EFFECT OF MOISTURE CONTENT ON SOME ENGINEERING PROPERTIES OF GROUNDNUTS GRAINS

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ABSTRACT

To develop appropriate technology for processing agricultural products, it is pertinent to have the full knowledge of the engineering properties of the biomaterial. The engineering property of groundnut grains was determined at 8.2, 12.3, 16.7 and 20.9 % moisture content. The axial dimension, mean diameter, sphericity, surface area, porosity, true and bulk density, angle of repose, coefficient of friction for metal and wood surfaces were determined as a function of pit moisture content. The result obtained from the study revealed that: With increasing the moisture content of groundnut grains length, width, thickness, mass of 1000-grains, volume, geometric diameter, arithmetic diameter, and surface area, true density, bulk density, porosity, static coefficient of friction, and angle of repose increased while percentage of aspect ratio and percentage of sphericity decreased from 50.54 to 49.75 % and 0.61 to 0.59 % respectively.

INTRODUCTION

Groundnut had been cultivated by ancient Egyptian science 5000 years ago. Is considered the most important protein-rich and it occupies the fifth position as oilseed crop globally after soybean, cottonseed, rape seed, and sunflower seed (El-Sayed et al., 2001). It is grown as annual crop on about 19million hectares of and in tropical regions and the warmer areas of temperate regions of the world (Adejumo et al., 2005). In Egypt, groundnut cultivated area was about 151853 feddans yearly producing about 1.304 ton/feddan (Statistical year book,2009). The physical and mechanical properties of groundnut play an important role in problems associated with design or development of sieve unit, a specific machine, handling, cleaning and storage. (Harmond et al.,1965) reported that the size of an object determines how much space can be occupied and it can be described in terms of length, width and thickness.

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They added also that the size is also important in selection or design of disks for precision planting and in proper adjustment
of clearances and screen openings in combining. Mohsenin,(1986) mentioned that the physical properties of material such as shape, size, volume, and surface area, are important in many problems associated with design or development of specific machine, analysis of the behavior of the product in handling of the material, stress distribution in the material under load, electrostatic separation of grain, light reflectance and color evaluation. One of the important design parameters in conveying of solid materials by air or water in the assumption for the shape of the materials. Accurate estimates of the frontal area and the related diameters are essential for the determination of terminal velocity, drag coefficient, and Reynolds number. Despite the economic potential of groundnut little is known about the physical properties. The processing operations are predominantly done manually. The manual processing of groundnut are time consuming and laborious, the condition prevalent at this level is generally unsanitary and inherent unhygienic conditions. The knowledge of physical and mechanical properties of groundnut like any other biomaterial is fundamental because it facilitates the design and development of equipment for harvesting, handling, conveying cleaning, delivering, separation, packing, storing, drying, mechanical oil extraction and processing of agricultural products, their physical properties have to be known (Mohsenin, 1980; Aviara et al., 1999). Presently, the equipment used in processing groundnut have been generally designed without taken into cognizant the physical properties of groundnut which include the size, mass, bulk density, true density, sphericity, porosity, coefficient of static friction and angle of repose and resultant systems leads to reduction in working efficiency and increase in product losses (Manuwa and A fuye, 2004; Razari et al., 2007). According to (El-Sayed et al., 2001)reported that Egyptian groundnut variety which have the following dimension, length, width, thickness, geometric diameter and mass 12.60 - 24.85mm, 5.35 -11.25mm, 4.40-10.80mm, 7.19-13.77mm, and 0.22-1.17g, respectively. He also reported three varieties of groundnut pod obtained from three different countries (China, America and Egypt) showed the following range of geometric diameter 21.05, 20.59, and

20.34mm and 2.21, 2.17 and 2.13g of mass, respectively. The corresponding average dimension values of African nutmeg as reported by (Burubai et al. ,2007) for length, width and thickness were 16.6762, 11.5193 and 9.9805 mm, respectively. Analysis of variance (ANOVA) revealed that the difference in physical dimensions of groundnut and African nutmeg were statistically significant at the level 0.05. The average diameter of the groundnut for arithmetic and geometric mean were 9.91 and 9.49 mm, respectively. There was no significant difference between at a significant level of 0.05. The corresponding true and bulk density for African nutmeg were 830.54 and 488.76 kgm!3 as reported by (Burubai et al., 2007).

