American Journal of
Food Technology

ISSN 1557-4571

Academic
Journals Inc.

www.academicjournals.com

American Journal of Food Technology 2 (3): 115-125, 2007
ISSN 1557-4571

Some Engineering Properties of Soybean Grains

Esref Işik
Department of Agricultural Machinary, Faculty of Agriculture,
Uludag University, Bursa, 16059, Turkey

Abstract: The some engineering properties of soybean grains were determined as a function of moisture content in the range of 10.62-27.06% dry basis (d.b.). The average length, width and thickness were 7.795, 7.123 and 4.189 mm, at a moisture content of 10.62% d.b., respectively. In the above moisture range, the arithmetic and geometric mean diameters increased from 6.369 to 8.048 mm and from 6.149 to 7.933 mm, respectively, while the sphericity increased from 0.788 to 0.835. In the moisture range from 10.62-27.06% d.b., studies on rewetted soybean grains showed that the thousand grain mass increased from 200 to 255 g, the projected area from 37.69 to 53.39 mm^2, the true density from 1090 to 1200 kg m^{-3}, the porosity from 40.36 to 54.16% and the terminal velocity from 8.01 to 9.1 m s^{-1}. The bulk density decreased from 650 to 550 kg m^{-3} with an increase in the moisture content range of 10.62-27.06% d.b. The static coefficient of friction of soybean grains increased the linearly against surfaces of six structural materials, namely, rubber (0.3443-0.3919), aluminum (0.2867-0.3115), stainless steel (0.2905-0.3443), galvanized iron (0.2962-0.3482), glass (0.2309-0.2773) and MDF (medium density fiberboard) (0.2126-0.2679) as the moisture content increased from 10.62-27.06%.

Key words: Soybean, grains, engineering properties, moisture content, physical and mechanical properties

INTRODUCTION

Soybeans are a cultivated plant grown for dry consumption and raw material of canned food industry. It contains 17 g protein, 1 g oil, 44 g total carbohydrates, 88 mg calcium, 4 mg iron, 1 mg sodium, 6% Calories from fat per 250 mL (dry) (Anonymous, 2006).

Turkey had about 14 000 ha of soybeans harvesting area, 50,000 t of soybeans production per annum with a yield of 3571 kg ha^{-1} of soybeans in 2004 (SIS, 2006).

Some engineering properties have been studied for various beans such as soybean (Deshpande *et al*., 1993), locust bean seed (Olajide and Ade-Omowage, 1999; Ogunjimi *et al*., 2002), Sakiz faba bean (Haciseferoğullari *et al*., 2003), barbunia bean (Çetin, 2006), cocoa beans (Bart-Plange and Boryeh, 2003), Turkish göynük bombay bean (Tekin *et al*., 2006) and faba bean (Altunta and Yildiz, 2007).

Despite an extensive search, limited work seems to have been carried out on the some engineering properties of soybean and their relationship with moisture content. Hence, this study was conducted to investigate some moisture dependent some engineering properties of soybean grains namely, grain dimensions, thousand grain mass, surface area, projected area, sphericity, bulk density, true density, porosity, terminal velocity, static coefficient of friction against different materials.

MATERIALS AND METHODS

The soybean grains used in the study were obtained from a local market (Marmara Region, Bursa, Turkey). The initial moisture content of the grains 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):

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

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).

The soybeans are harvested at about between 9 and 20% w.b.(wet basis) harvesting moisture and dried to the desired moisture contents of 13% w.b. for safe module storage (Işik and Alibaş, 2000). Therefore, all the engineering properties of the grains were determined at five moisture contents in the range of 10.62-27.06% d.b. with 10 replications at each moisture content.

To determine the average size of the grain, 100 grains 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 grains 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 soybean grains was found by analogy with a sphere of same geometric mean diameter, using the following relationship (Olajide and Ade-Omewaye, 1999).

