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Physical Properties of Sunflower Seeds (*Helianthus annuus* L.)

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Abstract: The physical properties of sunflower seeds (*Helianthus annuus* L.) were determined as a function of moisture content in the range of 10.06-27.06% dry basis (d.b.). The average length, width and thickness were 7.79, 7.12 and 4.18 mm, at a moisture content of 10.06% d.b., respectively. In the above moisture range, the arithmetic and geometric mean diameters increased from 6.37 to 8.05 mm and from 6.15 to 7.93 mm, respectively, while the sphericity decreased from 0.789 to 0.835. In the moisture range from 10.06-27.06% d.b., studies on rewetted sunflower seeds showed that the thousand grain mass increased from 66 to 70 g, the true density from 885.00 to 902 kg m^{-3}, the porosity from 53.06 to 54.93% and the terminal velocity from 4.07 to 4.57 m s^{-1}. The bulk density decreased from 415.40 to 406.56 kg m^{-3} with an increase in the moisture content range of 10.06-27.06% d.b. The static coefficient of friction of sunflower seeds increased the linearly against surfaces of six structural materials, namely, rubber (0.55-0.65), aluminum (0.50-0.57), stainless steel (0.49-0.56), galvanized iron (0.53-0.59), glass (0.41-0.45) and MDF (medium density fiberboard) (0.43-0.48) as the moisture content increased from 10.06-27.06% d.b.

Key words: Sunflower seeds, physical properties, moisture content

INTRODUCTION

Turkey has about 550.000 ha of sunflower (*Helianthus annuus* L.) harvesting area, 900.000 t of sunflower production per annual with a yield of 1,641 kg ha^{-1} of sunflower and therefore is one of the foremost sunflower producing countries of the world (SIS, 2004).

In order to design equipment for the handling, conveying, separation, drying, aeration, storing and processing of sunflower seeds, it is necessary to determine their physical properties as a function of moisture content. However, limited published study seems to have been carried out on the physical properties of sunflower seeds and their relationship with moisture content. Hence, this study was conducted to investigate some moisture dependent physical properties of sunflower seeds namely, grain dimensions, thousand grain mass, surface area, sphericity, bulk density, true density, porosity, terminal velocity and static coefficient of friction against different materials.

MATERIALS AND METHODS

The sunflower seeds used in the study were obtained from a farm of Uludag University Agricultural Faculty, Bursa, Turkey. The seeds were cleaned manually to remove all foreign matter such as dust, dirt, stones and chaff as well as immature, broken seeds. The initial moisture content of the seeds was determined by digital moisture meter (Pfeuffer HE 50, Germany) reading to 0.01%.

The samples of the desired moisture contents were prepared by adding the amount of distilled water as calculated from the following relation (Coşkun *et al*., 2006):

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$$Q = \frac{W_i(M_f - M_i)}{(100 - M_f)} \tag{1}$$

The samples were then poured into separate polyethylene bags and the bags sealed tightly. The samples were kept at 5°C in a refrigerator for a week to enable the moisture to distribute uniformly throughout the sample. Before starting a test, the required quantity of the grain was taken out of the refrigerator and allowed to equilibrate to the room temperature for about 2 h (Singh and Goswami, 1996).

All the physical properties of the seeds were determined at seven moisture contents in the range of 10.06-27.06% d.b. with 10 replications at each moisture content.

To determine the average size of the grain, 100 seeds were randomly picked and their three linear dimensions namely, length (L), width (W) and thickness (T) were measured using a digital compass (Minolta, Japan) with a accuracy of 0.01 mm.

The average diameter of grain was calculated by using the arithmetic mean and geometric mean of the three axial dimensions. The arithmetic mean diameter D_a and geometric mean diameter D_g of the grain were calculated by using the following relationships (Mohsenin, 1970).

$$D_a = (L + W + T)/3 \tag{2}$$

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

The sphericity of seeds ϕ was calculated by using the following relationship (Mohsenin, 1970):

$$\phi = \frac{(LWT)^{1/3}}{L} \tag{4}$$

The one thousand grain mass was determined by means of an electronic balance reading to 0.001 g.

The surface area A_s in mm^2 of sunflower seeds was found by analogy with a sphere of same geometric mean diameter, using the following relationship (Tunde-Akintunde and Akintunde, 2004).

$$A_s = \pi D_g^2 \tag{5}$$

The average bulk density of the sunflower seeds was determined using the standard test weight procedure reported by Singh and Goswami (1996) and Gupta and Das (1997) by filling a container of 500 mL with the grain from a height of 150 mm at a constant rate and then weighing the content.

