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PHYSICAL AND MECHANICAL PROPERTIES OF WHEAT GRAIN AFFECTED BY DIFFERENT STORAGE METHODS

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ABSTRACT: Wheat production and storage have become one of the most important issues facing Egypt at present and in the future due to the lack of suitable storage structures, which leads to large losses in food grains. The study was conducted to investigate the changes that may occur in some physical and mechanical properties of wheat grain during storage for 12 months in different vertical cylindrical silos with identical dimensions and sizes. Silos materials were Fiberglass, (FG), Plastic (PE), and galvanized steel (GS) and they were provided with mechanical aeration Strategy. Physical characteristics included grain moisture content, linear dimensions, geometric mean diameter, arithmetic mean diameter, volume, calculated surface area, sphericity, weight of one thousand grains, particle, bulk density and porosity. Mechanical properties included angle of repose, static shear stress, hardness and coefficient of static friction against three structural surfaces (plywood, galvanized iron, and rubber). Samples were analyzed before storage and after every 2 months during the storage period. Results showed that grain's moisture contents followed a fluctuating course for 360 days depending on the different storage methods. length (L), width (W), thickness (T) were influenced by the variation in the grain moisture content during the storage period. Geometric properties Arithmetic means diameter (Da), geometric mean diameter (Dg), sphericity (φ), grain surface area (Sa), and grain volume (V) have shown parallel changes to L, W, and T values. there was diversity in hardness, shear stress, angle of repose and the coefficient of friction on all surface (plywood, galvanized iron, and rubber) of stored grain this variation related to moisture variations during storage periods

Keywords: Wheat storage, fiberglass silo, plastic silo, galvanized steel silo, physical properties, Mechanical properties

INTRODUCTION

Wheat is a major food source for humans for being the basic raw material for the production of flour used in making bread. Bread is a staple food for more than three quarters of the global population. It's one of the most important components of Egypt's food security.it is consumed at a high level to feed the Egyptian individual because it is relatively cheap compared to other carbohydrate sources. In Egypt, wheat is grown on about 1.4 million ha in 2020, the average yield was about 6.42 tons/ha. *MALR, (2021*). Egypt remains the largest importer of wheat in the world, in 2019/2020, it imported about 12.80 million tons of wheat (about 53% of the total supply), and it is expected to rise to 12.85 million tons in 2021 USDA, (2020). The majority of government storage is in a system of traditional flat storage called (Shona). This basic system of storage in the Shona is extremely wasteful. The burlap bags often tear and leave wheat vulnerable to weather and pests. This results in high percentage of losses of wheat and reduces its quality. While there are no official estimates available of the quantitative losses at the Shona, these are believed to be in the range of 10-20 %. In this regard the current vertical steel silos in Egypt capacities can't encompass more than 20% of the country's wheat crop. The other 80 % is stored in open sites Matouk et al., (2017). Now days the national project of silos is considered one of the national projects that the state has paid special attention to and allocated to it private funding and all kinds of support for its modernization and development .This beside the construction of new silos for storing and preserving wheat and providing health and technical requirements that ensure the preservation of Egypt's food wealth and achieving self-sufficiency from it through minimizing losses and conserving the quality SIS, (2021). Grain temperature and moisture content during storage are influenced by many factors such as type of crop, initial grain temperature and moisture

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content, harvest date, bin size, and it's wall material, solar radiation and ground reflection, weather conditions (temperature, relative humidity, wind velocity and direction) Johnselvakumar and Dirk, (2011). Aeration is a process of great relevance to post-harvest engineering and cereal storage control. It reduces the risk of product degradation and helps control insect infestations and moisture migration, also it reduces grain damage and saving money Anişoara et al., (2021). The physical and mechanical properties of grains are important in designing of warehouses and silos and storage structures and for the proper design and development of harvest and postharvest processing equipment's. Knowledge of size, shape of cereal grain is helpful in threshing, separating and cleaning the grains from undesirable materials and hence in the proper design of combines and sizing machines. The bulk density, true density, porosity, Frictional properties and angle of repose are important parameters in the design of silos, bins, hoppers, and storage structures. surface area and volume values of the grains can be helpful in cooking, aeration and artificial drying processes. The thousand grain weights, can be used to determine the potential flour yield for stored wheat grain, Rupture force and deformation properties of the grains are useful in milling process for adjusting the grinding equipment's according to the hardness of the grain. Kalkan and Kara, (2011). Several studies on wheat have been conducted using different storage methods to study the changes that may occur in its physical and mechanical properties during storage for example, Hakan, (2015) studied how storage time (0–90 days) and temperature (10, 12 and 14 C°) affect the functional properties of wheat grains under typical storage conditions. The summary of the results was as follows, the moisture content of wheat grains, length, width and thickness, Thousand-grain weight and bulk density decreased with increases in storage time and temperature, and the changes in the storage time and temperature have minimal effect on the angle of repose of the stored wheat. The static coefficient of friction on the material surfaces decreased with increases in storage time and temperature. For all of the storage times, the static coefficient of friction was greatest on the concrete, followed by the wood and sheet metal, and was least on the galvanized steel. Dattatreya et al., (2016) studied the effect of different storage receptacles like silo bag, metal containers, plastic tank and in sacks on some physical and mechanical properties of wheat grains like moisture content, 1000-grain weight, bulk density, angle of repose and angle of friction for a period of 180 days. The results revealed decrease in moisture content, 1000-grain weight, bulk density, angle of repose and angle of friction in all the storage receptacles. the results showed that no significant ($P<0.05$) difference was observed between the storage receptacles under the study period. Hakan and İlker, (2020) studied the effect of different storage conditions adopted in room conditions with storage duration (initial, 60th, 120th, 180th, 240th, 300th, and 360th days) and temperatures (4°C, 10°C, and 20°C). on functional properties such as Thousand-grain weight, bulk, true densities, angle of internal friction and repose angle and dimensions properties such as length (L) width (W), thickness (T), Arithmetic means diameter (Da), geometric mean diameter (Dg), sphericity (φ), seed surface area (Sa), and seed volume (Sv) of einkorn wheat seeds during a storage period of 360 days. They found that the seed moisture contents (MC) followed a fluctuating course for 360 days depending on the storage period and temperature. Thousand-grain weight, bulk density, true density, repose angle and angle of internal friction also varied depending on the change in seed moisture content, the dimensional properties such as length (L) width (W) and thickness (T) have changed due to increases or decreases in seed moisture content. Because when the seed gains moisture, it expands by swelling and changes its shape. The geometric properties of Da, Dg, Sa, and Sv have shown parallel changes to L, W, and T values. the results showed that differences depending on storage duration and temperatures for L, W, T, Da, Dg, Sa, and Sv values were statistically significant at $p < .01$. The objective of this study was to evaluate the effects of storage duration and storage methods on change of some physical and mechanical properties of stored wheat grain.

MATERIALS AND METHODS

1. Experimental site and wheat grains

The experiment was conducted for 12 months during the period from (June 2020, to June 2021) at the Department of Agricultural, Bio systems Engineering., Faculty of Agriculture, Menoufia University, Shibin El-Kom, latitude angle 30º 54' North Egypt. Freshly harvested grains of wheat variety (Giza 171) were obtained from the 2020 harvest season.

