J.Soil Sci. and Agric. Eng., Mansoura Univ., Vol. 4 (10):, 2013

PHYSICAL AND MECHANICAL PROPERTIES OF SWEET LUPIN SEEDS

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ABSTRACT

The physical and mechanical properties of sweet lupin seeds is necessary for the design of equipment to handle, transport , milling , process and store the crop . The physical properties of sweet lupin seeds have been evaluated as a function of seed moisture content varying from 9.70 % to 26.53 % (db) . In this moisture range, seed length , width , thickness and geometric diameter increased from 11.067 to 11.838 mm, 9.992 to 10.591 mm, 5.174 to 5.734 mm and 8.291 to 8.944 mm respectively, the sphyericity of seeds calculated at different moisture content increased from 74.75 to 76.25 % with increase in moisture from 9.70 % to 21.07 % and reduced to 75.66 % with further increase in moisture content to 26.53 %, the 1000 seed mass increased from 0.433 to 0.670 g , true and bulk densities and rupture force decreased from 1.342 to 1.211 g/cm^3 and from 0.777 to 0.717-g/cm^3 and from 212.50 to 105.23 N respectively , the angle of repose increased from 14.41 to 21.82°and angle of friction with galvanized iron surface increased from 19.8 to 22.4° with increased in moisture content from 9.70 % to 26.53 % (d.b) .

INTRODUCTION

Lupin are cultivated for three main reasons : as a ruminant feed, as a green manure contributing to improved soil structure and for human nutrition because of their high protein and oil contents (Faluyi *et al*., 2000 and Huyghe, 1997). Seeds of white lupin have a protein content ranging from 33% to 47% according to genotype and location . Contrary to cereals, lupin proteins contain a high amount of lysine and a low amount of sulphur – containing amino acids (Dervas, *et al*., 1999).

Oil content varies from 6% to 13 % with a high concentration of polyunsaturated fatty acid (Hugyhe, 1997) .

Lupin flour can be used in production of different ferment products . It can be added to pasta, Crisps, bread and emulsified meat products to increase nutritional value, aroma as well as modify the texture of the end products .

Moreover, protein isolate produced from lupin seeds can be utilized for milk and meat imitation products . In the Middle East, lupin seeds are consumed as a snack after they are soaked in water, scalded and dehulled. Additionally, in some European counties, pickle is produced from lupin seeds (Dervas *et al*., 1999) .

Erbas *et al*., (2005) showed that lupin contained high amounted of protein 32.2% , fibre 16.2% , oil 5.95% and sugar 5.82% . Oil of seeds was composed of 13.5%, saturated 55.4% monounsaturated and 31.1% polyunsaturated fatty acids . Sucrose constituted 71% of total sugar content of seed . Lupin seeds contained 3.9 mg/kg of thiamin , 2.3 mg/kg of riboflavin and 39 mg/kg of niacin .It can be concluded that lupin is an excellent food material with a high nutritional value .

Knowledge of lupin physical and mechanical properties are very important in the design equipment for handling , drying , aeration , milling , storing structures and processing .

Erbas *et al*., (2005) showed that Lupin seeds (Lupinus albus L.), grown in Turkey, were investigated. Density, thousand grain weight, and hectolitre weight of seeds were 1.16 g/cm3, 411.4 g, and 68.12 kg/100 l, respectively.

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/m3 at a moisture content of 8.1% .

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.

Mohsenin (1970) mentioned that , physical properties of the materials such as shape , size , volume and surface area are important in many problems associated with design or developing a specific machine , analysis of the material behavior during handling process and stress distribution in the material under load .

Chakraerty (1972) defined the sphericity of grain as the ratio of surface area of sphere having the same volume as that of the particle to the surface area of the particle .

El-Raie (1987) studied some physical characteristics of shelled corn related to mechanical separation i.e. shape , size , moisture content , length , width , thickness , volume , geometric diameter , sphericity , area of flat surface and area of the transverse one of individual seeds . He suggested a set of equations that can be used for predicting some physical characteristics of corn with reasonable accuracy .

