

**SOME PHYSICAL PROPERTIES OF SAFFLOWER SEED (*CARTHAMUS TINCTORIUS* L.)**

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**ABSTRACT**

Some physical properties of safflower (*Carthamus tinctorius* L.) were determined as a function of moisture content. Also, physical properties such as dimensions, geometric mean diameter, sphericity, 1000 seeds mass, bulk and seed density, terminal velocity, projected area and porosity were measured at three moisture content levels (5.61 %, 14.08 % and 23.32 d.b. %). The values of length, mass, geometric mean diameter, sphericity, bulk density, seed density, terminal velocity, projected area and porosity were established as 6.89-7.56 mm, 0.035-0.054 g, 4.13-4.70 mm, 0.600-0.623, 526.9-488.6 kg m<sup>-3</sup>, 1096.7-1187.6 kg m<sup>-3</sup>, 3.84-5.02 ms<sup>-1</sup>, 24.60-27.50 mm<sup>2</sup> and 52.0- 56.7%, respectively. The coefficient of static friction on an iron sheet and a galvanized sheet were established.

**Key words:** safflower, *Carthamus tinctorius*, physical properties

**ASPIR TOHURLUĞUNUN BAZI FİZİKSEL ÖZELLİKLERİ (*CARTHAMUS TINCTORIUS* L.)**

**ÖZET**

Bu çalışmada aspir tohumunun (*Carthamus tinctorius* L.) üç farklı nem seviyesinde (5.61, 14.08 ve 23.32 % k.b.) fonksiyonu olarak porozite, izdüşüm alanı, son hız, hacim ve partikül yoğunluğu, bin tane ağırlığı, ortalama geometrik çap, küresellik ve tane boyutları gibi fiziksel özellikleri belirlenmiştir. Uzunluk, kütle, ortalama geometrik çap, küresellik, hacim yoğunluğu, partikül yoğunluğu, son hız, izdüşüm alanı ve porozite değerleri sırasıyla 6.89-7.56 mm, 0.035-0.054 g, 4.13-4.70 mm, 0.600-0.623, 526.9-488.6 kg m<sup>-3</sup>, 1096.7-1187.6 kg m<sup>-3</sup>, 3.84-5.02 ms<sup>-1</sup>, 24.60-27.50 mm<sup>2</sup> ve % 52.0-56.7 olarak bulunmuştur. Statik sürtünme katsayısı çelik ve galvaniz sac için belirlenmiştir.

**Anahtar Kelimeler:** Aspir, *Carthamus tinctorius* fiziksel özellikler

**Nomenclature**

<i>L</i>	length of safflower seed (mm)	<i>D<sub>g</sub></i>	geometric mean diameter (mm)
<i>W</i>	width of seed (mm)	<i>V<sub>t</sub></i>	terminal velocity of seed (m s <sup>-1</sup> )
<i>T</i>	thickness of seed (mm)	<i>P<sub>g</sub></i>	projected area (mm <sup>2</sup> )
<i>M</i>	mass of seed (g)	<i>R<sup>2</sup></i>	determination coefficient
$\emptyset$	sphericity	$\epsilon$	porosity (%)
<i>M<sub>c</sub></i>	moisture content of seed (%) d.b.	$\mu_s$	coefficient of static friction
<i>M<sub>1000</sub></i>	1000 seed mass (g)	$\rho_s$	seed density of safflower (kg m <sup>-3</sup> )
$\rho_b$	bulk density of safflower (kg m <sup>-3</sup> )		

**INTRODUCTION**

Safflower, *Carthamus tinctorius* L. is a member of the family Compositae or Asteraceae, cultivated mainly for its seed, which is used as edible oil, as engine fuel and as birdseed.

Traditionally, the crop is grown for its flowers, used for colouring and flavouring foods and making dyes, especially before cheaper aniline dyes became available for medicines.

Safflower is one of humanity's oldest crops, but generally it has been grown on small plots for the grower's personal use and it remains as a minor crop with world seed production 637.986 t in 2002 year, Anonymous (2003).