2. Wheat storage silos design and fabrication

Three types of vertical cylindrical wheat storage silos with identical dimensions and sizes were designed and constructed for this study. The types of silos included; fiberglass (FG), plastic (PE), and galvanized steel (GS) silo. They were manufactured in Sadat City, Menoufia Governorate. Silos can be considered smooth-walled silos. The silos were 80 cm in diameter and 120 cm high, with a wall thickness of 2 mm with discharging opening diameter of 4-inch and a capacity of 340 kg. Silos have been developed and designed to be mobile provided with four wheels' square metal frame-stand with supports of metal-angles, columns, bars, and ring-beams 50 cm high from the ground level to provide protection from moisture or rainwater, the wheels have been designed for repositioning the silos easily if the need arises as shown in Figure (1). Silos were filled with the grains at the 10.50 % moisture content (wet basis) after it was cleaned manually to remove all foreign matter such as dust, dirt, stones, and chaff as well as immature, broken seeds, and the pre-storage tests were done.

3. Aeration system

The aeration strategy used was based on operating fans for 4 h during the morning (5:00 to 9:00 a.m.) and evening (7:00 to 11:00 p.m.). with an airflow of 0.11 m^3 min^{-1} t^{-1}, during the Summer holding period from (June to September) and evening (5:00 to 9:00 p.m.) during Spring warm-up period from March to June. and There was no ventilation during the Winter holding period from the period (October to March). each silo was equipped with a mechanical ventilation system at the bottom of the silo. The aeration system consisted of a centrifugal fan blade run by a 0.5 hp engine, 2850 rpm. The fans were connected to the fan speed controller and placed in a device to restrict the entry of air, hence achieving the aeration airflow of 0.11 m^3. min^{-1}. t^{-1} as shown in Figure (2). The perforated floors were made of two perpendicular PVC tubes with a diameter of 3 inches and a length of 80 cm. Holes were made on vertical tubes of 5 mm in diameter and 40 mm apart between each hole. The tubes were surrounded by a plastic mesh as shown in Figure (3). The silo's roof had four outlet vents with a 2-inch diameter for air exhaust along the ridge pole of the roof in each silo. The air velocity was measured using hot wire anemometer inside a pipe (0.6m long × 7,62 cm diameter) attached to each aeration fan and the volume of airflow(m^3/min) was determined by multiplying the average velocity (m/min) by the cross-sectional area of the pipe (m^2), The number of hours the fan is turned on and off was automatically controlled by an analog timer and a power contactor as shown in figure (2).

4. Equipment and Measuring Procedures

4.1 Sampler probe

For analysis, the samples were drawn from the silos at three locations (bottom, middle and top layers) by using a sampler probe after every two months and then mixed completely to get a composite sample.

4.2 Grain Moisture Content

The wheat moisture content was determined using a moisture content meter (PM450 Moisture Meter) at the laboratory of Grain Quality, Al-Khattab Mills Company in Sadat City, Menoufia.

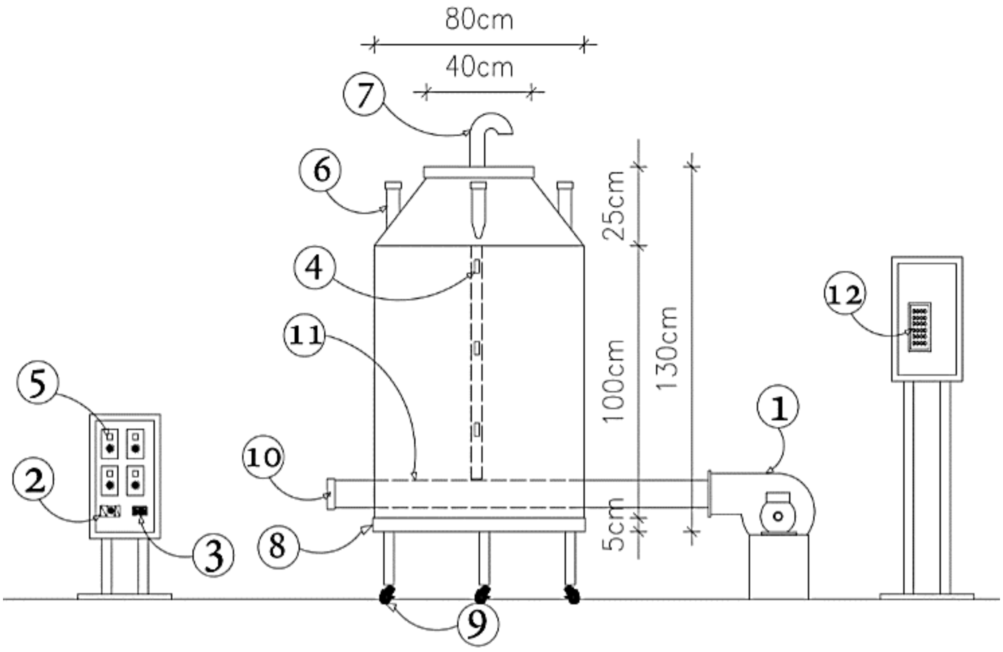

Figure (1): Schematic diagram showing the basic dimensions and components of the constructed storage silos components

1- centrifugal fan	**2- analog timer**	**3- power contactor**
4- T and RH sensor	**5- fan speed switch**	**6- sampling hole.**
7- air outlet	**8- mobile baise**	**9- wheels.**
10- discharge hole	**11- induct perforated floor**	**12- 2.4 TFT LCD Display Module**

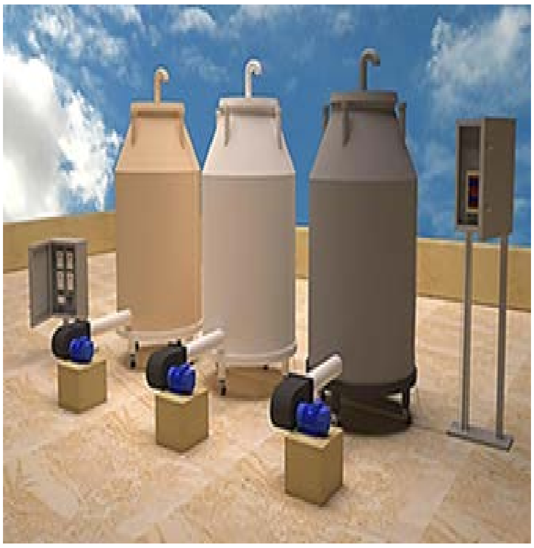

Figure (2): Storage system components

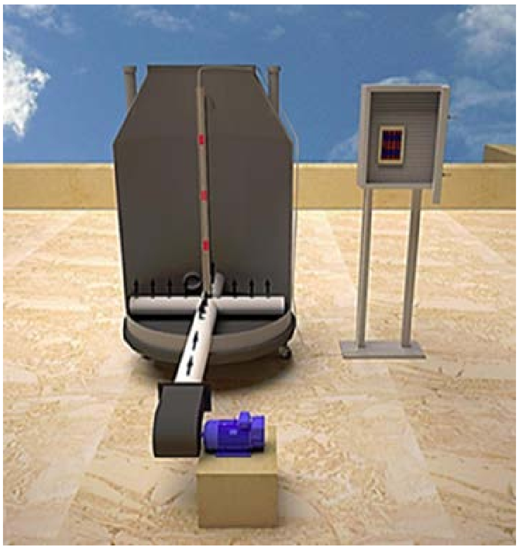

Figure (3): the direction of air movement

4.3 Dimensional Characteristics

Samples of (100) hundred grains from each silo every two months were randomly selected. The three linear dimensions of wheat grains, length (L), width (W), and thickness (T), were carefully measured using digital caliper with an accuracy of 0.01 mm. The obtained data were studied in terms of arithmetic means diameter (Da), geometric mean diameter (Dg), sphericity (φ), grain surface area (Sa), and grain volume (V) geometric mean. The arithmetic mean diameter (Da) and the geometric mean diameter (Dg), and grain volume (V) as the mean of the three dimensions, were calculated using the following expression (Ayman et al., 2010):

$Dg = (L*W*T)^{1/3}$ mm ……………….... (2.1)

$Da = (L+W+T) /3$ mm ….……….……. (2.2)

$V= \pi/6 (L*W*T)$, mm^3 ……………….…… (2.3)

According to Mohsenin (1986), the degree of sphericity (φ), and The surface area (S) can be expressed as equations (2.5).