The present investigation was therefore carried out to determine the engineering properties of groundnut seeds such as axial dimension, geometric and arithmetic mean diameter, sphericity, surface area, unit mass, 1000 grain mass, true volume, true and bulk densities, porosity, angle of repose and static coefficient of friction in order to be used for developing appropriate equipment that will alleviate laborious nature experience in processing the crop, transporting, separating and packing.

EXPERIMENTAL PROCEDURE

All the experimental tests were conducted at the Agricultural Engineering Research Institute, Dokki, Giza Egypt in 2010. The samples of groundnut Variety (Giza-5) were selected and cleaned manually. It was ensured that the seeds were free from dirt, broken ones and other foreign materials. The initial moisture content of the selected sample was about 32.35 % w.b. To obtain lower levels of moisture content , the groundnut samples were sun dried under shade by spreading them over 1 * 1 m screen tray and covered over night to prevent moisture changes during this period. The moisture content of the groundnut grains was determined every 1 hour until obtaining the required levels of moisture content. All measurements had been done on the pit of groundnuts pods at moisture content ranges from 8.20 to 20.9 % w.b. which are suitable for seed processing. Physical and mechanical properties of groundnut seeds were studied.

Physical properties of groundnuts seeds.

1- Grains dimension and related properties:

For the experimental work 100 groundnut seeds were randomly taken to determine the physical and mechanical properties. Dimensions like length (L), width (W), and thickness (T) mm, were measured using digital dial caliper with accuracy of 0.05mm in three axes x, y, and z volume (V) mm3, geometric diameter (Dg) mm, arithmetic diameter (Da) mm and percentage of sphericity (S) were also calculated according to (El-Raie et al., 1996) using the following relation ships:

$$Dg = (L*W*T)1/3 \text{ mm} \quad \text{----------(1)}$$

$$Da = (L+W+T)/3 \text{ mm} \quad \text{----------(2)}$$

$$S = (L*W*T)^{1/3}/L \ \% \quad \text{----------(3)}$$

$$V = \pi/6\ (L*W*T), \text{mm}^3 \quad \text{----------(4)}$$

The surface area of grains is very important characteristic in determining both volumetric and gravimetric heat transfer coefficients and in analyzing heat and moisture transfer during drying and frying processes and it is also useful for describing the re-hydration process. The following relation was used for calculating the surface area (Sa) in mm^2, according to (Mc Cabe et al. ,1986).

$$Sa = \pi\ Dg^2 \ \text{mm}^2 \quad \text{----------(5)}$$

The aspect ratio, Ra was calculated by applying the following relationships given by (Maduako and Faborode, 1990):

$$Ra = (W/L)100 \quad \text{----------(6)}$$

2- Grains bulk and true Density:

The grains bulk were poured into a container with known mass and volume (500 ml) from a height of 150mm at a constant rate (Milani et al., 2007). Bulk density was calculated from the mass of grains bulk divided by the volume containing the grains mass.

$$Db = Mb/Vb \quad \text{----------(7)}$$

where: Db = bulk density (kg/m^3),

Mb = mass of grains (kg) and

Vb = volume of container (m^3).

The true density was determined using the values of unit volume and unit mass of individual grain and calculated using the following relationship:

$$Dt = M/V \quad \text{----------(8)}$$

Where: Dt = true density (kg/m^3),
M = mass of individual grain (kg), and
V = volume (m^3).

3- Grains porosity:

The porosity (E) of the grains bulk was computed from the values of the true density and bulk density of the grains by using the relationship given by (Mohsenin 1980).

E=(1- Db/Dt)100 ----------(9)

Where: E = seeds porosity (%)
Db = bulk density (kg/m3)
Dt = true density (kg/m3)

4- Mass of 1000 grains :

The mass of 1000 grains was weighing by electronic balance. Its scale ranged from 0 to 1 kg max., with accuracy of 0.01 g.