High oleic safflower oil has promise as a pollutant reducing diesel fuel additive to reduce smoke and particulate emissions. High oleic safflower oil as a diesel fuel additive would also reduce acid rain, the greenhouse effect and surface pollution because safflower oil is virtually free of sulfur, totally lacks fossil carbon dioxide and is biodegradable (Bergman & Flynn, 2001). Commercial safflower varieties contain

32 to 52 percent oil (Armah-Agyeman, Coiland, Karow, Hang, 2002).

No detailed studies concerning physical properties of safflower seeds have been reported hitherto. Whereas the physical properties of equipment used must be known for plantation, harvesting, transportation, storage production of biodiesel and other processing of safflower.

The aim of this work is to establish some physical properties such as projected area, bulk density, grain density and dimensions of safflower seeds.

**MATERIAL AND METHODS**

Safflower (*Carthamus tinctorius* L.) seeds were obtained from Konya in Turkey in August 2002. The safflower seeds were transported in polypropylene bags and held at room temperature. The seeds were cleaned in an air screen cleaner to remove all foreign matters such as dust, dirt, stones, immature, damaged and broken seeds.

The initial moisture content of grains was determined by using standard methods (USDA, 1970; Brusewitz, 1975). Three samples were placed in an oven at 376 K for 72 h. The samples were then cooled

in a desiccator, weighed and the moisture content of the grain calculated. The moisture contents of grains were found to vary between 5.52 and 5.67 d.b. Grain samples of the desired moisture levels were prepared by adding calculated amounts of distilled water, thorough by mixing and then sealing in separate polyethylene bags. The samples were kept at 278 K in refrigerator for at least a week to enable the moisture to distribute throughout the sample. Before starting a test, the required quantity of seed was taken out of the refrigerator and was allowed to warm up to the room temperature (Desphande, Bal & Ojha, 1993).

All physical properties of safflower were determined using 10 repetitions at moisture contents of 5.61, 14.08 and 23.32 %.

To determine the size of the grains, ten groups of samples consisting of 100 grains were selected randomly. 10 grains were taken from each group and their linear dimensions - length, width and thickness- and projected areas were measured. Linear dimensions were measured using micrometer to an accuracy of 0.01mm.

Projected area of grains was determined by using a digital camera (Canon A 200) and the Sigma Scan Pro 5 program (Trooien & Heerman, 1992; Ayata, Yalçın & Kirişçi, 1997).

The mass of grains and a thousand grain mass were measured using an electronic balance to an accuracy of 0.001g. To evaluate 1000 grain mass, 100 randomly selected grains from the bulk were averaged.

Geometric mean diameter ( $D_g$ ) and sphericity ( $\emptyset$ ) values were found using the following formula; (Mohsenin 1970; Jain & Bal 1997)

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

$$\emptyset = (LWT)^{1/3} / L$$

The bulk density ( $\rho_b$ ) was determined with a weight per hectoliter tester which was calibrated in kg per hectoliter (Desphande et.al. 1993; Suthar & Das 1996; Jain & Bal 1997). Excess grains were removed by a stick. The grains were not compacted in any way.

The seed density ( $\rho_s$ ) is defined as the ratio of the mass of a sample to its solid volume (Desphande et al., 1993). The safflower seed volume was determined using the liquid displacement method. Toluene ( $C_7H_8$ ) was used in place of water because it is absorbed by seeds to a lesser extent. Also, its surface tension is low, so that it fills even shallow deeps in a seed and its dissolution power is low (Sitkei, 1986; Öğüt, 1998).

The porosity of the bulk ( $\epsilon$ ) safflower was computed from the values of seed density and bulk density using the relationship given by Mohsenin (1970) as follows:

$$\epsilon = [(\rho_s - \rho_b) / \rho_s] * 100$$

The terminal velocities of safflower seed at different moisture contents were measured using an air column. For each test, a sample was dropped into the air stream from the top of the air column, which air was blown to suspend the material. The air velocity near the location of the grain suspension was measured by an electronic anemometer having the least count of 0.1  $ms^{-1}$  (Joshi, Das & Mukherji, 1993; Hauhout- O'hara, Criner, Brusewitz & Solie, 2000).

