinaris Medik.) is an important traditional diet in developing countries like Egypt. Lentils are an excellent source of vitamins, energy, proteins, mineral elements, and carbohydrates, (Gharibzahedi, *et. al.,* 2014).

The knowledge of physical properties such as princibal dimensions, surface area, projected area, volume, sphericity, true and bulk densities and porosity is required for the design of equipment for handling, harvesting, processing and storing. The information related physical properties pertinent to engineers, processors, scientists of food, and else scientists who may employ these resources. (Kumar, *et. al.,* 2016)

Eissa, *et. al.,* (2010) found that, whenever seed moisture contents increased from 11.6 to 25.4% (d.b.) the average length, width and thickness for chickpea seeds increased from (7.92 to 8.14 mm), (6.10 to 6.37 mm) and (6.43 to 6.84 mm), respectively. They also stated that, the increase of moisture content at the same range increased the average surface and projected area for chickpea seeds from (46.53 to 48.93 mm^2) and from (46.53 to 48.93 mm^2), respectively.

Isik and Izli, (2016) found that, when the moisture contents of yellow lentil seeds increased from (15.6 - 22.5 % d.b) the diameter and thickness of increased from 4.29 to 4.60 mm and from1.22 to 1.42 mm, respectively with increasing the. They also found that, the porosity has a linear relationship with yellow lentil seed moisture contents. So, the results show that, the porosity increased from 37.49 to 53.18% with increasing of seeds moisture content from (15.6 - 22.5 % d.b).

Aghkhani, *et. al.,* (2012) mentioned that, when the range of moisture contents increased from (8.12 - 29.22 % d.b) the geometric and arithmetic diameter for lima bean seeds increased from 11.3 to 12.2 mm and from 13.2 to 14.2 mm, respectively.

Eze, *et. al.,* (2017) mentioned that, the increase in seeds volume may be due to the increase in size dimensions which was as a result of the displacement of more liquid. The volume of velvet bean seeds increased from 7.398 to 9.416 mm^3 when the seed moisture contents increased from (13 - 20 % w.b).

Dilmac, *et. al.,* (2016) found that, when the seed moisture contents increased from 11.4 to 25.8 % (w.b) the sphericity percentage for faba bean seeds increased from 57.32 to 57.39 %. They also found that, the true and bulk densities of faba bean seeds decreased from 1094 to 1049 kg/m^3 and from 760 to 723.9 kg/m^3, respectively as the seed moisture contents increased from (11.4 - 25.8% w.b).

Marimuthu, *et. al.,* (2013) mentioned that, the thousand grains mass increased linearly from 423 to 532 g, with increase in moisture content from 11.02± 0.05 to 24.15± 0.12 %.

The objective of this study is to select the physical properties of bean seeds and lentil seeds as well as their relationship with the moisture content of seeds. The tested properties included principal dimensions, projected area, volume, mass of 1000 seeds, true and bulk densities and porosity.

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 which were obtained from the Agricultural Research Center (ARC). While, the green beans were bought at farm land in Damietta City, Egypt. The samples were randomly chosen with cleanning them manually. The method of oven drying has used to determine sample initial moisture contents at 105^{o}C for 72h and 103^{o}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

Physical properties of faba bean and lentil seeds were measured and calculated at different levels of seeds moisture content. The measured properties included seeds principal dimensions, surface area, projected area, volume, mass of 1000 seeds, true and bulk densities and porosity.

Principal Dimensions

A digital caliper with accuracy of 0.01 mm, was used to measure the length (L), width (W) and thickness (T_h) for faba bean pods and seeds as shown in fig. (1) at different levels of seeds moisture content after selecting 100 seeds randomly for each test. As well, the diameter (2a) and thickness (2h) of lentil seeds was measured as shown in fig. (2).

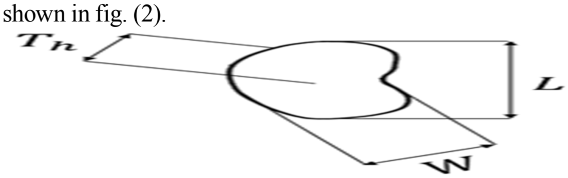

Fig. 1. Principal dimensions of faba bean seeds

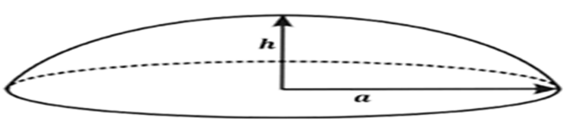

Fig. 2. Sphere segment to approximate the geometry of a half lentil seed

Geometric mean diameter (D_g)

Geometric mean diameter of faba bean pods and seeds and lentil seeds was calculated by using the following equations, respectively:

$$D_g = (LWT_h)^{1/3}, mm \quad \text{......} \quad (2)$$

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

(Sharma *et. al.,* 1985 and Mohsenin 1986)

Arithmetic mean diameter (D_a)

Arithmetic mean diameter of faba bean pods and seeds and lentil seeds was calculated by using the following equations, respectively:

$$D_a = \frac{L + W + Th}{3}, mm \quad \text{......} \quad (4)$$

$$D_a = \frac{2D + T_h}{3}, mm \quad \text{......} \quad (5)$$

(Mohsenin 1970 and Mohsenin 1986)

Surface area (A_s)

The surface area of faba bean pods and seeds and lentil seeds was measured by using the following equation, respectively:

$$A_s = \pi\, D_g^{\,2}, mm^2 \quad \text{......} \quad (6)$$

$$A_s = 2\pi\,(a^2 + h^2) \quad \text{......} \quad (7)$$

(Sacilik *et. al.,* 2003 and Tang and Sokhansanj, 1993)

Volume (V)

The actual volume of faba bean pods and seeds and lentil seeds was determined by measuring the displaced volume of toluene and using the graduated flask and pipette (100 ml capacity and 0.1 ml accuracy) fixed with a tube holder. On other hand, calculated volume of faba bean (pods and seeds) and lentil seeds was calculated by using the following equations, respectively:

$$V = \frac{\pi}{6}\, D_g^{\,3}, mm^3 \quad \text{......} \quad (8)$$

$$V = \frac{\pi\, h}{3}\,(3a^2 + h^2) \quad \text{......} \quad (9)$$

(Ozarslan, 2002 and Carman, 1996)

Sphericity (∅)

The percentage of sphericity of seeds was calculated by using the function of the three principal dimensions as shown below: (Mohsenin, 1980)

$$\emptyset = \left(\frac{D_g}{L}\right) \times 100, \% \quad \text{......} \quad (10)$$

Shape Parameters (Fr & Er)