$\varphi = \frac{(LWT)^{1/3}}{L}$ ……………………….……… (2.4)

$S = \pi Dg^2$……………………….……... (2.5)

4.4 Weight of one thousand grains:

Thousand kernel wheat (TKW) was measured by counting 100 seeds and weighing them in an electronic balance to an accuracy of .001g and then multiplied by 10 to give the mass of 1000 kernels the test was replicated five times and means values were calculated for the three silos.

4.5 True density:

True density (ρt). was measured by the liquid displacement method according to Eissa (2011). The true density calculated as the ratio of mass of seeds to the volume of displaced water. Five hundred millilitres of water were placed in a 1,000-mL graduated cylinder in which 20-g seeds were immersed. The immersion time was about 10 s that was too small to absorb water. The amount of displaced water was recorded from the graduated scale of the cylinder. The ratio of weight of seeds to the volume of displaced water gave the true density. The test was replicated three times and means values were calculated for the three silos as follows:

$\rho t = M / V_t$, Kg/m^3…………….… (2.7)

Where:

ρ_t is the true density of the bulk seeds, Kg/m^3;

M weight of the bulk seeds, Kg;

V_t real volume of the bulk seeds, m^3.

4.6 Bulk density:

The bulk density (ρb) measurement was conducted by measuring the kernel's mass using a digital balance and then measuring the total volume in a graduated cylinder. The bulk density was calculated as the ratio between the weight of the kernels and the volume in the cylinder. The test was replicated three times and means values were calculated for the three silos as follows:

$\rho b = M / V_b$ Kg/m^3……………….…. (2.8)

Where:

ρb is the bulk density of the bulk seeds, Kg/m^3;

M weight of the bulk seeds, Kg;

V_b volume of the weight sample of bulk seeds, m^3.

4.7 Porosity:

Porosity (P) was calculated as the relationship between the bulk density (ρb) and the true density (ρt) according to (Mohsenin, 1986) as follows:

$P = \frac{\rho_t - \rho_b}{\rho_t} * 100$, %……………… (2.9)

Where:

P is the porosity of seeds, %;

ρt the real density of the bulk seeds, Kg/m^3;

ρb is the bulk density of the bulk seeds, Kg/m^3.

The obtained values are the average of the three replications

4.8 Rupture strength:

Rupture strength was measured according to (Ayman et al., 2010). A rupture strength meter was used with an accuracy 0.1-Kg. The sharp end with 1 mm diameter of the penetrometer pressed a grain; meanwhile, the analog reading was increased with the increasing of the pressure on the grain until the seed has been cracked. At this point, the analog reading means seeds hardness. Only one reading was recorded of each seed for 100 seeds of the sample of wheat grains.

4.9 Seeds coefficient of friction:

The friction angle of stored wheat grain was measured on three surfaces (galvanized steel, rubber, and plywood plate) by a manual measuring device designed and fabricated in the laboratory of Department of Agricultural and Bio Systems Engineering, Faculty of Agricultural, Minufiya University. Seed samples were placed in the tray above the laboratory surface. During operation, the tray containing the seed sample was tilted around its side axis, and the friction angle was displayed when 75% of the seeds reached the bottom and the tray was stopped. The friction coefficient of the above samples is obtained from equation (2.10). The friction angle for seed samples was on average five replications.

According (Sharma et al., 2011), static coefficient of friction (μ) was calculated as the following formula:

$\mu = \tan \Phi$……………………………..… (2.10).

Where:

μ is the coefficient of friction

Φ = the angle of tilt.

4.10 Repose angle of seeds:

To measure the angle of repose, a specially constructed apparatus was used in which the kernels were left to flow freely and gently through a conical hopper to the base. According to (Ayman et al., 2010) a quantity of stored wheat grain was used to determine the repose angle. The seed was then poured under gravity from a suitable height to form a cone at the same spot. More seeds were let to be fallen on the top of the formed cone until the angle between the cone surface and the horizontal plan become constant. The angle between the cone surface and the horizontal plan was recorded to represent the repose angle of the seed. The recorded angle was the average of five replicates. The dynamic angle of repose was calculated by the following relationship:

$\theta = \tan^{-1}\left(\frac{2H}{DP}\right)$……………… (2.11)

θ = dynamic angle of repose, degree.
H = heap height, cm and
Dp = platform diameter, cm.

4.11 Static Shear Stress:

Static particle shear stress for wheat grains was measured using the apparatus developed by (Soliman et al., 2009) and fabricated locally. A selected grain from a randomly sample was put inside the suitable hole of the two discs. Then, the water was added slowly to the pail until the moving disc turned and the grain was cut as shown in Figure (4).

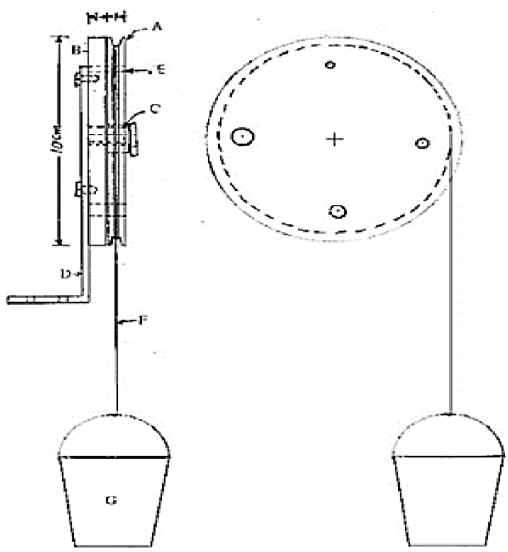

Figure (4): Static Shear Cell Apparatus.

A-Moving Disc B- Fixed Disc C- Ball Bearing D- Holder E- Hole F- Rope G- Water Bucket

The pail with water was weighed and the shear force was calculated as follows:

$F2 = \frac{F1 \times r1}{r2}$………………. (2.12)

Where: F_2 = shear force, kg
F1 = weight of the pail and water, kg
r_1 = the radius from disc center to groove bottom, cm
r_2 = the radius from disc center to hole center, cm
The cross-section area (Csa) of the grain was calculated as follows
Csa= (B x T x π)/4……. (2.13)

Where:
Csa = cross section area of grain, mm^2,
B = width of grain, mm,
T = thickness of grain, mm. The shear stress was calculated as follow:
$Ss = \frac{F2}{Csa}$……………. (2.14)

Where: Ss = shear stress, kg/mm^2,
F2 = shear force, kg,
Csa = cross section area of the grain, mm^2.

The particle shear stress for stored wheat grain was including twenty- five grains in four replicates.