The coefficient of static friction was measured by using iron sheet and galvanized sheet surfaces. For this measurement one end of the friction surface is attached to an endless screw. The grain was placed on the surface and it was gradually raised by the screw. Vertical and horizontal height values were read from the ruler when the grain started sliding over the surface, then using the tangent value of that angle the coefficient of static friction was found. Baryeh (2001), Dutta, Nema & Bhardwaj (1988), Suthar and Das (1996) have used similar methods.

Results were analyzed for statistical significance by analysis of randomized plots of factorial experimental design (Anonymous, 1991).

## RESULTS AND DISCUSSION

### Safflower seeds dimensions and mass distribution

Some dimensional properties of safflower seeds at 5.61, 14.08 and 23.32 d.b % moisture content were given in Table 1. The percentage distributions of the seed dimension properties are given in Fig 1.

96 % of safflower seeds have a mass ranging from 0.02 g to 0.05 g, 84 % of safflower seeds have a length from 6.15 mm to 7.43 mm, 85 % of safflower seeds have a width from 3.39 mm to 4.19 mm and 95 % of safflower seeds have a thickness ranging from 2.20 mm to 3.10 mm at a moisture content of 5.61 %.

The values given in Table 1 increased together with increase in moisture content. The reasons for this increase were probably due to some tiny air voids on the seeds. Similar results were found by Desphande *et al.* (1993) for soybeans; Baryeh (2001) for bambara groundnuts, Gezer *et al.* (2002) for apricot pits and kernels and Aydın (2002) for hazel nuts.

The coefficients of correlation show that the  $L/W$ ,  $L/M$ ,  $L/D_g$  and  $L/\emptyset$  ratios were highly significant (Table 2). The relationships between length, width, thickness and weight were given by the following equation.

$$L = 1.83xW = 2.54xT = 196.86xM$$

Table.1. Some dimensional properties of safflower seeds at different moisture contents d.b. %.

Properties	Moisture contents (d.b %)		
	5.61	14.08	23.32
Mass (g)	0.035±0.001	0.044±0.001	0.054±0.001
Length (mm)	6.89±0.056	7.25±0.057	7.56±0.052
Width (mm)	3.76±0.040	4.19±0.043	4.36±0.051
Thickness (mm)	2.71±0.028	3.03±0.035	3.19±0.040
Geometric mean diameter (mm)	4.13±0.038	4.50±0.034	4.70±0.039
Sphericity (-)	0.600±0.004	0.622±0.005	0.623±0.005

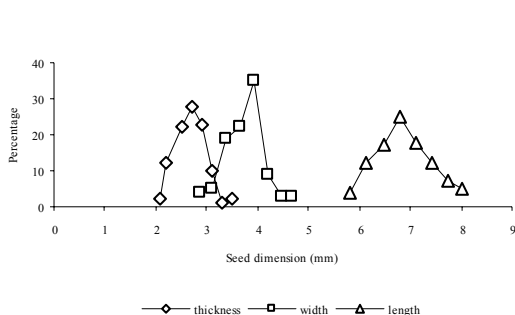


Fig 1. Percent distribution curves of length, width, and thickness measuring of safflower seed at a moisture content 5.61 d.b %.

Table 2. The correlation coefficient of safflower seeds at moisture content 5.61 d.b %.

Particulars	Ratio	Degree of freedom	Correlation coefficient (r)
L/W	1.832	98	0.485**
L/M	196.86	98	0.663**
L/Dg	1.668	98	0.624**
L/Ø	11.483	98	-0.347**

\*\* Significant at the level 1%.

### 1000 seed mass

The thousand seed mass values of safflower seeds at moisture contents of 5.61 % and 23.32 % varied between 36.1 and 47.2 g (Figure 2).

