J. Agric. Sci. Mansoura Univ., 33 (1): 297 - 307, 2008

DETERMINATION OF ENGINEERING CHARACTERISTICS RELATED TO PROPER MECHANICAL THRESHING AND HEAD CHOPPING OF SUNFLOWER CROP

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ABSTRACT

Some physical and mechanical properties of sunflower heads and the corresponding seeds were measured.. These properties were considered to be as the database necessary for the proper design of equipment for sequence threshing and chopping processes of sunflower crop heads. Seed length, seed width, seed thickness and unit mass of the seed at moisture content of 16.1% d.b ranging from 10.75 to 12.25 mm, 6.08 to 7.85 mm, 3.49 to 4.60 mm and 0.11 to 0.14 g, respectively. For heads diameter, thickness middle of head, thickness tip of head and unit mass at moisture content of 21.4% d.b ranged from 160 to 220 mm, 63.2 to 74 .0 mm, 26.8 to 40.0 mm and 235.12 to 422.18 g. For seed and head, friction increased with moisture content against galvanized metal sheet. It was also observed that the coefficient of friction for head was lower than that of seed against galvanized sheet metal. The angle of repose increased from 34.99 to 39.34º within the moisture content range of 10.2%~16.1% d.b. In general, physical properties of sunflower heads and the corresponding seeds were dependent on moisture content, and appear to be important in the design of post machinery equipments for threshing and chopping the crop stalks after threshing.

INTRODUCTION

Sunflower crop is a multiple benefits crop, beside its importance as world's leading oilseed crop; it is considered as a livestock feed. In addition, it have been reported that the sunflower oil can be used as a diesel engine fuel. Whereas, sunflower hybrid varieties almost exclusively used for commercial oilseed production (Santalla and Mascheroni, 2003). Many authors (Khairy and Tayel, 1988; Humeida and Hobani, 1993; Gupta and Das ,1997; El Raie *et al.*,1996; El-Raie *et al.*, 1998 and Abou El-Magd *et al.*, 2002) mentioned that the knowledge of the physical and mechanical characteristics of agricultural products is important in the design of agricultural machines. However, they studied the physical properties and characteristics of some agricultural crops. These properties included the mass, volume, diameter, surface area, mass density, and spherically. They showed that the densities were differed significantly and the difference in mean diameter of the various cultivars was also significant. They formulated equations to compute the surface area and volume using the mass or the mean diameter of the disk. The equipments for sunflower seed extraction and sunflower stalk chopping for livestock feed are not available in Egypt. In addition, the imported machines are expensive and complicated design and operation hours lead to low efficiency. This is because the equipments do not suit the properties of most Egyptian sunflower crop (Abou El-Magd *et al.*, 2002). Also,

Subramanian *et al.* (1990) reported that there were impact dehulling of sunflower seeds on effect of operating conditions and seed characteristics.
Despite extensive published literatures have been found and reported on the general physical properties of sunflower, a few published literatures were found on the effect of some physical and mechanical properties on an equipment design parameters. These properties are considered to be necessary for the proper design of equipment for handling, conveying, separation, dehulling, drying, mechanical expression of oil, storage and other processes (Mohamed, 2007). But no published literatures was found on the detailed physical and mechanical properties of sunflower seed and stalks which would be useful for the design purpose of a double propose equipment for threshing and chopping sunflower in the same time. Also, determining morphological and physical properties of sunflower seeds are often required to develop equipment for handling, storage, transportation, drying, and other processes involving the seed (Perez *et al.*, 2006).

