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SOME PHYSICAL AND MECHANICAL PROPERTIES OF WHEAT GRAIN

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ABSTRACT

Physical properties often required for developing the machines for cleaning of grain. Physical properties of wheat varieties (Sakha93) were determined and compared for moisture content 9, 11, 13 and 15% w.b. The average length, width and thickness were 7.46, 3.37 and 2.66 mm at a moisture content of 9% w.b., respectively. Studies on wheat grain showed that the thousand-kernel mass increased from 4٨.٥96 to 55.206g when the moisture content increased from 9 to 15%. The geometric, equivalent and arithmetic mean diameter at a moisture content of 9% were 4.06, 4.08 and 4.5mm. The average mass of one grain, volume and surface area were 0.048g, 35.49 mm^3 and 43.87 mm^2. Area of flat and transverse surface was 19.74 and 7.04 mm^2. Sphericity and index-k were 54.41% and 2.49. Bulk density decreased from 660 to 589.8 kg m^{-3}, when increasing the moisture content from 9 to 15% .True density decreased from 1244.6 to 1210.8 kg m^{-3}, when increasing the moisture content from 9 to 15%.Angle of repose varied from 16.8 to 21.6° when the moisture content increased from 9 to 15% .The static friction coefficient of wheat increased linearly against surfaces of four structural materials, namely, wood (0.379 – 0.399), galvanized iron (0.345 – 0.364), formica (0.306 – 0.344) and glass (0.299 – 0.335) as the moisture content increased from 9 to 15%.

INTRODUCTION

The total wheat area harvested in Egypt equal to 2.420 million feddan; wheat grain yield in Egypt equal to 2,7315 Mg/fed.; and wheat grain production is about 8.127 Tg (Ministry of Agric. 2009). In the design of machines, structures, processing and controls to be used in productions, handling, and processing of food and agricultural products, certain physical characteristics and engineering properties of the materials should constitute important and essential engineering data (Mohsenin 1986). The physical properties of wheat at different moisture contents must be known to design a machine for handling, cleaning, conveying, storing and milling, (Tabatabaeefar, 2003).The knowledge of some important physical properties such as shape, size, volume, surface area, thousand grain mass, density, porosity, angle of repose, of different grains is necessary for the design of various separating, handling, storing and drying systems (Sahay and Singh, 1994). (Dutta *et al.*, 1988) determined the various properties of the chickpea including shape, Thousand Kernel mass, sphericity, roundness, size, volume, surface area, bulk density, true density, porosity, static coefficient of friction and angle of repose. Principal axial dimensions of rough rice grains are useful in selecting sieve separators and in calculating power during the seed milling process. They can also be used to calculate surface area and volume of kernels which are important during modeling of grain drying, aeration, heating and cooling (Ghasemi Varnamkhasti *et al.*, 2007). The effects of size and surface area on drying rates of particulate materials can also be characterized by using the surface to volume ratio when diffusion of water within the particle limits drying rate, larger particles dry more slowly than smaller particles of the same shape. Also, the ratio of surface area to volume affects drying time and energy requirements (stroshin and hamann, 1998).The thousand-kernels mass (TKW), angle of repose and static coefficient of friction of faba beans increased with an increase in moisture content while bulk density decreased (Fraser *et al.*, 1978).

The objective of current study was to determine some physical properties of wheat grain at 9% moisture content such as dimensions (length, width and thickness); equivalent, geometric and arithmetic mean diameter; sphericity; surface area; area of flat and transverse surface; volume; mass of one grain; and then other properties under effect of moisture content variation such as density, thousand kernel mass, coefficient of friction against deferent materials and angle of repose.

MATERIALS AND METHODS

1- Materials:-

This study was carried on wheat (Sakha93). All treatments were replicated three times and the obtained data was analyzed statistically by using Minitab program.

2- Instrumention:-

1- Electric oven: - About five grams of whole wheat were placed in a shallow aluminum dish and dried for 22 hours at 130° according to ASAE standard 2003. At the end of this time the constant mass showed that all moisture was driven off.
2- Electrical balance: - Digital electric balance of 200 grams was used to determine the mass with an accuracy of 0.0001g.
3- Caliper: - A sliding caliper with accurate nearest to 0.05 mm was used to measure length, width and thickness of wheat grain.
4- Graduated glass cylinder (Flask): - A flask was used to determine the volume of the wheat in wheat density equation.
5- Bags: - Plastic bags were used to collect samples.