RESULTS AND DISCUSSION

1. Effect of storage on some physical properties of stored grain

1.1 Effect of storage methods on grain Moisture content

The variations in the grain moisture content of the wheat taken from silos every two months are presented in Table (3 a). It was observed that grain's moisture contents followed a fluctuating course for 360 days depending on the different storage methods. the highest moisture contents 11.46 % was observed in the plastic silo followed by the Fiberglass 10.97 % and lowest value 10.63% was observed in Galvanized steel silo as shown in Table (2a). These differences across the silo type can be attributed to the effect of the silo manufacturing materials and their thermal conductivity, which in turn affect the temperatures and relative humidity inside silos which in turn cause changes in the moisture content of the stored grains. during the first four months of storage from June to October 2020, the moisture content of wheat grains decreased from initial value of 10.50 % in all three silos at varying rates, this might be due to the presence of the mechanical ventilation during this period. After the fifth month onwards up to the eight-month from October 2020 to the February 2021, moisture content of wheat readings inside all silos followed the increasing trend. This increased moisture content is attributed to the high relative humidity of storage silos during these months due to the high humidity of the of the surrounding air which resulted in the increase in moisture due to the hygroscopic nature of all stored grain, For the last four months from February 2021 to the first of June 2021, moisture content of wheat grain readings inside all silos followed decreasing. This might be due to the presence of mechanical ventilation during this period as mentioned before. Analysis of variance indicated highly significant differences for storage methods, storage period and interaction between them ($p > 0:01$) on the grain moisture content by two-way ANOVA as shown in Table (1a).

1.2 The linear dimensions and geometric properties of stored grain

Results of L, W, T, D g, Da, Sac, V and ϕ values analysis of samples taken from silos every two months are presented in Table (3 a). and (3b). After 12 months of storage the highest length, width, thickness values (6.65, 3.62mm, and 3.26 mm respectively) were observed in the plastic silo followed by the Fiberglass (6.61mm, 3.58 mm and 3.20 mm respectively) and lowest values (6.57 mm, 3.55 mm and 3.14 mm respectively) were observed in Galvanized steel silo as shown in Table (2a). (L, W, T) were influenced by the variation in the grain moisture content during the storage period and the dimensional properties have changed due to increases or decreases in seed moisture content. when seed gains moisture, it expands by swelling and changes its shape. In this case, it directly affects the dimensional properties of the grain and the geometric properties of D g, Da, Sac, V and ϕ have shown parallel changes to L, W, and T values. For the geometric properties of Da, Dg, Sa, V and ϕ of stored grain the highest Dg, Da, Sa, V and ϕ values (4.27, 4.51 mm, 57.40 mm^2, 41.07 mm^3 and 64.39 % respectively) were observed in the plastic silo followed by the Fiberglass silo (4.22, 4.47mm, 56.15 mm^2, 39.74 mm3 and 63.97 % respectively) and lowest values (4.17, 4.42 mm, 53.57 mm2, 37.49 mm3 and 63.69% respectively) were observed in Galvanized steel silo as shown in Table (2a) and (2b). Analysis of variance indicated significant differences for storage methods and storage period for length, width, thickness, geometric and arithmetic mean diameter, calculated surface area, Volume, and Sphersity of grain. interaction between them ($p > 0:01$) showed no significant differences for length, width, thickness, geometric and arithmetic mean diameter and sphersity while for calculated surface area and volume there were significant differences at ($P \leq 0.01$). on the grain moisture content by two-way ANOVA as shown in table (1a) and (1b).

1.3 1000-Grain Weight

Results of thousand-grain weight analysis of samples taken from silos regularly every two months are presented Table (3b). It was observed that there was diversity in the thousand-grain weight of the grains during storage. It was observed that among the silo types, the highest weight value of 52.89 g was found in the plastic silo with the highest moisture content followed by fiberglass silo at 52.82 g, and the lowest thousand-grain weight was 52.66 g in the Galvanized steel silo with the lowest moisture content as shown in Table (2b), Thousand-grain weight decreased to get the lowest value after 2 months of storage and, then continued to increase till 8 months to get the highest value. There was minimal variation in the thousand-grain weight of grain stored in different silos, which could be related to moisture minimal changes (gain or loss) during storage periods. As The higher the moisture content of grains, the greater the thousand-grain weight. These findings were in line with those of Hakan and İlker (2020). Analysis of variance indicated no significant differences for storage methods on 1000-grain weight, while storage duration had significant ($P<0.01$) effect on thousand-grain weight, and interaction between them was not significant ($p > 0:01$) on thousand-grain weight by two-way ANOVA as shown in Table (1b).

1.4 Bulk density, true density and porosity of stored grain

Results of bulk density, true density and porosity analysis of samples taken from silos regularly every two months are presented in Table (3b). For the bulk and true densities, the highest bulk and true densities values (810.48 and 1280.70 $kg{\cdot}m^{-3}$ respectively) were observed in the galvanized steel silo followed by the fiberglass silo (809.87, and 1279.77 $kg{\cdot}m^{-3}$ respectively), lowest values (809.19 and 1279.01 $kg{\cdot}m^{-3}$ respectively) were observed in the plastic silo. For the grain porosity the highest porosity value was observed in the plastic silo (36.73%) followed by the fiberglass silo (36.73%) and the lowest value was observed in galvanized steel silo (36.71 %) as shown in Table (2 b). It was noticed that there was diversity in bulk density, true density and porosity of grain stored in different silos. Bulk density, true density and porosity values increased or decreased in parallel with the change in moisture content of grains. In this increase or decrease, the weight and volume of the grain change as the grain gains or moisture loses which reflect on values of bulk density, true density and porosity during storage periods. Analysis of variance indicated no significant differences for storage methods, storage period and interaction between them ($p > 0:01$) on bulk density, true density and porosity by two-way ANOVA as shown in Table (1b).

Table (1a): Mean square, F value, and Probability of some physical properties of stored wheat grains in three different silos at different storage periods

Items	Moisture content M.C.%	Length (L) (mm)	Width(W) (mm)	Thickness(T) (mm)	Geometric diameter (Dg) (mm)	Arithmetic diameter (Da) (mm)
Mean square						
Silo type	6.342	1.047	0.763	2.571	1.659	1.350
storage period	5.590	.549	0.734	1.134	0.836	0.679
S*P	0.591	0.037	0.043	0.128	0.065	0.048
error	0.009	0.160	0.092	0.087	0.047	0.045
F value and probability						
Silo type	728.631	6.527	8.298	29.579	35.189	29.922
	**	**	**	**	**	**
storage period	642.266	3.420	7.991	13.044	17.735	15.046
	**	**	**	**	**	*
S*P	67.958	0.234	0.468	1.474	1.372	1.074
	**	N. S	N. S	N. S	N. S	N. S

Note: ** Significant at level P≤ 0.01, * significant at level P≤ 0.05, N.S. non-significant Were, S is silos types; P storage period

Table (1 b): Mean square, F value, and Probability of some physical properties of stored wheat grains in three types of storage silo at different storage periods.

