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EFFECT OF MOISTURE CONTENT ON PHYSICAL AND ENGINEERING PROPERTIES OF SOME SEEDS

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ABSTRACT: Moisture content (MC) of seeds is considered one of the most influencing parameters affecting the machinery properties of harvesting and post-harvesting/handling operations. Therefore, this study is conducted to measure and realize the MC effect of some fine seeds are; cumin, sesame, anise and clover seeds on physical and engineering properties that represent an important parameter in research and development of agro-machinery (RDAM) doing harvesting, cleaning, grading and storing operations. Within MC average levels of 12-16% (w.b) for (cumin, sesame and anise) and 10-14% (w.b) for clover seeds, the obtained results revealed that physical properties in terms of length, width, thickness, mass of thousand seeds, volume of seed, arithmetic diameter, geometric diameter, flat surface area and transverse area increased by increasing of mentioned MC levels for the all studied seeds, in contrast, the bulk density decreased. Also, percent of sphericity decreased for sesame seeds but increased for clover seeds by increasing of mentioned MC levels. While, for Cumin and Anise seeds it was increased with increasing of moisture content of seeds from 12-14% (w.b.) and decreased with increasing of moisture content of seeds to 16% (w.b.). On the other hand, engineering properties in terms of angle of repose, terminal velocity and coefficient of friction for (seeds, wood surface, galvanized sheet, plastic surface) increased by increasing of mentioned MC levels for the studied seeds. Terminal velocity values at (12, 14 and 16%) MC levels, were (5.45, 5.78 and 5.9 m/s) for sesame, (3.53, 3.93 and 4.15m/s) for cumin, (3.6, 3.75 and 3.93) for anise, respectively, and (8.4, 8.75 and 8.95 m/s) for clover at (10, 12 and 14%), respectively.

Key words: Moisture content, physical properties, engineering properties, sesame, cumin, anise, clover.

INTRODUCTION

(RDAM) requires initially studying the design parameters for optimal operation of this machinery. Harvest and post-harvest machinery is the most equipment handling with seed-crops. Therefore, it is necessary to provide databases within physical and engineering properties of crops seeds. In this context, characterization of physical and engineering properties for these seeds is focused to select the proper design parameters of seeds apparatus or machinery for cleaning, grading, handling, processing and storing operations. Commonly used physical and mechanical properties are size dimensions (length, width, thickness and geometric diameter), shapes, flat surface area, density, angle of repose, terminal velocity and coefficient of friction, are playing important role in the design of harvesting, transporting, cleaning, separating, packing, storing, and processing equipment as reported by **El-Fawal *et al.* (2009)**. Also, bulk density and porosity affect the structural loads. The coefficient of friction of seeds against various surfaces is also essential in the design of conveying, transporting, and storing structures (**Altuntas and Demirtola, 2007**).

Harmond *et al.* (1965) stated that, size of a seed determines how much space can be occupied and it can be described in terms of length, width and thickness. So, the size is too important in design or selection of disks for modifying clearances and screen holes in combining.

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Islam *et al.* (1980) studied several techniques of seed separation and cleaning and reported that this is influenced with weight of seed, length, thickness and width.

Mohsenin (1986) reported early that, the physical properties such shape, volume, size and surface area, are significant in many problems related to development or design of specific machine particularly in separating of foreign materials by water and air. Accurate evaluates of the related diameters and the frontal areas are essential for the identification of drag coefficient and terminal velocity.

Matouk *et al.* (2004) studied mathematically the relationships showed the changes of the seed properties with the moisture content (MC). The seed dimensions and weight of 1000-seed were increased by increasing of seed-MC content while, coefficient of contact surface decreased.

No doubt that seed physical and mechanical properties are strongly affected by MC. Accordingly in view of similar previous literature, MC-dependent physical and/or mechanical properties had been reported by many researchers contributing to knowledge for proper machine design parameters related to physical and mechanical properties of such seeds as; sunflower, Pumpkin, sorghum, chick pea, lentil, wheat, maize, grass pea, moringa, soybean and fababean.

Matouk *et al.* (2008) studied various seed-physical properties of sunflower, soybean and canola were estimated as a function of MC in the range of 7.11 to 25.722% w.b. and found that terminal velocity of increased from (5.34 to 5.91 m/s), from (10.16 to 10.38 m/s) and from (5.10 to 5.32 m/s) for the mentioned seeds, respectively, by increasing MC from (7.35 to 23.7%), (9.52 to 24.644%) and (7.11 to 25.722% w.b.), respectively. Also, the coefficient of friction for stainless steel, galvanized iron and rubber surfaces of mentioned seeds increased linearly.

Mohamed (2013) studied physical and mechanical properties for fenugreek seeds. He found that, by increasing MC from 13 to 27% w.b. led to increase the average length, width, thickness, geometric mean diameter, seed volume and thousand seed weight from 4.29 to 5.13 mm, 2.97 to 3.11 mm, 1.87 to 2 mm, 2.87 to 3.17 mm, 19.5 to 26.6 mm^3 and 15.6 to 19.2 g, respectively, while sphericity and bulk density percent decreased from 67.4 to 61.9% and from 800.6 to 722.2 kg/m^3, respectively. On the same behavior, the static coefficient of friction on wire mesh screen and the terminal velocity increased from 0.43 to 0.56 and from 6.6 to 8.11 m/s, respectively.

Mollazade *et al.* (2009) studied some physical and mechanical properties of cumin (*Cuminum cyminum* L.) seeds they were obtained as MC changed from 7.24 to 21.38% d.b. Increasing of MC caused increasing the seed width (1.33-1.55 mm), length (5.14-5.58 mm), thickness (0.97-1.05 mm), geometric mean diameter (1.88-2.09 mm), arithmetic mean diameter (2.48-2.73), surface area (10.34-12.66 mm^2), porosity (51.22-64.11%), 1000-seed weight (2.9-3.9 g), true density (917.8-1030.6 kg/m^3), static angle of repose (43-49 deg), dynamic angle of repose (47-56.6 deg), and coefficient of static friction on the three surfaces: galvanized iron sheet (0.36-0.73), glass (0.48-0.77) and plywood (0.57-0.69) while, bulk density decreased from 447.66-369.88 kg/m^3. Also, sphericity increased from 36.63 to 37.5% until MC 14.5% d.b. then reduced to 37.5% with further MC increase to 21.38% d.b.

