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PHYSICAL AND MECHANICAL PROPERTIES OF FABA BEAN SEEDS

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ABSTRACT

Various physical and mechanical properties of three different varieties of faba bean seeds were evaluated as a function of moisture content in the range of 9.8 to 26.5% (dry basis, d.b.). Mathematical models describing the change of physical and mechanical properties as dependent variables with moisture content as independent variable were studied. The average length of faba bean seeds increased from 13.55 to 16.46mm, from 18.49 to 20.91mm and from 20.52 to 2224mm; the width increased from 10.69 to 13.23mm, from 13.26 to 15.53mm and from 14.99 to 16.82mm; the thickness from 6.29 to 8.42mm, from 7.51 to 9.32mm and from 14.99 to 16.82mm for medium$_1$, medium$_2$ and large-seeds, respectively as the moisture content increased from 9.8 to 26.5%. The geometric mean diameter, sphericity, surface area, volume of seed, thousand seeds mass and porosity were linearly increased, while the bulk and true densities were decreased with the increase in moisture content. The angle of repose and coefficient of friction of seeds on various surfaces increased with the increase in moisture content for all different varieties of faba bean seed. Plywood as a surface for sliding offered the maximum friction followed by galvanized iron, aluminum and stainless steel. The developed mathematical models were highly accurate and can be used to describe the physical and mechanical properties as a function of moisture content during handling processes of other faba bean seed varieties.

INTRODUCTION

Faba bean *(Visia Faba L.)* is the first legume crop in Egypt. The cultivated area is 102 thousand hectare with an annual production of 357 thousand tones ***(FLRP, 2004)***. The seed forms an important source of protein, with 28% protein content and 58% carbohydrate. Recently, strengthen support for take advantages of the modern biotechnology would be of paramount importance for Egypt to attain self-sufficiency of faba bean crop. Each year, seed developers release many varieties into the market that provide improved productivity and adaptability to adverse conditions. These varieties are nearly similar in their characteristics and different in their properties. Knowledge of faba bean physical and mechanical properties are very important in the design equipment for handling, drying, aeration, storing structures and processing. Faba bean size and shape varies with

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variety and seed moisture content. ***Fraser et al. (1978)*** reported that for faba bean, the thousand seed mass, angle of repose and static coefficient of friction increased with an increase in moisture content while bulk density decreased. ***Abu El-Kheir (1988)*** indicated that faba bean seed characteristic dimensions and varieties might have an effect on threshing and cleaning efficiencies. The seed form and dimensions are considered important as limiting factors in passing the grain between the concave holes for separating and cleaning machine. He also reported that there is a significant difference in seed dimensions with varieties of faba bean.

Bulk density is an important physical property that is required to estimate the volume of storage and pressure that act on storage bin walls ***(ASAE, 2000a, b, and d)***. Also, ***Thompson et al. (1988)*** explained soyabean bulk density behavior as a function of moisture content. They attributed bulk density changes to rearrangement of beans and to bean deformation. They also found that bulk density was directly related to moisture content. ***Muir and Sinha (1988)*** and ***Milani et al. (2000)*** indicated that soyabean bulk density and kernel density varied with variety and grain moisture content. They found that two soyabean varieties had bulk densities of 719 and 721 kg/m^3 at a moisture content of 8.1%. Also, ***Dutta et al. (1988)*** and ***Deshpande et al. (1993)*** found that as moisture content increases, all principal axes of beans expand while bean thickness shows the greatest increase. They also reported that bulk density decreases as moisture content increases due to the expansion of the beans. ***Carman (1996)*** evaluated dimensions, bulk density, porosity, projected area, terminal velocity, static and dynamic coefficients of friction of lentil seeds in the moisture range of 6.5 – 32.6% (d.b). ***Rumpf (1990)*** gives a value of 41.8% porosity for a random packing of uniform spheres and minimum possible value of porosity for a packing of uniform spheres of 24.9%. These values are independent of sphere diameter.

Nimkar and Chattopadhyay (2001) reported that the size, thousand grain mass, angle of response, geometric mean diameter, terminal velocity and bulk porosity of green gram were increased with increasing moisture content from 8.39 to 33.40% (d.b.), while, the sphericity, bulk density and true density were decreased with the specified moisture level. Moisture-dependent kernel- and bulk-density relationships and effects on porosity for cereal grain and other crops have also been reported by ***Nelson, (2002)*** and ***Matouk et al. (2002)***. ***Hindy et al. (2003)*** indicated that linear dimensions and thousand grain mass of soyabean was linearly related to moisture content and increases with increasing moisture content within the range of 11.9 to 29.2% (d.b.), while, bulk density, particle density and porosity was decreased with the increase in grain moisture content. A review of literature has revealed that limited research has been conducted on the physical properties of faba bean. However, detailed measurements of the principal dimensions and the variation of mechanical properties of faba bean varieties at various levels of moisture content have not been investigated.