Items	Surface area Sac /mm^2	Volume (V/mm^3)	Sphersity (ϕ/%)	Thousand seed weight (g)	True density(ρt) (kg·m^{-3})	Bulk density(ρb) (kg·m^{-3})	Porosity (P / %)
Mean square.							
Silo type	2678.753	2303.151	85.446	0.490	25.245	14.429	0.003
Storage period	420.398	502.077	65.632	1.394	34.955	19.522	0.016
S*P	295.536	214.462	10.603	0.029	1.367	1.534	0.003
error	33.296	38.279	15.185	0.127	23.677	27.407	0.222
F value and probability							
Silo type	80.452	60.167	5.627	3.865	1.066	0.526	0.014
	**	**	**	N. S	N. S	N. S	N. S
Storage period	12.626	13.116	4.322	10.997	1.476	0.712	0.072
	**	**	N. S	**	N. S	N. S	N. S
S*P	8.876	5.603	0.698	0.229	0.058	0.056	0.016
	**	**	N. S	N. S	N. S	N. S	N. S

Note: ** Significant at level P≤ 0.01, * significant at level P≤ 0.05, N.S. non-significant Were, S is silos types; P storage period

Table (2 a): Mean ± Standard error for some physical properties of stored wheat grains in three types of storage silo at different storage periods

items	Characteristics					
Silo	Moisture content M.C.%	Length (L) (mm)	Width (W) (mm)	Thickness (T) (mm)	Geometric diameter (Dg /mm)	Arithmetic diameter (Da/mm)
Fiber glass	10.97±0.016 ^{B}	6.61±.015^{A}	3.58±.011^{A}	3.20±.011^{B}	4.22±.008^{B}	4.47±.008^{B}
Plastic	11.46±0.016 ^{A}	6.65±.015^{A}	3.62±.011^{A}	3.26±.011^{A}	4.27±.008^{A}	4.51±.008^{A}
Galvanized steel	10.63±0.016 ^{c}	6.57±.015^{B}	3.55±.011^{B}	3.14±.011^{C}	4.17±.008^{C}	4.42±.008^{C}
Storage month						
June2020	10.50±0.024 ^{E}	6.64±.023^{AB}	3.54±.018^{BC}	3.15±.017^{D}	4.19±.013^{C}	4.44±.012^{B}
Aug,2020	10.36±0.024 ^{F}	6.54±.023^{C}	3.52±.018^{C}	3.10±.017^{E}	4.14±.013^{D}	4.39±.012^{C}
Oct,2020	10.43±0.024 ^{E}	6.57±.023^{BC}	3.55±.018 ^{BC}	3.16±.017^{CD}	4.19±.013^{C}	4.43±.012^{B}
Dec, 2020	11.10±0.023 ^{D}	6.59±.023^{ABC}	3.58±.018^{BC}	3.20±.017^{BC}	4.22±.013^{BC}	4.46±.012^{B}
Feb,2021	11.88±0.023 ^{A}	6.66±.023^{A}	3.65±.018^{A}	3.27±.017^{A}	4.29±.013^{A}	4.52±.012^{A}
Apr, 2021	11.31±0.024 ^{C}	6.62±.023^{AB}	3.62±.018^{AB}	3.23±.017^{AB}	4.26±.013^{AB}	4.49±.012^{A}
June, 2021	11.57±0.024 ^{B}	6.65±.023^{B}	3.63±.018^{AB}	3.25±.017^{A}	4.27±.013^{A}	4.51±.012^{A}

Table (2 b): Mean ± Standard error some physical properties of stored wheat grains in three types of storage silo at different storage periods

Items	Characteristics						
Silo	Surface area Sac /mm^2	Volume V/mm^3	Sphersity ϕ / %	Thousand seed weight (g)	True density(ρt) (kg·m^{-3})	Bulk density (ρb) (kg·m^{-3})	Porosity P / %
Fiber glass	56.15±.218^{B}	39.74±.234^{B}	63.97±.147^{B}	52.82±0.06	1279.77±.82	809.87±.88	36.73±.08
Plastic	57.40±.218^{A}	41.07±.234^{A}	64.39±.147^{A}	52.89±0.06	1279.01±.82	809.19±.88	36.74±.08
Galvanized steel	53.57±.218^{C}	37.49±.234^{C}	63.69±.147^{B}	52.66±0.06	1280.70±.82	810.48±.88	36.71±.08
Storage month							
June2020	55.29±0.33^{B}	38.89±0.36 ^{C}	63.27±0.22	52.53±0.09 ^{E}	1280.60±1.26	810.88±1.35	36.68±0.12
Aug,2020	54.06±0.33^{C}	37.55±0.36 ^{D}	63.54±0.22	52.45±0.09 ^{F}	1281.91±1.26	811.51±1.35	36.69±0.12
Oct,2020	55.08±0.33^{B}	38.59±0.36 ^{C}	63.89±0.22	52.54±0.09 ^{D}	1281.15±1.26	810.31±1.35	36.75±0.12
Dec, 2020	56.08±0.33^{B}	39.62±0.36 ^{BC}	64.20±0.22	52.71±0.09 ^{C}	1280.19±1.26	809.68±1.35	36.75±0.12
Feb,2021	57.91±0.33^{A}	41.66±0.36 ^{A}	64.50±0.22	53.19±0.09 ^{A}	1277.99±1.26	808.20±1.35	36.76±0.12
Apr, 2021	55.53±0.33^{B}	39.6±0.36 ^{BC}	64.33±0.22	53.01±0.09 ^{B}	1278.69±1.26	809.40±1.35	36.70±0.12
June, 2021	56.00±0.33^{B}	40.11±0.36^{B}	64.40±0.22	53.10±0.09 ^{A}	1278.26±1.26	808.94±1.35	36.71±0.12

Table (3 a): Mean ± Standard error for some physical properties of stored wheat grains in three types of silos at different storage periods

Type of storage silo	Storage period (Months)	Moisture content M.C.%	Length (L) (mm)	Width (W) (mm)	Thickness (T) (mm)	Geometric diameter (D g) (mm)	Arithmetic diameter (Da) (mm)
Fiber glass	June2020	10.50±0.04 ^{IJ}	6.64±0.04	3.54±0.03	3.15±0.03	4.19±0.02	4.44±0.02
	Aug, 2020	10.37±.0.04 ^{J}	6.54±0.04	3.52±0.03	3.11±0.03	4.14±0.02	4.39±0.02
	Oct,2020	10.45±0.04 ^{J}	6.57±0.04	3.55±0.03	3.17±0.03	4.19±0.02	4.43±0.02
	Dec, 2020	11.17±0.04 ^{F}	6.59±0.04	3.59±0.03	3.19±0.03	4.22±0.02	4.45±0.02
	Feb,2021	11.80±0.04 ^{D}	6.67±0.04	3.65±0.03	3.28±0.03	4.29±0.02	4.53±0.02
	Apr, 2021	11.07±0.04 ^{F}	6.63±0.04	3.62±0.03	3.25±0.03	4.26±0.02	4.50±0.02
	June, 2021	11.45±0.04 ^{E}	6.65±0.04	3.63±0.03	3.26±0.03	4.27±0.02	4.51±0.02
Plastic	June2020	10.50±0.04 ^{IJ}	6.64±0.04	3.54±0.03	3.15±0.03	4.19±0.02	4.44±0.02
	Aug,2020	10.47±0.04 ^{IJ}	6.60±0.04	3.54±0.03	3.13±0.03	4.17±0.02	4.42±0.02
	Oct,2020	10.60±0.04 ^{HI}	6.62±0.04	3.57±0.03	3.22±0.03	4.23±0.02	4.47±0.02
	Dec, 2020	11.48±0. 04^{E}	6.64±0.04	3.61±0.03	3.30±0.03	4.29±0.02	4.52±0.02
	Feb,2021	12.72±0.04 ^{A}	6.70±0.04	3.70±0.03	3.35±0.03	4.35±0.02	4.58±0.02
	Apr, 2021	12.05±0.04 ^{C}	6.66±0.04	3.67±0.03	3.32±0.03	4.32±0.02	4.55±0.02
	June, 2021	12.42±0.04 ^{B}	6.68±0.04	3.68±0.03	3.34±0.03	4.34±0.02	4.57±0.02
Galvanized steel	June2020	10.50±0.04 ^{IJ}	6.64±0.04	3.54±0.03	3.15±0.03	4.19±0.02	4.44±0.02
	Aug,2020	10.22±0.04 ^{K}	6.50±0.04	3.50±0.03	3.08±0.03	4.11±0.02	4.36±0.02
	Oct,2020	10.25±0.04 ^{K}	6.53±0.04	3.52±0.03	3.10±0.03	4.14±0.02	4.38±0.02
	Dec, 2020	10.65±0.04 ^{H}	6.54±0.04	3.55±0.03	3.12±0.03	4.16±0.02	4.40±0.02
	Feb,2021	11.12±0. 04^{F}	6.60±0.04	3.60±0.03	3.20±0.03	4.23±0.02	4.47±0.02
	Apr, 2021	10.80±0.04 ^{G}	6.58±0.04	3.56±0.03	3.14±0.03	4.18±0.02	4.43±0.02
	June, 2021	10.87±0.04 ^{G}	6.61±0.04	3.58±0.03	3.16±0.03	4.20±0.02	4.45±0.02