Pathak and Mehta (2018) reported that by increasing MC of cumin seeds from 9.01 to 18.23% d.b., the average length, width, thickness, geometric mean diameter, weight of 1000-seed, true density, porosity, angle of repose, terminal velocity increased from 5.07 to 5.68 mm, 1.37 to 1.58 mm and 1.23 to 1.35 mm, 2.04 to 2.30 mm, 4.56 to 5.11 g, 1068.04 to 1120.78 kg/m^3, 57.32 to 64.01%, 41.780 to 50.630 and 2.82 to 4.21 m/s, respectively, while the bulk density decreased from 455.82 to 403.34 kg/m^3.

Reviewing the previous studies, it is evident that, few studies were conducted on MC-dependent physical and mechanical properties of seeds. Therefore, it is necessary to provide clear information on like these seeds particularly cumin, sesame, anise and clover seeds due to selection of the proper handling parameters for each one has a special geometrical shape. Moreover, seeds of such crops have special equipment for both harvest and post-harvest/ handling treatments. Hence, the current study mainly aimed to compare and select the essential physical and engineering properties based on MC-effect for some seeds namely; cumin (*Cuminum cyminum* L.), sesame (*Sesamum indicum* L.), anise (*Pimpinella anisum* L.) and clover seeds (*Trifolium alexandrinum* L.) in order to use the obtained results to optimize the best design parameters and discuss the relationship between these seeds properties affecting cleaning in agricultural machinery.

MATERIALS AND METHODS

In this experiment seeds were studied namely; sesame (*Sesamum indicum* L.), cumin (*Cuminum cyminum* L.), anise (*Pimpinella anisum* L.) and clover seeds (*Trifolium alexandrinum* L.).

Instrumentation

Digital professional pocket scale

Used to measure the weight of samples. It was made in China with accuracy of 0.01 mg.

Digital vernier caliper

Used for measuring the dimensions of seeds including length, width and thickness. It was made in China, model DM 236. The range of reading is 0.01 to 150 mm with an accuracy of 0.01 mm.

Grain Moisture Meter

Used for measuring the MC in percentage of the studied seeds on wet basis (w.b.). It was made in China, Model of AR991, with an accuracy of 0.1%.

Terminal velocity device

Used for determining terminal velocity (V_{ter}) for seeds. It was made in USA, model 757 South Dakota, the base measures 20" L x 20" W x 30½" H. It utilizes airflow, which is generated by a blower motor and the air passes through a column size (3" I.D. x 34¼" H) constructed of clear Plexiglas. The air lifts light fluffy material or empty seed hulls into the top beveled area of the column, while larger heavier good seed stays at the bottom. The motor is 220V/60Hz and operates at 3450 rpm. Terminal velocities are accurately controlled by a calibrated valve cap in the top of the column. When the seeds partial were just suspended in it, the superficial air velocity was measured. The terminal velocity device used in this study is shown in Fig. 1 which is found in Seed Production Plant Lab, Mansoura, Dakahlia Governorate.

Fig. 1. Terminal velocity device: (1) Wooden box contain blower motor, (2) Column constructed of clear Plexiglas, (3) Calibrated valve cap

Experimental Procedures

The experiments were conducted to determine and estimate the physical and engineering properties of seeds under study considering MC range of 12, 14 and 16%. W.b. for cumin, anise and sesame seeds and 10, 12 and14%. W.b. for clover. A random sample was taken of about 250 g seeds for each crop. Physical characteristics including seed dimensions (length, width and thickness), volume, geometric diameter, arithmetic diameter, percent of sphericity, flat surface area and transverse area were measured with 20 replicates then the average values were recorded. While, weight of 1000-seed was measured and repeated five times whilst bulk density repeated four times then the average values were obtained. Engineering properties including terminal velocity, angle of repose and coefficient of friction were measured and repeated four times and the average values were obtained. All obtained data were statistically descripted as frequencies, minimum, maximum and mean values.

Seeds-samples preparation

For the present study, the cumin, anise and sesame seeds were acquired from a local market. Such seeds may well be a mix of several varieties. While, the clover seeds were acquired from a farmer. The initial MC of the seeds was estimated to be 9.9% d.b. The MC was determined by Grain Moisture Meter-SMART SENSOR-AR991.The samples of seeds were cleaned manually from foreign matter, immature and broken seeds. The samples with the desired MC were prepared by adding distilled water as calculated by **Sacilik *et al.* (2003)**:

$$Q = \frac{Wi\,(M_f - M_i)}{(100 - M_f)}$$

Where:

Q : the mass of water to be added, kg,

W_i: the initial mass of the sample, kg,

M_i: the initial moisture content of the sample, % d.b.,

M_f: the final moisture content, % d.b.

The samples were divided into separate polyethylene bags and then the bags closed tightly. The samples were kept at 5°C in a refrigerator for one week to enable the moisture to distribute uniformly through the seeds. Before beginning the experiment, the targeted quantity of the seeds were taken out of the refrigerator and allowed to equate to the room temperature for about 2 h **(Coskun *et al.* 2006)**.

Physical properties of seeds

Seed Physical properties in terms of length (L), width (W) and thickness (T) were measured using venier caliper, while volume (V), geometric diameter (D*g*), arithmetic diameter (Da), percent of sphericity (S), area of surface (A*f*), and area of transverse surface (A*t*) of the individual seeds were calculated according to **(Mohsenin, 1986; El-Raie *et al.*, 1996)** as follows:

$$V = \frac{\pi}{6}\,LWT \text{ , mm}^3$$

$$Dg = (LWT)^{\frac{1}{3}} \text{ , mm}$$

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

$$S = \frac{(LWT)^{\frac{1}{3}}}{L} \times 100 \text{ , \%}$$

$$Af = \frac{\pi}{4}\,LW \text{ , mm}^2$$

$$At = \frac{\pi}{4}\,TW \text{ , mm}^2$$

Bulk density

A Cylinder made from glass was used to measure bulk density. The weight of the cylinder, diameter and height were estimated 94.14g, 26.5mm and 30mm, respectively. Bulk density was determined using net seeds weight by the following equation:

$$\rho_b = \frac{m}{v} \text{ , kg/m}^3$$

Where:

ρ_b: the bulk density of the seed, kg/ m^3 , m: mass of seeds ,g

v: the bulk volume of the seeds , mm^3

Weight of 1000-seed

Thousand seed weight (TSW) was measured by counting a random 100 seeds and weighting them by the digital professional pocket scale then the average weight multiplied by 10 to give weight of 1000-seed.