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

The projected area A_p was determined from the pictures of soybean grains which were taken by a digital camera (Creative DV CAM 316; 6.6 Mpixels), in comparison with the reference area to the sample area by using the Global Lab Image 2-Streamline (trial version) program (Işik and Güler, 2003).

The average bulk density of the soybean grains 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 soybean grains in the toluene (Öğüt, 1998). 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 velocity which kept the grain suspension was recorded by a digital anemometer (Thies clima, Germany) having a least count of 0.1 m sec^{-1}.

The static coefficient of friction of soybean grains 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 (Singh and Goswami, 1996). The coefficient of friction was calculated from the following relationship:

$$\mu = \tan \alpha \tag{7}$$

Shelling resistance R_s was determined by forces applied to one axial dimension (thickness). The shelling resistance of grain was determined under the point load by using a penetrometer (Bosch BS45 tester, Germany).

RESULTS AND DISCUSSION

Grain Dimensions

As it can be seen in Fig. 1, the three axial dimensions increased with increase in moisture content from 10.62-27.06% d.b. The mean dimensions of 100 grains measured at a moisture content of 10.62% d.b. are: length 7.795±0.0549 mm, width 7.123±0.0246 mm and thickness 4.189±0.0673 mm.

The average diameters increased with the increase in moisture content as axial dimensions. The arithmetic and geometric mean diameter ranged from 6.369 to 8.048 and 6.149 to 7.933 mm as the moisture content increased from 10.62-27.06% d.b., respectively (Fig. 2).

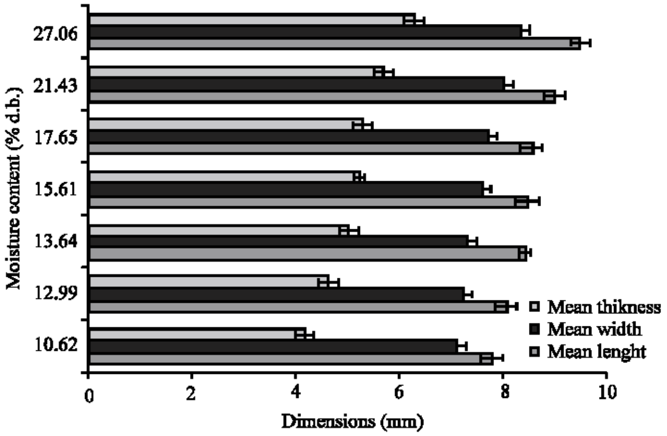

Fig. 1: Effect of moisture content dimensions of soybean

One Thousand Grain Mass

The one thousand soybean grain mass increased linearly from 200 to 255 g as the moisture content increased from 10.62-27.06% d.b. (Fig. 3). An increase of 27.5% in the one thousand grain mass was recorded within the above moisture range.

A linear increase in the one thousand soybean grains mass as the grain moisture content increases has been noted by Saçilik *et al.* (2003) for hemp, Deshpande *et al.* (1993) for soybean, Dursun and Dursun (2005) for caper seed and Nimkar and Chatopadhyay (2001) for green gram.

Surface Area of Grain

The Fig. 4 indicates that the surface area increases with increase in grain moisture content. The surface area of soybean grains increased polynomial from 118.756 to 197.654 mm^2 when the moisture content increased from 10.62-27.06% d.b.

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

Projected Area of Grain

The projected area of soybean grains linear increased from 37.69 to 53.39 mm^2, when the moisture content of grain increased from 10.62-27.06% d.b. (Fig. 5).

Similar trends have been reported by Tang and Sokhansanj (1993) for lentil, Özarslan (2002) for cotton and Konak *et al.* (2002) for chick pea grain and for Turkish mahaleb.