3- Experimental procedure:-

3-1 Physical properties:-

The grain moisture content was determined at moisture levels of 9 to 15 % w.b. at 4 levels of moistures is about (9, 11, 13 and 15%) for each moisture content 3 replications. For rewetting wheat grain a certain amount of pure water was added to the sample using a spray gun. The following Equation (1) was used to determine the mass of the added water. The sample was kept in a cold place for 104 h to reach to the proper uniform moisture content.

$$W_a = W_t \frac{(M_f - M_i)}{(100 - M_f)} \quad (1)$$ (Tabatabaeefar, 2003)

Where,

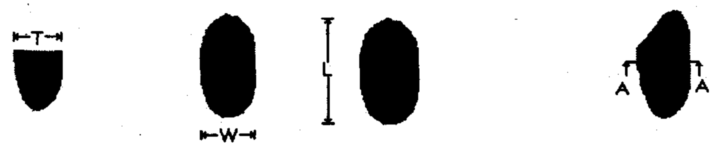
Wa = Mass of water added,g. Wt = Total grain mass,g.
Mi = Initial moisture content,%. Mf = Final moisture content,%.

The moisture content (w.b.,%) of grains were determined by oven method. About five grams of wheat were placed in a shallow aluminum dish and dried for 22 hours at 130°. At the end of this time the constant mass showed that all moisture was driven off.

$$M.C._{w.b.} = \frac{W_i - W_d}{W_i} \times 100 \quad (2)$$

Where
M w.b. = Moisture content, wet basis, %.
Wi = Initial mass of sample, g.
Wd = Dried mass of sample, g.

To determine the a average dimensions of the grain at a moisture content of around 9%, a sample of 100 randomly selected kernels were used to determine the dimensions of material under study. There were measured by caliper with an accuracy of 0.05 mm. The three linear dimensions of the grain, namely length (L), width (W) and thickness (T) were carefully measured in mm. Fig (1) shows the shape and the three mutually perpendicular diametrical dimensions L, W, and T of grain.



T = Thickness of largest section | W= width of largest section | L = Length of longest axis | AA-The largest section perpendicular to the longest axis of kernel.

Fig. (1) Dimensions of a kernel mutually perpendicular to each other

Grain volume (v) and surface area (Sa) given by the following equations:-

$$V = 0.25\left[\left(\frac{\pi}{6}\right)L(W+T)^2\right] \quad (3) \qquad Sa = \frac{\pi B L^2}{(2L-B)} \quad (4)$$

Where $B = \sqrt{WT}$ (5) (Jain and Bal 1997)

The geometric mean (Dgm), and equivalent diameter (Dem), in mm was calculated by Equation (6) and (7) respectively (Mohsenin, 1986).

$$D_{gm} = (LWT)^{1/3} \quad mm \quad (6) \qquad D_{em} = \left[L\frac{(W+T)^2}{4}\right]^{\frac{1}{3}} mm \quad (7)$$

The arithmetic mean diameter, of the grain was expressed by (Suliman 1987) using the following relationship $D_{am} = \frac{L+W+T}{3} mm$ (8)

The Percentage of sphericity (S) defined as the ratio of the surface area of the sphere having the same volume as that of the grain to the surface area of the grain. It was determined by using the following Equation

$$S = \frac{(LWT)^{1/3}}{L} \quad \% \qquad (9) \text{ (Mohsenin, 1986).}$$

The area of the flat surface was expressed by (Suliman 1987) using the following relationship $A_f = \frac{\pi}{4} LW \quad mm^2 \qquad (10)$

The area of transverse surface was expressed by (Suliman 1987) using the following relationship $A_t = \frac{\pi}{4} TW \quad mm^2 \qquad (11)$

The mass (M) of the individual grain was determined in gram by using an electric digital balance with an accuracy of 0.0001g. The measurement was replicated for 100 kernels which were taken randomly. Thousand kernel of wheat was measured by counting 100 grain and weighting them and then multiplied by 10 to give mass of 1000 kernels.