Engineering Characteristics of Seeds

Angle of repose (R_a)

A random sample of seeds were poured under gravity from 20cm height to flat plat to form a cone surface and the horizontal plan was recorded to represent repose angle of seeds using a protractor.

Coefficient of friction (C_F)

Friction coefficient was estimated for seeds between each other by two cardboard cylinders (45mm diameter and 45mm height). Both cylinder were put on top of each other above wooden surface (two plats of wood (40 x 5.5 x1 cm) for each one, they were connected by hinge), the friction angle was measured when the top cylinder begun to moved and the friction angle measured by a protractor. Friction coefficient were determined for seeds with (wood surface, galvanized sheet, plastic surface) by only one cylinder and the same two plats of wood, the friction angle was measured when the cylinder begun to moved and the friction angle measured by a protractor. Friction coefficients for the above-mentioned samples were obtained as follows:

$$C_F = \tan \alpha$$

Where: α = Friction angle.

RESULTS AND DISCUSSION

The obtained results were titled as the following:

Physical Properties of Seeds

Sesame

The obtained physical properties of sesame are showed in Table 1 with frequencies shown in Fig. 2.a,b,c,d. Average sesame-seed dimensions increased with increasing of MC from 12-16% (w.b.) concluding average increase in length, width and thickness as from 3.07 to 3.63, from 1.64 to 1.89 and from 0.84 to 0.92 mm, respectively. Also, average geometric diameter, arithmetic diameter, volume, area of surface, area of transverse surface and weight of 1000-seed increased from 1.61 to 1.84 mm, from 1.85 to 2.15 mm, from 2.21 to 3.32 mm^3, from 3.96 to 5.40 mm^2, from 1.07 to 1.37 mm^2 and from 3.26 to 3.7 g, respectively. While, average percent of sphericity and bulk density decreased from 52.48 to 50.80% and from 1064.16 to 1036.52 kg/m^3 by increasing of MC from 12-16% (w.b.). Similar results were reported by: **Baryeh and Mangope (2002)** for pigeon pea; **Coskun *et al.* (2006)** for sweet corn; and **Mohamed (2013)** for fenugreek seeds.

Cumin

The obtained physical properties of cumin are showed in Table 2 with frequencies shown in Fig.3a,b,c,d. Average cumin-seed dimensions increased with increasing of MC from 12- 16% (w.b.) concluding average increase in length, width and thickness from 6.15 to 6.63, from 1.38 to 1.86 and from 1.12 to 1.35 mm, respectively. Also, average geometric diameter, arithmetic diameter, volume, area of surface, area of transverse surface and weight of 1000-seed increased from 2.11 to 2.55 mm, from 2.88 to 3.28 mm, from 5.29 to 8.82 mm^3, from 6.74 to 9.71 mm^2, from 1.26 to 1.99 mm^2 and from 5.51 to 5.72 g, respectively. While, average bulk density decreased from 650.79 to 525.58 kg/m^3 by increasing of MC from 12- 16% (w.b.). Also, average percent of sphericity was increased from 34.32 to 39.35 % by increasing of MC from 12-14% (w.b.) and decreased to 38.69% by increasing of MC to 16% (w.b.) . Similar results were reported by: **Baryeh and Mangope (2002)** for pigeon pea; **Coskun *et al.* (2006)** for sweet corn; **Mollazade *et al.* (2009)** for cumin; and **Mohamed (2013)** for fenugreek seeds.

Anise

The obtained physical properties of anise are showed in Table 3 with frequencies shown in Fig.4 a,b,c,d). Average anise-seed dimensions increased with increasing of MC from 12- 16% (w.b.) concluding average increase in length, width and thickness from 3.56 to 4.18, from 1.62 to 1.79 and from 1.32 to 1.35 mm, respectively. Also, average geometric diameter, arithmetic diameter, volume, area of surface, area of transverse surface and weight of 1000-seed increased from 1.97 to 2.17 mm, from 2.17 to 2.45 mm, from 4.10 to 5.57 mm^3, from 4.55 to 5.96 mm^2, from 1.71 to 1.97 mm^2 and 4.34 to 5.72 g, respectively. While average bulk density decreased from 808.92 to 706.82 kg/m^3 by increasing of MC from 12- 16% (w.b.). Also, average percent of sphericity was increased

Table 1. Physical properties of sesame

Parameter	(MC 12%)			(MC 14%)			(MC 16%)		
	Min.	**Max.**	**Mean**	**Min.**	**Max.**	**Mean**	**Min.**	**Max.**	**Mean**
(L), mm	2.76	3.39	3.07	3.06	3.68	3.32	3.27	3.88	3.63
(W), mm	1.23	1.9	1.64	1.39	1.94	1.71	1.66	2.07	1.89
(T), mm	0.61	0.99	0.84	0.65	1.14	0.9	0.74	1.43	0.92
(Dg), mm	1.4	1.78	1.61	1.51	1.99	1.72	1.62	2.19	1.84
(Da), mm	1.6	2.04	1.85	1.8	3.23	1.98	1.95	2.4	2.15
(S), %	48.55	56.34	52.48	48.02	55.11	51.74	46.84	56.61	50.8
(V), mm^3	1.44	2.94	2.21	1.81	4.11	2.7	2.24	5.51	3.32
(Af), mm^2	2.67	4.85	3.96	3.44	5.41	4.48	4.47	6.13	5.4
(At), mm^2	0.78	1.3	1.07	0.86	1.67	1.21	0.98	2.13	1.37
Weight of 1000-seed, g	3.15	3.35	3.26	3.4	3.55	3.49	3.55	3.85	3.7
(ρ_b), kg/ m^3	1056	1069.29	1064.16	1046.94	1062.65	1053.58	1011.3	1047.54	1036.52