The objective of this study was to investigate moisture-dependent physical and mechanical properties, namely, principal dimensions, thousand seed mass, geometric mean diameter, sphericity, surface area, volume of seed, bulk density, kernel density, porosity, angle of repose and coefficient of friction of faba bean seed varieties.

MATERIAL AND METHODS

Under approximately the same operating conditions, seed size may take a significant role in processing ***(Subramanian et al.,1996***) therefore, three faba bean varieties of differing sizes and shapes, (medium$_1$-size seed, Misr 1, medium$_2$-size seed, Sakha 2, and large-size seed, Nobaria 1) which are widely cultivated in Egypt were tested. The crop was growing during 2003-2004 season at Sakha experimental farm of the Agriculture Research Center. The seed was cleaned manually to remove foreign matter and broken or immature seed. The clean seeds were sun-dried and the final moisture content of the dried seed was 8.5 %(wet bases).

Faba bean seeds at moisture content of 9.8, 13.5, 18.2, 22.4 and 26.5% (d.b.) were tested. The seed samples of the desired moisture levels were conditioned by adding calculated amounts of distilled water, mixing thoroughly and then sealing in separate polyethylene bags. The samples were kept at 5^{O}C in a refrigerator for at least a week to enable the moisture to distribute uniformly throughout the sample. Moisture content were measured using the oven method at 103^{o}C for 72h which described by ***Fraser et al., 1978*** and ***ASAE, 2000c***. Before starting a test, the required quantity of the seed was taken out of the refrigerator and was allowed to worm up to room temperature. All the physical properties of the seed were assessed at any moisture levels taking 10 replicates. The average ambient temperature was about 24.2^{O}C.

1. Physical Properties of Faba Bean Seeds:

Physical dimensions of length, width and thickness as well as shape of seeds vary according to the variety and are considered the first criteria of faba bean quality in developing new varieties for commercial production. To determine the average size of the seed, a sample of 100 randomly selected kernels and their three principal dimensions namely, length (*L*), width (*W*), and thickness (*T*) were measured using a digital micrometer reading to 0.01mm. The geometric mean diameter (G_m) of the seed was calculated by using the following relationship ***(Sharma et al., 1985)***:

$$G_m = (L.W.T)^{1/3} \qquad (1)$$

According to ***Mohsenin (1984)***, the degree of sphericity (ϕ) can be expressed as follows:

$$\phi = (L.W.T)^{1/3} / L \qquad (2)$$

The surface area (S_a) of faba bean seed was found by analogy with a sphere of geometric mean diameter for different values of moisture content using the following relationship ***(Deshpande et al., 1993)***:

$$S_a = \pi G_m^{\ 2} \text{...}(3)$$

Thousand seed mass was determined by using an electric digital balance sensitive to 0.01g. The bulk density of seed determines the bin volume required storing a certain mass of seed and it increases if the sphericity of the seed not of uniform size or shape. The greater the size range, the greater the bulk density ***(Milani et al., 2000).*** The bulk density was determined by filling a circular container of known volume with faba bean seeds and then weighing the cylinder. The ratio of mass to volume gives bulk density. The kernel density of a seed is defined as the ratio of the mass of a sample of seed to the solid volume occupied by the liquid displacement method (***Shepherd and Bhardwaj, 1986)***. The kernel density of randomized samples each of 50 seeds was calculated by weighing it and dropping it in a container of a known volume filled with paraffin oil. The volume of displaced oil was equal to the net volume of the sample. The kernel density was calculated by divided the mass of seeds by its net volume obtained from paraffin oil displacement method.