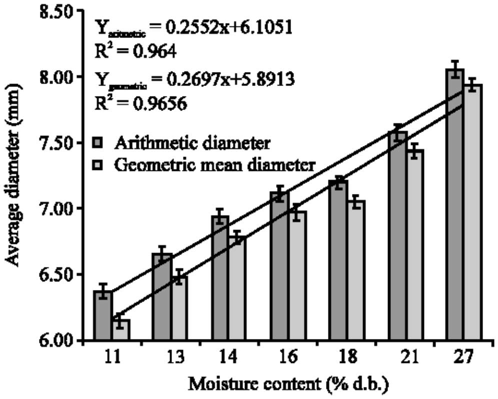

Fig. 2: Effect of moisture content average diameter of soybean

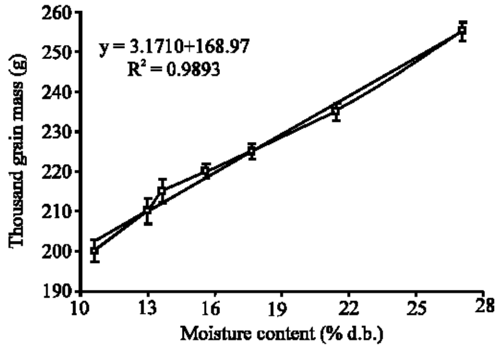

Fig. 3: Effect of moisture content one thousand grains mass of soybean

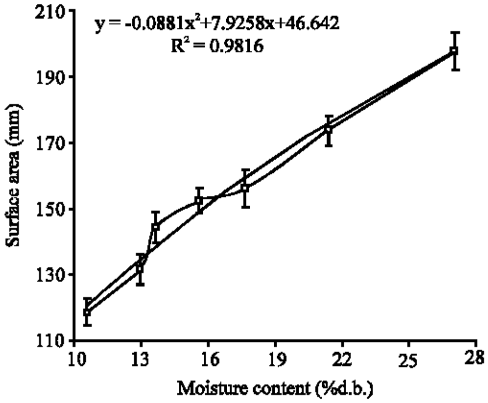

Fig. 4: Effect of moisture content on surface area of soybean

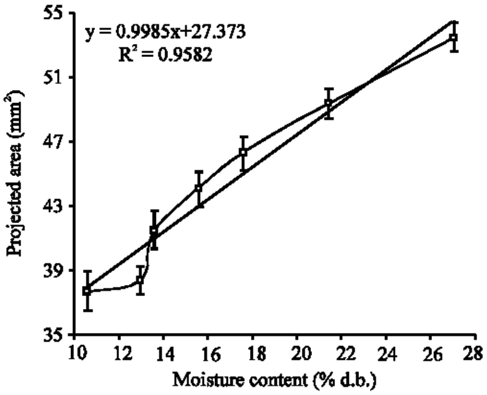

Fig. 5: Effect of moisture content on projected area of soybean

Sphericity

The sphericity of soybean grains increased polynomialy from 0.789 to 0.835 with the increase in moisture content (Fig. 6). However, linear 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.

Bulk Density

The values of the bulk density for different moisture levels varied from 650 to 550 kg m^{-3} (Fig. 7). Despite the bulk density soybean grains decreasing polynomialy, a linear decreasing trend in bulk density has been reported by Gupta and Das (1997) for sunflower grain, Nimkar and Chattapadhyay (2001) for green gram, Sahoo and Srivastava (2002) for okra, Konak *et al.* (2002) for chick pea, Saçilik *et al.* (2003) for hemp seed and Coskun *et al.* (2006) for sweet corn seed.

True Density

The true density of soybean grains polynomial increased from 1090 to 1200 kg m^{-3}, when the moisture level increased from 10.62-27.06% d.b. (Fig. 8). However, linear trends have been reported by Aviara *et al.* (2005) for *Balanites aegypticiaca* nuts and Coskun *et al.* (2006) for sweet corn seed.