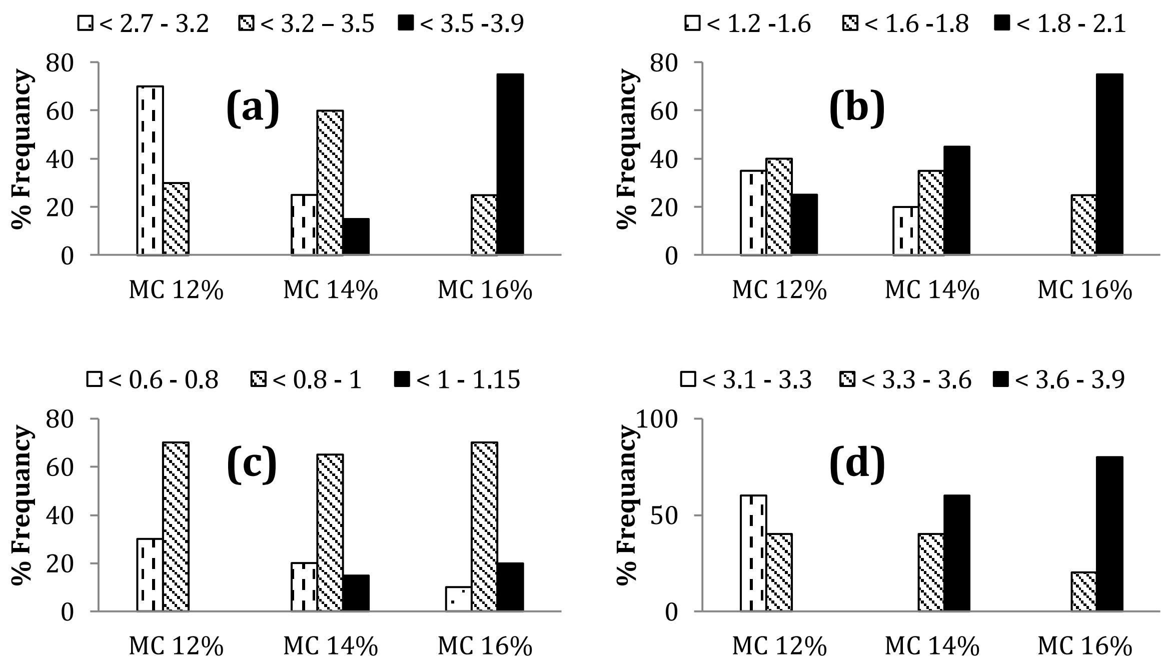

Fig. 2. Percent of sesame-seed frequency at different MC% of: (a) length, (b) width, (c) thickness and (d) weight of 1000-seed

Table 2. Physical properties of cumin

Parameter	(MC 12%)			(MC 14%)			(MC 16%)		
	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean
(L), mm	5.04	7.04	6.15	5.17	7.08	6.34	5.44	8.24	6.63
(W), mm	1.06	1.96	1.38	1.42	2.23	1.85	1.61	2.27	1.86
(T), mm	0.64	1.53	1.12	0.8	1.6	1.33	1.19	1.85	1.35
(Dg), mm	1.52	2.67	2.11	2.01	2.88	2.49	2.26	2.95	2.55
(Da), mm	2.27	3.29	2.88	2.73	3.53	3.17	2.84	3.77	3.28
(S), %	26.99	42.09	34.32	30.66	44.7	39.35	32.32	45.99	38.69
(V), mm^3	1.83	9.96	5.29	4.26	12.49	8.33	6.04	13.42	8.80
(Af), mm^2	4.28	9.76	6.74	6.75	11.72	9.25	7.55	11.79	9.71
(At), mm^2	0.54	2.36	1.26	0.97	2.75	1.96	1.52	3.14	1.99
weight of 1000-seed, g	5.4	5.7	5.51	5.55	5.8	5.64	5.6	5.85	5.72
(ρ_b), kg/ m^3	643.99	658.49	650.79	595.06	631.30	611.52	503.84	555.79	525.58

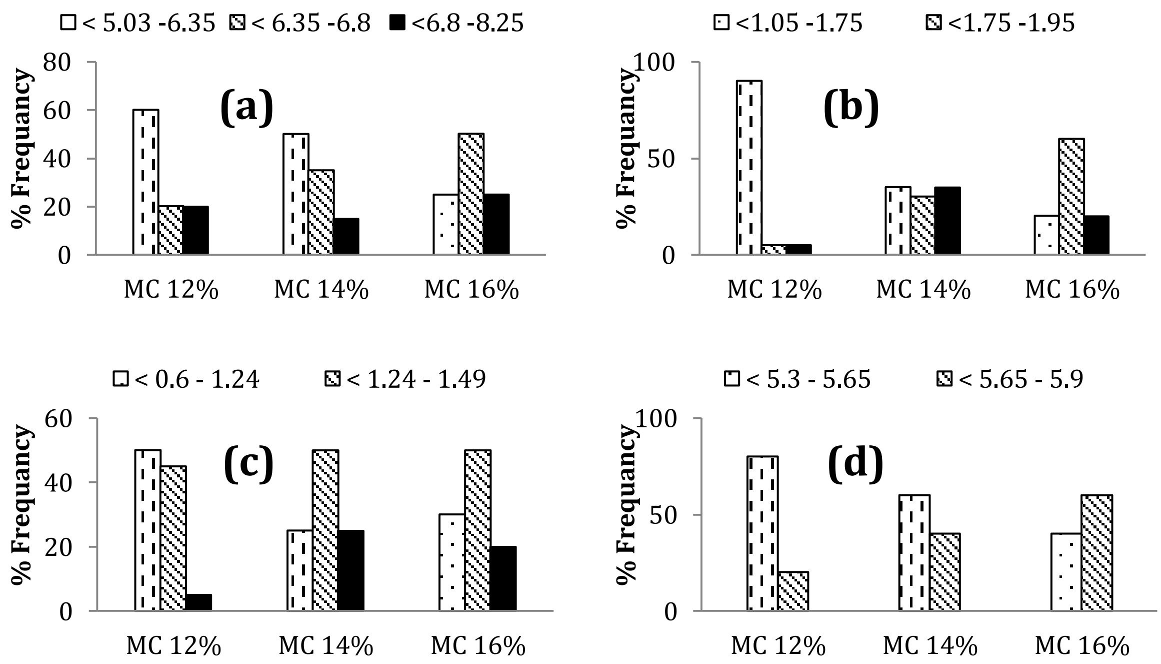

Fig. 3. Percent of cumin-seed frequency at different MC% of: (a) length, (b) width, (c) thickness and (d) weight of 1000-seed

