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DETERMINATION OF GRAINS DENSITY AND POROSITY FOR SOME CEREAL CROPS

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ABSTRACT

Bulk density, true density and porosity for different varieties of four different cereal crops (rice, wheat, corn and barley) were determined as a function of grain moisture content. The measured and calculated data of the study showed a variation of these properties between the studied crops and also between the varieties of each crop. These properties were also related to a wide range of grain moisture contents (10–26%) through a group of empirical equations representing various studied varieties of each crop.

INTRODUCTION

Increasing economic importance of food materials, together with complexity of modern technology for their production, handling, storage, processing, preservation, quality evaluation, distribution and marketing demands a better knowledge of the significant physical properties of these materials (El-Sahrigi 1997). In other words, it is essential to understand the physical law governing the response of agricultural biological materials, so that processing and handling machines can be designed for maximum efficiency and highest quality of the end product.

Chakraverty (1987) reported that the knowledge of important physical properties such as, shape, size, volume, surface area, density, porosity, color, etc., of different grains is necessary for the design of various separating, handling, storing and drying systems. The density and specific gravity values are also used for the calculation of thermal diffusivity and Reynolds number.

Ibrahim (1992) mentioned that the threshed materials differ considerably in their physical properties such as size, shape, density, volume, specific gravity, porosity, and surface texture. These characteristics are very important in many problems associated with design or developing of a specific machine, analysis of the behavior of the product during handling process, stress distribution of the material under load, mechanical, aerodynamical and electrostatical separation, light reflectance and color evaluation.

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Dorsey et al. (1990) revealed that most grain properties are affected by moisture content. Data collected on 10 selected samples from a group of 184 maize hybrids grown at Ames in central Iowa showed that grain density decreased linearly as moisture content increased. Hybrids varied in density but the slope of density on moisture was the same for all hybrids.

Muir and Sinha (1988) measured the physical properties of 14 cultivars of cereal grains at moisture contents of 12.7 and 16.4% wet basis and 17 cultivars of oilseeds at a moisture content of 8.1 % were also measured. Bulk and kernel densities were found to be significantly different among cultivars. Compacted bulk densities obtained by dropping the seeds 2.7 m high were up to 15% greater than the densities measured by standard methods.

Redding et al. (1999) reported that kernel density could increase or decrease with moisture loss, depending on the relative weight loss compared to volume reduction. Kernels differ in the amount of void space within them and in the ratio of dense horny endosperm to softer flour endosperm, which contains more microfissures.

Franceschini et al. (1996) studied the effect of grain moisture content on some physical properties of maize cv. BR-201. The results showed that as the moisture content of the grain decreased, porosity decreased and bulk density increased.

Jintian et al. (1997) studied the effect of harvest and conditioned moisture content on bulk density of rough, brown and white rice. The results indicated that harvest moisture content significantly affected the bulk density of freshly harvested and conditioned rough rice. Higher harvest moisture content resulted in lower bulk density levels for rough rice over the conditioned moisture content range from 11 to 29% (w. b). There was a strong linear relationship between rough rice bulk density and conditioned moisture content for a given harvest moisture content.

Benedetti and Jorge (1987) studied the effects of moisture content on bulk density, true density and porosity of peanuts, rough rice, beans, soybeans and wheat. Four levels of moisture content (10, 15, 20 and 25% w.b) were used. Regression analysis was performed to correlate these properties with moisture content. Bulk density values decreased with increasing moisture content for all products except rough rice. True density decreased with increasing moisture content for beans, maize, soybeans and wheat. Porosity values increased with increasing moisture content for all crops except peanuts.

Chang (1988) determined porosity, true density and apparent density of maize, wheat and sorghum grains with a gas pycnometer. The results showed that, average true densities for maize, wheat and sorghum grain were 1.45, 1.47 and 1.46 g/cm^3 and average apparent densities were 1.27, 1.39 and 1.32 g/cm^3 respectively. The average grain porosities for maize, wheat and sorghum were 12.5, 5.2 and 9.8% respectively.

The main objective of this study was to determine the bulk density, true density and porosity for different varieties of rice, wheat, corn and barley corps. Also, to develop a database and mathematical relationships relating the studied properties with the changes in grain moisture content to represent different stages of harvesting, handling and processing of each studied crop.

MATERIALS AND METHODS

Materials

To achieve the target of the experimental work, some varieties of each crop (rice, corn, wheat and barley) were selected, based on their recent coverage area and the expected future expansion of each variety, according to Ministry of Agriculture yearly bulletins. Samples of the selected varieties of each crop were procured from the experimental farm of Agricultural Research Center at Sakha, Kafer-Sheikh Governorate and cleaned from foreign matter, broken and immature grains.

Equipment:

1. Grain conditioning apparatus

The grain conditioning apparatus shown in figure (1) was used for adjusting different levels of grain moisture content. Structure details and description of the conditioning unit have been given by Matouk et al. (2002).

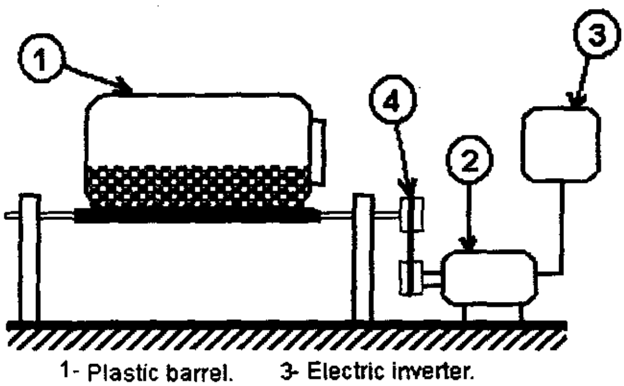

Fig. (1): Conditioning apparatus used for adjusting the levels of grain moisture content

2. Grain porosity apparatus

The grain porosity apparatus developed by Mohsenin (1984) was used for measuring porosity of different studied varieties. The apparatus consists of two identical stainless-steel tanks sealed by compressed rubber covers.