The porosity (ε) of bulk seed was computed from the values of bulk density ρ_b and kernel density ρ_k using the relationship given by ***Hindy et al. (2003)***:

$$\varepsilon = \frac{\rho_k - \rho_b}{\rho_k} \text{..}(4)$$

2. Mechanical Properties of Faba Bean Seeds:

Angle of repose and frictional properties of seeds play an important role in selection of design features of hoppers, chutes, dryers, storage bins and other equipment for seed flow. The angle of repose of the faba bean seeds was determined from the diameter and height of a heap on a circular plate. The seeds were allowed to fall on a circular plate of 200mm diameter from a height of 15cm so that a natural heap was formed. The height of the heap above a circular plate *H* and the diameter of the heap *D* at its base were measured with the help of a measuring scale and average value of the angle of repose was taken for each moisture contents with different varieties. The angle of repose of the faba bean seed θ was computed using the following expression, ***Jha (1998)***:

$$\theta = \tan^{-1}\left(\frac{2H}{D}\right) \text{..}(5)$$

The coefficient of friction between the seed µ and the surface on which the material moves is essential for engineers to make the right approach to the design of bins and hoppers. The static coefficient of friction µ was determined for four different structural materials, namely, plywood, galvanized iron, aluminum and stainless-steel. A galvanized iron cylinder of 100mm diameter and 50mm height was placed on an adjustable tilting plate, faced with the test surface, and filled with the sample. The cylinder was raised slightly so as not to touch the surface. The structural surface with the cylinder resting on it was inclined gradually with a screw device until the box just started to slide down and the angle of till was read from a graduated scale (friction angle, F_a). The coefficient of friction was determined as follows ***(Joshi et al, 1994)***:

$$Coefficient\ of\ friction = \tan(F_a), degree ....(6)$$

It should be noted that, five replicates for the measurements of the angle of repose and the same number for friction angle were carried out.

3. The Statistical Analysis:

The analysis of variance and linear regression analysis were employed in this experimental work to study, examine and assess the effect of moisture content changes on the physical and mechanical properties of faba bean seeds.

RESULTS AND DISCUSSION

1. Seed Dimensions:

Average means of the three principal dimensions (length, width and thickness) and standard errores for different varieties of faba bean seeds were determined in the moisture range of 9.8 to 26.5%,d.b. as indicated in Table 1. The results showed that each principal dimension appeared to be linearly dependent on the moisture content. Also, high signifficent effect was obseved between the three principal dimensions and moisture content with different varieties. It also indicated an increases of 21.5, 23.8. 33.9% for medium$_1$-seed; 13.1, 17.1, 24.1% for med$_2$-seed and 8.4, 12.2, and 24.6% for large-seed in lengh, width and thickness, respectively, due to the change of moisture content level from 9.8 to 26.5%,d.b. It can be seen that relatively, the seed expands more along its thickness in comparison to its other two principal axes. Also, the increase in medium$_1$-size variety was more than the two other varieties.This may be due to the arrangements of the cells in kernel and also to the cavity between the two halves of the cotyledons with increase in moisture content. This results was agree with the results obtained by ***Deshponde et al. (1993)***; ***Nimkar and Chattopadhyay (2001)*** and ***Matouk et al. (2004).***

2. Geometric Mean Diameter (G_m):

The geometric mean diameter was considered as the size of the seed. It was calculated using Equ.1 and it increased linearly from 9.69 to 12.24mm, from 12.26 to 14.46mm and from 13.73 to 15.84mm for medium$_1$, medium$_2$ and large-seed, respectively with the increase in moisture content as indicated in

Fig.1. This results show that the varation in seed size was significent in the range of moisture level of 9.8 to 26.5% d.b. Seed size (G_m)was found to bear the following relationship with moisture content (M_d):

$G_m = 8.37+14.84x\ 10^{-2}\ M_d$ ($r^2= 0.98$, $SE=0.12$) for medium$_1$ seed size (Misr 1),
$G_m = 11.17+12.82x\ 10^{-2}\ M_d$ ($r^2= 0.97$, $SE=0.18$) for medium$_2$ seed size (Sakha 2), and
$G_m = 12.49+12.83x\ 10^{-2}\ M_d$ ($r^2= 0.99$, $SE=0.06$) for large seed size (Nobaria 1).

Where: r^2 = the coefficient of determination, SE= the standard error.

3. Sphericity(S):

The values of faba bean sphericity were calculated indivedually using Equ.2 by using the data on geometric mean diameter and the length of the seed as presented in Fig.2. The results indicated that the sphericity of the seed increases linearly from 0.715 to 0.744mm; from 0.662 to 0.692mm and from 0.669 to 0.712mm for medium$_1$, medium$_2$ and large seed, respectively, in the specified moisture level. The relationship between sphericity(S) and the moisture content (M_d) for different varieties was obtained as:

$S= 0.703+ 1.63x10^{-3}M_d$ ($r^2=0.89$, $SE=4.4x10^{-3}$) for medium$_1$ seed size,
$S= 0.656+ 1.57x10^{-3}M_d$ ($r^2=0.63$, $SE=9.2x10^{-3}$) for medium$_2$ seed size, and
$S= 0.644+ 2.65x10^{-3}M_d$ ($r^2=0.98$, $SE=2.35x10^{-3}$) for large seed size.