The shape parameters (flakiness ratio Fr and elongation ratio Er) of seeds were measured by using the following equations according to (Mora and Kwan, 2000)

$$Fr = \frac{T_h}{W}, \% \quad \text{......} \quad (11)$$

$$Er = \frac{L}{W}, \% \quad \text{......} \quad (12)$$

Aspect ratios (R_1, R_2 and R_3)

The aspect ratios were determined by using the three principal dimensions according to (Mohsenin 1986)

$$R_1 = \frac{W}{L}, decimal \quad \text{......} \quad (13)$$

$$R_2 = \frac{L}{T_h}, decimal \quad \text{......} \quad (14)$$

$$R_3 = \frac{W}{T_h}, decimal \quad \text{......} \quad (15)$$

Projected area:

The projected area (A_p) of faba bean and lentil seeds at different levels of moisture content were determined by using a laptop computer (LENOVO, ideapad 110, China) equipped with Matlab 9.4 (MCR _R2018a_) software package specially, the image processing tool box as the following steps: images of seeds were scanned with a scanner for all samples (100 seeds) which distributed on the screen, the image of each sample was uploaded to the program separately then pressing the scan icon to convert image to black and white,the program deals with the white area only to calculate pixel values for its area. So, to select this white an invert icon was used. Finally, press the process icon to conduct the measurement. The number of pixels representing the area (A_p) of the faba bean and lentil seeds.

Mass of 1000 seeds

To measure the 1000 seeds mass, samples of one hundred seed were randomly selected and weighing it by a digital balance with accuracy of 0.01 gm. And so on, for 10 samples to obtain the average weight of 1000 seeds mass.

True density

The toluene liquid (C_7H_8) was used for the displacement process instead of water in order that it is absorbed by seeds to a less limit. Besides it fills even shallow dips in a seed and its dissolution is low because of lowing of surface tension. For that, the true density was calculated by using the following equation (Mohsenin, 1980)

$$\rho_t = \frac{M_s}{V_t}, kg/m^3 \quad \text{.........} \quad (16)$$

Where: ρ_t: *true density of sample*, kg/ m^3 ; M_s: *mass of simple*, *kg*; V_t: *displaced volume of toluene*, m^3

Bulk density

The bulk density was determined by filling a vessel of known mass and volume with seeds. To obtain the mass of seeds, the mass of the container was subtracted from the mass of the container. Then the bulk density was calculated by using that equation (Irtwange and Igbeka, 2002)

$$\rho_b = \frac{M_s}{V_o}, kg/m^3 \quad \text{.........} \quad (17)$$

Where: ρ_b: bulk density of sample, (kg/m^3); M_s: mass of sample, kg; V_o: volume occupied, m^3

Porosity

Porosity of faba bean and lentil seeds was determined as a percentage of volume of inters - seed space into the volume of seeds bulk using porosity measuring device as shown in fig. (3). The apparatus was designed by (Matouk *et. al.,* 2002). Seeds were filled in tank (2) before closing both of valves (2 and 3). The air was supplied to tank (1), when a suitable manometer displacement was achieved, valve (1) was closed and the steady state pressure (p_1) was recorded. After that, valve (2) was opened keeping valves (1 and 3) closed. A steady state manometer reading (p_2) was recorded. Then, the porosity of seeds was calculated as follow:

$$P = \frac{p_1 - p_2}{p_2} \quad \text{.........} \quad (18)$$

Where: P: **Porosity of seeds, % ;** p_1: **Steady state pressure inside tank (1), bar**
p_2: **Steady state pressure in both tank (1) and (2), bar**

Fig. 3. Apparatus used for measuring seeds porosity

RESULTS AND DISCUSSION

1. Principal Dimensions

The effect of seeds moisture content on seeds principal dimensions is shown in figs. (4) and (5).

For faba bean pods, variety Giza 716 the pods length increased from 119.47 to 125.33 mm, the width increased from 16.42 to 16.89 mm, while, the thickness increased from 11.46 to 12.05 mm when the moisture contents increased from 79.85 to 85.91 % (w.b).

On the other hand, the faba bean seeds, length increased from 15.76 to 18.81 mm when the seed moisture contents increased from 11.74 to 79.43% (w.b). As well, the seeds width increased from 11.48 to 12.72 mm and the seeds thickness increased from 6.64 to 8.78 mm.

Mean while, the diameter and thickness of lentil seeds variety Giza 370 were increased from 4.31 to 4.38 mm and 2.39 to 2.47 mm when the seed moisture contents increased from 12.18 to 22.33 % (w.b).

This finding is supported by other searchers like, Thonga *et. al.,* (2010); Kumar *et. al.,* (2016) and Mansouri, *et. al.,* (2017) for green bean, red lentil and melon seeds, respectively.

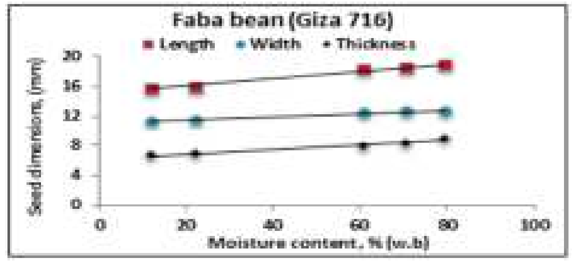

Fig. 4. Effect of moisture content on faba bean seeds length, width and thickness

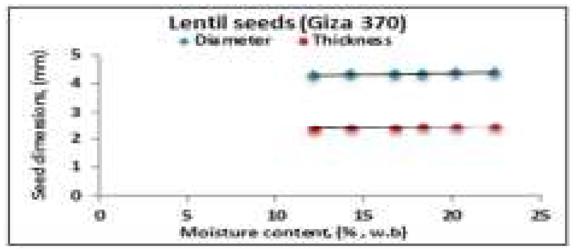

Fig. 5. Effect of moisture content on lentil seeds diameter and thickness

To relate the change in the principal dimensions with the change in seeds moisture content of faba bean and lentil seeds, a simple regression analysis was appointed. The nature of dependence could be described by the following empirical relationship:

$$L.W.Th.D = a + b\,(M.C.) \quad \text{.........} \quad (19)$$

Where:

L, W, Th and D: length, width, thickness and diameter, (mm).
M.C.: Moisture content, % (w.b)
a and b: Constant

The values of the constants a and b are shown in table (1).

Table 1.Values of constants (a and b) of eq. (19)

Crop	Dimension	a	b	R^2
Faba bean seeds	Length, L, (mm)	15.077	0.0487	0.988
	Width, W, (mm)	11.187	0.0204	0.981
	Thickness,Th,(mm)	6.1873	0.0305	0.982
Lentil seeds	Diameter, D, (mm)	4.2337	0.0066	0.9704
	Thickness,Th,(mm)	2.895	0.0084	0.9433

2. Geometric mean diameter (D_g) and Arithmetic mean diameter (D_a)

For faba bean pods, variety Giza 716 the geometric and arithmetic mean diameter increased from 28.194 to 29.350 mm and 49.118 to 51.424 mm, respectively when the moisture contents increased from 79.85 to 85.91 % (w.b).