The first tank was connected to an air compressor, pressure reducer and a control valve (1). The second tank was filled with grain samples and connected to control vales (2) and (3). A precise manometer was fixed to the main pipe for detecting the air pressure during different stages of measurement. Figure (2) shows a schematic diagram for the apparatus used for measuring grain porosity.

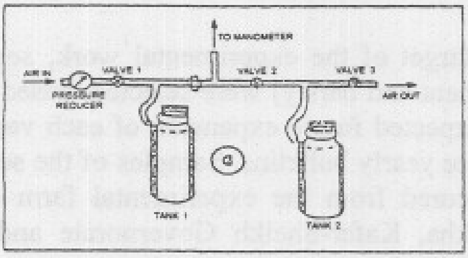

Fig. (2): The apparatus used for measuring grain porosity.

3. **Grain shaker**

A vertical vibrating grain shaker, shown in figure (3), was used for measuring grain bulk density under vibrating condition. The shaker consists of stainless-steel grain tank and a flat vibrated surface with two-iron handles, used for fixing the grain tank. The vibration process of the flat surface is accomplished through a vibrating system consists of four springs rested over an iron base and moves vertically through a cam welded to an iron bar. A 0.5 kW electric motor provides the power for rotating the iron bar and the cam through a rubber belt and two pulleys.

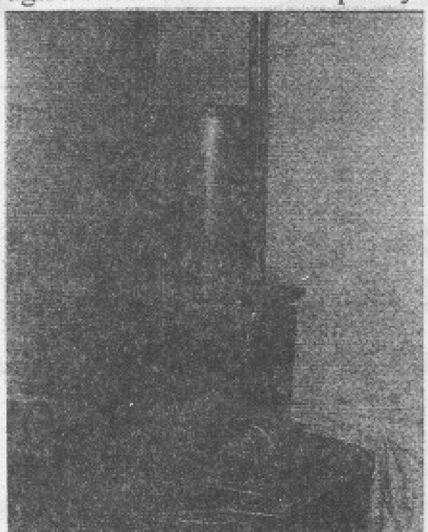

Fig. (3): Laboratory grain shaker.

Experimental procedure and measurements

The grains of each variety were mixed and the initial moisture content of the grains was determined by (Matouk *et. al.*, 2002). The five desired moisture levels of each variety were prepared by adding calculated amounts of tap water, thorough mixing in a grain conditioning apparatus for 72 hours. The conditioned samples of each level of grain moisture content were sealed in a separate polyethylene bags. The bags were stored in a freezer adjusted at temperature of - 5 ± 1 °C to prevent moisture loss and fungal growth throughout the storage period. Before each test, the required quantities of grains were taken out from the freezer and allowed to reach the normal room temperature. The moisture content of the samples was determined just before each test.

Measurements:

1. Grain moisture content

The oven drying method at 130 °C for 16 h proceeded by Matouk et. al., (2002) was used for determining grain moisture contents of the different studied varieties of each crop.

2. Bulk and true densities of grains

The bulk density was determined based on the volume occupied by grain bulk for different varieties of each crop and different levels of grain moisture content. Since the mass of grain is varied with many parameters such as, height of grains falling and grains vibrating conditions, so two kinds of bulk density were taken into consideration.

a- Bulk density at loose grain fill

Bulk density at loose fill condition was determined by filling a known container volume with the grains from a height of 150 cm at constant rate, then the weight of grain bulk was determined and the bulk density was calculated.

b- Bulk density at vibrated grain fill

Bulk density at vibrated grain fill was determined by filling the same container with grain under vibration using a laboratory grain shaker for two minutes (figure 3). The grain was filled from a height of 150 cm at a constant rate and then weighed.

c- True density measurement

The true density of each variety was determined using a toluene displacement method with a known weight of grains. The following equation was used for calculating the true density of each variety of the investigated crops as follows:

$$T_d = W / V_i$$

Where:

T_d = true density of the gain sample (g/cm^3).

W = weight of the grain sample (g).

V_I = displaced volume of toluene (cm^3).

1. Porosity

The porosity (pr) of the grain bulk at different levels of moisture content was measured using the grain porosity apparatus shown in figure (2) with the material in tank (2), valve (2) is closed and air was supplied to tank (1). When suitable manometer displacement is achieved, valve (1) is closed and after the manometer comes to equilibrium, pressure P_1 is read. Under this condition according to the well known perfect gas law:

$$P_1 V_1 = M R_1 T_1$$

Where (p_1) is the absolute pressure, (V_1) is the volume in tank (1), (M) is the mass of air, (R_1) is the gas constant for air, and (T_1) is the absolute temperature. Now, valve (3) is closed and valve (2) is opened and the pressure (P_3) is read. Under this condition with valves (1) and (3) closed, the total mass of air (M) is divided into (M_1) to fill tank (1) and (M_2) to fill pore space (V) in tank (2). Assuming $R_1T_1 = R_2T_2 = RT$, the following relationship can be deducted:

$$M = M_1 + M_2$$

$$\frac{P_1 V_1}{R T} = \frac{P_3 V_1}{R T} + \frac{P_3 V_2}{R T}$$

From which percent pore volume can be found as follows:

$$\frac{V_2}{V_1} = \frac{P_1 - P_3}{P_3}$$

RESULTS AND DISCUSSION

Bulk density of grains

In general, the effect of grains moisture content on bulk density indicated that, the values of bulk density at loose fill (BDL) was lower than that of vibrated (BDV) fill for all the varieties under study. The effect of grains moisture content on bulk density at loose and vibrated fills for rice varieties are shown in figures (4 and 5). The bulk density increased with the increasing of grain moisture content for all rice varieties. Rice variety (Giza 178) recorded the highest values of bulk density, which increased from 573.43 to 644.35 kg/m^3 and from 614.93 to 695.10 kg/m^3 with the increasing of grains moisture content from 12.57 to 26.22% at loose and vibrated fills respectively. Meanwhile, Yasmin variety recorded the lowest values of bulk density, which increased from 545.14 to 626.06 kg/m^3 and from 581.92 to 687.93 kg/m^3 with the increasing of grains moisture content from 12.80 to 25.11% for loose and vibrated fills respectively.