Mechanical properties of groundnuts grains:

Static coefficient of friction (degree), and angle of repose (degree), were determined as follows:

1- Static coefficient of friction (Ψ) :

It was measured between grains and both metal and wooden surfaces using a digital instrument similar to the one developed by (Matouk et al., 2003).

2- Angle of repose, degree (θ):

It is the angle between the horizontal base and the inclined side of the formed cone due to free fall of seeds sample. A rectangular vlaropen – top box (10.3 cm wide * 12.8 deep * 10.1 cm high) was employed for this purpose. Grain was poured (from a triangular tray held about 5 cm above) into the box and the top leveled with a blunt-edged striker. The front wall was then flicked open, allowing excess grain to fall at the front. The resulting angle of the grain mass surface line formed with the horizontal would be read directly from angles etched on the two side walls. The repose angle can be calculated as follows:-

tan θ = L / 0.5 x----------(10)

RESULTS AND DISCUSSION

This section determines the effect of different levels of moisture content on physical and mechanical properties of groundnut grains as follows:

1- Physical properties of groundnut grains:

Table (1) shows the mean, coefficient of variance of length, width, thickness, mass of 1000- grains, volume, percentage of sphericity, geometric diameter, arithmetic diameter, surface area and percentage of aspect ratio for groundnut seeds at different levels of moisture content.

Results show that with increasing moisture content of groundnut seeds, the physical properties including length, width, thickness, mass of 1000-grains, volume, geometric diameter, arithmetic diameter, and surface area were increased while the percentage of aspect ratio and percentage of sphericity decreased.

Table 1: Physical properties of groundnuts grains.

Grain parameter	Moisture content %			
	8.2	12.3	16.7	20.9
Length (mm)	18.4	18.7	19.2	19.9
Width (mm)	9.3	9.4	9.6	9.9
Thickness (mm)	8.3	8.4	8.5	8.6
1000 grain mass (g)	708.7	739.0	774.0	808.0
Arithmetic diameter(mm)	12.00	12.17	12.43	12.8
Geometric diameter (mm)	11.24	11.39	11.61	11.92
Sphericity %	0.611	0.609	0.583	0.599
Surface area (mm^2)	396.9	407.57	423.46	446.38
Volume (mm3)	743.67	773.12	820.33	887.13
Aspect ratio (%)	50.54	50.27	50.00	49.75

Axial dimensions of groundnut grains:

Axial dimensions, including length, width and thickness in mm of groundnut grains over the moisture content range from 8.2 to 20.09 % are shown in Fig. (1). Axial dimensions are important in deterring aperture size in design of handling machines. As shown in Fig.(1), by increasing moisture content the axial dimensions were increased. The reason for this increase was probably due to some tiny voids on the grains surface.

Using the mean values, the following general equations could be written to express the relationship between, length, width, and thickness of Groundnuts grains.

$$L = 1.76\ W = 1.84\ T \text{-------(9)}$$

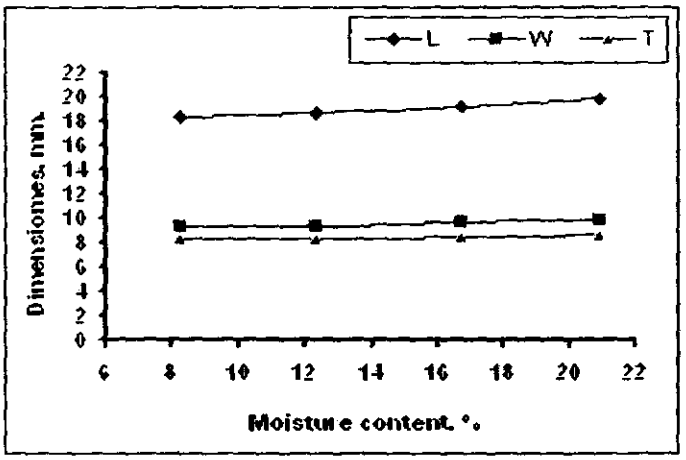

Fig.1: Effect of moisture content on dimensions of groundnut grains.