As well, the geometric and arithmetic mean diameter for faba bean seeds, increased from 10.621 to

12.797 mm and11.295 to 13.438, respectively when the seed moisture contents increased from 11.74 to 79.43% (w.b) as shown in fig. (6).

Also, as shown in fig. (7) both geometric and arithmetic mean diameter of lentil seeds were increased from 3.538 to 3.616 mm and from 3.669 to 3.742 mm, respectively with an increase in moisture contents from 12.18 to 22.33 % (w.b). Eze, *et. al.,* (2017) and Amin, *et. al.,* (2004) reashed to same results for velvet bean and lentil seeds.

For describing the nature of the relationship between the geometric and arithmetic mean diameter and the moisture content of faba bean and lentil seeds, a regression analysis was performed. So the relationship could be expressed as follows:

$$D_g . D_a = c + d\,(M.C.) \quad \text{......................} \quad (20)$$

Where:

D_g: The geometric mean diameter ; D_a: The arithmetic mean diameter

M.C.: Moisture content, % (w.b) ; C and d: constants

The values of the constants c and d are presented in table (2).

Table 2. Values of constants (c and d) of eq. (20):

Crop	Mean diameter, mm	c	d	R^2
Faba bean	D_g	10.142	0.0331	0.9949
Seeds	D_a	10.817	0.0332	0.9939
Lentil	D_g	3.4472	0.0078	0.9696
seeds	D_a	3.5858	0.0072	0.9753

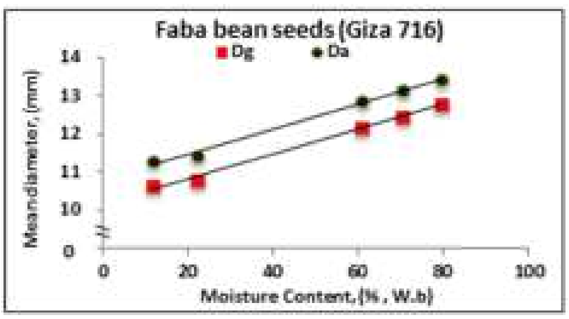

Fig. 6. Effect of moisture content on geometric and arithmetic mean diameters of faba bean seeds

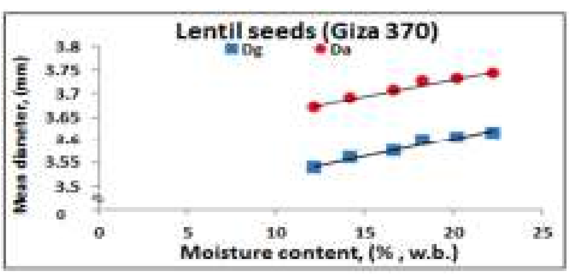

Fig. 7. Effect of moisture content on geometric and arithmetic mean diameters of lentil seeds

3. Surface area (A_s)

The surface area for faba bean pods increased from 2504.05 to 2719.76 mm^2 with an increase in moisture contents from 79.85 to 85.91 % (w.b) followed by faba bean seeds which increased from 354.82 to 516.77 mm^2 when the seed moisture contents increased from 11.74 to 79.43 % (w.b) as shown in fig. (8).

Meanwhile, fig. (9) shows that, the surface area of lentil seeds increased from 38.2584 to 39.781 mm^2 with increasing of the seed moisture contents from 12.18 to 22.33 % (w.b).

This result indicates that the increase in the surface area values may be depend on the size dimensions of the seeds which are similar to those report by Ghamari *et. al.,* (2014); Alibas and Koksal, (2015); (Eze, *et. al.,* 2017) for chickpea Seeds, soybean seeds and velvet bean, respectively.

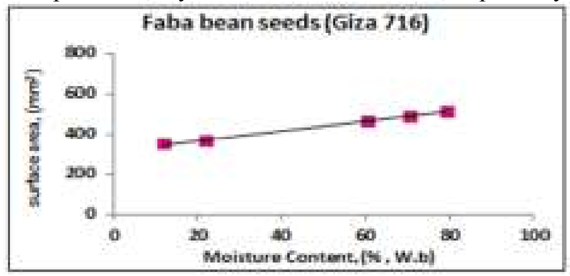

Fig. 8. Effect of moisture content on surface area of faba bean seeds

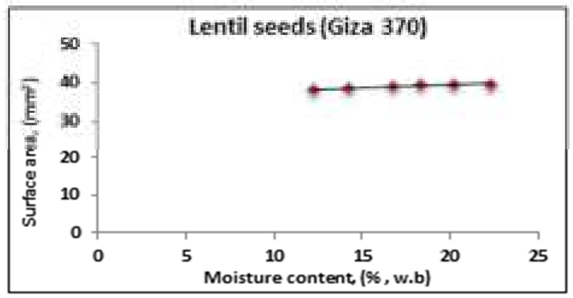

Fig. 9. Effect of moisture content on surface area of lentil seeds

4. Volume (V)

For faba bean pods, the actual volume (V_a), the geometric volume (V_{Dg}) and the arithmetic volume (V_{Da}) increased from 18800 to 21100 mm^3, 11830 to 13439.9 mm^3 and 62813.7 to 72672.2 mm^3, respectively with the increase of moisture content from 79.85 to 85.91 % (w.b).

In the same vein, fig. (10) shows that, the actual (V_a), the geometric (V_{Dg}) and the arithmetic volume (V_{Da}) increased from 910 to 1730 mm^3, from 629.632 to 1112.2 mm^3 and from 757.563 to 1288.3 mm^3, respectively when the moisture content increased from 11.74 to 79.43 % (w.b).

Also, the actual volume (V_a) and calculated volume (V_c) for lentil seeds increased from 22.773 to 30 mm^3 and from 23.027 to 24.624 mm^3, respectively with the increase of moisture content from 12.18 to 22.33 % (w.b) as shown in fig. (11).

These results are also in line with those of (Shoughy and Amer, 2006) for faba bean seeds; Alibas and Koksal, (2015) for soybean seeds.