Kaleem *et al*., (1993) reported that the angle of repose is very important in determining the inclination angle of the machine hopper tank .

Soliman (1994) studied that the effect of the moisture content on angle of repose of paddy rice . He mentioned that the dynamic angle of repose is one of the physical properties needed for the design of material handling system and storage facilities for rice and rice products .

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

MATERIALS AND METHODS

This work was carried out to determine some physical and mechanical properties of sweet lupin seed . Four levels of moisture content of the seeds were determined as follows : some seeds were taken from a seed storage. These seeds were divided into four groups . About 30g of seeds of each group were soaked in water for time intervals of : 0.0 (no soaking in water) , 1 , 2 and 3.5 h . then moisture content of each group was determined by drying the seeds under 105°C for 24h . The moisture content (MC) of the four groups (MC1,…,MC4) were found to be : 9.70 , 16.57, 21.07 and 26.53 % (d.b) respectively .

Measuring instrumentation :

1- Digital Vernire caliper , with accuracy 0.01 mm was used for measuring length , width and thickness .

2- Electrical balance : Sartorius type, accuracy 0.0001 g .

3- Electrical oven with forced hot air circulation no. 299 of maximum temperature of 300 ºC .

4- Rigidity force : A digital force gauge with accuracy of 0.2 % was used for measuring the rigidity force . It has a maximum reading of 2200 g , so , a lever construction was used for amplifying force reading , Fig. (1) reactions due to lever weight was take in consideration .

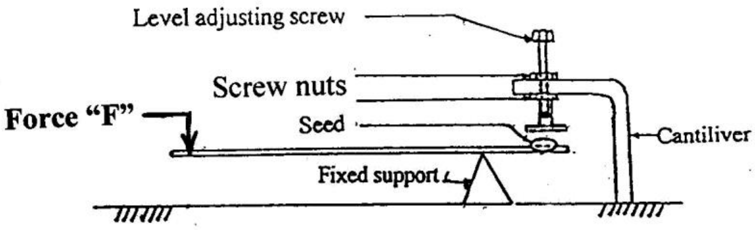

Fig.(1): Apparatus used for fracturing the seed

Experimental procedure :

1- Moisture content :

The moisture content was determined for lupin seeds using the oven methods according to ASAE standard ISBN 0-929355-50.4 Library of congress .(1994), i. e. drying for 24 h at 105ºC .

2- Seed dimensions :

The sample of seeds about 50 seeds was taken randomly to carrying out the required measurements . The main dimensions: length "L" , width " W " and thickness " T "were measured using a digital vernier calper and the mean value was calculated for each sample . The following equations(used by El- Raie *et al* .,(1996) for some agriculture products) were used to calculated of geometric diameter (D_g) of an individual grain in millimeters .

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

3- Friction and Repose angle of seed :

Friction" θ" and Repose "ϕ" angles were determined . The friction angle was determined between the seeds and a steel surface according to Mohsenin (1970) . The repose angle was measured according to the following formula :

$$\Phi = \tan^{-1} h / 0.5\,x \qquad (2)$$

Where :

h = height of the cone formed by the seeds ,
x = diameter of the base of the cone .

4- Real and Bulk densities:

Individual seeds were taken at randomly to determine the real density and quantities of seeds were taken , randomly to determine the bulk density . Real " ρ_g" and Bulk "ρ_b " densities of seeds were calculated according to the formula :

$$\rho_g = M / V \qquad (3)$$

Where :

ρ_g = real density of an individual seed , g /cm^3,
M = mass of an individual seed ,g ,
V = volume of an individual seed , cm^3.

$$\rho_b = M_b / V_b \qquad (4)$$

Where :

ρ_b =bulk density of seeds , g /cm^3
M_b= mass of the quantity , g ,
V_b = volume of an the quantity , cm^3 .