Deshpande et al (1993) showed that rolling or sliding of sunflower seeds on surfaces depends on their sphericity and tills parameter should be taken into account in designing handling and dehulling equipment for this seed. Mohamed (2007) studied the effects of some physical, mechanical and thermal properties on design parameters of handling and processing machinery of some oil seeds. Puchalski and Brusewitz (1996a) recommended that the sliding speed, measurement of harvested agricultural products, and type of abrasive surface had a significant effect on both friction coefficients, except sliding speed did not affect the dynamic coefficient of friction. Normal force did not affect either coefficient and two sunflower cultivars had similar coefficient in most cases . Puchalski and Brusewitz (1996b) determined the abrasion resistance of sunflower from a linear, sliding friction test. Destructive and non-destructive parameters, potentially related to abrasion resistance, were acquired from the sunflower, the test abrasive surface, and the force-displacement curve. The distance to the beginning of skin removal and the area of skin removed were selected as the primary indicators of abrasion resistance. Suitability of the remaining parameters as abrasion resistance indicators was assessed through correlation with the primary indicators. Width of skin removed, distance to threshold of failure, and area ratio (skin removed area: contact area) had the highest correlation with the primary indicators .

Matouk *et al.* (1999) evaluated the effect of some mechanical parameter on handling characteristics of sphere-like crops. They showed that the best ever handling result was obtained at 0.2 m/s speed of disk feeding chain, 200 rpm sieve rocking speed and 15 degree of sieve slope angle during heads handling using rectangular cell shape. The feasible methods and machine design feathers used for threshing sunflower crop have been illustrated in numerous literatures.

Vergano *et al.* (1992) studied that, the design aspects and performance of an axial-flow vegetable seed extracting machine. They compared the manual with the mechanical sunflower threshing for different vegetable heads. The factors affecting performance of sunflower threshing equipment have been also illustrated in numerous literatures. Abou El-Magd *et al.* (2002) studied that, the design aspects and performance of equipment for seed extracting machine. They compared the manual with the mechanical sunflower threshing for different vegetable heads. They found that that germination count for mechanically extracted seeds was higher than for the manually extracted seeds. This study aims to:

1. Determine some physical and mechanical properties of sunflower crop (seeds and heads).
2. Investigate the dependency of seed and head properties on their moisture content, through developing mathematical models relating to the change in their properties with the change in moisture content level.

MATERIALS AND METHODS

The experiments were carried out at Nubaria Research Station, Alexandria Governorate. Geza1 sunflower (hybrid variety) was used in the study. The samples were manually cleaned to remove foreign matters, dust, dirt, broken and immature seeds. The moisture content of the samples was determined by oven drying at 105 ± 1 °C for 24 h according to Srthar and Das (1996).

The physical and mechanical properties of the seeds were investigated at moisture content in the range of 10.2% to 16.1% d.b. Meanwhile, the physical and mechanical properties of the sunflower heads were investigated at moisture content in the range of 10.5% to 21.4% d.b. These ranges of moisture contents were obtained by harvesting sunflower crop at different days. The length, width, thickness and weight of sunflower seeds and the diameter, thickness from middle of head , thickness from tip of head and weight of sunflower heads were measured in randomly selected 100 sunflower heads and seeds.

The length, width and thickness of materials were measured by a micrometer to an accuracy of 0.05 mm. Fig.(1) shows characteristic dimensions of sunflower seed and the dotted lines represent the heads inside the seed.

The geometric mean diameter, Dg, and sphericity,φ, of the seeds and heads were calculated by using the following relationships (Mohsenin, 1970):

$$D_g = (LWT)^{1/3} \qquad (1)$$

$$\varphi = \left[\frac{(LWT)^{1/3}}{L}\right] \times 100 \qquad (2)$$

Where L is the length, W is the width and T is the thickness in mm for seeds. For heads, the length (L) and width (W) were considered as head diameter and thickness from middle of head as considered as (T) in equations.

the head shape were classified onto five categories according to the so-called the shape index (S_i). However, the shape index was obtained as follows (Abd Alla *et al.*1995):

$$S_i = \frac{L}{\sqrt{W \times T}} \qquad (3)$$

However, according to that classification the head shape index values of (less than 1.2), (1.2-1.29), (1.3 -1.39), (1.4-1.49) and (more than 1.5) are spherical, spherical oval, oval, elongated oval and elongated shapes, respectively.