Table 3. Physical properties of anise

Parameter	(MC 12%)			(MC 14%)			(MC 16%)		
	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean
(L), mm	2.66	4.07	3.56	3.19	4.1	3.65	3.5	4.92	4.18
(W), mm	1.28	1.94	1.62	1.32	2.28	1.71	1.39	2.61	1.79
(T), mm	1.01	1.8	1.32	1.06	1.83	1.35	1.1	1.91	1.38
(Dg), mm	1.63	2.40	1.97	1.65	2.48	2.03	1.89	2.68	2.17
(Da), mm	1.83	2.58	2.17	1.86	2.61	2.24	2.11	2.93	2.45
(S), %	45.55	65.01	55.35	47.58	65.13	55.69	44.43	59.61	52.06
(V), mm^3	2.28	7.26	4.1	2.34	7.94	4.54	3.56	10.08	5.57
(Af), mm^2	3.37	6.11	4.55	3.38	6.81	4.93	3.95	9.33	5.96
(At), mm^2	1.02	2.69	1.71	1.09	3.14	1.85	1.37	3.36	1.97
weight of 1000-seed, g	4.25	4.35	4.34	4.35	4.65	4.52	5.6	5.58	5.72
(ρ_b), kg/ m^3	796.83	822.81	808.92	732.79	763	748.05	648.22	757.57	706.82

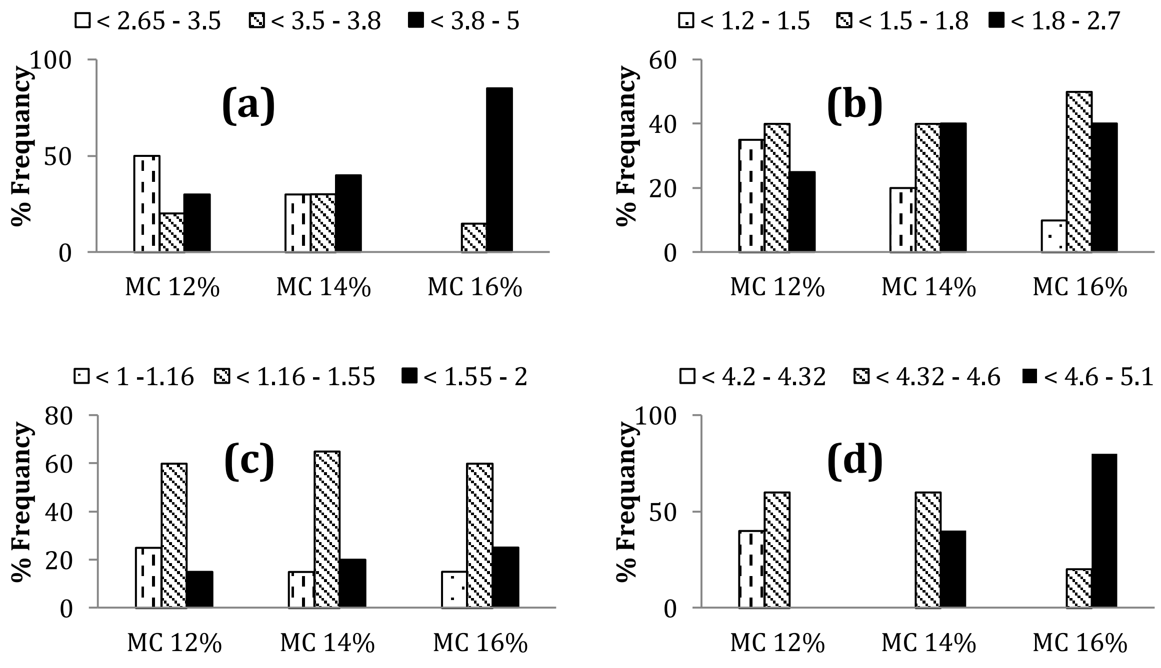

Fig. 4. Percent of anise-seed frequency at different MC% of: (a) length, (b) width, (c) thickness and (d) weight of 1000-seed

from 55.35 to 55.69% by increasing of MC from 12- 14% (w.b.) and decreased to 52.06% by increasing of MC to 16% (w.b.). Similar results were reported by: **Baryeh and Mangope (2002)** for pigeon pea; **Coskun *et al.* (2006)** for sweet corn; **Mollazade *et al.* (2009)** for cumin; and **Mohamed (2013)** for fenugreek seeds.

Clover

The obtained physical properties of clover are showed in Table 4 with frequencies shown in Fig.5 a,b,c,d. Average clover-seed dimensions increased with increasing of MC from 10- 14% (w.b.) concluding average increase in length, width and thickness from 2.41 to 2.49, from 1.48 to 1.79 and from 1.26 to 1.42 mm, respectively. Also, average geometric diameter, arithmetic diameter, volume, area of surface, area of transverse surface and weight of 1000-seed increased from 1.64 to 1.84 mm, from 1.72 to 1.89 mm, from 68.77 to 73.98 %, from 2.38 to 3.36 mm^3, from 2.79 to 3.52 mm^2, from 1.49 to 2.00 mm^2 and from 3.23 to 3.43g, respectively. While bulk density decreased from 1436.29 to 1365.01 kg/m^3. Similar results were reported by: **Matouk, *et al.* (2004)** for some Egyptian wheat varieties and **El-Fawal *et al.* (2009)** for seeds of some field crops.