The bulk density, β, of wheat grain was determined by using a box of known volume. A rectangular box dimensioned 210 x 145 x 72 mms was used. It was filled to the brim with grain samples. The grain was densely packed by gently tapping the container 10 times in the same manner for all measurements to allow the grain to settle in it so as to obtain uniform density. The grains which filled it respectively, was weighted. Its volume was estimated by filling with water. The water was then weighed and the volume was calculated by using the following equation. $V = \frac{M_w}{\rho_w} \qquad (12)$

Where: Mw : mass of water in kg
ρw : density of water, kg/m^3

The bulk density of grain was calculated as the ratio of the bulk mass and the volume of the container. β = m/v , kg/m^3 (13)

Where:
β : is the bulk density of the grain, kg/m^3
m : mass of wheat grain in kg
and v : volume of the container in m^3

The true density is the ratio of the mass sample of grain to its pure volume. The pure volume was estimated by putting the weighted sample in a measuring flask (250ml) filled to its a half with water and estimate the variance of water volume. It was determined by the toluene displacement method (Mohsenin, 1986). ρt = m/Vs , kg/m^3 (14)

Where: ρt : True density of the grains, kg/m^3,
m : Mass of wheat grain in kg,
and Vs : Variance of water volume m^3.

3-2 Mechanical properties:-

The Static Coefficient of Friction (Angle of External Friction):-

The coefficient of friction is necessary to design the hoper of the cleaning wheat machine. A cylinder of 75 mm diameter and 50 mm height filled with a bout 150 g of wheat sample. Friction coefficient was measured by method shown in Fig (2) on four friction surfaces (glass, Formica, galvanized steel and wood) at grain moisture content (9, 11, 13 and 15%).

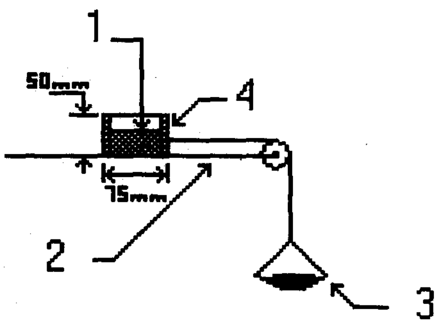
Fine sand was added gradually to the mass which makes cylinder start to move on horizontal plane with a regular movement. The friction coefficient (f) was determined from the following equation:-

$$f = Q/P \quad (15)$$

Where: Q= mass of sand, g
P= mass of block, g

$$f\ \text{wheat} = f\ \text{cylinder with wheat} - f\ \text{cylinder}$$

The friction coefficient of grain were the average of four replicates.



1-Wheat grains. 2-Friction surface. 3-Added sand 4-Cylinder

Fig. (2) Friction coefficient of

Repose Angle (Angle of Internal Friction) :-

It is the angle (θ) between the inclined side of the feeding cone and its horizontal base due to the free fall of wheat grain through it. It depends on things like size and shape of kernels, moisture content, fines and foreign material content, presence of mold, and filling or emptying method. It needed for hopper designing and estimating the grain capacity. It affects the grain bridging action at the feed gate opening. The quantity of wheat grain was used to determine repose angle, the grain was then poured under gravity from a suitable height to form a cone at same spot. More grain 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 repose angle of grain. Assuming that the horizontal base length of the cone (x) and the cone height (L), then the repose angle can be calculated using the following simple relations:-

$$\theta = \tan^{-1}\frac{L}{0.5X} \qquad (16)$$

The recorded angle was the average of five replicates.

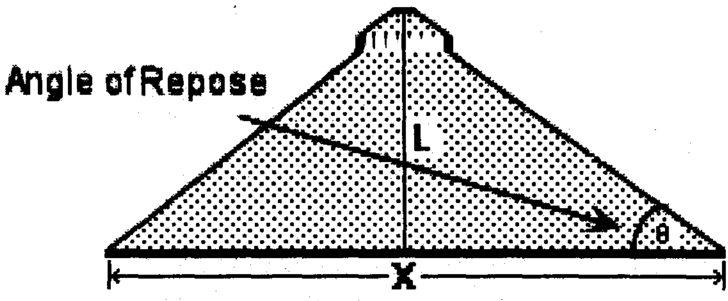


Fig. (3) Repose angle of wheat

All obtained data was replicated three times for each treatment and was analyzed statistically by using a computer program for estimating the probability.