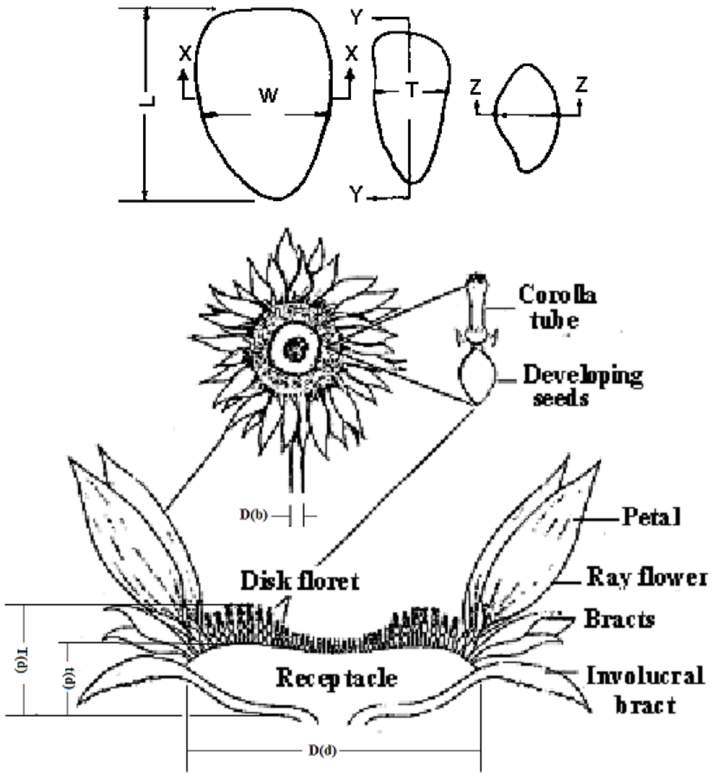

Fig. (1): Characteristic dimensions of sunflower seed and the dotted lines represent the heads inside the seed; L, length; W, w, width; T, t thickness.

To obtain the mass of the seed, thousand seed mass were measured by an electronic balance to an accuracy of 0.01 g then divided the total mass over thousand to obtain the mass of each seed.

The surface area of sunflower was found by analogy with a sphere of same geometric mean diameter, using the following expression (Olajide and Ade-Omowaye, 1999 and Sacilik *et al.*, 2003):

$$S = \pi D_g^2 \qquad (4)$$

Where S is the surface area in mm^2, and Dg is the geometric mean diameter in mm. The coefficient of static friction was determined with respect to galvanized metal sheet. This is common material used for sunflower crop processing machine. To determine the coefficient of static friction of sunflower seeds, a hollow metals cylinder 50 mm diameter and 50 mm high and open at both ends was used. The cylinder was filled by the seeds and placed on an adjustable tilting table. The surface was raised up gradually by a screw device until the cylinder just starts to slide down. The angle of the surface was read from a scale and the static coefficient of the friction was read as the tangent of this angle (Özarslan, 2002; Yalçin *et al.*, 2007).

To determine angle of repose, a box measuring 300mm×300mm×300mm, having a removable front panel was used. The box is filled with the seeds, and the front panel was quickly removed, allowing the seeds to flow to their natural slope. The angle of repose was calculated from measurements of seed free surface depths at the end of the box and midway along the sloped surface and horizontal distance from the end of the box to this midpoint (Mwithiga and Sifuna, 2006; Dursun *et al.*, 2007; Sacilik *et al.*, 2003).

RESULTS AND DISCUSSION

Fig. (2) Illustrates frequency distribution curves of seed length, width, thickness and unit mass of the seed at 16.1% (d.b) moisture content. It can be seen that about 86% of the seeds had a length in the rang of 10.75-12.25 mm, about 84% had a width in the rang of 6.08- 7.85 mm, about 68% had a thickness in the ranging of 3.49-4.60 mm and about 64% had a unit mass in the rang of 0.11-0.14 g. Meanwhile, Fig. (3) Illustrates frequency distribution curves of head diameter, thickness both middle and tip of head and unit mass at 21.4% d.b moisture content.