Engineering Properties of Seeds

The obtained engineering properties of sesame, cumin, anise and clover seeds are showed in Table 5 and Figs. 6-8. It is noticed that, the engineering properties of seeds were increased by increasing of MC from 12- 16% w.b. for sesame, cumin, anise seeds and from 10-14% w.b. for clover seeds. Mean values of repose angle for sesame, cumin, anise and clover seeds, as shown in Fig. 6, increased from 27 to 34, from 32.75 to 44.5, from 33 to 40.75 and from 31.25 to 36.75 deg, respectively. Mean values of terminal velocity for sesame, cumin, anise and clover seeds, as shown in Fig. 7, increased from 5.45 to 5.9, from 3.53 to 4.15, from 3.6 to 3.93 and from 8.4 to 8.95 m/s, respectively. Also mean coefficient of friction as function of MC from 12- 16% (w.b.) for sesame, cumin, anise seeds and from 10-14%w.b. for clover seeds for seeds, wood surface, galvanized sheet and plastic surface increased from 0.8923 to 0.958, from 1.283 to 1.542, from 1.121 to1.316 and from 0.966 to 1.073, respectively, for sesame, from 0.855 to 0.925, from 1.246 to 1.352, from 1.092 to 1.182 and from 0.892 to 0.983, respectively, for cumin, from 0.9005 to 0.958, from 1.5113 to 1.683, from 1.339 to 1.456 and from 1.1508 to 1.292, respectively, for anise and from 0.8845 to 0.983, from 1.3395 to 1.632, from 1.257 to 1.429 and from 0.9165 to 1.054, respectively, for clover. Similar obtained results were reported by **Matouk *et al.* (2004)** for some Egyptian wheat varieties, **Mollazade *et al.* (2009)** for cumin, **El-Fawal *et al.* (2009)** for grains of some field and **Mohamed (2013)** for fenugreek seeds.

Conclusion

The Mc-dependence physical and engineering properties for cumin, sesame, anise and clover seeds were determined in MC of 12 to 16% w.b. (except clover was 10 to 14% w.b.). From mean values of experimental results, by increasing MC:

- Length, width and thickness increased from: (6.15 to 6.63, 1.38 to 1.86 and 1.12 to 1.35 mm, respectively); (3.07 to 3.63, 1.64 to 1.89 and 0.84 to 0.92 mm, respectively); (3.56 to 4.18, 1.62 to 1.79 and 1.32 to 1.35, respectively) and (2.41 to 2.49, 1.48 to 1.79 and 1.26 to 1.42 mm, respectively), respectively for the mentioned seeds.
- Weight of 1000-seed increased from 5.51 to 5.72, 3.26 to 3.7, 4.34 to 5.72 and 3.23 to 3.43 g, respectively for the mentioned seeds.
- Bulk density decreased from 650.79 to 525.58, 1064.16 to 1036.52, 808.92 to 706.82 and 1436.29 to 1365.01 kg/ m^3, respectively for the mentioned seeds.
- Angle of repose increased from 32.75 to 44.5, 27 to 34, 33 to 40.75 and 31.25 to 36.75 degree, respectively for the mentioned seeds.
- Coefficient of friction increased from for seeds, wood surface, galvanized sheet and plastic surface increased from; (0.8923 to 0.958, 1.283 to 1.542, 1.121 to1.316 and 0.966 to 1.073, respectively); (0.855 to 0.925, 1.246 to 1.352, 1.092 to 1.182 and 0.892 to 0.983, respectively); (0.9005 to 0.958, 1.5113 to 1.683, 1.339 to 1.456 and 1.1508 to 1.292, respectively); (0.8845 to 0.983, 1.3395 to 1.632, 1.257 to 1.429 and 0.9165 to 1.054, respectively), respectively for the mentioned seeds.
- Terminal velocity increased from 5.45 to 5.9, 3.53 to 4.15, 3.6 to 3.93 and 8.4 to 8.95 m/s, respectively for the mentioned seeds.
- This study was for determine the physical and engineering properties for the mentioned seeds affecting mechanical cleaning.

Table 4. Physical properties of clover

Parameter	(MC 10%)			(MC 12%)			(MC 14%)		
	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean
(L), mm	1.99	2.76	2.41	2.05	2.79	2.43	2.11	2.82	2.49
(W), mm	1.12	1.88	1.48	1.28	2.22	1.69	1.42	2.39	1.79
(T), mm	1.07	1.53	1.26	1.1	1.59	1.32	1.25	1.89	1.42
(Dg), mm	1.35	1.92	1.64	1.51	2.01	1.75	1.63	2.28	1.84
(Da), mm	1.41	1.98	1.72	1.56	2.08	1.81	1.66	2.3	1.89
(S), %	54.98	78.55	68.77	64.09	85.79	72.01	65.29	86.97	73.97
(V), mm^3	1.29	3.7	2.38	1.81	4.27	2.87	2.26	6.19	3.36
(Af), mm^2	1.82	3.8	2.79	2.33	4.6	3.24	2.63	4.92	3.52
(At), mm^2	0.96	2.23	1.49	1.2	2.42	1.76	1.55	3.55	2
Weight of 1000-seed, g	3.2	3.3	3.23	3.35	3.4	3.36	3.4	3.45	3.43
(ρ_b), kg/ m^3	1417.263	1469.82	1436.29	1342.35	1406.99	1377.84	1304.29	1401.65	1365.01