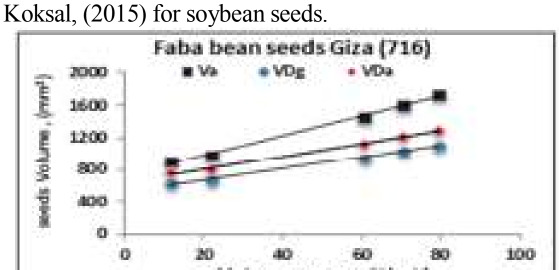

Fig. 10. The change in both actual and calculated volumes with moisture content for faba bean seeds

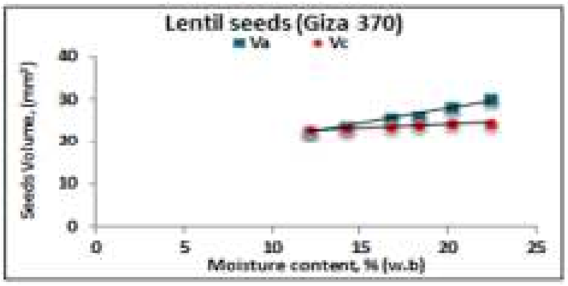

Fig. 11. The change in both actual and calculated volumes with moisture content for lentil seeds

A simple regression analysis was examined for describing the relationship between the actual and the calculated volume and moisture content for the studied crops. The relationship was found to be as the following equation:

$$V = g + h\,(M.C) \quad \text{.......................} \quad (21)$$

Where:

V: Volume of seeds, mm^3. ;M.C: Moisture content, % (wb); g and h: Constants.

The values of constants g and h are shown in table (3).

Table 3. Values of constants (g and h) of eq. (21)

Crop	Seeds volume, mm^3	g	h	R^2
Faba bean Seeds	V_a	736.69	12.262	0.9956
	V_{Dg}	520.75	7.2689	0.9924
	V_{Da}	636.72	8.1632	0.9938
Lentil seeds	V_a	13.907	0.7043	0.9748
	V_c	20.976	0.1672	0.9676

5. Sphericity (∅)

Sphericity for faba bean seeds, was increased from 66.3573 to 68.7 % with the increase of moisture content from 11.74 to 79.43 % (w.b) as shown in the fig. (12). Also, the sphericity of lentil seeds increased from 82.15 to 82.67 % with the increasing of moisture content from 12.18 to 22.33 % (w.b) as shown in fig. (13).

These results are also in line with those of Gursoy and Guzel, (2010); Tarighi, *et. al.,* (2011); Isik and Izil, 2016) for (wheat, barley, lentil and chickpea), corn seeds, and yellow lentil seeds, respectively who found that the sphericity of seeds linearly increased when the moisture content was increased.

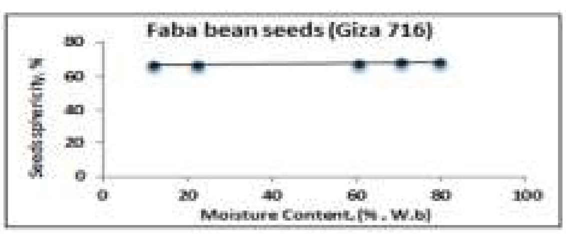

Fig. 12. Effect of moisture content on Sphericity of faba bean seeds

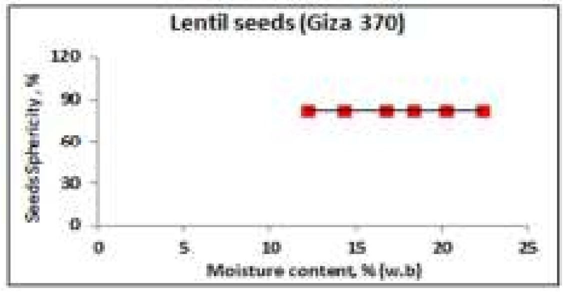

Fig. 13. Effect of moisture content on Sphericity of lentil seeds

A simple regression analysis was also proceeded for describing the relationship between the sphericity and moisture content of seeds. The relationship was found to be as the following equation:

$$\emptyset = i + j\,(M.C) \quad \text{.......................} \quad (22)$$

Where:

∅: Sphericity of seeds, %. ; M.C: Moisture content, % (w.b); i and j: Constants.

The values of constants i and j are shown in table (4).

Table 4. Values of constants (i and j) of eq. (22)

Crop	MoistureContent % (w.b.)	i	j	R^2
Faba bean seeds	11.72 – 79.43	65.887	0.0348	0.9953
Lentil seeds	12.18 – 22.33	81.423	0.0559	0.9587

6. Shape Parameters (Fr & Er)

Table (5) shows that, the values of flakiness ratio Fr and elongation ratio Er for faba bean pods were increased from 0.6995 to 0.7163 and from 7.298 to 7.477as the moisture content increased from 79.85 to 85.91 % (w.b), respectively.

As well, the the values of flakiness ratio Fr and elongation ratio Er for faba bean seeds was increased from 0.5803 to 0.691 and 1.376 to 1.481 with the increase of moisture content from % (w.b) , respectively.

7. Aspect ratios (R_1, R_2 and R_3)

Table (5) also shows that, the values of all ratios R_1, R_2 and R_3 for faba bean pods were decreased from 0.138 to 0.1357, from 10.569 to 10.462 and from 1.436 to 1.4099, respectively as the moisture content increased from 79.85 to 85.91 % (w.b).

Also, the results stated that, for faba bean seeds as the moisture content increased from 11.74 to 79.43 % (w.b) the aspect ratios R_1, R_2 and R_3 decreased from 0.7305 to 0.6781, from 2.3831 to 2.2267 and from 1.7350 to 1.4541, respectively.

These results are like to those reported by (Eze, *et. al.,* 2017) for velvet bean; Alibas and Koksal, (2015) for soybean seeds.

Table 5. Values of flakiness ratio Fr, elongation ratio Er and ratios R_1, R_2 and R_3

Crop		M.C., % (w.b.)	Fr T_h/W	Er L/W	R_1 W/L	R_2 L/T_h	R_3 W/T_h
Faba bean	Pods	79.85	0.6995	7.2984	0.138	10.569	1.436
		85.91	0.7163	7.47659	0.1357	10.462	1.4099
	Seeds	11.74	0.5803	1.376	0.7305	2.3831	1.7350
		22.13	0.5902	1.384	0.7257	2.3547	1.7039
		60.6	0.6348	1.45908	0.6878	2.311	1.5866
		70.48	0.6553	1.46575	0.6858	2.2501	1.5388
		79.43	0.691	1.481	0.6781	2.2267	1.4541

8- Projected area:

The projected area of seeds which obtained by using Matlab software generally increased with the increasing of moisture content.

For faba bean seeds, fig. (14) show that, the seeds projected area increased from 161.6521 to 238.0033 mm^2, respectively with the increasing of seeds moisture content from 11.74 to 79.43% (w.b).

Meanwhile, the lentil seeds projected area were increased from 22.59 to 24.002 mm^2, respectively with the increasing of seeds moisture content from 12.18 to 22.33 % (w.b) as shown fig. (15).

Similar trends have also been reported by Aghkhani, *et. al.,* (2012) for lima bean seeds, by Isik and Izil, (2016) for yellow lentil seed, by Dilmac, *et. al.,* (2016) for faba bean seeds. This may be due to the extension in principal dimensions with increasing in moisture content.