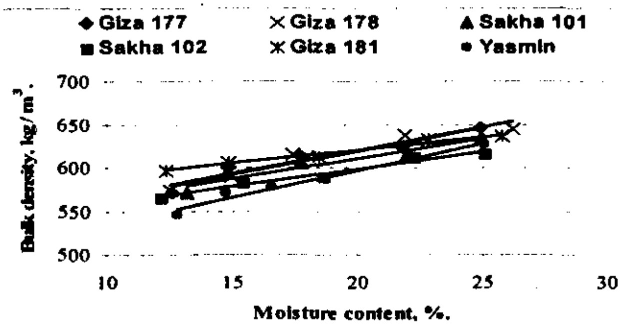

Fig. (4) : Effect of grain moisture content on grain bulk density at loose fill for the investigated rice varieties.

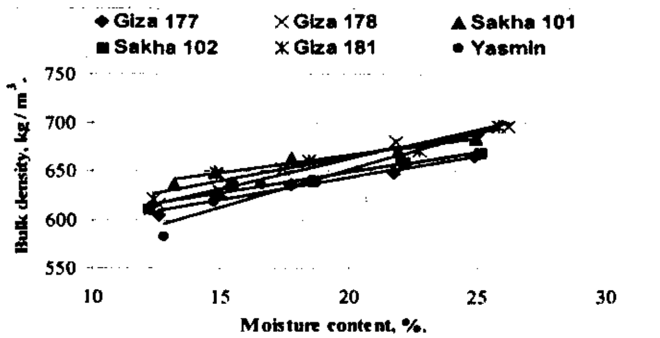

Fig. (5): Effect of grain moisture content on grain bulk density at vibrated fill for the investigated rice varieties.

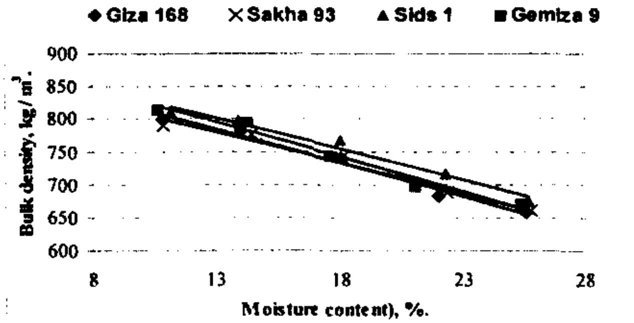

Fig. (6): Effect of grain moisture content on grain bulk density at loose fill for the investigated wheat varieties.

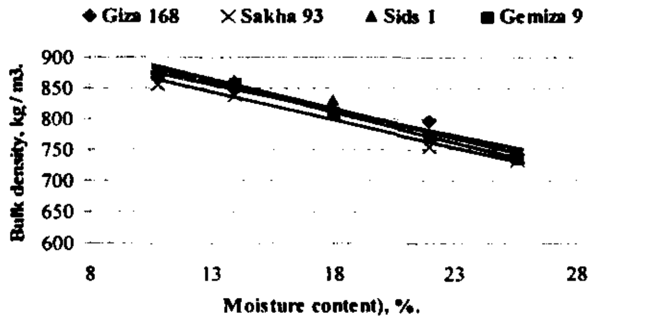

Fig. (7): Effect of grain moisture content on grain bulk density at vibrated fill for the investigated wheat varieties.

In contrast, the bulk density of wheat at loose and vibrated fills decreased with the increasing of grain moisture content for all studied varieties. As shown in figures (6 and 7), Sids 1 variety recorded the highest values of bulk density, which decreased from 808.59 to 673.72 kg/m^3 and from 876.94 to 742.62 kg/m^3 with the increasing of grains moisture content from 11.17 to 25.7% at loose and vibrated fills respectively. Meanwhile, Sakha 93 showed the lowest values of bulk density, which decreased from 789.85 to 659.57 kg/m^3 and from 865.00 to 731.7 kg/m^3 with the increasing of grains moisture content from 10.87 to 25.77% at loose and vibrated fills respectively.

For corn varieties, the bulk density at loose and vibrated fills also decreased with the increasing of grain moisture content for all the studied varieties. As shown in figures (8 and 9), Balady variety recorded the highest values of bulk density, which decreased from 784.69.79 to 730.61 kg/m^3 and from 820.48 to 786.91 kg/m^3 for the increasing of grains moisture content from 10.40 to 26.65% at loose and vibrated fills respectively. Meanwhile, Triple hybrid 310 showed the lowest values of bulk density, which decreased from 762.44 to 653.22 kg/m^3 and from 788.66 to 721.50 kg/m^3 with the increasing of grains moisture content from 9.92 to 26.24% at loose and vibrated fills respectively.

For barley crop, figures (10 and 11) illustrate the relationship between grain moisture content and bulk density for different studied barley varieties. The bulk density of barley decreased with the increasing of grains moisture content for both loose and vibrated fills. In general, Giza 123 variety showed the highest values of bulk density which decreased from 630.65 to 572.18 kg/m^3 and from 692.90 to 655.80 kg/m^3 with the increasing of grain moisture content from 11.81 to 24.58% at loose and vibrated fills receptively. Meanwhile, Giza 125 variety showed the lowest values of bulk density which decreased from 606.90 to 533.44 kg/m^3 and from 663.97 to 607.39 kg/m^3 with the increasing of grain moisture content from 11.95 to 24.71% at loose and vibrated fills receptively.