1000 grains mass:

The variation of the 1000 grains mass with grains moisture content is shown in Fig. (2) and table (1). Results show that 1000 grains mass increased with the increase of moisture content. At moisture contents of 8.2, 12.3, 16.7 and 20.9 % (w.b) the recorded grains mass were 708.7, 739.0,774.0 and 808.0 g respectively.

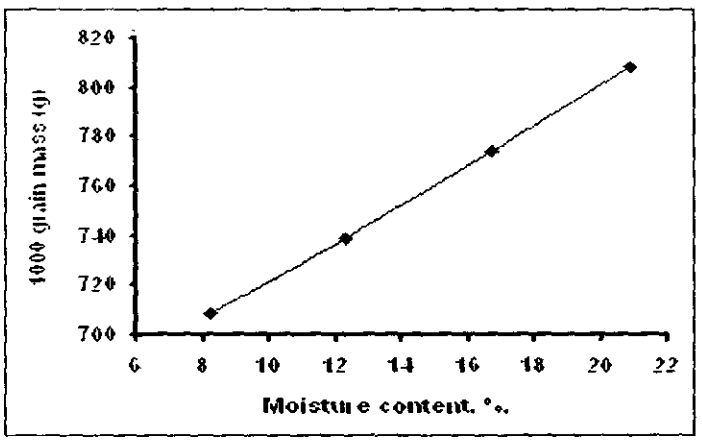

Fig.2: Effect of moisture content on 1000 grains mass of groundnut.

Diameter of groundnut grains:

Grains diameters obtained from the experiments are shown in table (1) and Fig.(3). The figure indicates that the geometric and arithmetic

diameter of groundnut grains increased by increasing grains moisture content.

Arithmetic and geometric diameter increased from 12 to 12.8 and 11.24 to 11.92 mm by increasing moisture content from 8.2 to 20.9 % respectively.

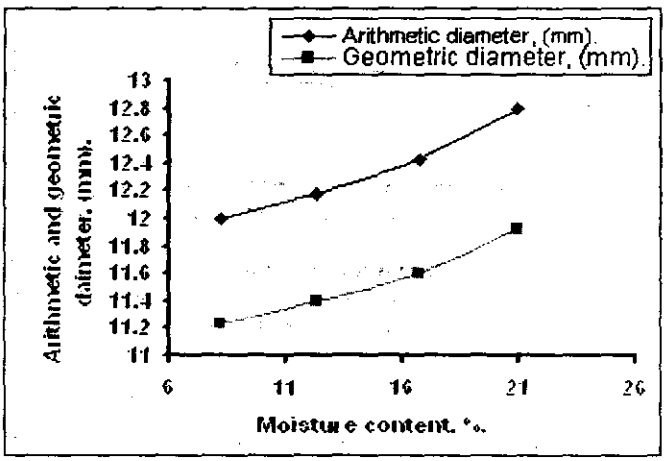

Fig.3: Effect of moisture content on arithmetic and geometric diameter of groundnut grains.

Sphericity:

As shown in Fig. (4) and table (1) the sphericity of groundnut grains decreased from 0.611 to 0.599 % as the moisture content increased from 8.2 to 20.9 % (w.b) respectively.

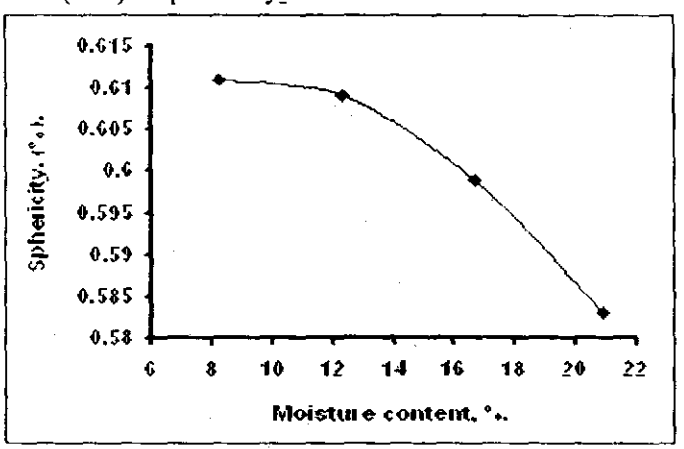

Fig.4: Effect of moisture content on sphericity of groundnut grains.