Table (3 b): Mean ± Standard error for some physical properties of stored wheat grains in three types of silos at different storage periods

Type of storage silo	Storage period (Months)	Surface area (Sac) (mm^2)	Volume (V) (mm^3)	Sphersity (ϕ) (%)	True density(ρt) ($kg \cdot m^{-3}$)	Bulk density(ρb) ($kg \cdot m^{-3}$)	Porosity (P) (%)
Fiber glass	June2020	55.29±0.58^{FG}	38.89±0.62 ^{FG}	63.27±0.39	1280.60±2.18	810.88±2.34	36.68±0.21
	Aug,2020	54.01±0.58^{HI}	37.42±0.62 ^{GH}	63.62±0.39	1281.78±2.18	811.45±2.34	36.69±0.21
	Oct,2020	55.13±0.58^{FGH}	38.59±0.62 ^{FG}	63.93±0.39	1280.70±2.18	810.22±2.34	36.74±0.21
	Dec, 2020	55.97±0.58^{EF}	39.46±0.62 ^{EF}	64.11±0.39	1280.29±2.18	809.40±2.34	36.78±0.21
	Feb,2021	57.96±0.58^{ABCD}	41.73±0.62 ^{ABCD}	64.36±0.39	1277.96±2.18	808.11±2.34	36.77±0.21
	Apr, 2021	57.17±0.58^{CDE}	40.90±0.62 ^{CDE}	64.27±0.39	1278.86±2.18	809.22±2.34	36.72±0.21
	June, 2021	57.55±0.58^{BCDE}	41.22±0.62 ^{BCDE}	64.22±0.39	1278.18±2.18	808.92±2.34	36.71±0.21
Plastic	June2020	55.29±0.58^{FG}	38.89±0.62 ^{FG}	63.27±0.39	1280.60±2.18	810.88±2.34	36.68±0.21
	Aug,2020	54.81±0.58^{FGH}	38.26±0.62 ^{FG}	63.40±0.39	1281.63±2.18	811.33±2.34	36.70±0.21
	Oct,2020	56.28±0.58^{DEF}	39.79±0.62 ^{DEF}	64.13±0.39	1280.54±2.18	810.11±2.34	36.74±0.21
	Dec, 2020	57.81±0.58^{ABCD}	41.46±0.62 ^{BCD}	64.69±0.39	1279.06±2.18	809.08±2.34	36.74±0.21
	Feb,2021	59.56±0.58^{A}	43.46±0.62 ^{A}	64.97±0.39	1276.87±2.18	807.19±2.34	36.78±0.21
	Apr, 2021	58.79±0.58^{ABC}	42.55±0.62 ^{ABC}	64.99±0.39	1277.33±2.18	807.94±2.34	36.75±0.21
	June, 2021	59.28±0.58^{AB}	43.11±0.62 ^{AB}	65.25±0.39	1277.02±2.18	807.83±2.34	36.74±0.21
Galvanized steel	June2020	55.29±0.58^{FG}	38.89±0.62 ^{FG}	63.27±0.39	1280.60±2.18	810.88±2.34	36.68±0.21
	Aug,2020	53.36±0.58^{I}	36.97±0.62 ^{GHI}	63.59±0.39	1282.33±2.18	811.76±2.34	36.69±0.21
	Oct,2020	53.85±0.58^{HI}	37.41±0.62 ^{GH}	63.60±0.39	1282.21±2.18	810.60±2.34	36.78±0.21
	Dec, 2020	54.46±0.58^{FGH}	37.93±0.62 ^{FG}	63.79±0.39	1281.21±2.18	810.57±2.34	36.73±0.21
	Feb,2021	56.22±0.58^{DEF}	39.81±0.62 ^{DEF}	64.16±0.39	1279.13±2.18	809.30±2.34	36.73±0.21
	Apr, 2021	50.63±0.58^{J}	35.41±0.62 ^{I}	63.71±0.39	1279.87±2.18	810.15±2.34	36.70±0.21
	June, 2021	51.17±0.58 ^{J}	35.98±0.62 ^{HI}	63.73±0.39	1279.57±2.18	810.08±2.34	36.69±0.21

2 Effect of storage on some mechanical properties of stored grain.

2.1 hardness of stored grain

Results of hardness analysis of samples taken from silos every two months are presented in Table (6). It was observed that there was diversity in hardness of grain stored in different silos also this variation may be related to moisture variations (gain or loss) during storage periods.as the rupture strength along any of the three major axes of wheat grains is highly dependent on the moisture content and the rupture force of wheat grains decreased as the moisture content increased and the small rupturing forces at higher moisture content might have resulted from the fact that the grains became more sensitive to cracking at high moisture . The change in the hardness of wheat stored in the three silos was minimal during the storage, due to the minimal change in the moisture content of the grains, it was observed that among the silo types, the highest hardness 6.57 kg was found in the galvanized steel silo with the lowest moisture content followed by fiberglass silo 6.55 kg and lowest hardness 6.53 kg in the plastic silo with the highest moisture content as shown in Table (5). Analysis of variance indicated no significant differences for storage methods, storage period and interaction between them (p > 0:01) on rupture strength of the stored grain by two-way ANOVA. as shown in Table (4).

2.2 Particle shear stress of stored grain

Results of static shear stress analysis of samples taken from silos every two months are presented in Table (6). It was observed that there was diversity in static shear stress of grain stored in different silos as it increased to get the highest value after 2 months and, then continued to decrease till 8 months. This variation may be related to moisture variations (gain or loss) during storage periods. The change in the static shear stress of wheat stored in the three silos was minimal, due to the minimal change in the moisture content of the grains. It was cleared from the results, that among the across silo types, the highest grain static shear stress 6.52 MPa was found in the galvanized steel silo with the lowest moisture content followed by fiberglass silo 6.48 MPa and lowest static shear stress 6.43 MPa in the plastic silo with the highest moisture content as shown in Table (5). in general, after 12 month of storage grains static shear stress decreased throughout storage for stored wheat grain in all silos. Analysis of variance indicated no significant differences for storage methods, storage period and interaction between them (p > 0:01) on shear stress of the stored grain by two-way ANOVA as shown in Table (4).

Table (4): Mean square, F value, and Probability for some mechanical properties of stored wheat grains in three types of silos at different storage periods.