True density of grains

The effect of grain moisture content on true density of different rice varieties is shown in figure (12). The true density increased with the increasing of grain moisture content for all studied varieties. The figure also shows that long grain varieties (Yasmin and Giza 181) recorded the highest values of true density as compared with short grain varieties. The true density of Yasmin variety increased from 1180.36 to 1262.23 kg/m^3 with the increasing of grain moisture content from 12.80 to 25.11%. The corresponding values for Giza 181 were (1202.81 to 1249.07 kg/m^3) for increasing grains moisture content from 12.39 to 25.82%. On the other hand, Sakha 102 variety recorded the lowest values of true density, which increased from 1075.36 to 1192.07 kg/m^3 with the increasing of grain moisture content from 12.17 to 25.09%.

Figures (13, 14 and 15) show the effect of grains moisture content on true density for wheat, corn and barley varieties respectively. Thefigures show that for these varieties, the true density decreased with the increasing of grain moisture content. This could be attributed to the increase of grain mass in a higher rate than

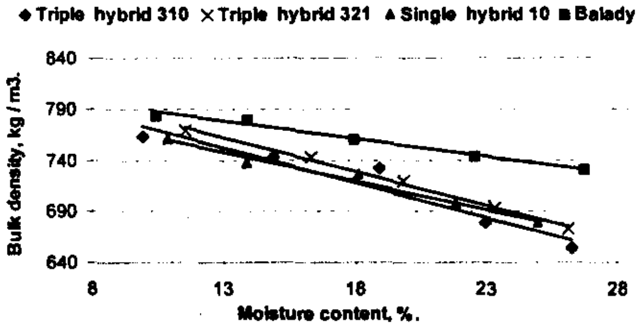

Fig. (8) : Effect of grain moisture content on grain bulk density at loose fill for the investigated corn varieties.

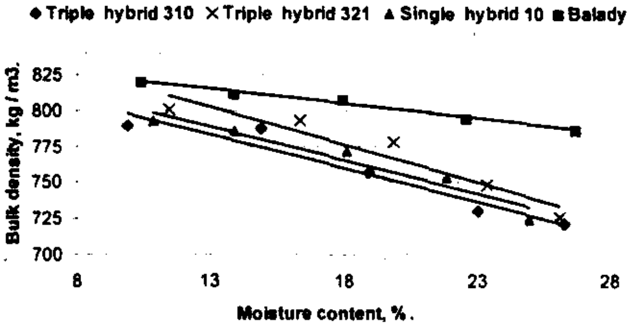

Fig. (9) : Effect of grain moisture content on grain bulk density at vibrated fill for the investigated corn varieties.

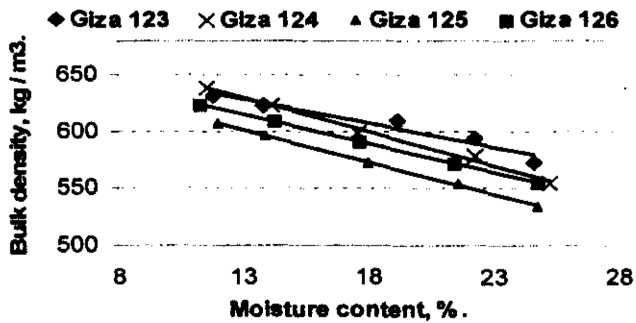

Fig. (10) : Effect of grain moisture content on grain bulk density at loose fill for the investigated barley varieties

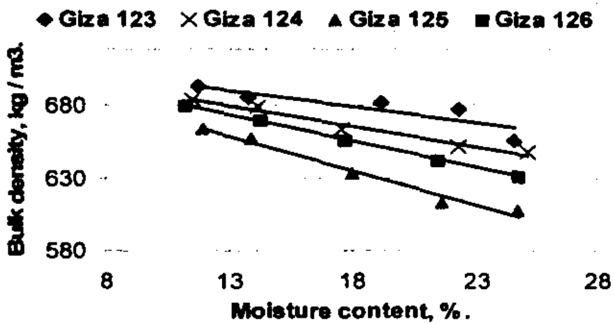

Fig. (11) : Effect of grain moisture content on grain bulk density at vibrated fill for the investigated barley varieties.

the increase in grain principal dimension which lead to an inversely relationship between the true density and moisture content. For wheat crop figure, (13) shows that Giza 168 variety recorded the highest value of true density, which decreased from 1394.44 to 1260.28 kg/m^3 with the increasing of grains moisture content from 10.85 to 24.14%. While, Sakha 93 showed the lowest values of true density, which decreased from 1349.22 to 1231.51 kg/m^3 with the increasing of grains moisture content from 10.87 to 24.86%.

For corn crop, figure (14) shows that Balady variety recorded the highest values of true densities, which decreased from 1303.79 to 1232.03 kg/m^3 with the increasing of grain moisture content from 10.40 to 25.93%. Meanwhile Triple hybrid 310 variety showed the lowest values of true density, which decreased from 1237.55 to 1174.21 kg/m^3 with the increasing of grains moisture content from 9.95 to 27.74%.

Similarly, figure (15) shows that for barley, Giza 123 variety recorded the highest values of true density which decreased from 1390.31 to 1147.06 kg/m^3 with the increasing of grains moisture content from 11.81 to 24.68%. Meanwhile, Giza 124 variety recorded the lowest values, which decreased from 1258.89 to 1155.10 kg/m^3 with the increase of grain moisture content from 11.51 to 24.67%.