The average true density was determined using the toluene displacement method. The volume of toluene (C_7H_8) displaced was found by immersing a weighed quantity of sunflower seeds in the toluene (Coşkun *et al*., 2006).

The porosity was calculated from the following relationship (Mohsenin, 1970):

$$P_f = (1 - \frac{\rho_b}{\rho_t})100 \tag{6}$$

where P_f is the porosity in %; ρ_b is the bulk density in kg m^{-3} and ρ_t is the true density in kg m^{-3}.

The terminal velocities of grain at different moisture contents were measured using a cylindrical air column in which the material was suspended in the air stream (Nimkar and Chattopadhyay, 2001).

The air column was 28 mm in diameter. Relative opening of a regulating valve provided at blower output end was used to control the airflow rate. In the beginning, the blower output was set at minimum. For each experiment, a sample was dropped into the air stream from the top of the air column. Then airflow rate was gradually increased till the grain mass gets suspended in the air stream. The air velocity which kept the grain suspension was recorded by a digital anemometer (Thies clima, Germany) having a least count of 0.1 m s^{-1} (Ozdemir and Akinci, 2004).

The static coefficient of friction of sunflower seeds against six different structural materials, namely rubber, galvanized iron, aluminum, stainless steel, glass and MDF was determined. A polyvinylchloride cylindrical pipe of 50 mm diameter and 100 mm height was placed on an adjustable tilting plate, faced with the test surface and filled with the grain sample. The cylinder was raised slightly so as not to touch the surface. The structural surface with the cylinder resting on it was raised gradually with a screw device until the cylinder just started to slide down and the angle of tilt was read from a graduated scale (Nimkar and Chattopadhyay, 2001). The coefficient of friction was calculated from the following relationship:

$$\mu = \tan \alpha \quad (7)$$

where μ is the coefficient of friction and α is the angle of tilt in degrees.

RESULTS AND DISCUSSION

Grain Dimensions

The mean values of the axial dimensions of the sunflower seeds at different moisture contents are presented in Fig. 1. As can be shown in Fig. 1, the three axial dimensions increased with increase in moisture content from 10.06-27.06% d.b. The mean dimensions of 100 seeds measured at a moisture content of 10.06% d.b. are: length 7.795±0.213 mm, width 7.123±0.174 mm and thickness 4.189±0.188 mm.

The average diameters increased with the increase in moisture content as axial dimensions (Fig. 2). The arithmetic and geometric mean diameter ranged from 6.37 to 8.05 mm and 6.15 to 7.93 mm as the moisture content increased from 10.06-27.06% d.b., respectively.

One Thousand Grain Mass

The one thousand sunflower grain mass M_{1000} increased linearly from 66 to 70 g as the moisture content increased from 10.06-27.06% d.b. (Fig. 3). An increase of 6.66% in the one thousand grain mass was recorded within the above moisture range.

An increase in the one thousand sunflower seeds mass as the grain moisture content increases has been noted by Saçılık *et al.* (2003) for hemp, Yalçın and Özarslan (2004) for vetch, Öğüt (1998) for white lupine, Deshpande *et al.* (1993) for sunflower, Aviara *et al.* (2005) for Balanites aegyptiaca nuts, Vilche *et al.* (2003) for quinoa seeds, Dursun and Dursun (2005) for caper seed and Nimkar and Chatopadhyay (2001) for green gram.

Surface Area of Grain

The variation of the surface area with the sunflower seeds moisture content is plotted in Fig. 4. The figure indicates that the surface area increases polynomial with increase in grain moisture content. The surface area of sunflower seeds increased from 118.76 to 197.65 mm^2 when the moisture content increased from 10.06-27.06% d.b.

Different increasing trends have been reported by Dursun and Dursun (2005) for caper seed, Deshpande *et al.* (1993) for sunflower and Saçılık *et al.* (2003) for hemp seed.