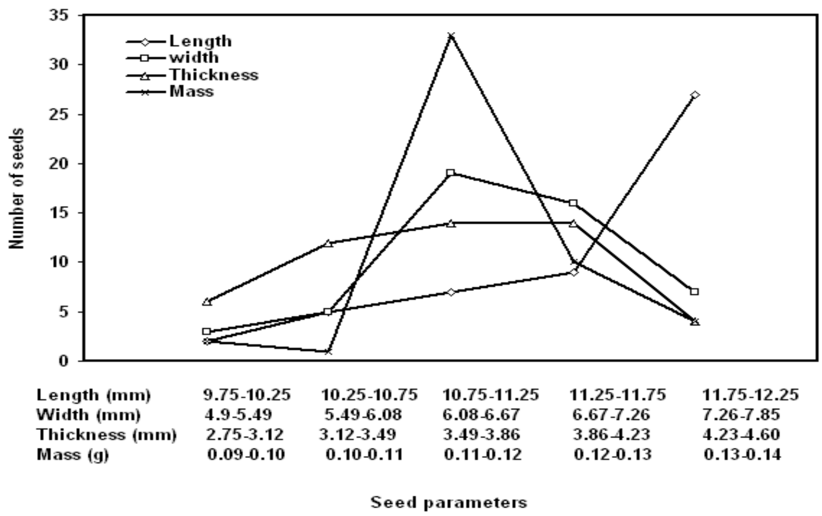

Fig. (2). Frequency distribution curves of seed length, width, thickness and unit mass of the seed at moisture content of 16.1% d.b.

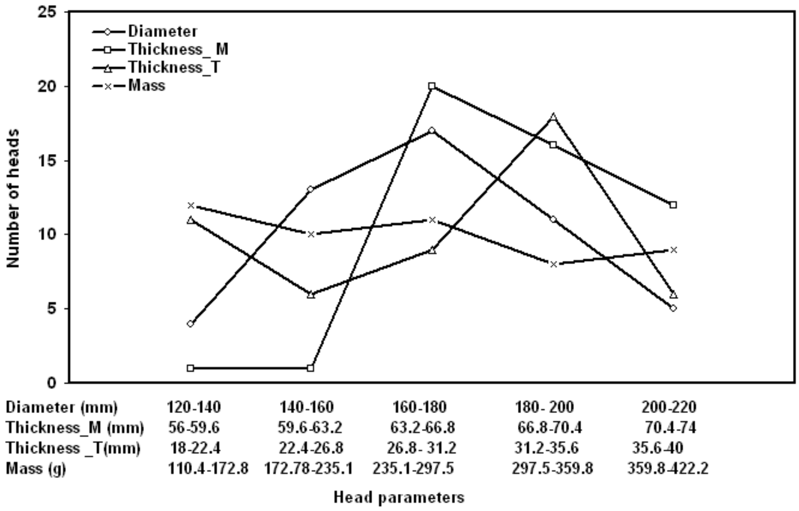

Fig. (3): Frequency distribution curves of head diameter, thickness both middle (thickness_M) and tip (thickness_T) of head and unit mass of the head at moisture content of 21.4%d.b.

It can be seen that about 66% of the heads had a diameter in the rang of 160-220 mm, about 96% had a thickness middle of head in the rang of 63.2- 74 mm and about 35% had a thickness tip of head in the rang of 26.8 - 40.0 mm, and about 56% had a head mass in the rang of 235.12-422.18 g.