Grain porosity

Grain porosity was also determined at loose and vibrated grain fill conditions. Figures (16 and 17) show the relationship between porosity and moisture contents of different rice varieties filled under loose and vibrated conditions, respectively. Grain porosity decreased with the increasing of grain moisture content for all studied varieties. The observed reduction in grain porosity with the increase of grain moisture content could be attributed to the increase in principal dimensions of grain and the resulted reduction in void area between grains. The figures also show that the values of porosity at loose fill condition was lower than that at vibrated fill for all varieties.

In contrast, the grain porosity increased with the increasing of grain moisture content at loose and vibrated fill conditions for all wheat varieties. As shown in figures (18 and 19), Giza 168 variety recorded the highest values of porosity, which increased from 44.35 to 50.80% for loose fill condition and from 40.57 to 46.15% for vibrated fill condition with the increasing of grains moisture content from 10.85 to 25.56%. Meanwhile, Gemiza 9 variety recorded the lowest values of porosity, which ranged from 42.96 to 47.54% and from 40.14 to 45.00% at loose and vibrated fills respectively with the increasing of grains moisture content from 10.60 to 25.40%.

For corn crop, the porosity at loose and vibrated fill conditions increased with the increasing of grain moisture content for all studied varieties. As shown in figures (20 and 21), Single hybrid 10 variety showed the highest values of porosity, which increased from 45.97 to 51.56% and from 43.61 to 48.44% with the increasing of grains moisture content from 10.87 to 24.94% at loose and vibrated fills respectively. Meanwhile, Balady variety resulted in the lowest values of

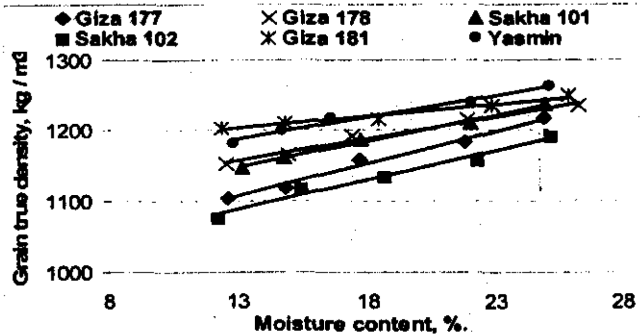

Fig. (12) : Effect of grain moisture content on grain true density for the investigated varieties of rice.

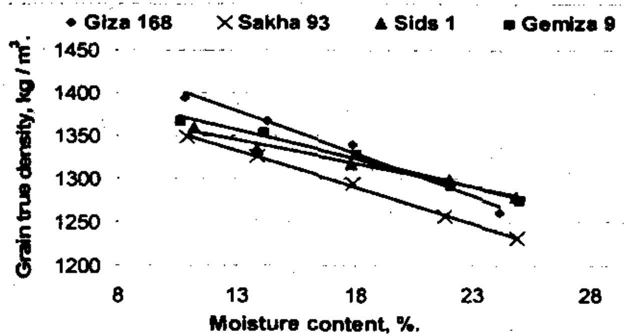

Fig. (13) : Effect of grain moisture content on grain true density for the investigated varieties of wheat.

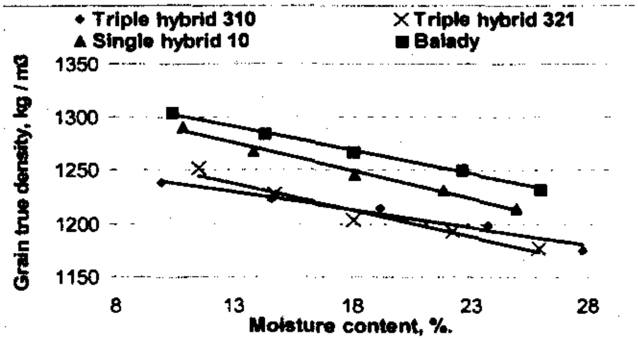

Fig. (14) : Effect of grain moisture content on grain true density for the investigated varieties of corn.

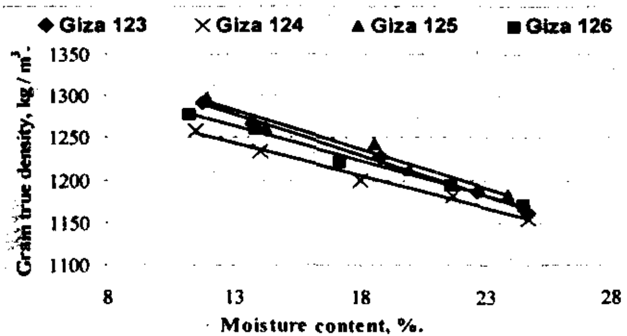

Fig. (15) : Effect of grain moisture content on grain true density for the investigated varieties of barley.

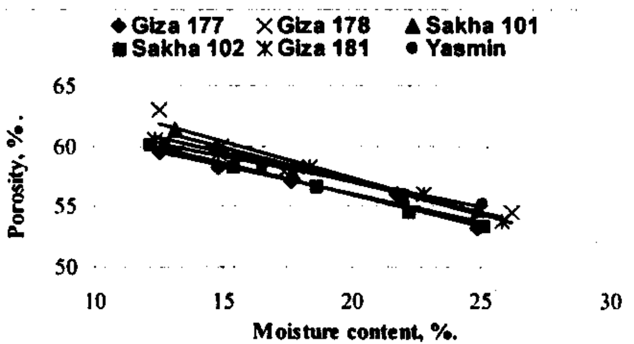

Fig. (16) : Effect of grain moisture content on grain porosity at loose fill for the investigated rice varieties.