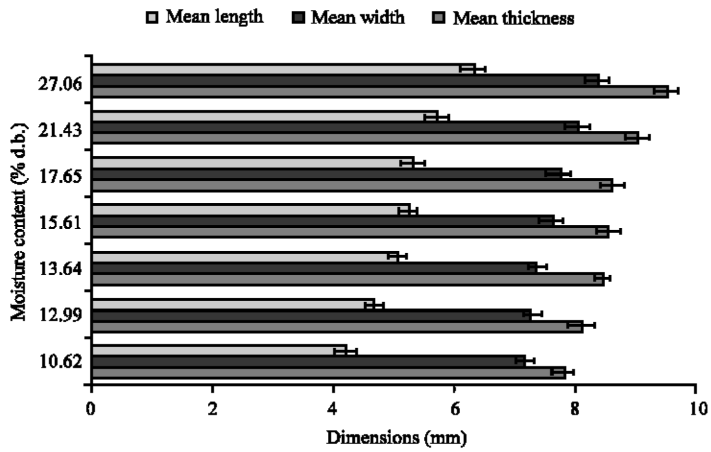

Fig. 1: Dimensions of sunflower seeds

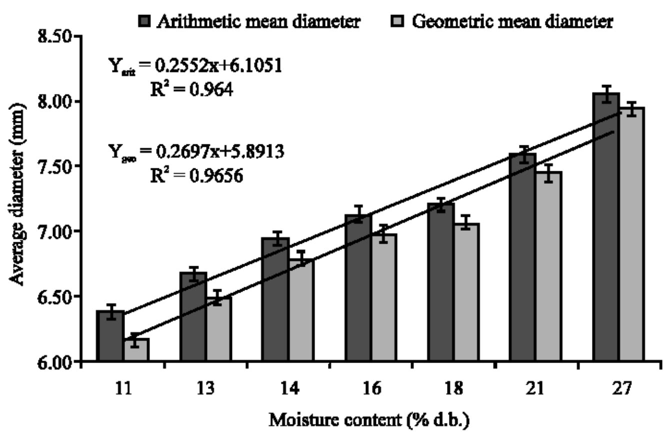

Fig. 2: Arithmetic and geometric diameter of sunflower seeds

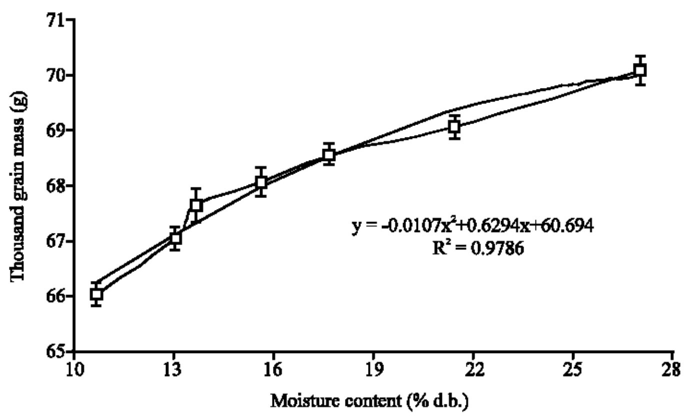

Fig. 3: Effect of moisture content on thousand seeds mass of sunflower

Sphericity

The sphericity of sunflower seeds increased from 0.789 to 0.835 with the increase in moisture content (Fig. 5).