RESULTS AND DISCUSSION

1- Physical properties

Dimension of wheat with a moisture content of 9%:- Fig. (4). Show grain dimensions, frequency and cumulative curves of wheat grain dimensions. Due to the mentioned figure the followings can be concluded.

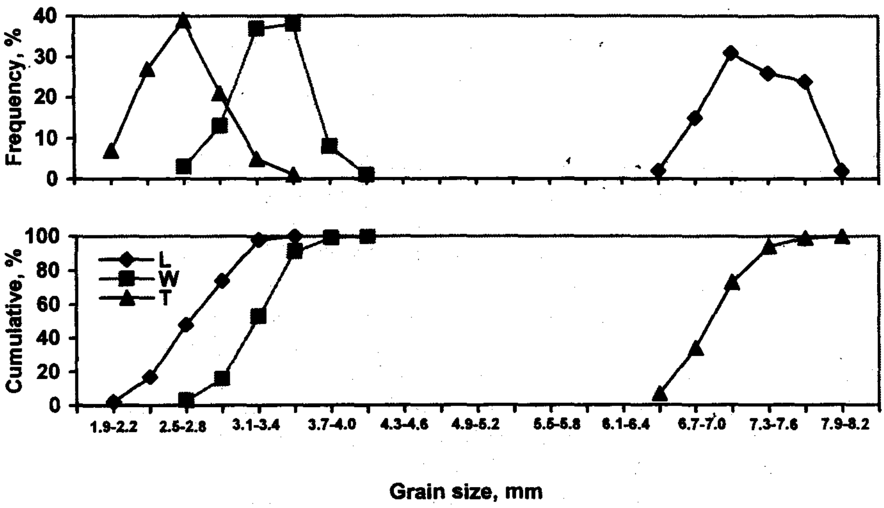


Fig. (4): Distribution Curves of Grains Dimensions (Length, Width and Thickness) for Wheat (Sakha93).

The grain length varied from 6.5 to 8.2 mm with a mean of 7.46 mm and a C.V. of 4.56 %. Because of the irregular nature of the shape and sizes of agricultural products, coefficient of variation (CV) may be used to characterize the quality of dispersion to the measured parameters about their means. Low CVs indicate more uniform dispersion. The grain width varied from 2.5 to 4.2 mm with a mean of 3.37 mm and a C.V. of 8.90 %. The grain thickness varied from 2 to 3.8 mm with a mean of 2.66 mm and a C.V. of 11.28%.

The grain thickness (T) varies directly as the width (W) vary due to the equation:- $T = 1.28 + 0.410\ W$ (probability < 0.01).

The grain thickness (T) varies directly as length (L) vary due to the equation:-

$$T = 1.57 + 0.146\ L \text{ (probability} < 0.01).$$

The grain thickness (T) varies directly as the width (W) and length (L) vary due to the equation:-

$$T = 1.30 + 0.412\ W - 0.0049\ L \text{ (probability} < 0.01).$$

Table (1): presents the mean of some physical of wheat grain.

Physical Properties	Mean	C. V.,%
Volume (V), mm^3.	35.49	18.92
Surface area (Sa), mm^2.	43.87	12.18
Aspect ratio (Ra).	0.45	8.52
Geometric mean diameter (Dgm), mm.	4.06	6.44
Equivalent mean diameter (Dem), mm.	4.08	6.40
Arithmetic mean diameter (Dam), mm.	4.50	5.12
Sephircity (S), %.	54.41	5.56
Area of flat surface (Af), mm^2.	19.74	11.51
Area of transverse surface (At), mm^2.	7.04	17.33

Grain mass (Individual and Thousand- Kernels mass) :-

Fig. (5) shows grain mass and frequency and cumulative curves of grain mass. The mass of individual grain of taken sample varied from 0.045 to 0.050 gram with a mean of 0.048 gram and a C.V. of 2.083%. The mass value of 1000 kernels (TKW) for ten replicates varied from 48.12 to 48.99 gram with a mean of 48.596 gram and a C.V. of 0.597 % at 9% moisture content.