Surface area:

The variation of the surface area with grain moisture content is plotted in Fig. (5) and table (1). The figure indicates that the surface area of groundnut grains increased from 396.9 to 446.38 mm2 with increase of grain moisture content from 8.2 to 20.9 % (w.b) respectively .

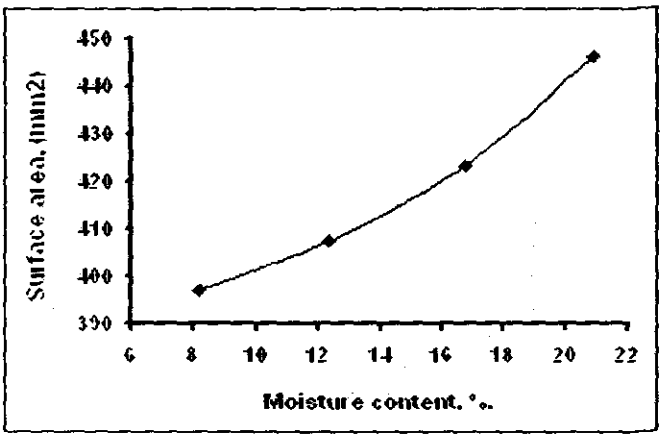

Fig.5: Effect of moisture content on surface area of groundnut grains

Volume:

Data in table 1 and Fig. (6) show the effect of moisture content on the volume of groundnut seeds. The grains volume of groundnuts increased from 743.67 to 887.13 mm^3 as the moisture content increased from 8.2 to 20.9 % (w.b) respectively.

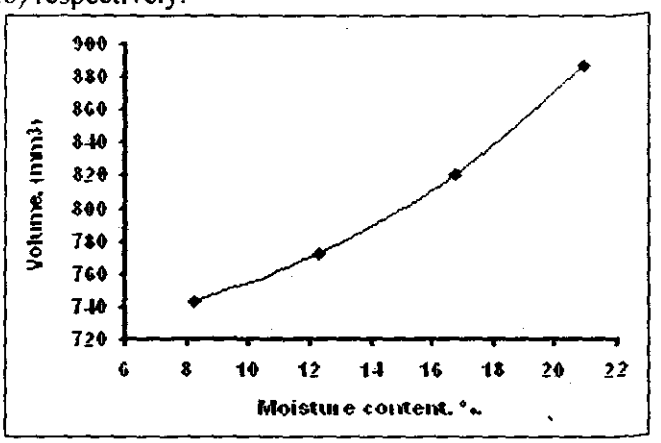

Fig.6: Effect of moisture content on volume of groundnut grains

Aspect ratio:

Data in table (1) and fig. (7) show the effect of moisture content on aspect ratio of groundnut seeds. The grains aspect ratio of groundnuts gains decreased from 50.54 to 49.75 % as the moisture content increased from 8.2 to 20.9 % (w.b) respectively.

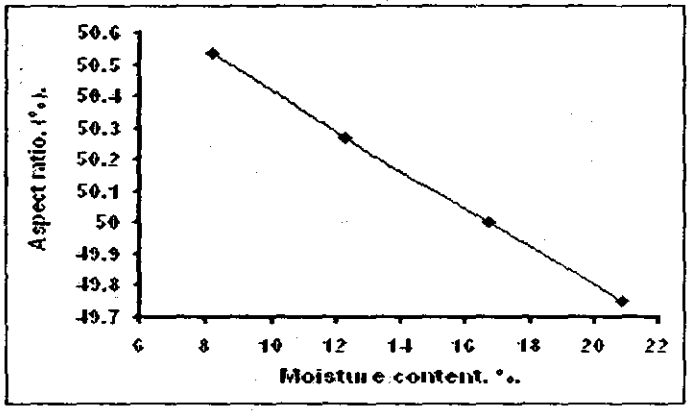

Fig.7: Effect of moisture content on aspect ratio of groundnut grains

2- **Mechanical properties of goundnut grains:**

True density, bulk density, porosity, static coefficient of friction, and angle of repose of groundnuts grains are shown in table (2).