5- Sphericity :

Mohsenin (1970) expressed the degree of sphericity as follows:

$$\Phi = (L\ W\ T)^{1/3} / L \qquad (5)$$

6- Rigidity force:

The force required to breaking the seed "F" (N) was measured using the lever setup with digital force gauge . Lever setup it was used for amplifying the force measured by the digital force gauge. The digital force is a small range of the force measured by it (2200 g). Fig. (1) Shows the lever setup and the force acting on their arms. A total force (F_2) on the short arm end can be determined as follows:

$$F_2 = c (F_1 L_1 / L_2) + F_3$$
$$= 8.88 F_1 + 2.86 \qquad (6)$$

Where :

F_1= Force exerted by the gauge sensor , N ,
F_2 = Total force exerted by the lever on the seed , N ,
F_3 = Reaction caused by the lever weight at zero, F_1, N
L_1= Length of the long arm of the lever = 44.4 cm,
L_2 = Length of the short arm of the lever = 5 cm,
c = conversion factor.

RESULTS AND DISCUSSION

1-Linear dimension:-

The length, width and thickness of seeds increased from 11.067 to 11.838 mm, 9.992 to 10.591 mm and 5.174 to 5. 734 mm respectively with increase in moisture content from 9.70 to 26.53 % (Fig .2) . Similarly, the geometric mean diameter increased from 8.291 to 8.944 mm in the same moisture content. The following linear regression equations described the relationship between each of length (L) , width (W) , thickness (T) and geometric diameter (Dg) seeds and moisture content in percent (d.b) .

$L = 10.80 + 0.2383\ Mc$ ($R2 = 0.9114$)
$W = 9.771 + 0.2024\ Mc$ ($R^2 = 0.9946$)
$T = 5.03 + 0.1734\ Mc$ ($R2 = 0.9478$)
$Dg = 8.09 + 0.2067\ Mc$ ($R^2 = 0.9732$)

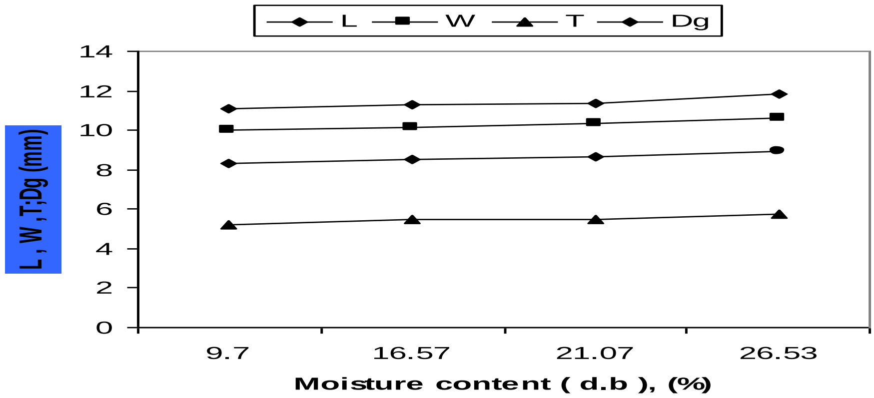

Fig. (2) Effect of moisture content on seed dimensions .

2- Sphyericity :

The sphyericity of seeds calculated at different moisture content increased from 74.75 to 76.25 % with increase in moisture from 9.70 % to 21.07 % and reduced to 75.66 % with further increase in moisture content to 26.53 % (Fig. 3).