An increasing relationship was found between 1000 seed mass and moisture content. The equations are as follows;

$$M_{1000} = 32.938 + 0.6251 M_c \quad (R^2 = 0.9894)$$

Similar results were found by Desphande *et al.* (1993) for soybeans; Singh & Goswami (1996) for cumin seeds and Öğüt (1998) for lupin seeds.

### Bulk density

The bulk density values of safflower seed at moisture contents of 5.61 % and 23.32 % varied between 526.9 and 488.6 kg m<sup>-3</sup> (Figure 3). The

relationship between bulk density and moisture content was found to be as follows;

$$\rho_b = 531.51 - 2.0841 M_c \quad (R^2 = 0.7115)$$

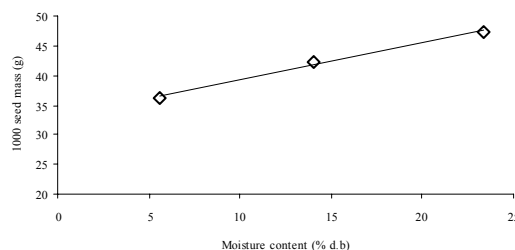


Fig. 2. 1000 seed mass versus moisture content

As the moisture content increased, the bulk density values decreased. Çarman (1996) for lentil seeds, Desphande *et al.* (1993) for soybean and Gupta & Das (1997) for sunflower seeds had found similar results. These changes are probably due to the structural properties of the grains.

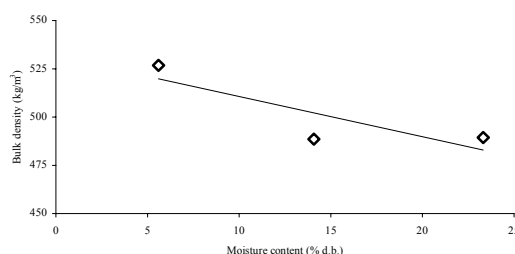


Fig. 3. Bulk density variation with moisture content

### Seed density

The seed density values of safflower seeds at moisture contents of 5.61 % and 23.32 % varied between 1096.7 and 1187.6 kg m<sup>-3</sup> (Figure 4). The relationship between seed density of safflower seeds and moisture content was found to be as following;

$$\rho_s = 1059 + 5.1735 M_c \quad (R^2 = 0.9100)$$

As the moisture content increased, the seed density values increased Singh & Goswami (1996) for cumin seeds, Gupta & Das (1997) for sunflower seeds, Chandrasekar & Viswanathan (1999) for coffee and Aviara *et al.* (1999) for guna seeds had found similar results. These changes are probably due to the structural properties of the grains.

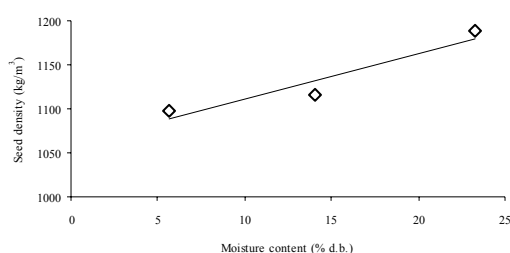


Fig. 4. Seed density variation with moisture content

### Porosity

The variations of porosity depending on moisture content are shown in Figure 5. The porosity values of safflower seeds at moisture contents of 5.61 and 23.32 % varied between 52.0 % and 56.7 %. The relationship between porosity value and moisture content was found to be as follows;

$$\varepsilon = 50.708 + 0.264 M_c \quad (R^2 = 0.9818)$$

Gupta & Das, (1997) for sunflower, Çarman (1996) for lentil and Singh & Goswami (1996) for cumin seeds stated that as the moisture content increased so the porosity value increased.