4. Surface Aera of Seed(S_a):

The surface area (S_a) of faba bean seed was found by analogy with a sphere of geometric mean diameter for different values of moisture content and calculated by Equ.3. The results indicated that, the surface area of the seed was increased with moisture content for different varieties of faba bean as shown in Fig.3. The relationship between surface area (S_a) and the moisture content (M_d) to different varieties was obtained as:

$S_a= 2.03+ 0.10M_d$ ($r^2=0.99$, $SE=0.053$) for medium$_1$ seed size,
$S_a= 3.73+0.12M_d$ ($r^2=0.95$, $SE=0.20$) for medium$_2$ seed size, and
$S_a = 4.83+0.11M_d$ ($r^2=0.98$, $SE=0.09$) for large seed size.

5. Volume of Faba bean Seed (V):

The average volume of a single seed of faba bean showed **a** marked variation with the moisture content in the range of 9.8 to 26.5%, d.b. as indicated in Fig.4. The volume of seed increased linearly with the increase in moisture content.This result was confirmed with the results obtained by ***Dutta et al.(1988).***The relationship between the volume of seed and moisture content can be represented as:

$V= 0.123+2.8x10^{-2}M_d$ ($r^2=0.99$, $SE=1.3x10^{-2}$) for medium$_1$ seed size,

$V= 0.643+ 3.6x10^{2}M_d$ $(r^2=0.98, SE=3.8x10^{-2})$ for medium$_2$ seed size, and

$V= 0.913+ 4.4x10^{-2}M_d$ $(r^2=0.99, SE=1.8x10^{-2})$ for large seed size.

6. Thousand Seed Mass (M_t):

Fig.5 indicated that thousand seed mass was increases linearly with moisture content for different varieties of faba bean seeds. It was increased from 0.625 to 0.920kg for medium$_1$, from 0.950 to 1.235kg for medium$_2$ and from 0.980 to 1.325kg for large-seed with the increase of moisture content from 9.8 to 26.5%, d.b. Faba bean has a relatively large seed size, compared with other commonly grown pulse crops; for example at moisture content 13.5%, d.b., the thousand seed mass (M_t) for faba bean (Nobaria 1) is 1073g while it is 129g for soyabean ***(Hindy et al., 2003)*** and 179g for Chickpea ***(Dutta et al., 1988).*** A regression equation for the best fit to the data was as follows:

$M_t= 0.44+ 1.76x10^{2}M_d$ $(r^2=0.99, SE=6.3x10^{-3})$ for medium$_1$ seed size,

$M_t= 0.79+ 1.69x10^{-2}M_d$ $(r^2=0.99, SE=6.4x10^{-3})$ for medium$_2$ seed size, and

$M_t= 0.78+ 2.05x10^{-2}M_d$ $(r^2=0.99, SE=8.3x10^{-3})$ for large seed size.

7. Bulk density (ρ_b):

Fig.6 showed that the bulk density of faba bean seed was decreased with an increases in moisture content in the specified moisture range with high significant variation. It was decreased to 9.7, 12.7 and 11% for medium$_1$, medium$_2$ and large-seed varieties respectively with increasing moisture content from 9.8 to 26.5%, d.b. This was due to the fact that an increase in mass resulting from the moisture in the seed sample is lower than the accompanying volumetric expansion of the bulk. The negative linear relationship of bulk density with moisture content was also observed by ***Deshpande et al. (1993)*** and ***Hindy et al. (2003)*** for soyabean and ***Nimkar and Chattopadhyay (2001)*** for Green gram. The relationship between bulk density(ρ_b) and moistue content can be represented with the following relationship:

$\rho_b=874.15-5.48M_d$ $((r^2=0.97, SE=7.23)$ for medium$_1$seed size ,

$\rho_b=928.34-6.64M_d$ $((r^2=0.98, SE=5.84)$ for medium$_2$ seed size, and

$\rho_b=958.16-6.73M_d$ $((r^2=0.99, SE=4.01)$ for large seed size.

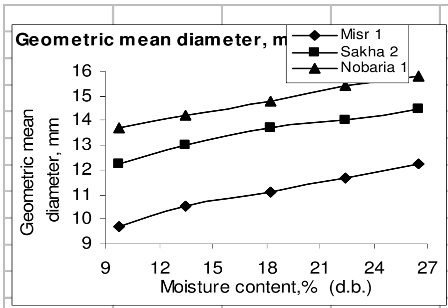

Fig.(1): Effect of moisture content on seed geometric mean diameter.