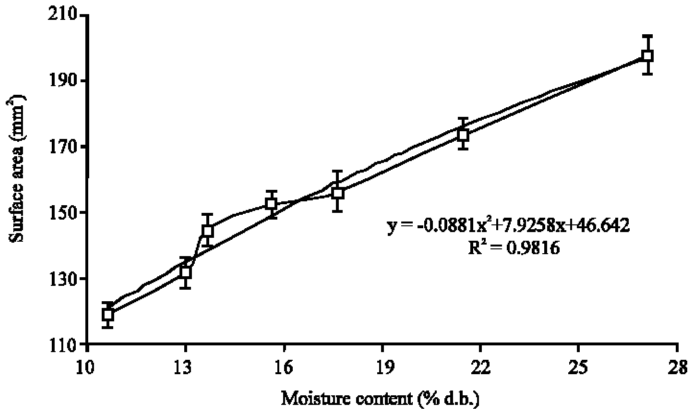

Fig. 4: Effect of moisture content on surface area of sunflower

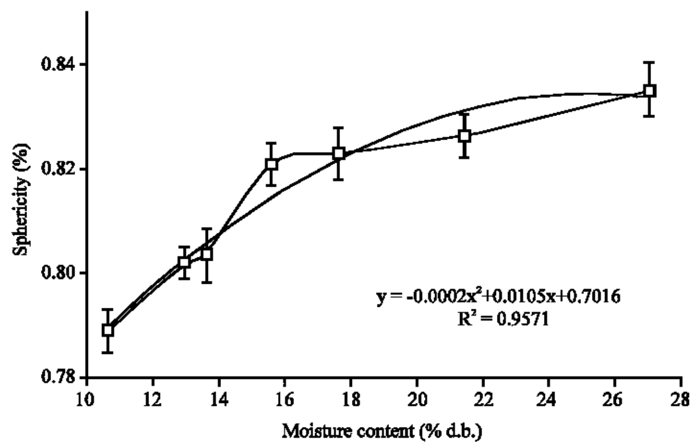

Fig. 5: Effect of moisture content on sphericity of sunflower

Increasing trends have been reported by Nimkar and Chattopadhyay (2001) for green gram, Aydin *et al.* (2002) for Turkish Mahaleb, Baryeh and Mangope (2002) for pigeon pea, Sahoo and Srivastava (2002) for okra grain and Saçılık *et al.* (2003) for hemp grain.

Bulk Density

The values of the bulk density for different moisture levels varied from 415.40 to 406.56 kg m^{-3} (Fig. 6).

A linear decreasing trend in bulk density has been reported by Gupta and Das (1997) for sunflower grain, Öğüt (1998) for white lupin, Nimkar and Chattapadhyay (2001) for green gram, Sahoo and Srivastava (2002) for okra, Konak *et al.* (2002) for chick pea, Saçılık *et al.* (2003) for hemp seed and Coşkun *et al.* (2006) for sweet corn seed.

True Density

The true density varied from 885 to 902 kg m^{-3} when the moisture level increased from 10.06-27.06% d.b. (Fig. 7).

The results were different increasing trend to those reported by Singh and Goswami (1996) for cumin grain, Özarslan (2002) for cotton, Yalçın and Özarslan (2004) for vetch seed, Aviara *et al.* (2005) for *Balanites aegypticiaca* nuts and Coşkun *et al.* (2006) for sweet corn seed.

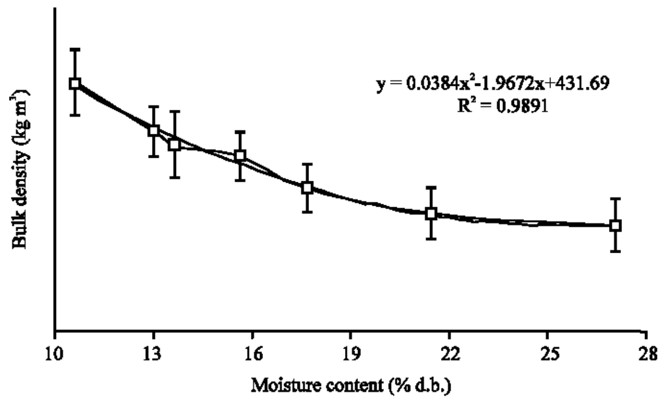

Fig. 6: Effect of moisture content on bulk density of sunflower

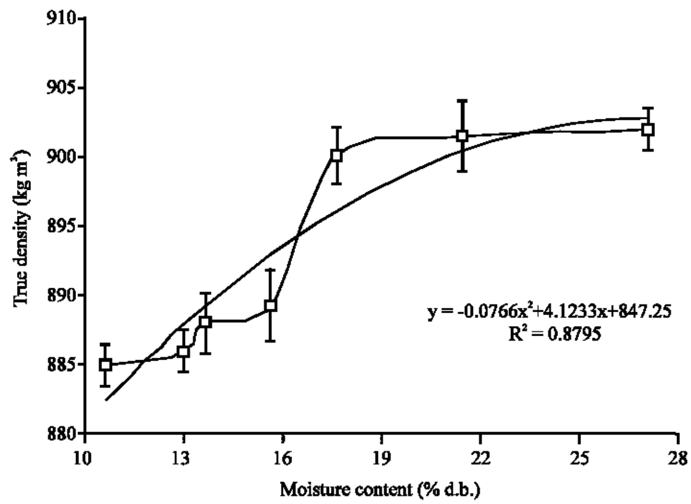

Fig. 7: Effect of moisture content on true density of sunflower

Porosity

The porosity of sunflower seeds increased from 53.06 to 54.93% with the increase in moisture content from 10.06-27.06% d.b. (Fig. 8).