The initial increase of sphericity could be due to relatively proportional increase in length, width and thickness. However, beyond 21.07 % moisture content there was relatively greater increase in thickness as compared to length and width which might probably resulted in slight reduction in sphericity. The relationship between sphericity and moisture content is described by a second degree polynomial equation .

$$\Phi = 72.68 + 0.4395\ Mc - 0.02.503\ Mc^2 \qquad (R^2 = 0.998)$$

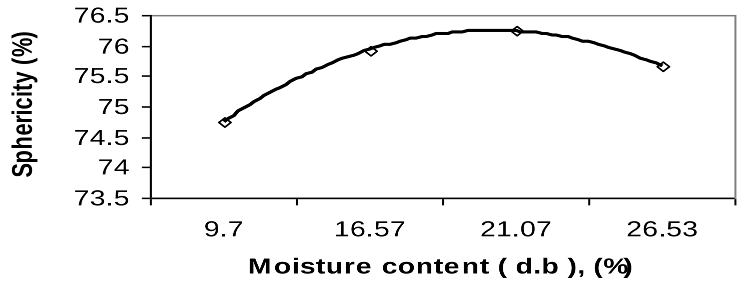

Fig. (3) Effect of moisture content on sphericity.

3- Thousand seed mass (TSM):

The thousand seed mass shown in Fig.(4) increased from 433 to 670 g with increased in moisture content from 9.70 to 26.53 %, which could be attributed to the moisture absorbed by the seeds. The relationship between thousand seed mass and moisture content was found to be linear equation:

$$TSM = 321.0 + 7.109\ Mc \qquad (R^2 = 0.6728)$$

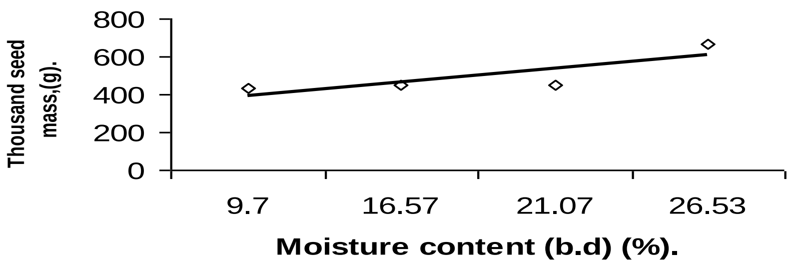

Fig. (4) Effect of moisture content on thousand seed mass .

4- Bulk density and True density:

The bulk and true densities of sweet lupin seeds shown in Fig.(5) decreased from 0.777to 0.717 g/ cm^3 and 1.342 to 1.211 g / cm^3 respectively with increased in moisture content from 9.70 to 26.53 %. The following linear regression equations described the relationship between each of true density and bulk density and moisture content in percent (d.b).

$$\rho_{true} = 1.376 - 0.0415\ Mc \qquad (R^2 = 0.9681)$$
$$\rho_{bulk} = 0.791 - 0.0205\ Mc \qquad (R^2 = 0.9042)$$

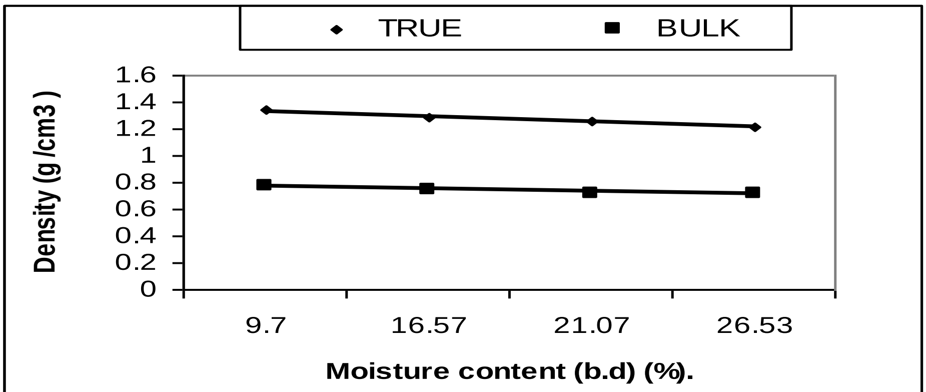

Fig.(5) Effect of moisture content on true density and bulk density .