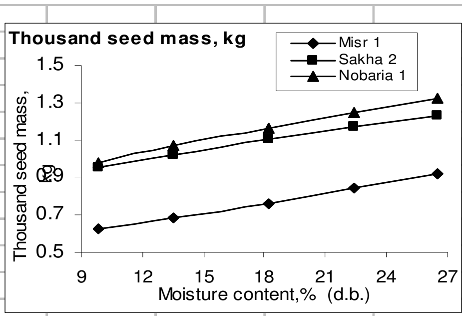

Fig.(5): Effect of moisture content on thousand seed mass.

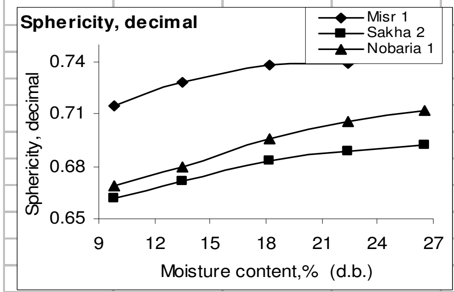

Fig.(2): Effect of moisture content on seed sphericity.

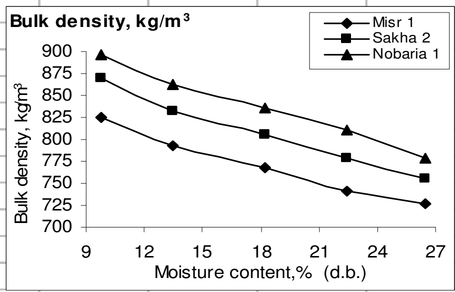

Fig.(6): Effect of moisture content on seed bulk density.

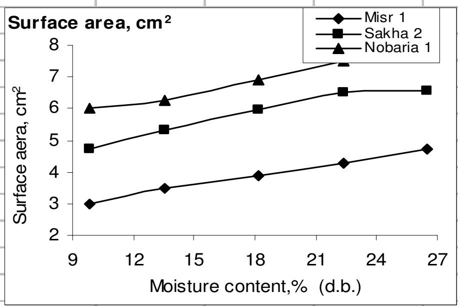

Fig.(3): Effect of moisture content on seed surface area.

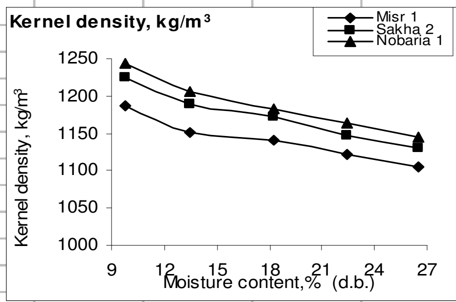

Fig.(7): Effect of moisture content on seed kernel density.

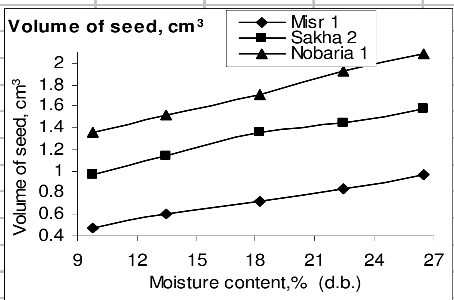

Fig.(4): Effect of moisture content on seed volume.

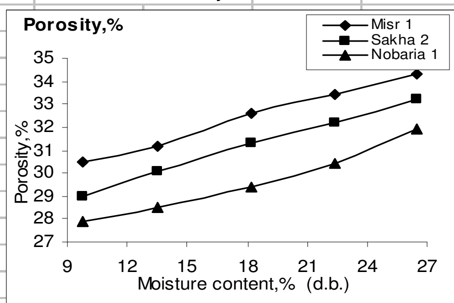

Fig.(8): Effect of moisture content on seed bulk porosity.

8. Kernel density (ρ_k):

The effect of moisture content on kernel density of faba bean seed showed a linear decrease with moisture content for different varieties as indicated in Fig.7. The kernel density was decreases of 6.9, 7.8 and 7.1% for $medium_1$, $medium_2$ and large-seed,respectively in the specified moisture range. The variation of kernel density of different varieties of faba bean was highly significant with moisture content. The decrease in kernel density values with increase in moisture content might be attributed to the relatively higher kernel volume as compared to the corresponding mass of the seed attained due to absorption of water. The results were in conformity with the other researchers, ***Desponde et al. (1993); Dutta et al. (1988); Nimkar and Chattopadyay (2001)*** and ***Hindy et al. (2003).*** A regression equation for the best fit to the data was as follows:

$\rho_k = 1235.26 - 4.89 M_d$ *((*$r^2=0.99$*, SE=0.64)* for $medium_1$ seed size,

$\rho_k = 1278.52 - 5.96 M_d$ *((*$r^2=0.98$*, SE=5.68)* for $medium_2$ seed size, and

$\rho_k = 1288.9 - 5.58 M_d$ *((*$r^2=0.96$*, SE=7.85)* for large seed size.