The mass of thousand- kernels (TKW) increased linearly from 48.596 to 55.206 g. when the moisture content increased from 9 to 15% w.b. as shown in fig. (4-3). The relationship between the TKW and the moisture content can be represented as:-

$TKW= 46.8 + 2.19\ M$ with a value for R^2 of 0.964. A linear increase in the one thousand kernel mass as the grains moisture content increases has been noted by (Sacilik *et al.* 2003) for hemp, and (Karababa 2006), for popcorn. And (Tabatabaeefar 2003) for wheat represented that the TKW increased linearly from 23.2 to 39.7 g when the moisture content increased from 0 to 22 % d.b.

Wheat Density:-

The bulk density at different moisture levels varied from 589.8 to 660 Kg/m^3 and indicated a decrease in density with an increase in moisture content with significant (probability < 0.01) variations as shown in Fig (7). This is due to the fact that an increase in mass owing to moisture gain in the grains sample was lower than the accompanying volumetric expansion. The grains density was found to bear the following relationship with moisture content: $\rho b = 680 - 22.9\ M$ with a value for R^2 of 0.98.

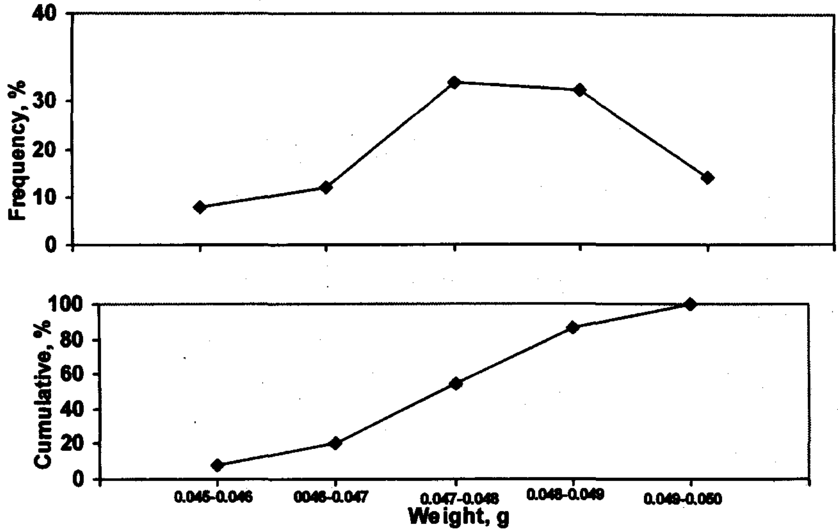


Fig (5): Distribution curve of one grain mass (g) for wheat (Sakha93).

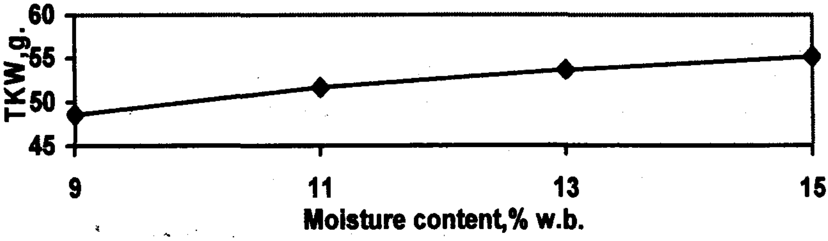


Fig (6): Effect of moisture content on the TKW.

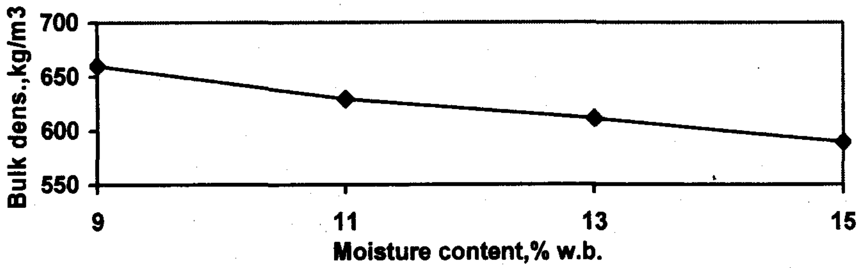


Fig (7): Effect of moisture content on wheat bulk density, Kg/m^3.