Gupta and Das (1997), Öğüt (1998), Nimkar and Chattopadhyay (2001), Konak *et al.* (2002), Nimkar *et al.* (2005), Aviara *et al.* (2005), Çalışır *et al.* (2005) and Coşkun *et al.* (2006) reported increasing trends in the case of sunflower grain, white lupine, green gram, chick pea, moth gram, Balanites aegyptiaca nuts, okra seed and sweet corn seed, respectively.

Terminal Velocity

The experimental results for the terminal velocity of sunflower seeds at various moisture levels are shown in Fig. 9. The terminal velocity was found to increase linearly from 4.07 to 4.57 m s^{-1} as the moisture content increased from 10.06-27.06% d.b

Different results were reported by Joshi *et al.* (1993), Suthar and Das (1996) and Gupta and Das (1997) and in the case of pumpkin seeds, sunflower, karingda and respectively.

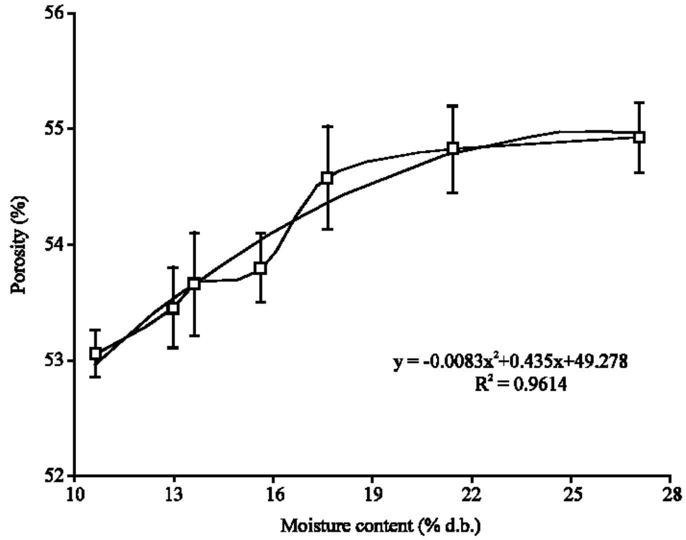

Fig. 8: Effect of moisture content on porosity of sunflower

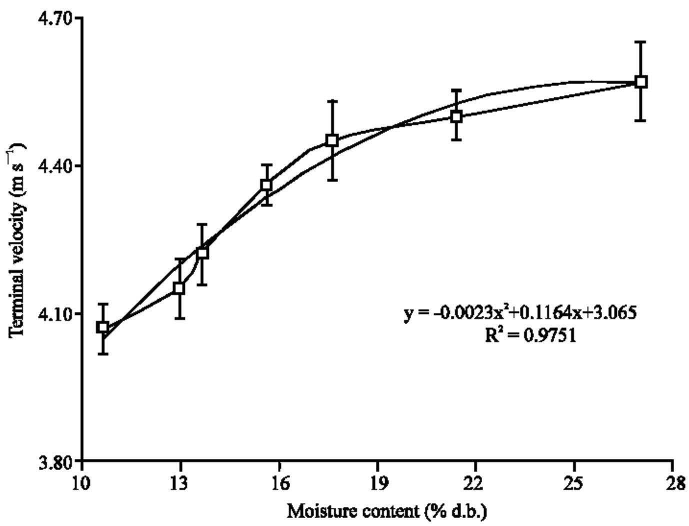

Fig. 9: Effect of moisture content on terminal velocity of sunflower

Static Coefficient of Friction

The static coefficient of friction of sunflower seeds on six surfaces (rubber, stainless steel, aluminum, glass, MDF and galvanized iron) against moisture content in the range 10.06-27.06% d.b. are presented in Fig. 10. It was observed that the static coefficient of friction increased with increase in moisture content for all the surfaces. This is due to the increased adhesion between the grain and the material surfaces at higher moisture values. Increases of 18.18, 14.28, 14, 9.75, 11.62 and 11.32% were recorded in the case of rubber, stainless steel, aluminum, glass, MDF and galvanized iron, respectively, as the moisture content increased from 10.06-27.06% d.b. At all moisture contents, the least static