9. Porosity (ε):

Bulk porosity was evaluated using mean values of bulk density and kernel density in Equ.4. Resistance of bulk seed to airflow is, in part, a function of the porosity and the kernel size. The bulk porosity was found to increase linearly with different varieties of faba bean with an increae in moisture content from 9.8 to 26.5%,d.b. as indicated in Fig.8. It was an increase of 7.1, 11.6 and 10.3% with $medium_1$, $medium_2$ and large-seed, respectovely. A similar decrease in porosity was obtained by ***Hindy et al. (2003)*** for soybean grain with increases of moistre content. The relationship between bulk porosity and the moisture content of the seed was obtained as :

$\varepsilon = 28.98 + 0.195 M_d$ *(*$r^2=0.90$*, SE= 0.49)* for $medium_1$ seed size,

$\varepsilon = 27.02 + 0.225 M_d$ *(*$r^2=0.96$*, SE= 0.34)* for $medium_2$ seed size, and

$\varepsilon = 25.39 + 0.234 M_d$ *(*$r^2=0.97$*, SE= 0.29)* for large seed size .

10. Angle of Repose(θ):

Angle of repose is important in filling of a flat storage facility when seed is not piled at a uniform bed depth but rather is peaked. Fig.9 show the values of angle of repose with moisture content for different varieties of faba bean which computed by using Equ. (5). The values were increases from 34.2^o to 39.3^o, from 31.4^o to 36.8^o , and from 29.5^o to 36.1^o for $medium_1$, $medium_2$ and large-seed, respectively, with change of moisture content from 9.8 to 26.5%, d.b. The values of angle of repose of $medium_1$-seed variety was higher than the values of other two vareities due to its small volume. This may be due to the increased adhesion between the seed to the seed at higher values of moisture content. The relationship between angle of repose (θ) and moistue content can be represented by the following relationship:

$\theta = 31.60 - 0.352M_d$ $((r^2=0.98, SE=0.343)$ for $medium_1$ seed size,

$\theta = 28.01 - 0.433M_d$ $((r^2=0.99, SE=.154)$ for $medium_2$ seed size, and

$\theta = 26.13 - 0.421M_d$ $((r^2=0.98, SE=0.341)$ for large seed size.

11. Static Coefficient of Friction (μ):

The change of static coefficient of friction for faba bean seeds with moisture content for different varieties on all surfaces were computed by using Equ. (6) and indicated in Table 2. At the same variety, large-seed, the static coefficient of friction was greatest against plywood (0.35 – 0.45), stainless-steel sheet (0.28 - 0.33) with increases of moisture content from 9.8 to 26.%,d.b. Also, the values of coefficient of friction for $medium_1$-seed variety was lower than for $medium_2$ and large-seed varieties. It was also indicated that moisture had more effect than the material surface on the static coefficient of friction. This is owing to the increased adhesion between the seed and the material surface at higher moisture values. This result was agreed with the results reported by ***Chung and Verma (1989)*** and ***Nimkar and Chattopadyay (2001).***

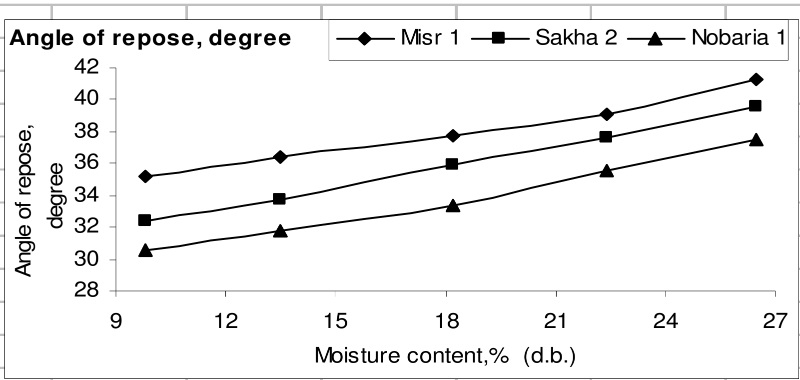

Fig.(9): Effect of moisture content on angle of repose of seed.