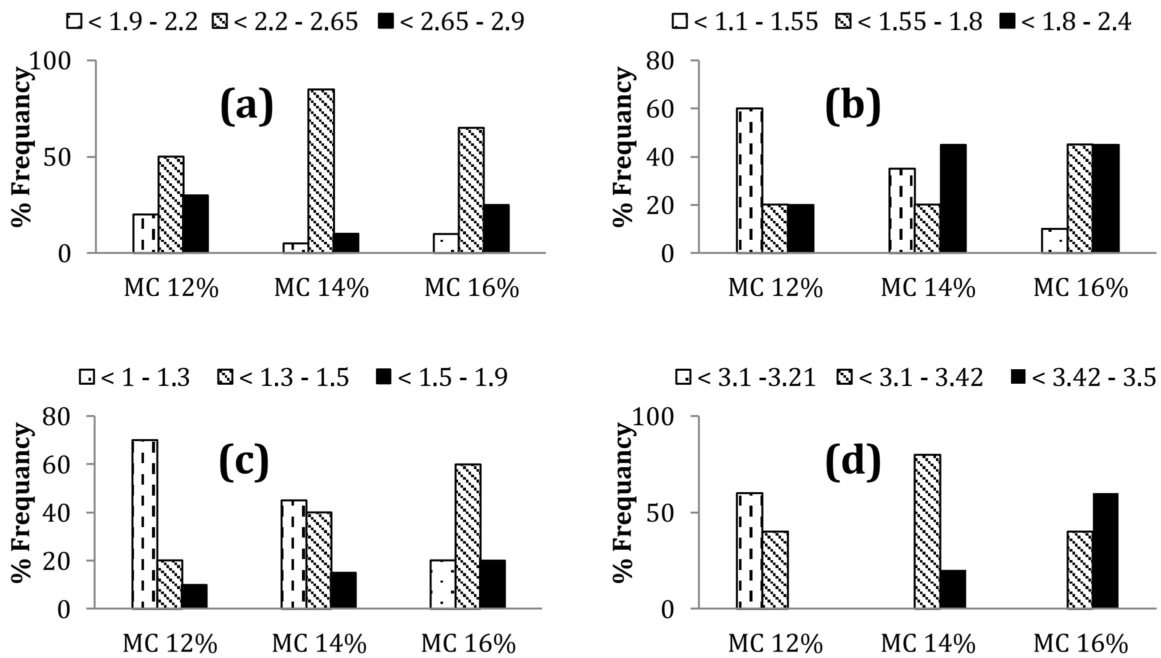

Fig. 5. Percent of clover-seed frequency at different MC% of: (a) length, (b) width, (c) thickness and (d) weight of 1000-seed

Table 5. Engineering properties of sesame, cumin, anise and clover seeds

Crops	Sesame			Cumin			Anise			Clover		
Properties / Moisture content	MC_1	MC_2	MC_3	MC_1	MC_2	MC_3	MC_1	MC_2	MC_3	MC_1	MC_2	MC_3
R_a , degree	27	29.5	34	32.8	41.5	44.5	33	39.75	40.75	31.3	34.5	36.75
V_{ter}, m/s	5.45	5.78	5.9	3.53	3.93	4.15	3.6	3.75	3.93	8.4	8.75	8.95
C_f for (Seeds)	0.89	0.93	0.96	0.88	0.95	0.983	0.90	0.93	0.96	0.86	0.90	0.93
C_f for (Seeds) with (Wood surface)	1.28	1.46	1.54	1.34	1.51	1.63	1.51	1.73	1.68	1.25	1.30	1.35
C_f for (Seeds) with (Galvanized sheet)	1.12	1.22	1.32	1.26	1.35	1.43	1.34	1.39	1.46	1.09	1.12	1.18
C_f for (Seeds) with (Plastic surface)	0.97	1.04	1.07	0.92	0.98	1.05	1.15	1.24	1.29	0.89	0.95	0.98

N.B.: **MC_1, MC_2, MC_3** are 12, 14, 16 % for sesame, cumin, anise seeds.

N.B.: **MC_1, MC_2, MC_3** are 10, 12, 14 % for clover seeds.

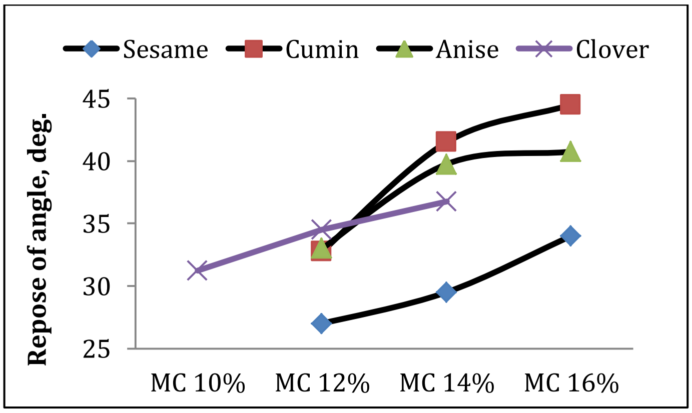

Fig. 6. Effect of seed-moisture content on repose angle of sesame, cumin, anise and clover

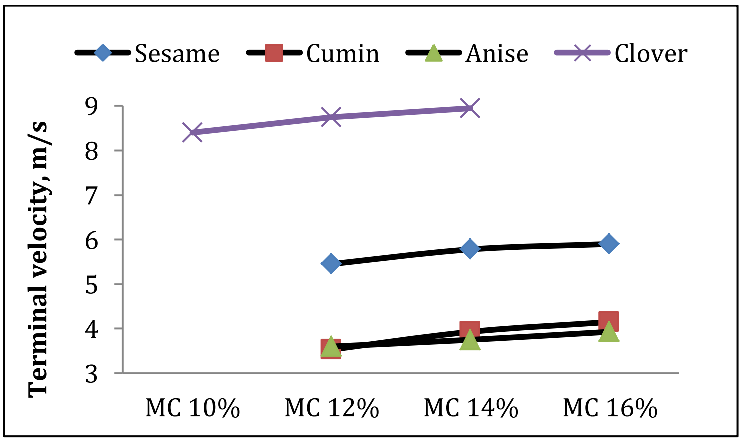

Fig. 7. Effect of seed-moisture content on terminal velocity, cumin, anise and clover