Table (1) shows dimensional properties of sunflower seeds at three different moisture contents in the range of 10.2-16.10% d.b. Geometric mean diameter, sphericity and surface area of sunflower seeds increased with increase in moisture content. Geometric mean diameter, sphericity and surface area of sunflower seeds increased from 5.92 to 7.52 mm, 54.34 to 57.54 % and 110.33 to 177.53 mm^2, respectively in the moisture content range.

Table (1): Dimensional properties of sunflower seeds.

Characteristics	**Mean**	**S.D**	**Mean**	**S.D**	**Mean**	**S.D**
Moisture (% d.b)	10.24	0.35	12.51	0.30	16.10	0.15
Geometric mean diameter (mm)	5.92	0.25	7.37	0.25	7.52	0.18
Sphericity (%)	54.34	0.58	56.00	1.40	57.54	0.97
Surface area (mm^2)	110.33	9.07	170.78	11.56	177.53	8.39

S.D = Standard deviation

The regression analysis which can explain the relationship between head moisture content and head diameter as independent variables and head weight as dependent variable could be put in a linear expression. The linear regression equation between head moisture content (H_{mc},% d.b), and head diameter (H_{dia}, mm) and head weight (H_{wei}, g) could be put as follows:

$$H_{wei} = 3.23 \times H_{mc} + 24.00 \times H_{dia} - 256.59 \quad (5)$$

The fitting of data is excellent with coefficient of determination (R^2) equals to 0.9893 with average absolute percentage error equals to 1.87. Also, linear regression equation between head moisture content (H_{mc}, % d.b) and head diameter (H_{dia}, mm), and head thickness ($H_{thick,}$ mm) could be put as follows:

$$H_{thich} = 1.88 \times H_{mc} + 1.46 \times H_{dia} - 1.53 \qquad (6)$$

The fitting of data is excellent with coefficient of determination (R^2) equals to 0.9316 with average absolute percentage error equals to 3.81.

The linear regression equation between head diameter (H_{dia}, mm) and number of seed (S_n) could be put as follows:

$$S_n = 156.35 \times H_{dia} - 1245.63 \qquad (7)$$

The fitting of data is excellent with coefficient of determination (R^2) equals to 0.8831 with average absolute percentage error equals to 7.59. The linear regression equation between seed moisture content (S_{mc}, %d.b) and seed length (S_L,mm) could be put as follows:

$$S_L = 0.34 \times S_{mc} + 7.68 \qquad (8)$$

The fitting of data is excellent with coefficient of determination (R^2) equals to 0.8304 with average absolute percentage error equals to 3.96.The linear regression equation between seed moisture content (S_{mc}, %d.b) and seed width (S_w, mm) could be put as follows:

$$S_w = 0.27 \times S_{mc} + 3.41 \qquad (9)$$

The fitting of data is excellent with coefficient of determination (R^2) equals to 0.7957 with average absolute percentage error equals to 3.62.The linear regression equation between seed moisture content (S_{mc}, %d.b) and seed thickness (S_{thick}, mm) could be put as follows:

$$S_{thick} = 0.16 \times S_{mc} + 1.71 \qquad (10)$$

The fitting of data is excellent with coefficient of determination (R^2) equals to 0.7451 with average absolute percentage error equals to 4.94.
The following relationships could determine as follows:

$$S_L = 1.74 \times S_w = 3.12 \times S_{thich} = 97.45 \times M_s \qquad (11)$$

$$H_{dia} = 2.58 \times H_{thick} = 0.652 \times H_{mc} \qquad (12)$$

Table (2) shows the relationship and correlation coefficients between sunflower heads and corresponding seeds dimensions at 16.1% d.b moisture content for seeds and at 21.4% d.b moisture content for heads.

Table (2): Relationship and correlation coefficients between sunflower heads and corresponding seeds dimensions at 16.1% moisture content d.b for seeds and at 21.4% moisture content d.b for heads.