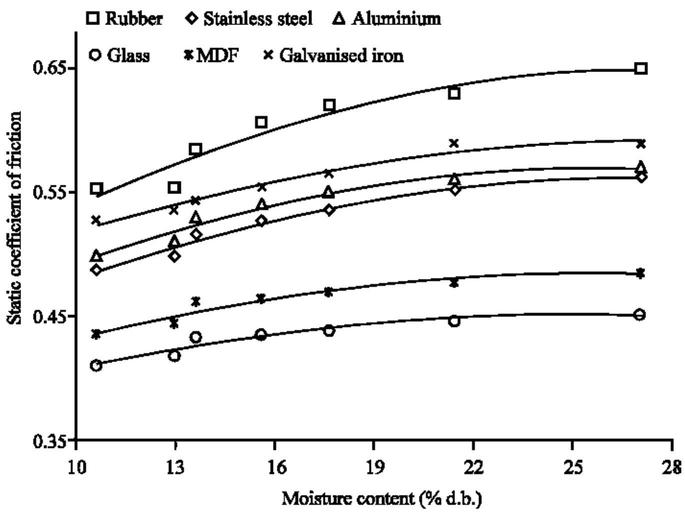

Fig. 10: Effect of moisture content on of sunflower against various surfaces

coefficient of friction were on glass. This may be owing to smoother and more polished surface of the glass sheet than the other materials used. The relationships between static coefficients of friction and moisture content on rubber (μ_{rub}), stainless steel (μ_{ss}), aluminum (μ_{al}), glass (μ_{gl}), MDF (μ_{mdf}) and galvanized iron (μ_{gi}) can be represented by the following equations:

$$\mu_{ru} = 0.374 + 4.10^{-4} M_c^2 + 0.0201 M_c \qquad (R^2 = 0.936) \tag{8}$$

$$\mu_{ss} = 0.361 - 3.10^{-4} M_c^2 + 0.0146 M_c \qquad (R^2 = 0.979) \tag{9}$$

$$\mu_{al} = 0.363 - 3.10^{-4} M_c^2 + 0.016 M_c \qquad (R^2 = 0.966) \tag{10}$$

$$\mu_{gl} = 0.336 + 2.10^{-4} M_c^2 + 0.009 M_c \qquad (R^2 = 0.934) \tag{11}$$

$$\mu_{mdf} = 0.345 + 2.10^{-4} M_c^2 + 0.0108 M_c \qquad (R^2 = 0.935) \tag{12}$$

$$\mu_{gi} = 0.411 + 2.10^{-4} M_c^2 + 0.0129 M_c \qquad (R^2 = 0.971) \tag{13}$$

Different increasing trends were found by Singh and Goswami (1996), Chandrasekar and Viswanathan (1999), Nimkar and Chattopadhyay (2001), Sahoo and Srivastava (2002), Yalçın and Özarslan (2004), Dursun and Dursun (2005), Nimkar *et al.* (2005) and Coşkun *et al.* (2006) and for cumin, coffee, green gram seeds, okra, vetch, caper, moth gram and sweet corn, respectively.

CONCLUSIONS

The average length, width and thickness of seeds ranged from 7.795 to 9.500, 7.123 to 8.345 and 4.189 to 6.300 mm as the moisture content increased from 10.06-27.06% d.b., respectively. The arithmetic and geometric mean diameters were found to increase from 6.37 to 8.05 mm and 6.15 to

7.93 mm, respectively. The thousand grain mass increased from 66 to 70 g and the sphericity increased from 0.789 to 0.835 with the increase in moisture content from 10.06-27.06% d.b. The bulk density decreased polynomial from 415.40 to 406.56 kg m^{-3}, whereas the true density increased from 885 to 902 kg m^{-3}. The terminal velocity increased polynomial from 4.07 to 4.57 m s^{-1} as the moisture content increased from 10.06-27.06% d.b. The static coefficient of friction increased for all four surfaces, namely, rubber (0.55-0.65), stainless steel (0.49-0.56), aluminum (0.50-0.57), glass (0.41-0.45), MDF (0.43-0.48) and galvanized iron (0.53-0.59).