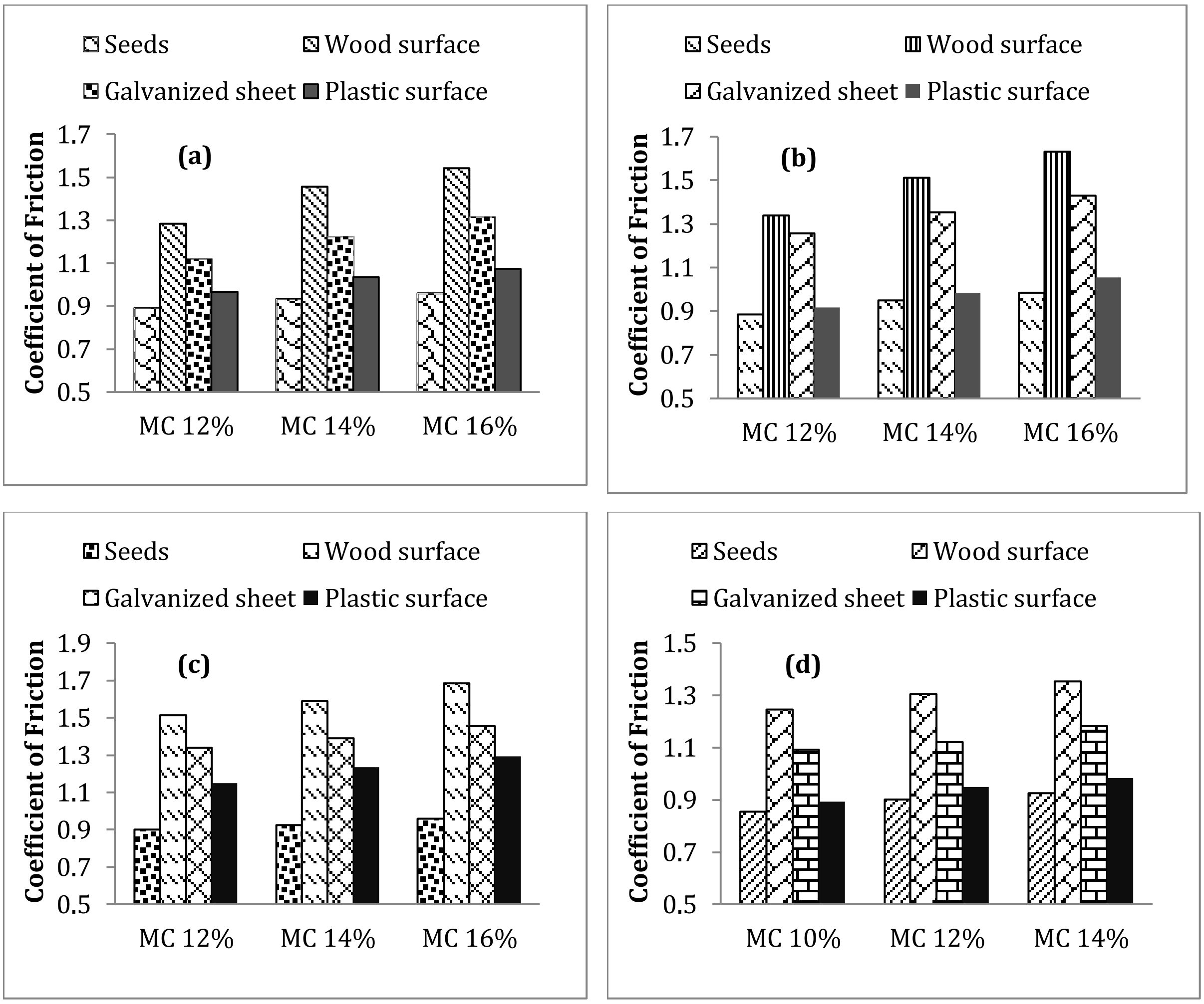

Fig. 8. Coefficient of friction on different surfaces in mean variation within different moisture content for seeds of: (a) sesame, (b) cumin, (c) anise and (d) clover

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تأثيــر المحتــوى الـرطـوبــي علـــى الخصــائـص الفيـزيــائيــة والهندسـية لبعض البــذور

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أجريت هذه الدراسة بهدف دراسة تأثير المحتوي الرطوبى في بذور محاصيل (الكمون، الينسون، السمسم والبرسيم) علي خصائصها الفيزيائية والهندسية لما لها من أهمية في خصائص عمليات الحصاد، والتنظيف، والتدريج، والتخزين لهذه البذور ذات الأهمية الاقتصادية والغذائية العالية. الخصائص الطبيعية (الفيزيائية) التي تم قياسها شملت كل من الطول، العرض، السمك، الحجم، وزن الألف بذرة، نسبة الكروية، القطر الهندسي، القطر الرياضي، مساحة السطح، الكثافة الظاهرية، بينما الخصائص الهندسية شملت كل من معامل الاحتكاك، زاوية التكويم وسرعة التعليق عند محتوي رطوبي للسمسم والينسون والكمون يتراوح من 12- 16% (على أساس رطب) بينما للبرسيم كان يتراوح بين 10- 14% (على أساس رطب) ويمكن تلخيص النتائج كالتالي: زادت الخصائص الفيزيائية (الطول، العرض، السمك، وزن الألف بذرة، الحجم، القطر الرياضي، القطر الهندسي و مساحة السطح) للبذور تحت الدراسة بزيادة المحتوي الرطوبي، تناقصت الكثافة الظاهرية للبذور تحت الدراسة بزيادة المحتوي الرطوبي، نسبة الكروية نقصت في حالة محصول السمسم بزيادة الرطوبة، أما محصول البرسيم زادت بزيادة الرطوبة، نسبة الكروية لمحصولي الكمون والينسون زادت بزيادة نسبة الرطوبة من 12 – 14%، وتنخفض بزيادة نسبة الرطوبة إلى 16% (على أساس رطب)، بينما زادت الخصائص الهندسية (زاوية التكويم، سرعة التعليق، ومعامل الاحتكاك بين (البذور، الخشب، الصاج المجلفن و البلاستيك) للبذور تحت الدراسة بزيادة المحتوي الرطوبي، سرعة التعليق كانت(5,45، 5,78 و 5.9 م/ث) لبذور السمسم عند محتوي رطوبي (12، 14 و16%) بالترتيب، و(3,53 ، 3,93 و4,15 م/ث) لبذور الكمون عند محتوي رطوبي (12، 14و 16%) بالترتيب، و(3,6، 3,75 و3,93 م/ث) لبذور الينسون عند محتوي رطوبي (12، 14و 16%) بالترتيب، و(8,4، 8,75 و8,95 م/ث) لبذور البرسيم عند محتوي رطوبي (10، 12و 14 %) بالترتيب.

المحكمـــــون:

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