The true density of the wheat was measured at different moisture levels and it was found to be varied from 1244.6 to 1210.8 Kg/m^3 (Fig.- 8). The variation in true density with the increasing in moisture content was significant with a value for:

$$\rho t = 1257 - 11.8\ M,\ R^2 = 0.996$$

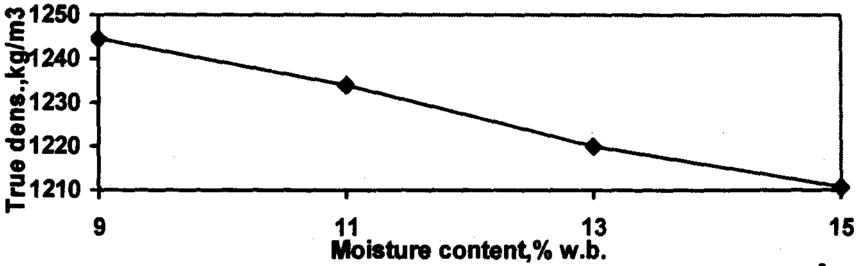


Fig (8): Effect of moisture content on wheat true density, Kg/m^3.

2- Mechanical properties:-

Angle of Repose:-

The experimental results for the angle of repose with respect to moisture content are shown in fig. (9).The values were found to increase from 16.8 to 21.6° in the moisture range of 9 to 15% w.b. so it's recommended to use a hopper angle and outlet angle about 20°. The angle of repose for wheat has the following relationship with its moisture content:

$$\theta = 14.8 + 1.72 (M) \text{ with a value } R^2 \text{ of } 0.933.$$

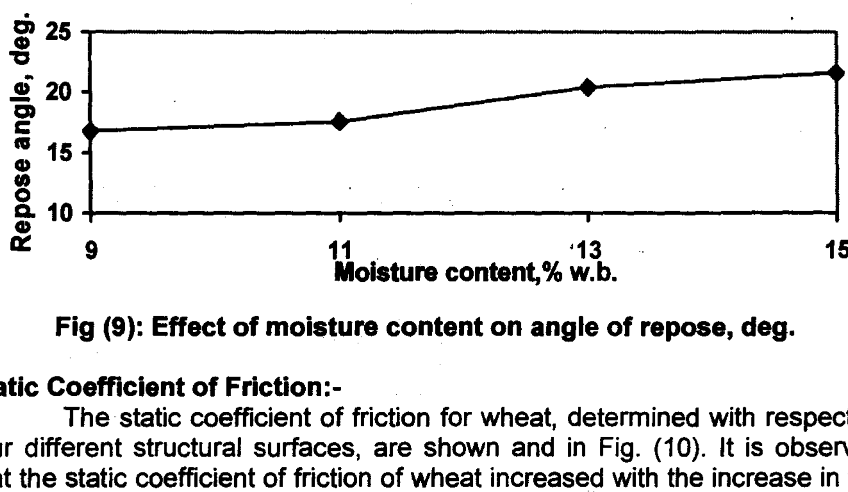


Fig (9): Effect of moisture content on angle of repose, deg.

Static Coefficient of Friction:-

The static coefficient of friction for wheat, determined with respect to four different structural surfaces, are shown and in Fig. (10). It is observed that the static coefficient of friction of wheat increased with the increase in the moisture content on all surfaces. At all moisture contents, the static coefficient of friction was greatest against wood (0.379 - 0.399) followed by galvanized steel (0.345 - 0.364) and Formica (0.306 – 0.344) and the least for glass sheeting (0.299 - 0.335). It was observed that moisture had more effect than did the material's surface on the static coefficient of friction. This is due to the increased adhesion between the grains and the material surfaces at higher moisture values. The highest static coefficient of friction was on wood. This may be owing to more unpolished surface of the wood than the other materials used. The relationships between static coefficient of friction and moisture content on wood, galvanized steel, Formica and glass can be represented by the following equations, respectively:

fGlass = 0.244 + 0.00605 M, R^2 = 0.999

*f*Formica = 0.292 + 0.0132 M, R^2 = 0.984
*f*Galvanized= 0.318 + 0.00320 M, R^2 = 0.936
*f*Wood = 0.350 + 0.00335 M, R^2 = 0.985

Similar results were found by (Sahoo and Srivastava 2002), (Ozarslan 2002), (Tabatabeefar 2003), (Bulent Coskun *et al* 2005) and (Shepherd and Bhardwaj 1986) for okra, cotton, lentil, wheat, sweet corn and pigeon pea grain , respectively. (Parde *et al* 2003) reported that the friction coefficient against plywood, galvanized steel and concrete surfaces for the Koto buckwheat cultivar increased significantly 0.26 to 0.31, 0.25 to 0.29 and 0.38 to 0.43 respectively, with increase in moisture content from 14.8 % to 17.9 %.