Results show that with increasing moisture content of groundnut grains, its mechanical properties increased as the moisture content increased from 8.2 to 20.9 % (w.b) .

Table (2): Mechanical properties of groundnuts grains.

Grain parameter	Moisture content %			
	8.2	12.3	16.7	20.9
True density (kg/m^3)	731.52	734.11	737.89	740.21
Bulk density (kg/m^3)	511.16	516.78	522.14	529.11
Porosity (%)	30.12	29.60	29.23	28.52
Angle of repose, degree (θ)	30	32	34	36
static coefficient of friction:-				
- for metal surface	0.16	0.21	0.27	0.33
- for wood surface	0.15	0.19	0.26	0.31

True density:

As shown in Fig. (8) and table 2, the volume weight of groundnut grains inceased from 731.52 to 740.21 kg/m^3 by increasing moisture content from 8.2 to 20.9 % respectively.

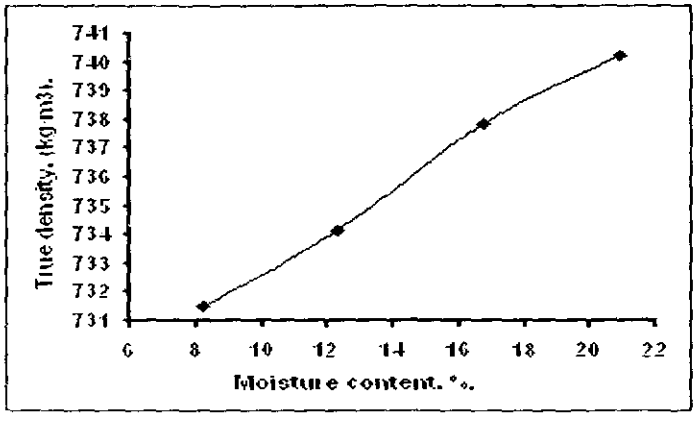

Fig.8: Effect of moisture content on true density of groundnut grains.

Bulk density:

As shown in Fig. (9) and table (2), the bulk density of groundnut grains was varied from 511.16 to 529.11 kg/m^3 by increasing grains moisture content from 8.2 to 20.9 % (w.b) respectively. It also revealed a significant difference between the average values of true and bulk density.

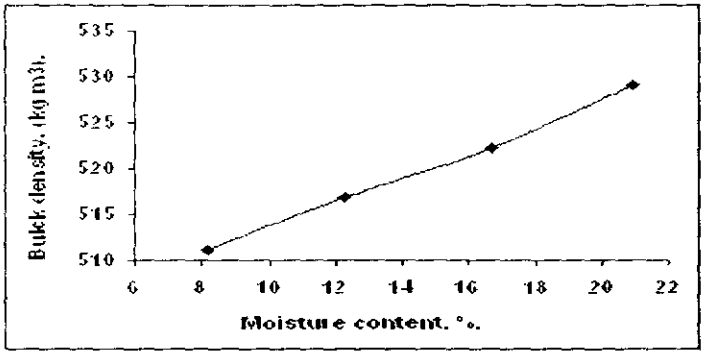

Fig.9: Effect of moisture content on bulk density of groundnut grains.

Porosity (%):

As shown in the Fig. (10) and table (2), the porosity (%) of groundnut grains decreased from 30.12 to 28.52 by increasing grain moisture content from 8.2 to 20.9 % (w.b) respectively.

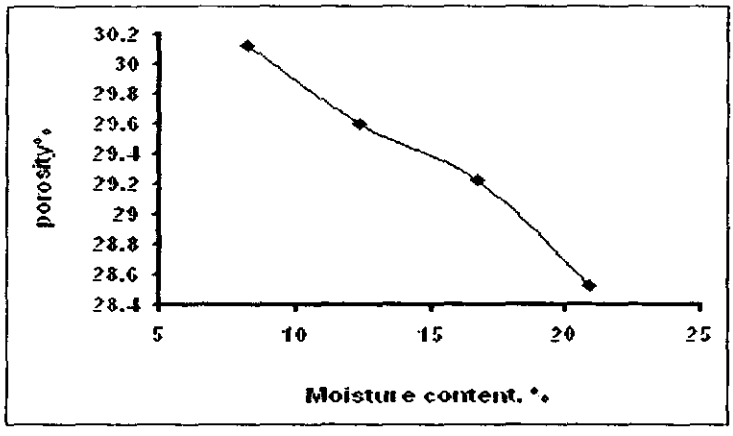

Fig10: Effect of moisture content on the porosity (%) of groundnut grains

Angle of repose:

As shown in the Fig. (11) and table (2), the angle of repose of groundnut grains increased from 30 to 36 degree by increasing grain moisture content from 8.2 to 20.9 % (w.b) respectively.