Mean square.						
Items	shear stress (MPa)	Hardness (kg)	Angle of repose A.R./deg	coefficient of friction		
				Wood (µ W)	Galvanized iron (µGi)	Rubber (µ R)
Silo type	0.317	0.081	0.038	0.001	0.005	9.114E-05
period	0.249	0.081	0.086	0.000	0.000	0.000
S*P	0.056	0.015	0.003	4.220E-05	0.000	1.021E-05
error	0.847	0.236	0.051	4.827E-05	5.086E-05	7.501E-05
F value and probability						
Silo type	0.374	0.343	0.745	14.699	100.427	1.215
	N. S	N. S	N. S	**	**	N. S
storage period	0.294	0.344	1.675	5.810	4.826	3.876
	N. S	N. S	N. S	**	**	**
S*P	0.066	0.063	0.050	0.874	2.616	0.136
	N. S	N. S	N. S	*	*	N. S

Note: ** Significant at level P≤ 0.01, * significant at level P≤ 0.05, N.S. non-significant Were, S is silos types; P storage period

Table (5): Mean ± Standard error for coefficient of friction of stored wheat grains in three types of storage silo at different periods

items	Characteristic					
Silo	shear stress (MPa)	hardness (kg)	Angle of repose A.R./deg	coefficient of friction		
				Wood (μ W)	Galvanized iron (μGi)	Rubber (μ R)
Fiber	6.48±0.03	6.55±0.06	24.56±0.03	0.539±0.001 ^{A}	0.446±0.001 ^{A}	0.615±0.001
Plastic	6.43±0.03	6.53±0.06	24.59±0.03	0.541±0.001 ^{A}	0.446±0.001 ^{A}	0.616±0.001
Steel	6.52±0.03	6.57±0.06	24.53±0.03	0.533±0.001 ^{B}	0.427±0.001 ^{B}	0.613±0.001
Storage Month						
June2020	6.52±0.05	6.59±0.09	24.51±0.05	0.535±0.002 ^{C}	0.442±0.002 ^{A}	0.611±0.002 ^{B}
Aug,2020	6.54±0.05	6.61±0.09	24.46±0.05	0.533±0.002 ^{C}	0.434±0.002 ^{C}	0.611±0.002 ^{B}
Oct,2020	6.52±0.05	6.59±0.09	24.51±.05	0.535±0.002 ^{C}	0.435±0.002 ^{BC}	0.611±0.002 ^{B}
Dec, 2020	6.48±0.05	6.55±0.09	24.58±0.05	0.538±0.002 ^{BC}	0.439±0.002 ^{ABC}	0.616±0.002 ^{AB}
Feb,2021	6.40±0.05	6.51±0.09	24.66±0.05	0.545±0.002 ^{A}	0.444±0.002 ^{A}	0.621±0.002 ^{A}
Apr, 2021	6.44±0.05	6.52±0.09	24.58±0.05	0.537±0.002 ^{BC}	0.440±0.002 ^{AB}	0.616±0.002 ^{AB}
June, 2021	6.43±0.05	6.50±0.09	24.61±0.05	0.540±0.002 ^{AB}	0.443±0.002 ^{A}	0.618±0.002 ^{A}

Table (6): Mean ± Standard error for some mechanical properties of stored wheat grains in three types of silos at different storage periods

Type of storage silo	Storage period (Months)	shear stress (MPa)	hardness (kg)	Angle of repose A.R./deg	coefficient of friction		
					Wood (μ W)	Galvanized iron (μGi)	Rubber (μ R)
Fiber glass	June2020	6.52±0.09	6.59±0.16	24.51±0.10	0.535±.003 ^{def}	0.442±.003 ^{ab}	0.611±.004
	Aug,2020	6.55±0.09	6.60±0.16	24.46±0.10	0.533±.003 ^{ef}	0.439 ±.003 ^{b}	0.609 ±.004
	Oct,2020	6.53±0.09	6.59±0.16	24.50±0.10	0.536±.003 ^{cdef}	0.441±.003 ^{ab}	0.613±.004
	Dec,2020	6.49±0.09	6.55±0.16	24.58±0.10	0.539±.003 ^{bcde}	0.447±.003 ^{ab}	0.618±.004
	Feb,2021	6.40±0.09	6.52±0.16	24.68±0.10	0.545±.003 ^{abc}	0.455 ±.003 ^{a}	0.625±.004
	Apr, 2021	6.43±0.09	6.52±0.16	24.59±0.10	0.541 ±.003 ^{bcdef}	0.451 ±.003 ^{ab}	0.620 ±.004
	June,2021	6.41±0.09	6.51±0.16	24.61±0.10	0.543±.003 ^{abcd}	0.453 ±.003 ^{a}	0.620 ±.004
Plastic	June2020	6.52±0.09	6.59±0.16	24.51±0.10	0.535±.003 ^{def}	0.442±.003 ^{ab}	0.611±.004
	Aug,2020	6.52±0.09	6.60±0.16	24.48±0.10	0.535±.003 ^{def}	0.440 ±.003 ^{ab}	0.610 ±.004
	Oct,2020	6.48±0.09	6.57±0.16	24.53±0.10	0.537±.003 ^{bcdef}	0.443±.003 ^{ab}	0.615 ±.004
	Dec, 2020	6.42±0.09	6.53±0.16	24.60±0.10	0.542±.003 ^{abcde}	0.446±.003 ^{ab}	0.619 ±.004
	Feb,2021	6.33±0.09	6.48±0.16	24.72±0.10	0.550±.003 ^{a}	0.457 ±.003 ^{a}	0.628 ±.004
	Apr, 2021	6.38±0.09	6.50±0.16	24.62±0.10	0.546 ±.003 ^{abcde}	0.452 ±.003 ^{ab}	0.621±.004
	June, 2021	6.36±0.09	6.47±0.16	24.65±0.10	0.548 ±.003^{ab}	0.454 ±.003 ^{a}	0.623±.004
Galvanized steel	June2020	6.52±0.09	6.59±0.16	24.51±0.10	0.535±.003 ^{def}	0.442±.003 ^{ab}	0.611±.004
	Aug,2020	6.56±0.09	6.62±0.16	24.44±0.10	0.531±.003 ^{f}	0.420±.003 ^{d}	0.607 ±.004
	Oct,2020	6.54±0.09	6.60±0.16	24.49±0.10	0.533 ±.003 ^{f}	0.421±.003 ^{cd}	0.612 ±.004
	Dec, 2020	6.53±0.09	6.58±0.16	24.55±0.10	0.536 ±.003 ^{ef}	0.424±.003 ^{cd}	0.616 ±.004
	Feb,2021	6.46±0.09	6.54±0.16	24.59±0.10	0.540 ±.003 ^{bcdef}	0.430±.003 ^{c}	0.622±.004
	Apr, 2021	6.51±0.09	6.55±0.16	24.54±0.10	0.537 ±.003 ^{f}	0.423±.003 ^{cd}	0.614±.004
	June, 2021	6.51±0.09	6.53±0.16	24.57±0.10	0.539 ±.003 ^{f}	0.426±.003 ^{cd}	0.617 ±.004

2.3 Angle of repose of stored grain

Results of angle of repose analysis of samples taken from silos every two months are presented in Table (6). It was observed that there was minimal diversity in angle of repose of grain stored in different silos. This variation may be related to moisture variations (gain or loss) during storage periods. The change in the Angle of repose of wheat stored in the three silos was minimal, due to the minimal change in the moisture content of the grains. Also it can be observed that among silo types, the highest angle of repose of grains 24.59±0.03° was found in the plastic silo where the highest moisture content followed by fiberglass silo 24.56±0.03° and lowest angle of repose of grains 24.53±0.03° in the galvanized steel silo with the lowest moisture content as shown in table (5), This is may be due to the increased adhesion between the grain to the grain at higher values of moisture content. In general, after 12 month of storage angle of repose increased throughout storage for stored wheat grain for all silos. These results agreed with the findings of Hakan and İlker (2020). Analysis of variance indicated no significant differences for storage methods, storage period and interaction between them (p > 0:01) on the repose angle of the stored grain by two-way ANOVA as shown in Table (4).