Particulars	Ratio	Degrees of freedom	Correlation coefficient
	Seeds		
Length/Width	1.74	98	0.996
Length/Thickness	3.12	98	0.993
Length/Mass	97.45	98	0.998
	Heads		
Diameter/ Thickness_M	2.58	98	0.997
Diameter/Mass	0.65	98	0.975

The coefficient of correlation (Table 2) show that the Length/Width, Length/Thickness and Length/Mass are significant with same level and this indicates that the width, thickness and mass of the sunflower seed are closely related to its length. Also, for sunflower heads, the Diameter/ Thickness_M and Diameter/Mass are significant with same level and this indicates that the thickness at the middle of head (Thickness_M) and mass of the sunflower head are closely related to its diameter.

The relationship between head diameter and sphericity (φ) can be represented by the following regression equation

$$\varphi = -0.06 \times H_{dia} + 78.74 \ldots\ldots \quad (13)$$

The fitting of data is excellent with coefficient of determination (R^2) equals to 0.8073. The relationship between aspect ratio H (D/T) between head diameter and thickness with it's and sphericity (φ) appears linear and can be represented by the following regression equation

$$\varphi = -7.53 \times H + 78.74 \ldots\ldots \quad (13)$$

The fitting of data is excellent with coefficient of determination (R^2) equals to 0.8072. The relationship between seed width and sphericity (φ) appears linear and can be represented by the following regression equation

$$\varphi = 4.46 \times S_w + 27.10 \ldots\ldots \quad (14)$$

The fitting of data is excellent with coefficient of determination (R^2) equals to 0.5345. The relationship between seed thickness (S_{thick}) and sphericity (φ) can be represented by the following regression equation

$$\varphi = 7.68 \times S_{thick} + 28.44 \ldots\ldots \quad (15)$$

The fitting of data is excellent with coefficient of determination (R^2) equals to 0.766.

The regression analysis which can explain the relationship between seed moisture contents (S_{mc}, %d.b) as an independent variable, and static coefficients of friction for sunflower seed (μ_s) as dependent variable could be put in a linear expression, and the regression analysis which can explain the relationship between head moisture contents (H_{mc}, %d.b) as an independent variable, and static coefficients of friction for sunflower head (μ_H) as dependent variable could be put in a linear expression. The static coefficient of friction for sunflower seed and head bears the following relationship with their corresponding moisture contents.

$$\mu_s = 0.011 \times S_{mc} + 0.359 \ldots\ldots \quad (16)$$

The fitting of data is excellent with coefficient of determination (R^2) equals to 0.919.

$$\mu_H = 0.007 \times H_{mc} + 0.344 \ldots\ldots \quad (17)$$

The fitting of data is excellent with coefficient of determination (R^2) equals to 0.864.

Table (3) shows angle of repose of sunflower seed and coefficient of friction of sunflower heads and corresponding seeds at different moisture content. The static coefficient of friction of both heads and corresponding seeds increased linearly with the moisture content range. It was also observed that the coefficient of friction for head was lower than that of seed against galvanized metal sheet.

Table (3): Angle of repose of sunflower seed and coefficient of friction of sunflower heads and corresponding seeds at different moisture content.

Moisture content		Angle repose degree	Coefficient of friction	
Seed	Head	seed	Seed	Head
(% d.b)		(Degree)	(------)	(------)
16.10	21.40	39.43	0.53	0.49
12.51	16.78	35.99	0.49	0.45
10.24	10.50	34.99	0.47	0.42

The angle of repose increased from 34.99 to 39.34º within the moisture content range of 10.20%~16.10% d.b. The regression analysis which can explain the relationship between seed moisture content (S_{mc}, %d.b) as an independent variable and the angle of repose (θ,°) as dependent variable could be put in a linear expression. The relationship between seed moisture content (S_{mc}, % d.b) and angle of repose (θ) can be represented by the following regression equation:

$$\theta = 0.773 \times S_{mc} + 26.82 \quad (18)$$

The fitting of data is excellent with coefficient of determination (R^2) equals to 0.892. The linear increase of angle of repose within increase of moisture content was found in other literatures for grains (Zewdu and Solomon, 2007; Dursun and Dursun, 2005).