5- Rupture force :

The force required to initiate sweet lupin seed rupture at different moisture content is shown in Fig. (6). The rupture force sweet lupin seeds decreased from 212.50 to 105.23 N with increase in moisture content from 9.70 to 26.53 %. The following linear regression equation described the relationship between rupture force of sweet lupin seeds and moisture content in percent (d.b).

$$F = 244.09 - 37.512\ Mc \qquad (R^2 = 0.9423)$$

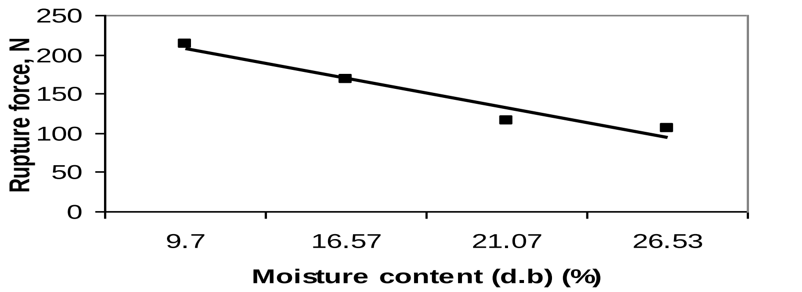

Fig.(6) Effect of moisture content on rupture force.

6- Angle of repose :

The angle of repose for sweet lupin seeds at different moisture content is shown in Fig. (7). The angle of repose sweet lupin seeds increased from 14.41 to 21.82° with increase in moisture content from 9.70 to 26.53 %. The following linear regression equation described the relationship between dynamic repose angle (θ) in degree and moisture content in percent (d.b).

$$\Theta = 13.305 + 0.2419\,Mc \qquad (R^2 = 0.8242)$$

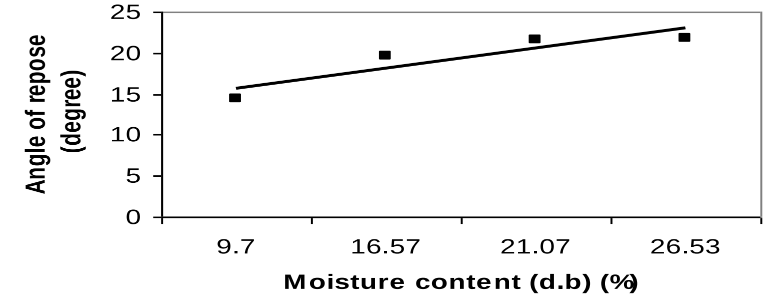

Fig.(7) Effect of moisture content on angle of repose .

7- Angle of friction :

The angle of friction for sweet lupin seeds at different moisture content is shown in Fig. (8) determined with galvanized iron surface. The angle of friction sweet lupin seeds increased from 19.8 to 22.4° with increase in moisture content from 9.70 to 26.53 % . The following linear regression equation described the relationship between static coefficient of friction and moisture content in percent (d.b).

$$\Phi = 18.6 + 0.094\,Mc \qquad (R^2 = 0.9301)$$

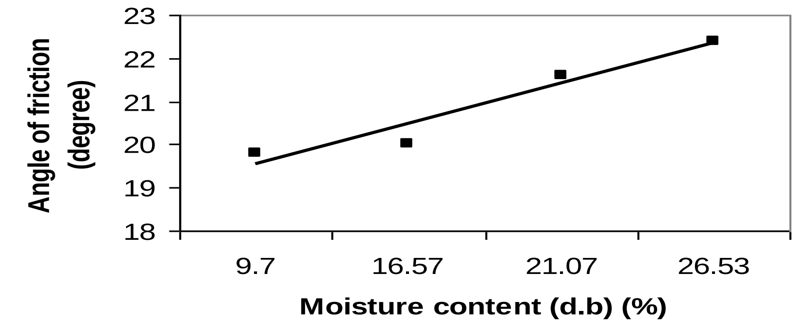

Fig.(8) Effect of moisture content on angle of friction .