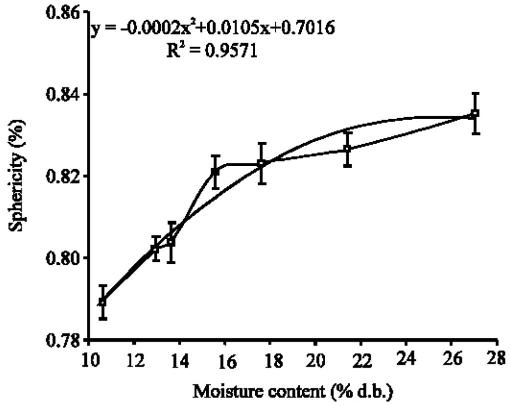

Fig. 6: Effect of moisture content on sphericity of soybean

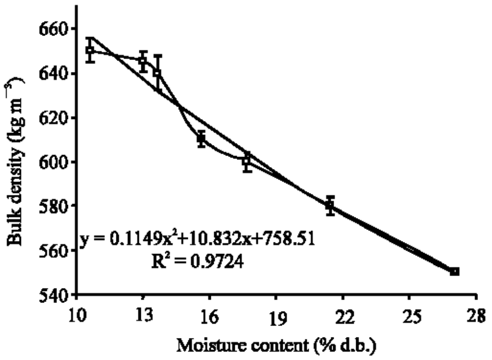

Fig. 7: Effect of moisture content on bulk density of soybean

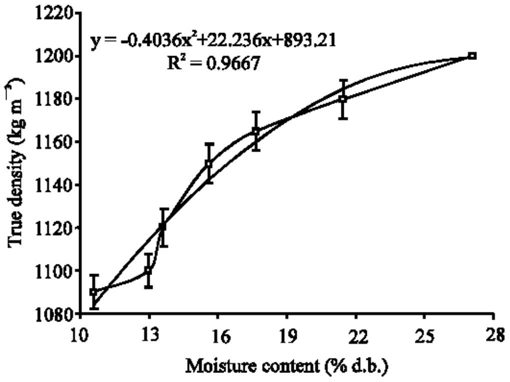

Fig. 8: Effect of moisture content on true density of soybean

Porosity

The porosity of soybean grains increased from 40.36 to 54.16% with the increase in moisture content from 10.62-27.06% d.b. (Fig. 9). Gupta and Das (1997), Konak *et al.* (2002), Nimkar *et al.* (2005) and Çalişir *et al.* (2005) reported increased trends in the case of sunflower grain, chick pea, moth gram and okra seed, respectively.

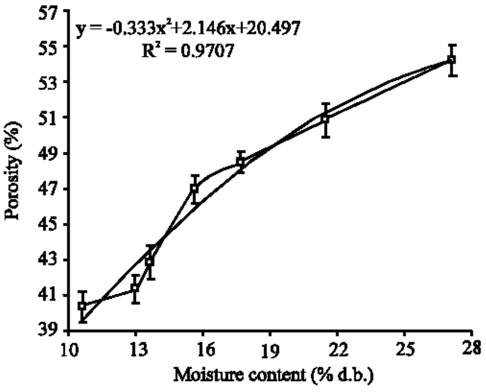

Fig. 9: Effect of moisture content on porosity of soybean

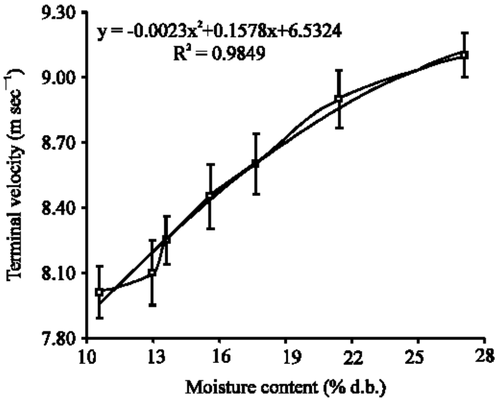

Fig. 10: Effect of moisture content on terminal velocity of soybean

Terminal Velocity

The terminal velocity was found to increase polynominaly from 8.01 to 9.1 m sec^{-1} as the moisture content increased from 10.62-27.06% d.b. (Fig. 10). Different increasing trend were reported by Joshi *et al*. (1993) and Suthar and Das (1996), in the case of pumpkin grains and karingda, respectively.