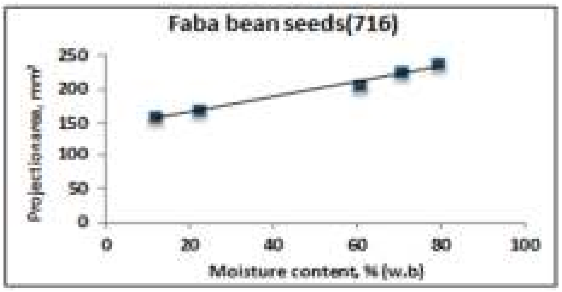

Fig. 14. Effect of moisture content on projection area of faba bean seeds

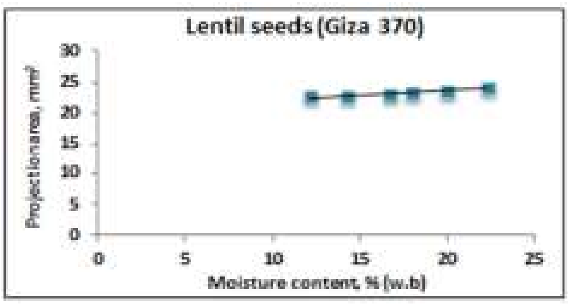

Fig. 15. Effect of moisture content on projection area of lentil seeds

A simple regression analysis was also achieved to relate the change in the projected area with the change in moisture content of seeds. The nature of dependence could be explicated by the following equation:

$$A_p = k + l\,(Mc) \quad \text{.......................................} \quad (23)$$

Where:

A_p: projection area, mm3.
MC: seeds moisture content, % (w.b).
***k and l*: Constants.**

The regression parameters for the obtained regression equation were tabulated for both studied crops in table (6).

Table 6. Values of constants (k and l) of Eq. (23)

Projection area, mm^2		Regression parameters		
		k	l	R^2
Crop	Faba bean seeds	145.85	1.1205	0.9864
	Lentil seeds	20.786	0.1413	0.9782

9- Mass of 1000 seeds

As for the faba beans pods varity Giza 716, the mass of 1000 pods increased from 14575.6 to 15683.8 g with an increase in moisture content from 79.85 to 85.91 % (w.b).

Mean while, for faba bean seeds, varity Giza 716 fig. (16) shows that, the mass of 1000 seeds increased from 1033.9 to 1736.4 g when the moisture content increased from 11.74 to 79.43 % (w.b).

Also, the mass of 1000 seeds for lentil seeds increased from 29.7 to 32.9 g when the moisture content increased from 12.18 to 22.33 % (w.b) for the varity Giza 370 as shown in fig. (17).

Such linear relationship between M1000 and moisture content has been reported for cowpea seeds (Aderinlewo, *et. al.,* 2011); soybean (Wandkar, *et. al.,* 2012) and cucumber seeds and kernels (Mirzabe, *et. al.,* 2017).

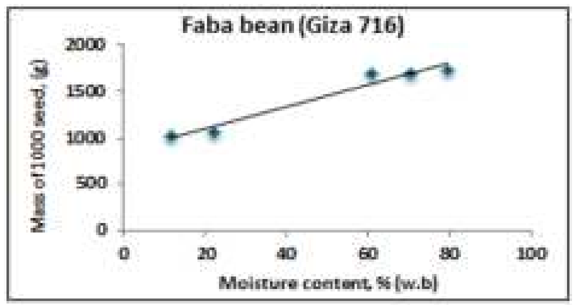

Fig. 16. Effect of moisture content on mass of 1000 seeds for faba bean

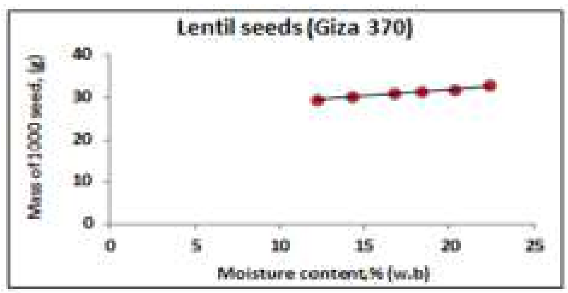

Fig. 17. Effect of moisture content on mass of 1000 seeds for lentil

10- Bulk density

The effect of moisture content on bulk density indicated that, the values of bulk density decreased with increasing of moisture content. For faba bean pods when the moisture content increased from 79.85 to 85.91 % (w.b), the bulk density decreased from 283.061 to 281.909 kg/m^3.

As well, the values of bulk density for faba bean seeds varity Giza 716 decreased from 742.880 to 571.384 kg/m^3 with an increase in moisture content from11.74 to 79.43 % (w.b) as shown in fig. (18).

Meanwhile, for lentil seeds, varity Giza 370 fig. (19) shows that, the bulk density decreased from 828.244 to 784.880 kg/m^3 as the moisture content increased from 12.18 to 22.33% (w.b) because of the increasing in volume of seeds.

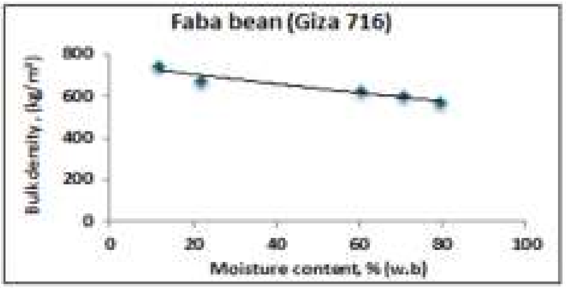

Fig. 18. Effect of moisture content on seeds bulk density of faba bean

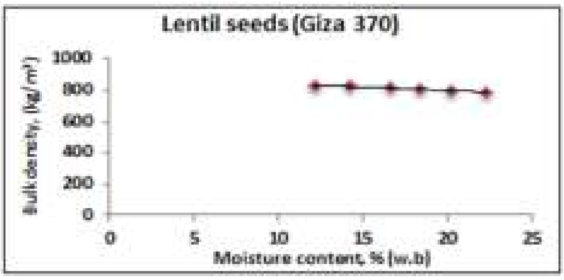

Fig. 19. Effect of moisture content on seeds bulk density of lentil

The bulk density (Bd) of seeds was found to bear the following relationship with moisture content (M.C.):

$$B_d = a' e^{b' \cdot M.C} \quad \text{......} (24)$$

Where: **Bd: Bulk density, kg/m^3; M.C: Seeds moisture content, % (w.b); a' and b': Constants.**

The regression parameters for the obtained regression equations were tabulated for both studied crops as presented in Table (7).