SUMMARY AND CONCLUSION

1- The dimensional properties and thousand seed mass of sweet lupin seed increased depending on moisture content as following : length , width , thickness and geometric diameter thousand seed mass increased from 11.067 to 11.838 mm, 9.992 to 10.591 mm, 5.174 to 5.734 mm , 8.291 to 8.944 mm and from 0.433 to 0.670 g respectively.

2- The rupture force decreased from 212.50 to 105.33 N with increased moisture content from 9.70 to 26.53 %.
3- The bulk density and true density decreased from 0.777 to 0.717 g / cm^3 and 1.342 to 1.211 g / cm^3 respectively with increased moisture content from 9.70 to 26.53 %.
4- The angle of repose and angle of friction increased from 14.41 to 21.82° and 19.80 to 22.40° respectively with same moisture content .

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الخواص الطبيعية و الميكانيكية لبذور الترمس الحلو

رأفت وربي ، أشرف كامل زعلوك و سمير حافظ دسوقي
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يعتبر محصول الترمس ذو فوائد كثير لما يحتويه من مركبات لها تأثير مضاد للسرطان و خفض الكوليسيترول كما أن له دور فاعل في خفض جلوكوز الدم لمرضي السكر من النوع الثاني ، و أضافه دقيق الترمس الحلو للمنتجات الغذائية يزيد معامل هضم البروتين و الاستفادة من الأحماض الأمينية .
وأضافه دقيق الترمس الحلو كبديل للدقيق في خبز الكيزر يحسن من الخواص الحسية للمنتج ، و أيضا استخدام مركز البروتين (الدكستريز) كبديل للبروتين الحيواني في منتجات اللحوم و استخدام معزول بروتين الترمس الحلو كبديل للبيض في الكريم كراميل . و أيضا أضافه دقيق الترمس الحلو مع دقيق القمح لرفع نسبة البروتين في منتجات دقيق القمح بالاضافه لتحسين الخواص التصنيعية للمنتجات .
تهدف هذه الدراسة إلي توفير قاعدة معلومات للخصائص الطبيعية لبذور الترمس الحلو و علاقتها بالمحتوي الرطوبى عند أربعة مستويات رطوبة هي ٩,٧٠ %، ١٦,٥٧ % ، ٢١,٠٧ % ، ٢٦,٥٣ % ، أما الخصائص الطبيعية المدروسة فكانت الخصائص البعدية و تشمل طول ، عرض ، سمك ، القطر الهندسي و الكثافة الحقيقة والكثافة الظاهرية جم/ سم^{3} و وزن الألف بذرة و قوة الكسر و زاوية المكوث و زاوية الأحتكاك للبذور علي سطح الحديد المجلفن .
و يمكن تلخيص متوسط النتائج المتحصل عليها في الأتي :
١- الخصائص الطبيعية للترمس الحلو عند التغيير في المحتوى الرطوبى من ٩,٧٠ إلي ٢٦,٥٣ % (علي أساس جاف) فكان تغيير الطول من (١١,٠٦٥ إلي ١١,٨٣٨ مم) و العرض من (٩,٩٩٢ إلي ١٠,٥٩١ مم) و السمك من (٥,١٧٤ إلي ٥,٧٣٤ مم) .
٢- زاد متوسط القطر الهندسي و كتلة الألف بذرة ودرجة التكور بزيادة المحتوى الرطوبى للبذور . بينما انخفضت كل من الكثافة الظاهرية و الحقيقية لبذور الترمس الحلو
٣- زادت زاوية المكوث و أيضا زاوية الأحتكاك للبذور مع سطح الحديد المجلفن بزيادة المحتوى الرطوبى للبذور .
٤- تم استنباط نماذج رياضية توصف التغيير في الخواص الطبيعية و الميكانيكية نتيجة التغيير في المحتوى الرطوبى للبذور يمكن ان تستخدم في وصف التغيير في الصفات الطبيعية والميكانيكية للترمس الحلو أثناء التداول .

قام بتحكيم البحث

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