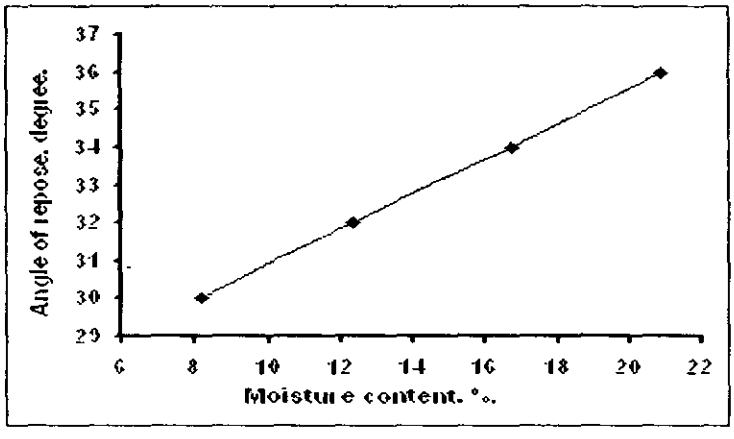

Fig11: Effect of moisture content on angle of repose of groundnut grains

Coefficient of static fraction of groundnut grains on two surfaces (metal and wood surfaces):

Figure (12) and table (2) show the values of coefficient of static fraction on metal and wood surfaces. As it is clear, with increasing moisture content, this coefficient increased for both surfaces. This result may be attributed to the fact that, at higher levels of moisture content the water

present in the seeds surface offering a cohesive force on the surface of contact.

In general, at all studied levels of grain moisture content the values obtained on metal surface, were higher than that obtained on wooden surface.

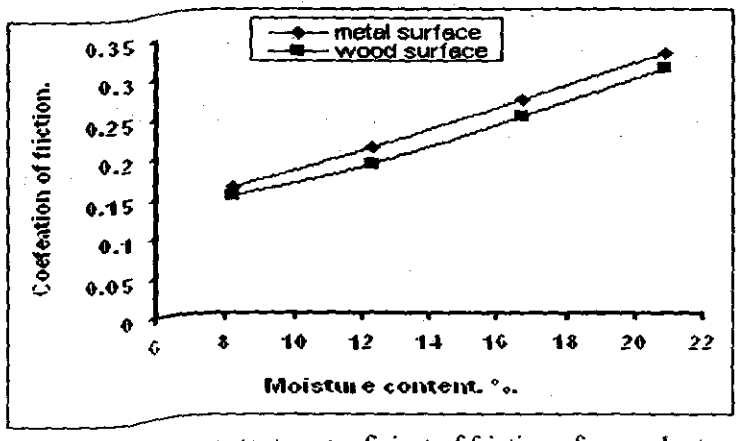

Fig12: Effect of moisture content on coeficient of friction of groundnut grains.

CONCLUSION

The main results on the some engineering properties of groundnut grains variety (Giza-5) at moisture content ranged from 8.2 to 20.9 %, can be summarized as follows:-

With increasing groundnut moisture content from 8.2 to 20.9 % (w.b) length, width, thickness, mass of 1000- grains, volume, geometric diameter, arithmetic diameter, and surface area, true density, bulk density, porosity, static coefficient of friction, and angle of repose were increased. While percentage of aspect ratio and percentage of sphericity were decreased from 50.54 to 49.75 % and from 0.611 to 0.599 % respectively.