CONCLUSIONS

1. The averages length, width and thickness of faba bean seeds were increased to 21.5, 23.8, 33.9% for $medium_1$ seed, 13.1, 17.1, 24.1% for $medium_2$-seed and 8.4, 12.2, and 24.6% for large-seed, respectively, with change of moisture content from 9.8 to 26.5%d.b. Also, geometeric mean diameter was increased linearly from 9.69 to 12.24mm, from 12.26 to 14.46mm and from 13.84 to 15.84mm for the same seed varieties.
2. The sphericity, surface area and volume of faba bean seed were linearly increases with the studied moisture range for different varieties.

3. The thousand seed mass and porosity were increases, while the bulk and kernel densities were decreases with increase of moisture content of different varieties.
4. The angle of repose and coefficient of friction of faba bean seeds were increases with increase of moisture content from 9.8 to 26.5%. Also, the values of angle of repose and ceofficient of friction for $medium_1$-seed was higher than with $medium_2$ and large-seed varieties. The plywood surface offered the maximum friction followed by galvanized iron, aluminum and stainless steel.
5. The regression equations were found and can be used to predict the change of physical and mechanical properties of other varieties of faba bean with the change of moisture content with different conditions.

It is belived that, this study may be initiate a large program that is so essential to faba bean industry in Egypt, offers a promising alternative to reduce the excessive postharvest losses and also improve farm profitability by encuraging the cultural production of faba bean crops as an alternative crop pattern to the monoculture farming.

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الملخص العربى

الخواص الطبيعية والميكانيكية لبذور الفول البلدى

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أجرى هذا البحث فى معمل مركز ميكنة الارز بميت الديبة وتم الحصول على العينات من قسم المحاصيل البقولية بمحطة بحوث سخا بعد موسم حصاد ٢٠٠٤م بهدف دراسة التغير فى الخواص الطبيعية والميكانيكية لبذور الفول البلدى نتيجة التغير فى المحتوى الرطوبى. تم أستخدام ثلاثة أصنلف من الفول البلدى مختلفة الحجم وهى مصر ١ (متوسط البذرة ١)، سخا٢ (متوسطة البذرة ٢)، ونوبارية ١ (كبيرة البذرة) عند خمس محتويات مختلفة للرطوبة (٩,٨، ١٣,٥، ١٨,٢، ٢٢,٤، ٢٦,٥% على اساس جاف) التى تشتمل مراحل الحصاد والتداول المختلفة للمحصول. وتم قياس الخواص الطبيعية والميكانيكية واجراء التحليل الاحصائى واستنباط النمازج الرياضية التى توصف العلاقة بين تلك الخواص (كعامل متغير) مع التغير فى المحتوى الرطوبى (كعامل مستقل) للاصناف المختلفة تحت الدراسة.

<u>ومن أهم النتائج ما يلى:</u>

١- أوضحت النتائج من التجارب وجود اختلاف عالى المعنوية بين الاصناف المختلفة وكذلك نتيجة التغير فى المحتوى الرطوبى للبذور من ٩,٨ الة ٢٦,٥% (على أساس جاف). فقد زاد متوسط الطول والعرض والسمك للبذور بنسبة ٢١,٥، ٢٣,٨، ٣٣,٩% فى الصنف ذو البذور متوسطة الحجم١ (مصر ١)، وبنسبة ١٣,١، ١٧,١، ٢٤,١% فى البذور المتوسطة الحجم٢ (سخا٢)، وبنسبة ٨,٤، ١٢,٢، ٢٤,٦% فى البذور كبيرة الحجم (نوبارية١). وكانت نسبة التغير فى الحجم فى الصنف متوسط البذرة١ أعلى منها فى الصنفين المتوسط البذرة٢ والكبير البذرة.

٢- زاد متوسط القطر الهندسى وكتلة الالف بذرة والمسامية ودرجة التكوير وحجم البذرة ومساحة سطح البذرة بزيادة المحتوى الرطوبى للبذور بينما أنخفضت كل من الكثافة الظاهرية والحقيقية لبذور الفول البلدى فى الاصناف تحت الدراسة.

٣- زادت زاوية الراحة وكذلك معامل الاحتكاك للبذور مع الاسطح المختلفة بزيادة المحتوى الرطوبى للبذور وكان أعلى معامل الاحتكاك مع الخشب يليه الحديد المجلفن، والالومنيوم وأقل معامل أحتكاك مع الاستنلستيل نتيجة لزيادة قوى الالتصاق بين البذور والمواد المختلفة بزيادة المحتوى الرطوبى.وكان مقدار الزيادة نتيجة التغير فى المحتوى الرطوبى اكبر منه نتيجة تغير اسطح الاحتكاك.