Table 7. Values of constants (a' and b') of eq. (24)

Crop	Moisture Content % (w.b.)	Regression parameters		
		a'	b'	R^2
Faba bean seeds	11.72 – 79.43	753.33	- 0.003	0.9471
Lentil seeds	12.18 – 22.33	884.85	- 0.005	0.9808

11- True density

The results show that, the true density for faba bean pods decreased from 845.949 to 813.425 kg/m^3 as the moisture content increased from 79.85 to 85.91 % (w.b).

Also, the values of the true density for faba bean seeds varity Giza 716 decreased from 1128.77 to 931.78 kg/m^3 with the increase of moisture content from 11.74 to 79.43 % (w.b) as shown in fig. (20).

On the same time, fig. (21) shows that, the bulk density for lentil seeds, varity Giza 370 decreased from 1272.75 to 1009.5 kg/m^3 as the moisture content increased from 12.18 to 22.33%.

The relationship between true density and moisture content may be expressed as the following regression equation:

$$T_d = c' + d'(M.c) \quad \text{......} (25)$$

Where: **T_d: true density, kg/m^3; M.C: seeds moisture content, % (w.b); c' and d': constants.**

The regression parameters for the obtained regression equations were tabulated for both studied crops as presented in Table (8).

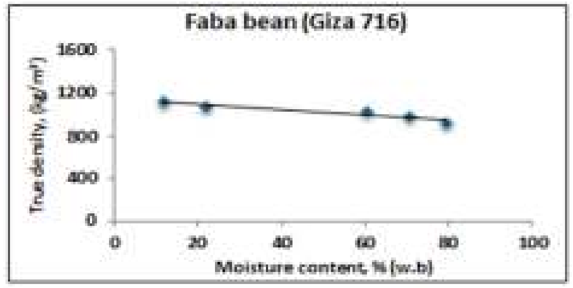

Fig. 20. Effect of moisture content on seeds true density of faba bean

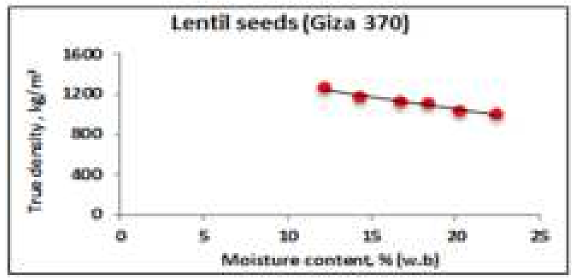

Fig. 21. Effect of moisture content on seeds true density for lentil

Table 8. Regression parameters of eq. (25) relating the change in seeds moisture contents with the true density

Crop	Moisture Content, % (w.b.)	Regression parameters		
		c'	d'	R^2
Faba bean seeds	11.72 – 79.43	1146.8	- 2.411	0.9205
Lentil seeds	12.18 – 22.33	1558	- 25.01	0.966

The negative linear relationship for both bulk and true density was also observed by other investigators like Irvine, *et. al.,* (1991) for flaxseed, lentils, and faba beans; Amin, *et. al.,* (2004) for lentil seeds; Wandkar, *et. al.,* (2012) for soybean; Ghamari, *et. al.,* (2014) for Chickpea and Eze, *et. al.,* (2017) for velvet bean.

12- Porosity

As shown in fig. (22), faba bean seeds porosity increased from 36.172 to 41.308 % with an increase in seed moisture contents from 11.74 to 79.43 % (w.b).

As well, fig. (23) points that, the seeds porosity of lentil was increased from 33.597 to 35.044 % as the seed moisture contents increased from 12.18 to 22.33 % (w.b), respectively.

This finding is supported from other investigators who have also similar observations for different seeds like Aderinlewo, *et. al.,* (2011) for cowpea seeds; Wandkar, *et. al.,* (2012) for soybean; Thong, *et. al.,* (2010) for green bean and Mirzabe, *et. al.,* (2018) for cucumber seeds and kernels.

A similar linear regression analyses was assigned to express the change in porosity of seeds at different levels of moisture content. The relation was expressed by the following equation:

$$Po = e' + f'(M.C) \quad \text{......} (26)$$

Where: **Po: Seeds porosity, %; $M.C$: Moisture content, % (w.b); e' and f': Constances.**

The regression parameters(e' and f') for the obtained regression quations were tabulated for both studied crops as presented in Table (9).

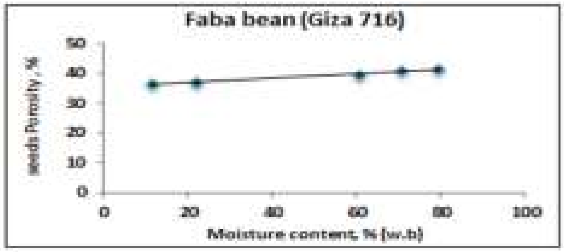

Fig. 22. Effect of moisture content on seeds porosity of faba bean

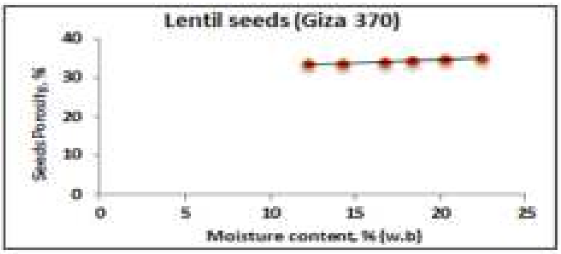

Fig. 23. Effect of moisture content on seeds porosity of for lentil

Table 9. Regression parameters of eq. (26) relating the change in seeds moisture contents with the seeds porosity:

Crop	Moisture Content, % (w.b.)	Regression parameters		
		e	f	R^2
Faba bean seeds	11.72 – 79.43	35.313	0.0739	0.9912
Lentil seeds	12.18 – 22.33	31.769	0.1423	0.9461

CONCLUSION

1- The principal dimensions of faba bean pods, seeds including length, width and thickness and lentil seeds including diameter and thickness were increased with the increase of moisture content.
2- The geometric and arithmetic mean diameter of faba bean pods, seeds and lentil seeds were increased with an increase in moisture content.
3- The surface area of faba bean pods, seeds and lentil seeds were increased with the increase in moisture content.
4- The actual and calculated volume of faba bean pods, seeds and lentil seeds were increased with the increase of moisture content.
5- Sphericity of faba bean and lentil seeds increased with the increase of moisture content.
6- Shape parameters (flakiness ratio Fr and elongation ratio Er) of faba bean pods and seeds increased but aspect ratios (R_1 R_2 and R_3) decreased with the increase of moisture content.
7- By using the image processing tools (Matlab software), the values of projected area for faba bean and lentil seeds increased with the increase of moisture content.
8- Mass of 1000 seed and seeds porosity increased linearly by increasing the moisture content. While, both of bulk and true densities decreased by increasing the moisture content.