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الملخص العربى

تأثير المحتوى الرطوبى على بعض الخصائص الهندسية لحبوب الفول السودانى

د/ جمال كمال عرفة*

يهدف البحث الى معرفة تاثير المحتويات الرطوبية المختلفة عند (٨.٢، ١٢.٣، ١٦.٧، ٢٠.٩ %) على الخصائص الطبيعية للفول السودانى (الطول ، العرض ، السمك ، الحجم ، القطر الهندسي ، القطر الحسابي ، نسبة التكور، وزن الألف حبة ، ومساحة السطح، نسبة الطول للعرض) وكذلك الخصائص الميكانيكية (معامل الاحتكاك لسطحين من المعدن والخشب ، ودراسة زاوية التكويم ،المسامية، والكثافة الظاهرية والحقيقية).

وكانت النتائج المتحصل عليها كالتالى:

(ا) الخواص الطبيعية

وجد ان طول وعرض وسمك حبوب الفول السودانى انخفض من ١٩.٩ الى ١٨.٤ %، ومن ٩.٩ الى ٩.٣ % ومن ٨.٦ الى ٨.٣ % بانخفاض المحتوى الرطوبى من ٢٠.٩ الى ٨.٢ % على الترتيب. و ان وزن ١٠٠٠ حبة من حبوب الفول السودانى قلت من ٨٠٨ الى ٧٠٨.٧ جم بانخفاض المحتوى الرطوبى من ٢٠.٩ الى ٨.٢ % على الترتيب. و ان القطر الهندسي ، القطر الحسابي لحبوب الفول السودانى قل من ١١.٩٢ الى ١١.٢٤ مم، ومن ١٨.٨ الى ١٢مم بانخفاض المحتوى الرطوبى من ٢٠.٩ الى ٨.٢ % على الترتيب. وان نسبة التكور لحبوب الفول السودانى زادت من ٠.٥٩٩ الى ٠.٦١١ مم ، بانخفاض المحتوى الرطوبى من ٢٠.٩ الى ٨.٢ % على الترتيب. و ان مساحة السطح لحبوب الفول السودانى قلت من ٤٤٦.٣٨ الى ٣٩٦.٩ مم، بانخفاض المحتوى الرطوبى من ٢٠.٩ الى ٨.٢ % على الترتيب. و ان حجم حبوب الفول السودانى قل من ٨٨٧.١٣ الى ٧٤٣.٦٧ مم، بانخفاض المحتوى الرطوبى من ٢٠.٩ الى ٨.٢ % على الترتيب. و ان نسبة الطول الى العرض لحبوب الفول السودانى زادت من ٤٩.٧٥الى ٥٠.٥٤ مم، بانخفاض المحتوى الرطوبى من ٢٠.٩ الى ٨.٢ % على الترتيب.

(ب) الخواص الميكانيكية.

وجد ان الكثافة الحقيقية لحبوب الفول السودانى قلت من ٧٤٠.٢١ الى ٧٣١.٥٢ مم، بانخفاض المحتوى الرطوبى من ٢٠.٩ الى ٨.٢ % على الترتيب. و ان الكثافة الظاهرية لحبوب الفول السودانى قلت من ٥٢٩.١١ الى ٥١١.١٦ مم، بانخفاض المحتوى الرطوبى من ٢٠.٩ الى ٨.٢ % على الترتيب. و ان نسبة المسامية لحبوب الفول السودانى زادت من ٢٨.٥٢ الى ٣٠.١٢%، بانخفاض المحتوى الرطوبى من ٢٠.٩ الى ٨.٢ % على الترتيب. و ان زاوية المكوث لحبوب الفول السودانى زادت من ٣٦ الى ٣٠، بانخفاض المحتوى الرطوبى من ٢٠.٩ الى ٨.٢ % على الترتيب. و أن معامل الاحتكاك لسطح الصاج ، والخشب انخفض من ٠.٣٣ الى ٠.١٦ ومن ، ٠.٣١ الى ٠.١٥ على الترتيب .

(ج) تم التوصل الى علاقة تربط بين الأبعاد الأساسية للبذور (الطول والعرض والسمك) وهى:

$$L = 1.76\ W = 1.84\ T$$

*باحث – معهد بحوث الهندسة الزراعية – مركز البحوث الزراعية – دقى – جيزة.