٤- تم أستنباط نمازج رياضية توصف التغير فى الخواص الطبيعية والميكانيكية نتيجة التغير فى المحتوى الرطوبى للبذور يمكن أن تستخدم فى وصف التغير فى الصفات الطبيعية والميكانيكية لاصناف الفول المختلفة أثناء تداولها.

من هذه الدراسة يتضح أهمية دراسة التغير فى الخواص الطبيعية والميكانيكية للبذور عند التغير فى المحتوى الرطوبى لكى تستخدم فى التشغيل الامثل لالات أثناء عمليات التداول (الحصاد والدراس والتنظيف والتدريج والتجفيف والتخزين والتهويه والتعبئه) بهدف تقليل الفواقد والحصول على جودة عالية للمحاصيل الزراعية.

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Table (1): The average dimensions and standard errors at different moisture content for three faba bean varieties.

Moisture Content, % (d.b.)	Medium₁-seed size (Misr 1)			Medium₂-seed size (Sakha 2)			Large-seed size (Nobaria 1)		
	Length, mm	Width, mm	Thickness , mm	Length, mm	Width, mm	Thicknes s, mm	Length, mm	Width, mm	Thickness , mm
9.8	13.55 (0.14)	10.69 (.21)	6.29 (0.16)	18.49 (0.29)	13.26 (0.19)	7.51 (0.22)	20.52 (0.38)	14.99 (0.19)	8.41 (0.21)
13.5	14.25 (0.16)	11.82 (.20)	6.90 (0.28)	19.01 (0.10)	13.90 (0.21)	8.20 (0.29)	20.94 (0.23)	15.37 (0.16)	8.98 (0.14)
18.2	15.01 (0.13)	12.20 (0.21)	7.52 (0.12)	19.74 (0.23)	14.63 (0.18)	8.95 (0.22)	21.47 (0.21)	15.91 (0.15)	9.52 (0.10)
22.4	15.82 (.25)	12.56 (0.18)	8.03 (0.17)	20.35 (0.11)	15.01 (0.17)	9.03 (0.21)	21.89 (0.21)	16.46 (0.13)	10.24 (0.12)
26.5	16.46 (0.15)	13.23 (0.20)	8.42 (0.16)	20.91 (0.22)	15.53 (0.18)	9.32 (0.13)	22.24 (0.32)	16.82 (0.12)	10.63 (0.11)

Each data point is the average of 10 observations. Numbers in parentheses are S.Ds.

Table (2): static coefficient of friction for faba bean seeds.

Moisture content % (d.b.)	Misr 1 (medium₁-seed size)				Sakha 2 (medium₂ seed size)				Nobaria 1 (large seed size)			
	Plywood	Galvanized iron	Aluminum	Stanless steel	Plywood	Galvaniz-ed iron	Aluminum	Stanless steel	Plywood	Galvani-ed iron	Aluminum	Stanless steel
9.8	0.30 (0.01)	0.29 (0.02)	0.27 (0.02)	0.24 (0.03)	0.33 (0.02)	0.31 (0.01)	0.29 (0.02)	0.27 (0.01)	0.35 (0.01)	0.33 (0.02)	0.31 (0.02)	0.30 (0.02)
13.5	0.32 (0.02)	0.30 (0.01)	0.28 (0.01)	0.26 (0.01)	0.35 (0.02)	0.33 (0.02)	0.31 (0.02)	0.29 (0.02)	0.37 (0.02)	0.35 (0.02).	0.33 (0.01)	0.32 (0.01)
18.2	0.35 (0.01)	0.33 (0.02)	0.30 (0.02)	0.27 (0.02)	0.38 (0.03)	0.35 (0.02)	0.33 (0.02)	0.31 (0.02)	0.39 (0.020	0.37 (0.03)	0.35 (0.02)	0.34 (0.03)
22.4	0.37 (0.02)	0.35 (0.02)	0.32 (0.02)	0.29 (0.02)	0.40 (0.02)	0.38 (0.02)	0.36 (0.03)	0.34 (0.02)	0.41 (0.03)	0.39 (0.02)	0.37 (0.01)	0.36 (0.01)
26.5	0.39 (0.02)	0.36 (0.01)	0.34 (0.03)	0.32 (0.02)	0.42 (0.01)	0.40 (0.02)	0.38 (0.01)	0.36 (0.02)	0.43 (0.02)	0.41 (0.02)	0.40 (0.02)	0.38 (0.01)