REFERENCES

Aderinlewo, A. A.; A. O. Raji and T. M. A. Olayanju, (2011). "Effect of moisture content on some physical properties of cowpea (Vigna unguiculata)". J. Nat. Sci. Engr. Tech. 10(2): 133-145.

Aghkhani, M. H.; S. H. M. Ashtiani; J. B. Motie, and M. H. Abbaspour-Fard, (2012). "Physical properties of Christmas Lima bean at different moisture content". Int. Agrophys., 26, 341-346.

Alibas, I. and N. Koksal, (2015). "The effect of moisture content on physical, mechanical and rheological properties of soybean (Glycine max cv. ATAEM-II) seed". Legume Research Volume 38 (3): 324 - 333 (available on line at http :// www .arccjournals.com/www. legumeresearch.in

Amin, M. N.; M. A. Hossain and K. C. Roy, (2004). "Effects of moisture content on some physical properties of lentil seeds". Journal of Food Engineering, 65: 83-87. Http: // www .elsevier. com/ locate/jfoodeng.

ASAE (1993). ASAE-S3252.2 Des 92- Moisture measurement-unground seed and seeds. In ASAE Standards 1993, 449. St. Joseph, M.I. ASAE.

ASAE (2000C). ANSI/ASAE EP433. Loads exerted by freeflowing grain on bins. St. Joseph, Mic.: ASAE.

Carman, K. (1996). "Some physical properties of lentil seeds". Journal of Agricultural Engineering Research, 63, 87-92.

Central Agency for Public Mobilization and Statistics, 2012.

Dilmac, M.; S. Tarhan and H. Polatic, (2016). "Aerodynamic properties of Faba bean (Vicia faba L.) Seeds". Agricultural research communication centre, Legume Research, 39 (3): 379-384

Eissa, A. H. A.; M. A. Mohamed; H. Moustafa and A. R. O. Alghannam, (2010). "Moisture dependent physical and mechanical properties of chickpea seeds". Int J Agric & Biol Eng, 3(4): 80—93.

Eze, P. C.; C. N. Eze and R. S. Agu, (2017). "Determination of Physicomechanical Properties of Velvet bean (Mucuna Pruriens) From South Eastern Nigeria". Nigerian Journal of Technology (NIJOTECH) Vol. 36, No. 2, pp. 628 – 635.

Ghamari, S., K. Mohammadi, A. Khanahmadzadeh and H. Goli, (2014). "Evaluation the Some Physical Properties of Chickpea Seeds in Kurdistan Region of Iran". International Journal of Agriculture and Forestry 4(3A): 4-7

Gharibzahedi, S. M. T.; Z., Emam-Djomeh; S. H. Razavi and S. M., Jafari, (2014). Mechanical behavior of lentil seeds in relation to their physicochemical and microstructural characteristics. International Journal of Food Properties 17(3): 545-558.

Gursoy, S. and E. Guzel, (2010). "Determination of Physical Properties of Some Agricultural Grains". Res. J. Appl. Sci. Eng. Technol., 2(5): 492-498.

Irtwange, S. V., and J. C. Igbeka, (2002). "Some physical properties of two African yam beans (Sphenostylisis stenocappa): accession and their interrelations with moisture content". Applied Engineering in Agriculture, 18(5): 567-576. ISBN 978-0-521-64853-0

Irvine, D. A.; D. S. Jayas, N. D. G. White and M.G. Brixton, (1991). "Physical properties of flaxseed, lentils, and fababeans". Canadian Agricultural Engineering, 34, (1):75-81.

Izik, E. and N. Izil, (2016). "Effects of moisture content on some physical properties of the yellow lentil". J. of Agricultural sciences. Vol. (22): 307-316.

Kumar, M. M.; K. Prasad; T. S. Chandra and S. Debnath, (2016). "Evaluation of physical properties and hydration kinetics of red lentil (Lens culinaris) at different processed levels and soaking temperatures". Journal of the Saudi Society of Agricultural Sciences, http: // dx. doi.org/ 10.1016/ j.jssas. 2016.07.004.

Liny, P., S. K. Manish, and M. Shashikala, (2013). " Geometric and Gravimetric Characteristics of black gram". International Journal of Development Research Vol. 3, Issue, 9, pp.013 – 016.

Mansouri A.; A. H. Mirzabe and A. Raufi, (2017). "Physical properties and mathematical modeling of melon (Cucumis melo L.) seeds and kernels". Journal of the Saudi Society of Agricultural Sciences (16), 218–226.

Marimuthu, M., M. Venkatesh, and M. Poongodi, (2013) "Effect of the moisture content on some physical, Mechanical properties of Lima bean (Phaseolus Lunatus), an underutilized common food legum". Innovare Journal of Agricultural Sciences, Vol 1, Issue 2, 2013, 8-16.

Matouk, A. M.; S. M. Radwan.; A. S. Hamam.; G. H. El sayed.; M. M. El- Kholy. and T. R. Owies, (2002). "Study of physical properties and characteristics of some agricultural crops for development and designing harvesting and handling equipment and systems". Ministry of Higher Education and Scientific Research - Academy of Scientific Research and Technology. Agric. Engng. Dept. Fac. of Agric. Mansoura Univ.

Mirzabe, A. H.; M. B. kakolaki; B. Abouali and R. sadin, (2017). "Evaluation of some engineering properties of cucumber (Cucumis sativus L.) seeds and kernels based on image processing. Information processing in agriculture 4:300–315.

Mohsenin, N. N. (1986). "Physical properties of plant and animal material". Revised edition. Gordon and Breach series science publishers. New York ISBN 0677213700.

Mohsenin, N . N ., (1980) . " Physical Properties of Plant and Animal Materials ". Second ed . Gordon and Breach Science Publishers , New York , USA.

Mohsenin, N. N., (1970). "Physical Properties of Plant and Animal Materials". Gordon and Breach Science Publishers, NewYork,USA.

Mora, C. F.; and A. K. H. Kwan, (2000). "Sphericity, shape factor, and convexity measurement of coarse aggregate for concrete using digital image processing". Cement and Concrete Research 30:351–358.

Ozarslan C., (2002). "Physical properties of cotton seed". Biosystems Eng., 83, (2): 169-174.

Sacilik, K.; R. Ozturk and R. Keskin, (2003). "Some physical properties of hemp grain. Biosyst". Eng. 86 (2), 213–215.

Sharma S. K.; R. K. Dubey and C. K. Teckchandani, (1985). "Engineering properties of black gram, soybean and green gram". Proc. Indian Soc. Agric. Eng. 3, (12): 181-185.

Shoughy, M. I and M. I. Amer, (2006). "Physical and mechanical properties of faba bean seeds". Misr J. Ag. Eng. 23(2): 434 – 447.