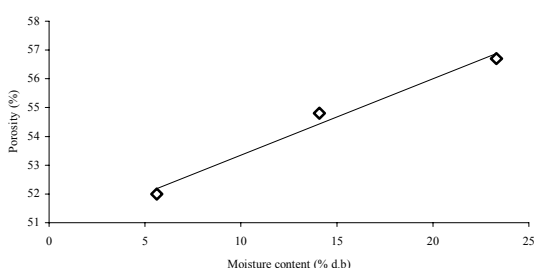


Fig. 5. Porosity variation with moisture content

### Projected area

Projected areas values of safflower seeds at moisture contents of 5.61 and 23.32 % varied between 24.60 and 27.50 mm<sup>2</sup>. Projected areas of safflower seeds are given in Figure 6. The relationship between projected area and moisture content of safflower seeds was found to be as follows;

$$P_a = 23.558 + 0.1643 M_c \quad (R^2 = 0.9814)$$

Desphande *et al.*, (1993) for soybean, Çarman, (1996) for lentil, Öğüt, (1998) for lupin found similar results.

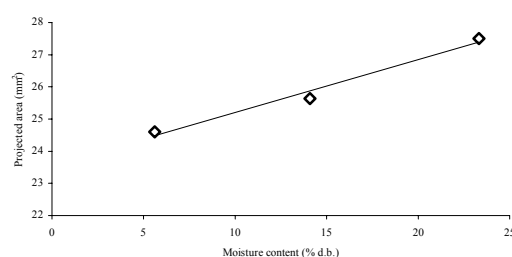


Fig. 6. Projected area variation with moisture content

### Terminal velocity

Terminal velocities values for safflower at moisture contents of 5.61 and 23.32 % varied between 3.84 and 5.02 m s<sup>-1</sup> (Figure 7). The relationship between terminal velocity and moisture content was found as follows;

$$V_t = 3.4825 + 0.0666 M_c \quad (R^2 = 0.9980)$$

As the moisture content of grains increased, so the values of terminal velocity increased. Ramakrishna, (1986) for melon, Joshi *et al.*, (1993) for pumpkin, Çarman, (1996) for lentil and Aydın, (2002) for hazel nuts found similar results.

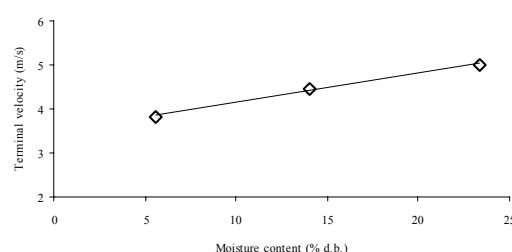


Fig. 7. Terminal velocity variation with moisture content

### Coefficient of static friction

The variations of the coefficient of static friction with moisture content of safflowers are given in Figure 8 for iron sheet and galvanized sheet. It can be seen from the figure that the coefficient of static friction values on an iron sheet and on a galvanized sheet increased with increasing moisture content. This relationship was found to be as follows;

$$\mu_s = 0.3942 + 0.0085 M_c \quad (R^2 = 0.9775) \quad (\text{for the galvanized sheet})$$

$$\mu_s = 0.4470 + 0.0086 M_c \quad (R^2 = 0.8365) \quad (\text{for the iron sheet})$$

Joshi *et al.* (1993); Tsang-Mui- Chung, Verma & Wright, (1984); Çarman (1996); Öğüt (1998); Peker (1996) and Aydın, (2002) reported that as the mois-

ture content increased so the coefficient of static friction increased.

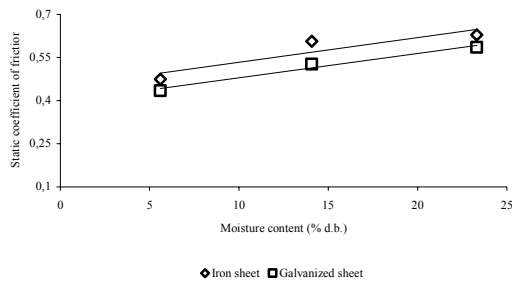


Fig. 8. Coefficient static of friction versus of moisture content

### CONCLUSION

All the dimensions of the safflower seed increased with increase in moisture content.

The 1000 seed mass, sphericity and seed density increased with increase in moisture content.

The porosity, projected area, terminal velocity and coefficient of static friction increased with increase in moisture content.

Bulk density decreased with increase in moisture content.

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