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 sphericity 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/cm³ and from 0.777 to 0.717 g/cm³ 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 amounts 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 Vernier 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 °C.
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](attachment:fig1.png)

**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 105°C.

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 (Dg) of an individual grain in millimeters.
   \[ D_g = \left( \frac{L \times W \times T}{3} \right)^{1/3} \]  
   (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:
   \[ \Phi = \tan^{-1} \left( \frac{h}{0.5x} \right) \]  
   (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 random to determine the real density and quantities of seeds were taken, randomly to determine the bulk density. Real "\( \rho_g \)" and Bulk "\( \rho_b \)" densities of seeds were calculated according to the formula:

\[ \rho_g = \frac{M}{V} \]

Where:
\( \rho_g = \) real density of an individual seed, g/cm\(^3\),
\( M = \) mass of an individual seed, g,
\( V = \) volume of an individual seed, cm\(^3\).

\[ \rho_b = \frac{M_b}{V_b} \]

Where:
\( \rho_b = \) bulk density of seeds, g/cm\(^3\),
\( M_b = \) mass of the quantity, g,
\( V_b = \) volume of the quantity, cm\(^3\).

**5- Sphericity:**

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

\[ \Phi = \left( \frac{L W T}{L} \right)^{1/3} \]

**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:

\[ F_2 = c \left( \frac{F_1 L_1}{L_2} \right) + F_3 \]

\[ = 8.88F_1 + 2.86 \]

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, 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 (\( D_g \)) seeds and moisture content in percent (d.b).
L = 10.80 + 0.2383 Mc \quad (R^2 = 0.9114)
W = 9.771 + 0.2024 Mc \quad (R^2 = 0.9946)
T = 5.03 + 0.1734 Mc \quad (R^2 = 0.9478)
Dg = 8.09 + 0.2067 Mc \quad (R^2 = 0.9732)

2- Sphericity:

The sphericity 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.
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\[ \Phi = 72.68 + 0.4395 \, \text{Mc} - 0.02503 \, \text{Mc}^2 \quad (R^2 = 0.998) \]

![Graph (3) Effect of moisture content on sphericity.](image)

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:

\[ \text{TSM} = 321.0 + 7.109 \, \text{Mc} \quad (R^2 = 0.6728) \]

![Graph (4) Effect of moisture content on thousand seed mass.](image)

4- Bulk density and True density:

The bulk and true densities of sweet lupin seeds shown in Fig. (5) decreased from 0.777 to 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).
\[ \rho_{\text{true}} = 1.376 - 0.0415 \text{Mc} \quad (R^2 = 0.9681) \\
\rho_{\text{bulk}} = 0.791 - 0.0205 \text{Mc} \quad (R^2 = 0.9042) \]

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).

\[ F = 244.09 - 37.512 \text{Mc} \quad (R^2 = 0.9423) \]

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
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).

\[ \Phi = 18.6 + 0.094 \text{Mc} \quad (R^2 = 0.9301) \]

### 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.

REFERENCES


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الخواص الطبيعية والميكانيكية لبذور الترمس الحلول

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يعتبر محصول الترمس ذو فوائد كثيرة لما يحتويه من مركبات لها تأثير مضاد للسرطان وخفض الكولسترول كما أن له دور فعال في خفض جلوكوز الدم لمرضى السكر من النوع الثاني، وأيضًا دقيق الترمس الحلول الملتقطة الذائبة يزيد معامل هضم البروتين و الاستفادة من الأحماض الأمينية. وأيضًا دقيق الترمس الحلول كبدية للتفريخ في خبر الكوز يحسن من الخواص الصحية للمنتج، و أيضا استخدام مركز البروتين (الدكتور) كبدية للبروتين الحيوي في منتجات اللحوم و استخدم معروج بروتين الترمس الحلو كبدية للبيض في الكريم كراميل. أيضاً أضافه دقيق الترمس الحلول مع دقيق الفصح لرفع نسبة البروتين في منتجات دقيق الفصح بالإضافة لتحسن الخواص الصحية للمستهلك.

تهدف هذه الدراسة إلى توفير قاعدة بيانات لخصائص الطبيعية لبذور الترمس الحلول و علاجاتها بالمحتويات البطولية عند أسمدة محتويات رطوبة هي 13.57%، 10.73%، 21.02%، أما الخصائص الطبيعية المدرسية كنال الخصائص البدنية وتشمل طول، عرض، سمك، قطر الهندسي و الكثافة الباقية والكثافة الظاهرية جمسم/ سم، وزن الألف بذرة وز Cree المكرور و زاوية المكروك و زاوية الاحتكاك للبذور على سطح الحديقة المحلف.

و يمكن تلخيص متوسط النتائج المتحصل عليها في الآتي:
1- الخصائص الطبيعية لبذور الترمس عند التغريب في المحتوى البطولبي من 9.70 إلى 11.838% (على أساس جاف) فكان تغريب الطول من (135 إلى 11.838) ومحتوي (9.921 إلى 11.838)
2- زاد متوسط قطر الهندسي و كثافة الألف بذرة ودرجة الكروي빙ة المحتوى البطولبي للبذور. بينما خفضت كل من الكثافة الظاهرية والكروي빙ة لبذور الترمس الحلول
3- زيادة زاوية المكروك و أيضاً زاوية الاحتكاك للبذور مع سطح الحديقة المحلف بزيادة المحتوى البطولبي للبذور.
4- تم استنداًة مراجعة رياضية لوصف التغيير في الخواص الطبيعية والميكانيكية نتيجة التغيير في المحتوى البطولبي للبذور يمكن أن تستخدم في وصف التغيير في صفوف الطبيعية والميكانيكية لبذور الترمس الحلول أثناء التأهيل.

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