Tang, J. and S. Sokhansanj, (1993). "Geometric changes in lentil seeds caused by drying". J. agric. Engng Res. 56, 313-326.

Tarighi, J.; A. Mahmoudi and N. Alavi, (2011). "Some mechanical and physical properties of corn seed (Var. DCC 370)". African Journal of Agricultural Research Vol. 6 (16), pp. 3691-3699.

Thonga, P. T.; N. K. D. Hongb, and S. Surbkar, (2010). "Physical properties of green bean (Vigna radiata L.)". Proceedings of the 5th International Conference on Innovations in Food and Bioprocess Technology7-9.

Wandkar, S. V.; P. D. Ukey and D. A. Pawar, (2012). "Determination of physical properties of soybean at different moisture levels". Agric Eng Int: CIGR Journal, 14 (2): 138 - 142.

تقدير الخصائص الطبيعية لبعض المحاصيل البقولية

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تم إجراء هذا البحث فى معمل هندسة تصنيع وتداول المنتجات الزراعية بقسم الهندسة الزراعية والعينات المستخدمة تم الحصول عليها من قسم المحاصيل البقولية بمركز البحوث الزراعية بالقاهرة بهدف دراسة التغير فى الخواص الطبيعية لبعض المحاصيل البقولية واعداد قاعدة بيانات لها وشملت تلك الخصائص: الأبعاد ,الأقطار , مساحة السطح, مساحة الاسقاط الضوئي, الحجم, الكروية, معاملات الشكل, نسب الأبعاد Aspect ratio, كتلة الـ 1000 حبة, الكثافة الظاهرية,الكثافة الحقيقية والمسامية وذلك لصنف جيزة 716 من قرون الفول البلدي و بذور الفول البلدى و صنف جيزة 370 من العدس عند مستويات مختلفة من المحتويات الرطوبية. ولقد أوضحت النتائج المتحصل عليها: زيادة الأبعاد الرئيسية لكل من الفول البلدي والعدس حيث زاد كل من الطول والعرض والسمك لقرون وبذور الفول البلدي وكانت على الترتيب بالنسبة للقرون (119.74 : 125.33 مم و 16.42 : 16.89 مم و 11.46 : 12.05 مم) وذلك عند زيادة المحتوى الرطوبي من 79.85 : 85.91 % (على أساس رطب) أما بالنسبة للبذور (15.76 : 18.81 مم و 11.48 : 12.72 مم و 6.64 : 8.78 مم) وذلك عند زيادة المحتوى الرطوبي من 11.74 : 79.43 % (على أساس رطب) كما زاد القطر والسمك أيضاً لبذور العدس وكانت على الترتيب (4.31 : 4.38 مم و 2.39 : 2.47 مم) وذلك عند زيادة المحتوى الرطوبي من 12.18 : 22.33 % (على أساس رطب). كما زادت قيم كلاً من القطر الهندسي والحسابي لقرون وبذور الفول البلدي وبذور العدس بزيادة المحتوى الرطوبي وكانت على الترتيب (28.194 : 29.350 مم و 49.118 : 51.424 مم) لقرون الفول البلدي (10.621 : 12.797 مم و 11.295 : 13.438 مم) لبذور الفول البلدي (3.538 : 3.616 مم و 3.669 : 3.742 مم) لبذور العدس . كما زادت مساحة السطح لقرون وبذور الفول البلدي وبذور العدس بزيادة المحتوى الرطوبي وكانت على الترتيب (2504.05 : 2719.76 مم^{2}) ومن (354.82 : 516.77 مم^{2}) ومن (38.2584 : 39.781 مم^{2}). كما زادت مساحة الاسقاط الضوئي لكل من بذور الفول البلدي والعدس وكانت على الترتيب (161.6521 : 238.0033 مم^{2}) و (22.59 : 24.002 مم^{2}). وكذلك زاد الحجم الفعلي (V_a) لقرون وبذور الفول البلدي وبذور العدس من (18800 : 21100 مم^{3}) ومن (910 : 1730 مم^{3}) ومن (22.773 : 30 مم^{3}) وذلك بزيادة المحتوى الرطوبي كما زاد الحجم الهندسي (V_{Dg}) لقرون وبذور الفول البلدي من (11830 : 13439.9 مم^{3}) ومن (629.632 : 1112.2 مم^{3}) وأيضاً زاد الحجم الحسابي (V_{Da}) لقرون وبذور الفول البلدي من (62813.7 : 72672.2 مم^{3}) ومن (757.563 : 1288.3 مم^{3}) كما زاد الحجم الحسابي (V_c) لبذور العدس من (23.027 : 24.624 مم^{3}). كما زادت نسبة الكروية لكلاً من بذور الفول البلدي والعدس وكانت على الترتيب من (66.36 : 68.7 %) ومن (82.15 : 82.67 %). كما زادت معاملات الشكل Fr و Er لكلاً من قرون وبذور الفول البلدي وكانت (0.6995 : 0.7163 و 7.298 : 7.477) للقرون أما البذور كانت (0.5803 : 0.691 و 1.376 : 1.481). في حين قلت نسب الأبعاد Aspect ratio (R_1, R_2 and R_3) لكلاً من قرون وبذور الفول البلدي وكانت (0.138 : 0.1357 و 10.569 : 10.462 و 1.436 : 1.4099) للقرون أما البذور كانت (0.7305 : 0.6781 و 2.3831 : 2.2267 و 1.7350 : 1.4541). كما قلت الكثافة الظاهرية لكلاً من قرون وبذور الفول البلدي وبذور العدس وكانت على الترتيب (283.061 : 281.909 كجم/م^{3}) و (742.880 : 571.384 كجم/م^{3}) و (828.244 : 784.880 كجم/م^{3}). كذلك قلت الكثافة الحقيقية لكلاً من قرون وبذور الفول البلدي وبذور العدس وكانت على الترتيب (845.949 : 813.425 كجم/م^{3}) و (1128.77 : 931.78 كجم/م^{3}) و (1272.75 : 1009.5 كجم/م^{3}). بينما زادت كتلة الألف قرن للفول من (14575.6 : 15683.8 جرام) كما زادت كتلة الألف حبة لبذور الفول البلدي والعدس وكانت على الترتيب (1033.9 : 1736.4 جرام) و (29.7 : 32.9 جرام). كما زادت نسب المسامية لكلاً من بذور الفول البلدي والعدس بزيادة المحتوى الرطوبي وكانت على الترتيب (36.172 : 41.308 %) و (33.597 : 35.044 %). وأخيراً تم تطوير بعض العلاقات الرياضية والتي تصف طبيعة التغير في قيم الخصائص الطبيعية المختلفة تبعاً للتغير في المحتوى الرطوبي لبذور المحاصيل موضوع الدراسة.