Static Coefficient of Friction

The static coefficient of friction of soybean grains on six surfaces (rubber, stainless steel, aluminum, glass, MDF and galvanized iron) against moisture content in the range 10.62-27.06% d.b. are presented in Fig. 11. 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 13.82, 18.51, 8.65, 20.09, 26.01 and 17.55% were recorded in the case of rubber, stainless steel, aluminum, glass, MDF and galvanized iron, respectively, as the moisture content increased from 10.62-27.06% d.b. At all moisture contents, the least static coefficient of friction were on MDF.

The logarithmic 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:

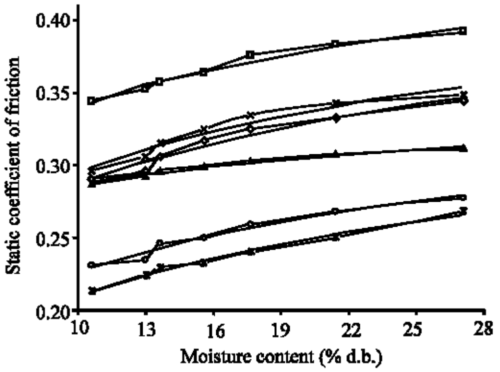

Fig. 11: Effect of moisture content on static coefficient of friction of soybean against various surface: (☐) rubber; (x) galvanized iron; (Δ) aluminium; (◇) stainless steel; (o) glass; (✖) MDF

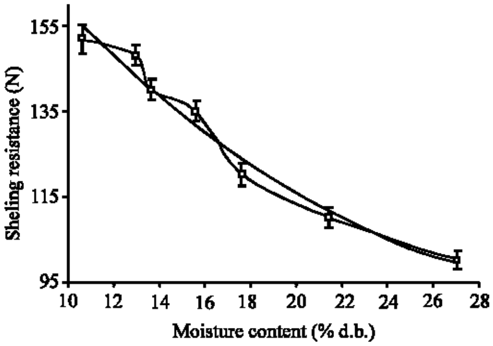

Fig. 12: Effect of moisture content on shelling resistance of soybean

$$\mu^{ru} = 0.2166+0.054 \text{ Ln } (M_c) \quad (R^2 = 0.9786) \quad (8)$$

$$\mu_{ss} = 0.1468+0.0607 \text{ Ln } (M_c) \quad (R^2 = 0.9679) \quad (9)$$

$$\mu_{al} = 0.252+0.0267 \text{ Ln } (M_c) \quad (R^2 = 0.99726) \quad (10)$$

$$\mu_{gl} = 0.105+0.052 \text{ Ln } (M_c) \quad (R^2 = 0.9704) \quad (11)$$

$$\mu_{mdf} = 0.0782+0.056 \text{ Ln } (M_c) \quad (R^2 = 0.9878) \quad (12)$$

$$\mu_{gi} = 0.1598+0.0589 \text{ Ln } (M_c) \quad (R^2 = 0.9471) \quad (13)$$

Shelling Resistance

The shelling resistance of soybean was found to decrease with the increase in moisture content (Fig. 12). The small shelling resistance at higher moisture content might have resulted from the fact that the grain became more sensitive to cracking at high moisture. The variation in shelling resistance of soybean R_s in N with moisture content can be represented by the following Eq.:

$$R_s = 224.8 - 7.7631M_c + 0.1152M_c^2 \quad (14)$$

with value for R^2 of 0.9744.

CONCLUSIONS

The average length, width and thickness of grains ranged from 7.80 to 9.5, 7.12 to 8.34 and 4.189 to 6.3 mm as the moisture content increased from 10.62-27.06% d.b., respectively.