The static coefficient of friction for Formica and glass is nearly the same so, it's recommended to cover the machine hopper with Formica.

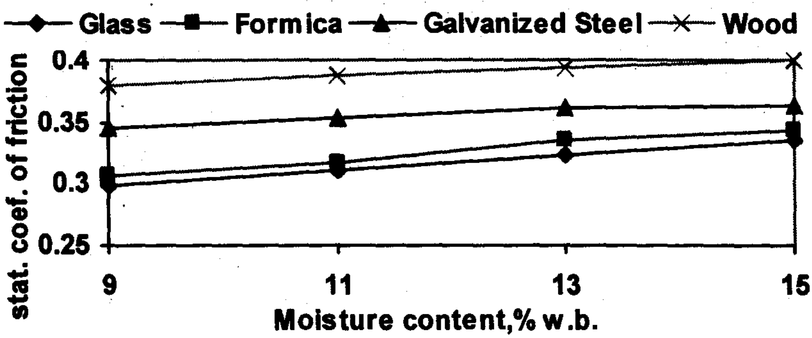


Fig. (10): Effect of moisture content on static coefficient of friction

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دراسات هندسية علي حبوب القمح

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تعد الخواص الطبيعية للمحصول من أهم القياسات المطلوبة لتطوير آلات تنظيف الحبـوب وبنـاء عليه فقد تمت دراسة الخواص الطبيعية لمحصول القمح صنف سخا ٩٣ عند مـستويات رطوبـة ٩ ، ١١، ١٣، ١٥ % علي أساس جاف وكانت النتائج المتحصل عليها كالتالي متوسط طول وعرض وسـمك الحبـة علي التوالي هو ٧,٦٤، ٣,٣٧، ٢,٦٦ مم عند محتوي رطوبة حوالي ٩% علي أساس جـاف كمـا بينـت الدراسة كذلك زيادة وزن ١٠٠٠ حبة من ٤٨,٥٩٦ إلي ٥٥,٢٠٦ جم بزيادة المحتوي الرطوبي من ٩ إلـي حوالي ١٥ % كما قدر القطر الهندسي المتوسط عند مستوي رطوبة ٩% بحوالي ٤,٠٦ مم والقطر المكـافئ المتوسط ٤,٠٨مم والقطر المتوسط الحسابي ٤,٥% ووزن الحبة الواحدة ٠,٠٤٨ جـم ومـساحة سـطحها ٤٣,٨٧ مم^2 وحجمها ٣٥,٤٩مم^3 ومساحة سطحها العريض ١٩,٧٤ مم^2 والمستعرض ٧,٠٤مـم^2 ونـسبة الاستدارة هي ٥٤% والمعامل المظهري هو ٢,٤٩ كل ذلك عند محتوي رطوبي حوالي ٩%. كمـا لـوحظ أيضا انخفاض كثافة الحبوب الظاهرية من ٦٦٠ إلي ٥٨٩,٨ كجم/م^3 وكـذلك الحقيقيـة مـن ١٢٤٤,٦ إلـي ١٢١٠,٨ كجم/م^3 بزيادة المحتوي الرطوبي من ٩ إلي ١٠% كما لوحظ زيادة زاوية التكويم من ٣٦,٨ إلي ٤١,٦° بزيادة المحتوي الرطوبي من ٩ إلي ١٥% وكان معامل الاحتكاك للحبوب علي الأسطح المختلفة مثل الخشب من ٠,٣٧٩ : ٠,٣٩٩ وعلي السطح المعدني من ٠,٣٤٥ : ٠,٣٦٤ وعلي الفورميكا مـن ٠,٣٠٦ : ٠,٣٤٤ وعلي الزجاج من ٠,٢٩٩ : ٠,٣٣٥بزيادة المحتوي الرطوبي من ٩ الي ١٥%.

قام بتحكيم البحث

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