2.4 Coefficient of friction of stored grain.

Results of Static friction coefficient on the surface (plywood, galvanized iron, and rubber) of stored wheat grains inside three types of storage silos at different storage periods are presented in Table (6). It was observed that there is a fluctuation in the values of the static coefficient on the surfaces of the materials. This variation may be related to grain moisture variations (gain or loss) depending on different storage duration. It was observed that among the across silo types, the highest static friction coefficient for all surface plywood, galvanized iron, and rubber (0.541, 0.446 and 0.616 respectively) was found in the plastic silo with the highest moisture content followed by fiberglass silo (0.539, 0.446 and 0.615 respectively) and lowest static friction coefficient in the galvanized steel silo (0.533, 0.427 and 0.613 respectively) with the lowest moisture content as shown in table (5). It may be explained by as by increasing moisture content, the friction coefficient increased due to more roughness of the grains. The highest coefficient of static friction of grains was found over rubber (μR) surface followed by plywood (μW)) and lowest for galvanized iron (μGi) across silo types in all storage times as shown in table (5). These results agreed with the findings of (HAKAN 2015). Analysis of variance indicated that there were highly significant differences among storage methods for coefficient of static friction with wood and galvanized iron (P≤0.01) except for the Rubber surface. It was noticed that there were no significant differences. Storage duration had a highly significant on all surface (plywood, galvanized iron, and rubber). For interaction between storage methods and Storage duration there were significant differences for coefficient of static friction with wood and galvanized iron (P≤0.01) except for the rubber surface there were no significant differences by two-way ANOVA as shown in table (4).

CONCLUSIONS

The present study was aimed to examine and investigate changes that may occur in some physical and mechanical properties of wheat grain stored in silos with different materials fiberglass, (FG), plastic (PE), and galvanized steel (GS) for 12 months during the period from (June 2020 to June 2021). Results revealed that There was a fluctuation in all physical and mechanical properties of stored wheat grain during the taken period. The main factor that influenced was the changes in the moisture content of the grain as a result of the grain gaining and losing moisture during storage. However, the physical and mechanical properties of wheat grains remained within the reference range during storage period.

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الخواص الطبيعية والميكانيكية لحبوب القمح وتأثرها بطرق التخزين المختلفة

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الملخص العربى

تهدف هذه الدراسة إلى فحص التغيرات التي قد تحدث في بعض الخواص الفيزيائية والميكانيكية لحبوب القمح المخزنة لمدة ١٢ شهرًا ، خلال الفترة من (يونيو ٢٠٢٠ ، يونيو ٢٠٢١) في صوامع تخزين القمح الأسطوانية الرأسية ذات الأبعاد والأحجام المماثلة والمجهزة بنظام تهوية ميكانيكي في قاع الصومعة. تشمل ؛ صومعة الفيبرجلاس، صومعة بلاستيكية ، صومعة من الصلب المجلفن .

ويمكن تلخيص النتائج التي توصل إليها البحث فيما يلي

١- الخواص الفيزيائية

- سجلت الصومعة البلاستيكية أعلى قيمة للمحتوى الرطوبى (١١,٤٦ ٪) البلاستيكية تليها صومعة الفيبرجلاس (١٠,٩٧ ٪) وأقل قيمة (١٠,٦٣ ٪) سجلت في صومعة الصلب المجلفن ، لكن المحتوى الرطوبي لعينات القمح في الثلاثة صوامع كانت أقل من المحتوى الرطوبي الموصى به (١٤٪) للتخزين الآمن مع بقاء القيم النهائية ضمن المستوى الآمن.
- كان هناك تذبذب في جميع الخواص الفيزيائية لحبوب القمح المخزنة خلال فترة التخزين بسبب التقلب في المحتوى الرطوبي للحبوب.
- تتأثر الابعاد الطول والعرض والسمك بالمحتوى الرطوبى . كما ان الخصائص الهندسية كالقطر الهندسى والحسابى والحجم ومساحة السطح والكروية أظهرت تغيرات متوازية لقيم الطول والعرض والسمك .
- لوحظت أعلى قيم لكل من الطول والعرض والسمك والقطر الهندسي والحسابي ، ومساحة السطح المحسوبة ، الحجم والكروية للحبوب المخزنة في الصومعة البلاستيكية تليها صومعة الفيبرجلاس والقيمة والأدنى في الصلب المجلفن خلال جميع فترات التخزين .
- تم الحصول على أعلى قيمة لوزن الالف حبة من حبوب القمح ٥٢,٨٩ جم في الصومعة البلاستيكية تليها صومعة الفيبرجلاس ٥٢,٨٢ جم وأدنى قيمة ٥٢,٦٦ جم في صومعة الصلب المجلفن .
- تم تسجيل أعلى قيمة للكثافة الظاهرية والحقيقية (٨١٠,٤٨ و ١٢٨٠,٧٠ كجم / م ٣) في صومعة الصلب المجلفن مع أدنى محتوى رطوبة يليها صومعة الفيبرجلاس (٨٠٩,٨٧ و ١٢٧٩,٧٧ كجم / م ٣) فحين كانت اقل قيم تم تسجيلها للحبوب المخزنة (٨٠٩,١٩ و ١٢٧٩,٠١ كجم / م ٣) في الصومعة البلاستيكية ذات المحتوى الرطوبي الأعلى .
- تم تسجيل اعلى قيم للمسامية (٣٦,٧٤ ٪) في الصومعة البلاستيكية متبوعًا بصومعة الفيبرجلاس (٣٦,٧٣ ٪) وأقل قيمة (٣٦,٧١٪) سجلت في صومعة الصلب المجلفن على التوالي.

٢- الخواص الميكانيكية

- كان هناك تذبذب في جميع قيم الخواص الميكانيكية لحبوب القمح المخزنة خلال فترة التخزين بسبب التقلبات في المحتوى الرطوبي للحبوب.
- تم تسجيل أعلى قيمة لكل من إجهاد القص والصلابة (٦,٥٢ ميجا باسكال و ٦,٥٧ كجم) على الترتيب في صومعة الصلب المجلفن يليها صومعة الفيبرجلاس (٦,٤٨ ميجا باسكال و ٦,٥٥ كجم) وأدنى قيم إجهاد قص والصلابة (٦,٤٣ ميجا باسكال و ٦,٥٣ كجم) سجلت في الصومعة البلاستيكية.
- اظهر التحليل الاحصائى ان أعلى قيمة لزاوية الراحة ٢٤,٥٩ درجة في الصومعة البلاستيكية يليها صومعة الفيبرجلاس ٢٤,٥٦ درجة وأدنى زاوية راحة ٢٤,٥٣ درجة سجلت في صومعة الصلب المجلفن .
- اوضحت التحليلات الاحصائية ان أعلى قيمة لمعامل الاحتكاك الاستاتيكى للحبوب المخزنة على جميع الأسطح (الخشب الرقائقي، الحديد المجلفن ، والمطاط) (٠,٥٤١ ، ٠,٤٤٦ و ٠,٦١٦) تم الحصول عليه في الصومعة البلاستيكية تليها صومعة الفيبرجلاس (٠,٥٣٩ ، ٠,٤٤٦ و ٠,٦١٥) وأدنى معامل احتكاك ثابت (٠,٥٣٣ ، ٠,٤٢٧ و ٠,٦١٣) في صومعة الصلب المجلفن على الترتيب .
- أعلى معامل احتكاك استاتيكى كان مع المطاط (μ_R) متبوعًا بالخشب الرقائقي (μ_W)) وأقلها للحديد المجلفن (μ_{Gi}) عبر أنواع الصوامع في جميع أوقات التخزين.