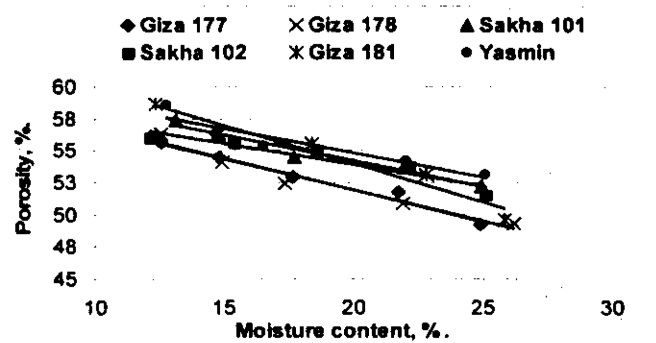

Fig. (17) : Effect of grain moisture content on grain porosity at vibrated fill for the investigated rice varieties.

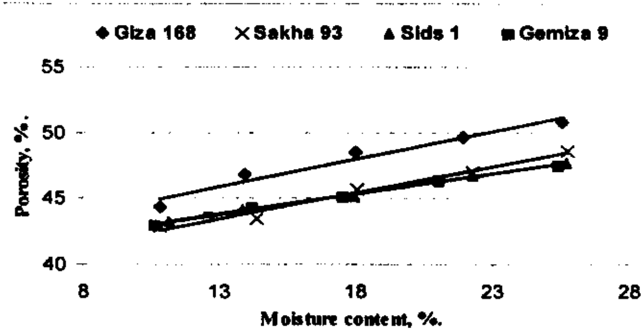

Fig. (18) : Effect of grain moisture content on grain porosity at loose fill for the investigated wheat varieties.

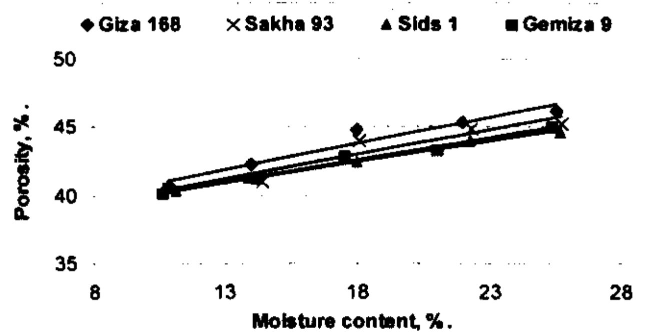

Fig. (19) : Effect of grain moisture content on grain porosity at vibrated fill for the investigated wheat varieties.

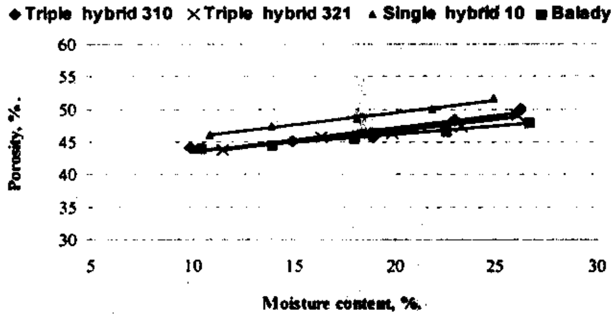

Fig. (20) : Effect of grain moisture content on grain porosity at loose fill for the investigated corn varieties.

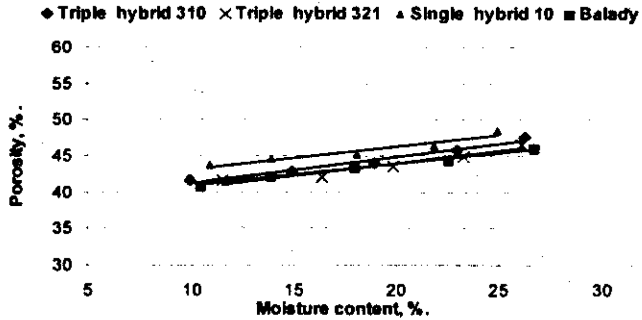

Fig. (21) : Effect of grain moisture content on grain porosity at vibrated fill for the investigated corn varieties.

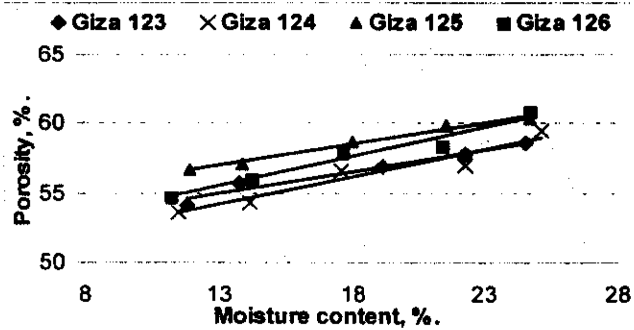

Fig. (22) : Effect of grain moisture content on grain porosity at loose fill for the investigated barley varieties.

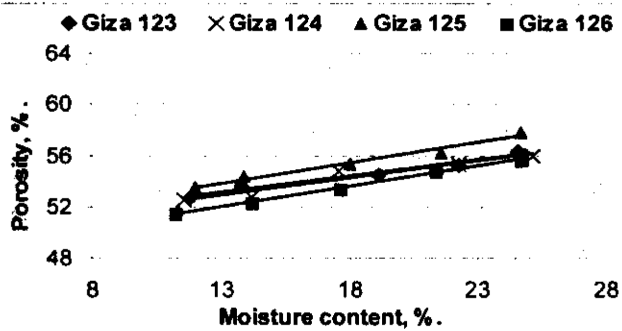

Fig. (23) : Effect of grain moisture content on grain porosity at vibrated fill for the investigated barley varieties.

porosity, which increased from 43.97 to 48.00% and from 40.88 to 46.03 with the increasing of grains moisture content from 10.40 to 26.65% at loose and vibrated fills respectively.