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NOMENCLATURE

A_s	Surface area (mm^2)
D_a	Arithmetic mean diameter of grain (mm)
D_g	Geometric mean diameter of grain (mm)
L	Length of grain (mm)
M_i	Initial moisture content of sample (%d.b.)
M_f	Final moisture content of sample (%d.b.)
M_c	Moisture content (% d.b.)
P_f	Porosity (%)
R^2	Coefficient of determination
Q	Mass of water to added (kg)
T	Thickness of grain (mm)
W	Width of grain (mm)
W_i	Initial mass of sample (kg)
α	Angle of tilt (degree)
μ	Static coefficient of friction
ρ_b	Bulk density (kg m)$^{-3}$
ρ_t	True density (kg m)$^{-3}$
ϕ	Sphericity of grain
Subscripts	
$_{al}$	Aluminium
$_{gi}$	Galvanised iron
$_{gl}$	Glass
$_{mdf}$	Medium density fibreboard
$_{ru}$	Rubber
$_{ss}$	Stainless steel

REFERENCES

Aviara, N.A., E. Mamman and B. Umar, 2005. Some physical properties of *Balanites aegyptiaca* nuts. Biosyst. Eng., 92: 325-334.

Aydin, C., H. Öğüt and M. Konak, 2002. Physical properties of chick pea seeds. Biosyst. Eng., 82: 231-234.

Baryeh, E.A. and B.K. Mangope, 2002. Some physical properties of QP-38 variety pigeon pea. J. Food Eng., 56: 341-347.

Çalışır, S., M. Özcan, H. Hacıseferoğulları and M.U. Yıldız, 2005. A study on some physico-chemical properties of Turkey okra (*Hibiscus esculenta* L.) seeds. J. Food Eng., 68: 73-78.

Chandrasekar, V. and R. Viswanathan, 1999. Physical and thermal properties of coffee. J. Agric. Eng. Res., 73: 227-234.

Coşkun, M.B., I. Yalçın and C. Özarslan, 2006. Physicaş properties of sweet corn seed (*Zea mays saccharata* Sturt.). J. Food Eng., 74: 523-528.

Deshpande, S.D., S. Bal and T.P. Ojha, 1993. Physical properties of sunflower. J. Agric. Eng. Res., 56: 89-98.

Dursun, E. and I. Dursun, 2005. Some physical properties of caper seed. Biosyst. Eng., 92: 237-245.

Gupta, R.K. and S.K. Das, 1997. Physical properties of sunflower seeds. J. Agric. Eng. Res., 66: 1-8.

Joshi, D.C., S.K. Das and R.K. Mukherjee, 1993. Physical properties of pumpkin seeds. J. Agric. Eng. Res., 54: 219-229.

Konak, M., K. Carman and C. Aydin, 2002. Physical properties of chick pea seeds. Biosyst. Eng., 82: 73-78.

Mohsenin, N.N., 1970. Physical Properties of Plant and Animal Materials. Newyork: Gordon and Breach Science Publishers.

Nimkar, P.M. and P.K. Chattopadhyay, 2001. Some physical properties of green gram. J. Agric. Eng. Res., 80: 183-189.

Nimkar, P.M., D.S. Mandwe and R.M. Dudhe, 2005. Physical properties of moth gram. Biosyst. Eng., 91: 183-189.

Ozdemir, F. and I. Akinci, 2004. Physical and nutritional properties of four major commercial Turkish hazelnut varieties. J. Food Eng., 63: 341-347.

Öğüt, H., 1998. Some physical properties of white lupin. J. Agric. Eng. Res., 69: 273-277.

Özarslan, C., 2002. Physical properties of cotton seed. Biosyst. Eng., 83: 169-174.

Saçılık, K., R. Özturk and R. Keskin, 2003. Some physical properties of hemp seed. Biosyst. Eng., 86: 191-198.

Sahoo, P.K. and A.P. Srivastava, 2002. Physical properties of okra seed. Biosyst. Eng., 83: 441-448.

Singh, K.K. and T.K. Goswami, 1996. Physical properties of cumin seed. J. Agric. Eng. Res., 64: 93-98.

SIS, 2004. Agricultural Statistic, Ankara, Turkey.

Suthar, S.H. and S.K. Das, 1996. Some physical properties of karingda [*Citrullus lanatus* (thumb) mansf] seeds. J. Agric. Eng. Res., 65: 15-22.

Tunde-Akintunde, T.Y. and B.O. Akintunde, 2004. Some physical properties of sesame seed. Biosyst. Eng., 88: 127-129.

Vilche, C., M. Gely and E. Santalla, 2003. Physical properties of Quinoa seeds. Biosyst. Eng., 86: 59-65.

Yalçın, I. and C. Özarslan, 2004. Physical properties of vetch seed. Biosyst. Eng., 88: 507-512.