The arithmetic and geometric mean diameters were found to increase from 6.369 to 8.048 mm and 6.149 to 7.933 mm, respectively. The thousand grain mass increased from 472.5 to 696.2 g and the sphericity increased from 0.536 to 0.619 with the increase in moisture content from 10.62-27.06% d.b. The bulk density decreased from 650 to 550 kg m^{-3}, whereas the true density increased from 1090 to 1200 kg m^{-3}. The terminal velocity increased linearly from 8.01 to 9.1 m sec^{-1} as the moisture content increased from 10.62-27.06% d.b. The static coefficient of friction increased for all four surfaces, namely, rubber (0.3443-0.3919), stainless steel (0.2905-0.3443), aluminum (0.2867-0.3115), glass (0.2309-0.2773), MDF (0.2126-0.2679) and galvanized iron (0.2962-0.3482).

ACKNOWLEDGMENT

This study was supported by the Research Fund of The University of Uludag and DPT Project number: Z-004/49 and Z-2005/3.

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_s	Shelling resistance (N)
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
ϕ	Sphericity of grain

Subscripts

$_{al}$	Aluminium
$_{gi}$	Galvanised iron
$_{gl}$	Glass
$_{mdf}$	Medium density fibreboard
$_{ru}$	Rubber
$_{ss}$	Stainless steel

REFERENCES

Anonymous, 2006. http://www.americanbean.org/HealthNutrition/Home.htm

Altuntaş, E. and M. Yildiz, 2007. Effect of moisture content on some physical and mechanical properties of faba bean (*Vicia faba* L.) grains. J. Food Eng., 78: 174-183.

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

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

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

Bart-Plange, A. and E.A. Baryeh, 2003. The physical properties of Category B cocoa beans. J. Food Eng., 60: 219-227.

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

Çetin, M., 2006. Physical properties of barbunia bean (*Phaseolus vulgaris* L. cv. 'Barbunia') seed. J. Food Eng. (In Press).

Coşkun, M.B., I. Yalçin and C. Özarslan, 2006. Physicas 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 soybean. 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. Agr. Eng. Res., 66: 1-8.

Haciseferoğullari, H., I. Gezer, Y. Bahtiyarca and H.O. Menges, 2003. Determination of some chemical and physical properties of Sakiz faba bean (*Vicia faba* L. var. *major*). J. Food Eng., 60: 475-479.

Isik, E. and I. Alibas, 2000. Tarimsal Ürünlerin Kurutulmasinda Kullanilan Yöntemler ve Kurutma Sistemleri. Uludağ Üniversitesi Ziraat Fakültesi Yardimci Ders Notu No: 3, Bursa.

Isik, E. and T. Güler, 2003. Determination of Surface Area for Apples with image analysis technique. J. Uludag University Agricultural Faculty, 17: 59-64.

Joshi, D.C., S.K. Das and R.K. Mukherjee, 1993. Physical properties of pumpkin grains. J. Agri. 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. New York: Gordon and Breach Sci., Publishers.

Nimkar, P.M. and P.K. Chattopadhyay, 2001. Some physical properties of green gram. J. Agri. 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.

Olajide, J.O. and B.I.O. Ade-Omowage, 1999. Some physical properties of locust bean seed. J. Agri. Eng. Res., 74: 15-22.

Ogunjimi, L.A.O., N.A. Aviara and O.A. Aregbesola,2002. Some engineering properties of locust bean seed. J. Food Eng., 55: 95-99.

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.

Saçilik, 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, 2006. 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.

Tang, J. and S. Sokhansanj, 1993. Geometric changes in lentil seeds caused by drying. J. Agric. Eng. Res., 56: 313-326.

Tekin, Y., E. Isik, H. Ünal and R. Okursoy, 2006. Physical and Mechanical Properties of Turkish Göynük Bombay Beans (*Phaseolus vulgaris* L.). Pak. J. Biol. Sci., 9: 2229-2235.