For barley figures (22 and 23) show the relationship between grains moisture content and. porosity for different studied varieties. The figures show that, grain porosity increased with the increasing of grain moisture content at loose and vibrated fill conditions. In general, Giza 125 variety recorded the highest values of porosity, which increased from 56.70.97 to 60.30% and from 53.50 to 57.80% with the increasing of grains moisture content from 11.95 to 24.71% for loose and vibrated fills respectively. Meanwhile, Giza 126 variety recorded the lowest values of porosity, which increased from 54.70 to 60.80% and from 51.40 to 55.60% with the increasing of grains moisture content from 11.22 to 24.72% at loose and vibrated fills respectively.
A simple linear regression analyses was applied to relate the change in bulk density, true density and porosity with the change in grain moisture content for all crops. The obtained regression equation was in the form of:
$Y = a + b X$
The regression parameters (a and b) for all the regression equations are tabulated in table 1 through 12.

Table (1): Regression parameters of equations relating the change in grain moisture contents (M.C %, w.b) with bulk density of different rice varieties at loose and vibrated fill conditions.

Variety	Grain M.C	Regression parameters (Loose fill)			Regression parameters (Vibrated fill)		
		a	b	R^2	a	b	R^2
Giza 177	12.58 to 24 90	511.80	5.3578	0.938	551.81	4.5481	0.969
Giza 178	12.56 to 26.22	512.49	5.3467	0.927	541.23	6.0527	0.978
Sakha 101	13.18 to 24.95	517.09	4.6855	0.930	593.65	3.5807	0.957
Sakha 102	12.17 to 25.09	518.75	3.9599	0.969	563.13	4.2652	0.962
Giza 181	12.39 to 25.82	558.93	5.0608	0.978	565.75	4.9390	0.941
Yasmin	12.80 to 25.11	473.13	6.1631	0.976	498.13	7.6063	0.938

Table (2): Regression parameters of equations relating the change in grain moisture contents (M.C %, w.b) with bulk density of different wheat varieties at loose and vibrated fill conditions.

Variety	Grain M.C	Regression parameters (Loose fill)			Regression parameters (Vibrated fill)		
		a	b	R^2	a	b	R^2
Giza 168	10.85 to 25.56	918.66	-10.329	0.981	965.12	-8.3297	0.966
Sakha 93	10.87 to 25.77	900.79	-9.3063	0.980	961.09	-8.9365	0.977
Sids 1	11.17 to 25.70	923.86	-9.4288	0.975	992.34	-9.6460	0.983
Gemiza 9	10.60 to 25.40	932.09	-10.559	0.973	988.85	-10.052	0.982

Table (3): Regression parameters of equations relating the change in grain moisture contents (M.C %, w.b) with bulk density of different corn varieties at loose and vibrated fill conditions.

Variety	Grain M.C	Regression parameters (Loose fill)			Regression parameters (Vibrated fill)		
		a	b	R2	a	b	R2
Triple Hybrid 310	9.92 to 26.24	841.36	-6.8724	0.926	843.51	-4.6637	0.924
Triple Hybrid 321	11.50 to 26.08	848.04	-6.6294	0.993	870.17	-5.2141	0.910
Single Hybrid 10	10.87 to 24.94	820.18	-5.5938	0.981	848.65	-4.6320	0.936
Balady	10.40 to 26.65	824.04	-3.5057	0.988	841.99	-2.0665	0.984

Table (4): Regression parameters of equations relating the change in grain moisture contents (M.C %, w.b) with bulk density of different barely varieties at loose and vibrated fill conditions.

Variety	Grain M.C	Regression parameters (Loose fill)			Regression parameters (Vibrated fill)		
		a	b	R^2	a	b	R^2
Giza 123	11.81 to 24.58	682.06	-4.1735	0.939	720.29	-2.2648	0.874
Giza 124	11.51 to 25.17	705.94	-5.9363	0.993	716.79	-2.8218	0.977
Giza 125	11.95 to 24.71	674.69	-5.6731	0.998	720.92	-4.7663	0.980
Giza 126	11.22 to 24.72	681.07	-5.0987	0.999	721.95	-3.6744	0.999

Table (5): Regression parameters of equations relating the change in grain moisture contents (M.C %, w.b) with porosity of different rice varieties at loose and vibrated fill conditions.

Variety	Grain M.C	Regression parameters (Loose fill)			Regression parameters (Vibrated fill)		
		a	b	R^2	a	b	R^2
Giza 177	12.58 to 24 90	65.338	-0.4658	0.958	61.874	-0.4963	0.978
Giza 178	12.56 to 26.22	69.290	-0.5954	0.925	61.671	-0.4888	0.954
Sakha 101	13.18 to 24.95	68.311	-0.5607	0.976	62.290	-0.4055	0.953
Sakha 102	12.17 to 25.09	66.539	-0.5296	0.998	60.567	-0.3321	0.897
Giza 181	12.39 to 25.82	66.830	-0.4910	0.981	65.992	-0.6026	0.947
Yasmin	12.80 to 25.11	65.489	-0.4196	0.978	62.504	-0.3846	0.893

Table (6): Regression parameters of equations relating the change in grain moisture contents (M.C %, w.b) with porosity of different wheat varieties at loose and vibrated fill conditions.

Variety	Grain M.C	Regression parameters (Loose fill)			Regression parameters (Vibrated fill)		
		a	b	R^2	a	b	R^2
Giza 168	10.85 to 25.56	40.471	0.4160	0.961	36.945	0.3788	0.933
Sakha 93	10.87 to 25.77	38.214	0.3980	0.980	36.571	0.3563	0.914
Sids 1	11.17 to 25.70	39.845	0.3036	0.996	36.960	0.3040	0.995
Gemiza 9	10.60 to 25.40	39.770	0.3080	0.997	36.745	0.3242	0.982

Table (7): Regression parameters of equations relating the change in grain moisture contents (M.C %, w.b) with porosity of different corn varieties at loose and vibrated fill conditions.