CONCLUSION

The following conclusions are drawn from this investigation on sunflower heads and corresponding seeds.

1. Geometric mean diameter, sphericity and surface area of sunflower seeds increased from 5.92 to 7.52 mm, 54.34 to 57.54 % and 110.33 to 177.53 mm^2, respectively in the moisture content range (10.2-16.10% d.b).
2. There was a linear relationship between head weight and head moisture content and head diameter with coefficient of determination (R^2) equals to 0.9893.
3. The static coefficient of friction of both heads and corresponding seeds increased linearly with the moisture content range. It was also observed that the coefficient of friction for head was lower than that of seed against galvanized metal sheet.
4. The angle of repose increased from 34.99 to 39.34º within the moisture content range of 10.20%~16.10% d.b.
5. There was a linear relationship between head diameter and number of seed with coefficient of determination (R^2) equals to 0.8831

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تعيين الخصائص الهندسية لمحصول عباد الشمس الضرورية لعمليات دراس وتقطيع الأقراص آليّا

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يهدف هذا البحث إلى توفير قاعدة من البيانات عن الخواص الفيزيقية والميكانيكية لمكونات محصول عباد الشمس (خاصة البذور والأقراص) اللازمة لتحديد الخصائص الهندسية لتلك المكونات والضرورية لتحديد أبعاد التصميم الملائم لمعدة تقوم على التعاقب بدراس الرؤوس وفصل البذور وكذلك تقطيع أقراص وعيدان عباد الشمس. بالإضافة إلى توضيح حدود و مدى اعتماد عوامل التصميم والتشغيل لماكينات دراس وتقطيع الأقراص عباد الشمس على تلك الخصائص الهندسية تحت ظروف مختلفة من أقطار وحجم الأقراص وأيضا المحتوى الرطوبى بها. ولتحقيق هذا الهدف تضمنت الدراسة قياس وتقدير الأبعادَ الرئيسيةَ لبذور عبّادِ الشمس وكذلك الأقراصِ والعيدان، تحديد الخصائصَ الهندسية ذات العلاقةِ بالأبعاد الرئيسيةِ المقاسة و اشتقاق العِلاقاتِ الضروريةِ بين أبعادِ القرص والبذرةِ والصفات الطبيعيةِ والميكانيكيةِ الأخرى باستعمال تحليلِ الانحدار. وقد أظهرت النتائج أن كل منحنيات طولِ ، عرض، سُمك البذرةِ ووحدة كتلة البذرةِ عند محتوى رطوبةِ ١٦,١ % (على أساس الوزن الجاف) أن حوالي ٨٦ % من البذور تراوح طولِه مِنْ ١٠,٧٥ إلى ١٢,٢٥ مليمترِ، حوالي ٨٤ % تَرَاوُح عرضه مِنْ ٦,٠٨ إلى ٧,٨٥ بذرة لها طول يَتراوحُ مِنْ ٣,٤٩-٤,٦٠ وحوالي ٦٤ % ترَاوُح سُمكِه مِنْ ٠,١١-٠,١٤ حوالي ١٦,١ % (على أساس الوزن الجاف) . لوحظ أن حوالي ٦٦ % من الرؤوسِ لَهُا قطرِ يتراوح مِنْ ١٦٠-٢٢٠ مليمتر، حوالي ٩٦ % منتصف سُمكِ القرصِ ٦٣,٢- ٧٤. ٠ مليمترِ وحول نصف يَتراوحُ مِنْ ٢٦,٨ -٤٠,٠ مليمتر، وحوالي ٥٦ % من كتلة الحبوب ترَاوُح بينْ ٢٣٥,١٢-٤٢٢,١٨ عند ٢١,٤ % محتوى رطوبى على الأساس الجاف.