Variety	Grain M.C	Regression parameters (Loose fill)			Regression parameters (Vibrated fill)		
		a	b	R^2	a	b	R^2
Triple Hybrid 310	9.92 to 26.24	39.725	0.3697	0.922	37.616	0.3597	0.968
Triple Hybrid 321	11.50 to 26.08	39.733	0.3465	0.972	37.111	0.3402	0.931
Single Hybrid 10	10.87 to 24.94	41.773	0.3833	0.990	39.694	0.3154	0.929
Balady	10.40 to 26.65	41.134	0.2497	0.984	37.868	0.3016	0.989

Table (8): Regression parameters of equations relating the change in grain moisture contents (M.C %, w.b) with porosity of different barely varieties at loose and vibrated fill conditions.

Variety	Grain M.C	Regression parameters (Loose fill)			Regression parameters (Vibrated fill)		
		a	b	R^2	a	b	R^2
Giza 123	11.81 to 24.58	50.885	0.3110	0.957	49.841	0.2511	0.961
Giza 124	11.51 to 25.17	48.965	0.3976	0.936	49.374	0.2693	0.925
Giza 125	11.95 to 24.71	53.094	0.2998	0.987	49.755	0.3142	0.979
Giza 126	11.22 to 24.72	49.984	0.4225	0.964	47.811	0.3189	0.997

Table (9): Regression parameters of equations relating the change in grain moisture contents (M.C %, w.b) with the true density of different rice varieties at loose and vibrated fill conditions.

Variety	Grain M.C	Regression parameters		
		a	b	R^2
Giza 177	12.58 to 24 90	511.80	5.3578	0.938
Giza 178	12.56 to 26.22	512.49	5.3467	0.927
Sakha 101	13.18 to 24.95	517.09	4.6855	0.930
Sakha 102	12.17 to 25.09	518.75	3.9599	0.969
Giza 181	12.39 to 25.82	558.93	5.0608	0.978
Yasmin	12.80 to 25.11	473.13	6.1631	0.976

Table (10): Regression parameters of equations relating the change in grain moisture contents (M.C %, w.b) with the true density of different wheat varieties at loose and vibrated fill conditions.

Variety	Grain M.C	Regression parameters		
		a	b	R^2
Giza 168	10.85 to 24.14	918.66	-10.329	0.981
Sakha 93	10.87 to 24.86	900.79	-9.3063	0.978
Sids 1	11.17 to 24.85	923.86	-9.4288	0.975
Gemiza 9	10.60 to 24.92	932.09	-10.559	0.973

Table (11): Regression parameters of equations relating the change in grain moisture contents (M.C %, w.b) with the true density of different corn varieties at loose and vibrated fill conditions.

Variety	Grain M.C	Regression parameters		
		a	b	R^2
Triple Hybrid 310	9.95 to 27.74	841.36	-6.8724	0.926
Triple Hybrid 321	11.50 to 25.90	848.04	-6.6294	0.993
Single Hybrid 10	10.87 to 24.94	820.18	-5.5938	0.981
Balady	10.40 to 25.93	824.04	-3.5057	0.988

Table (12): Regression parameters of equations relating the change in grain moisture contents (M.C %, w.b) with the true density of different barley varieties at loose and vibrated fill conditions.

Variety	Grain M.C	Regression parameters		
		a	b	R^2
Giza 123	11.81 to 24.68	682.06	-4.1735	0.939
Giza 124	11.51 to 24.67	705.94	-5.9363	0.993
Giza 125	11.95 to 23.87	674.69	-5.6731	0.998
Giza 126	11.22 to 24.41	681.07	-5.0987	0.999

CONCLUSIONS

1-Physical properties of the studied four different crops were found to be dependent upon grain moisture contents.

2-Bulk density at loose and vibrated fill conditions was found to be inversely proportional to grain moisture content for the studied varieties of wheat, corn and barley, while it was directly proportional to grain moisture content for rice varieties.

3-True density for rice varieties increased with the increasing of grain moisture content, while it was decreased for barley, corn and wheat varieties.

4-Grain porosity at loose and vibrated fill conditions decreased with the increasing of grain moisture content for rice varieties. Meanwhile, it was increased with the increasing of grain moisture content for wheat, corn and barely varieties.

5-Grain porosity at loose fill condition was lower than that of vibrated fill condition for all studied crops.

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تعيين الكثافة والمسامية لحبوب بعض المحاصيل

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تضمنت الدراسة تعيين بعض الخواص الطبيعية لمحاصيل (الأرز – القمح – الذرة – الشعير) والتى تضمنت الكثافة الحقيقية والكثافة الظاهرية والمسامية للأصناف المختلفة التى تم اختيارها وذلك عند مدى من المحتويات الرطوبية يشمل مراحل الحصاد والتداول المختلفة لتلك المحاصيل.

وقد أظهرت النتائج أن العلاقة بين التغير فى المحتوى الرطوبى وكلا من الكثافة الحقيقية،الكثافة الظاهرية علاقة خطية عكسية لمحاصيل الذرة، القمح، الشعير وعلى العكس من ذلك كانت العلاقة بين التغير فى المحتوى الرطوبى للحبوب وكلا من الكثافة الحقيقية، الكثافة الظاهرية لمحصول الأرز علاقة خطية طردية وذلك نتيجة لتغير الأبعاد الرئيسية لحبوب الأرز بتغير المحتوى الرطوبى بصورة اختلفت عن محاصيل الذرة، القمح والشعير.

من ناحية أخرى تناقصت مسامية الحبوب في حالتي الملء الحر والملء تحت ظروف الاهتزاز بزيادة المحتوى الرطوبي لأصناف الأرز المختلفة، بينما زادت المسامية بزيادة المحتوى الرطوبي للحبوب وذلك للأصناف المختلفة في محاصيل القمح والذرة والشعير. وبصفة عامة كانت مسامية الحبوب في حالة الملء الحر أقل منها في حالة الملء تحت ظروف الاهتزاز لجميع المحاصيل.

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