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Some Physical and Aerodynamic Properties of Soybean

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Abstract: Some physical and aerodynamic properties of soybean were determined in order to design processing equipment and facilities. In this study, some physical properties of soybean were evaluated as a function of moisture content in the range of 6.7-15.3% (db). At the 6.7% (db) moisture content the average length, width, thickness, unit mass, the geometric mean diameter, arithmetic mean diameter, sphericity, porosity, true and bulk density soybean were 7.41 mm, 5.34 mm, 4.50 mm, 121.76 g, 5.62 mm, 5.75 mm, 75.0, 51.0, 1062.6 and 804.8 kg m^{-3}, respectively. Corresponding values at 15.3% (db) moisture content were 9.57 mm, 6.75 mm, 5.17 mm, 223.65 g, 5.62 mm, 5.75 mm, 72.0%, 44.2%, 1086.4 and 689.3 kg m^{-3}, respectively. In soybean, terminal velocity increased from 7.13 to 9.24 m sμ^{-1} and the coefficient of static friction increased linearly against all the tested surfaces as the moisture content increased.

Key words: Soybean, size and shape indices, physical properties, aerodynamic properties

INTRODUCTION

Soybean (*Glycine max* (L.) Merr.) is an important annual plant. The requirements for soybean used directly or indirectly for human consumption increases in parallel with population increase. It is estimated that soybean production in world is about 180 million tones per year. Of all, 50% in USA, 35-40% is carried out in Brazil, Argentina and China and the remaining parts is obtained from different countries in Asia and South America (FAO, 2002). Soybean is coming first with 56% seed production among oily seed production in the world. The percentage of rape, cotton, peanut, sun-flower, palm oil and copra is about 12, 11, 10, 7, 2 and 2% of oily seed production, respectively (Anonymous, 2001). Soybean is the most important leguminous plant in both production area and international trade (Hymowitz, 1990; Denis, 1994). Soybean is consumed conventionally in Asia; however, in America continent it is usually used as a source of protein and oil (Hymowitz and Newell, 1981; Singh, 1992). The monetary value of soybean protein is higher than its oil value (Smith and Huyser, 1992). Our country has extremely appropriate ecology for soybean cultivation, however; recently it is cultivated as a second crop in Aegean, Mediterranean and Southeast Anatolia. Unfortunately our country has already imported soybean oil cake and vegetable oil (Arslan and Isler, 2002). Approximately, 65 000 tones soybean produced from 25000 ha area in Turkey could supply only 1/6 of internal consumption. National politics supporting soybean cultivation and crop buying and attractiveness of support premium system have encouraged soybean producers. Soybean is produced as first and second crop. Planting soybean as a main crop begins in middle of April, while the second crop had planted until the second week of July.

The physical and mechanical properties of soybean are important to design the equipments and machines for sorting, separation, transportation, processing and storing. Designing of such equipments and machines without taking these into consideration may yield poor results. For this reason the determination and consideration of these properties has an important role. The major moisture-dependent physical properties of biological materials are shape, size, mass, bulk density, true density, porosity and static friction coefficient against various surfaces (Mohsenin, 1980). In recent years, many researchers have investigated these properties for various agricultural crops as pistachio nuts (Kashaninejad *et al*., 2005). Shea kernel (Olajide *et al*., 2000), apricot pit and its kernel (Gezer *et al*., 2002), pumpkin seeds (Joshi *et al*., 1993) and sunflower seeds (Gupta and Das, 1997). In addition to the physical properties of soybean have determined by Dehspande *et al*. (1993). But there is limited information on properties of soybeans which is inadequate to design equipment and machines in the scientific literatures for soybeans to growed in Turkey.

The objective of this study was to investigate some physical and mechanical properties of soybean at

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different moisture content. The properties examined include: size distrubitions, sphericity, volume, density, static coefficient of fraction, porosity and terminal velocity.

MATERIALS AND METHODS

Sample preparation: This research conducted in Turkey in 2005 year. Soybean used for all the experiments were obtained from the local experimental areas of agricultural faculty at Sanliurfa province, in the south east of Turkey for this study. The samples were cleaned manually to remove foreign matter, broken and immature soybeans.

The moisture content of samples was determined by air convection oven drying at 103±2°C until a constant weight was reached (Kashaninejad *et al*. 2003). The average moisture content of the soybeans was found to be 6.7% (db). Soybeans were conditioning by adding a calculated quantity of water, mixing thoroughly and then sealing in separate polyethylene bags (Karababa, 2005). The samples were kept at 5°C in a refrigerator for 15 days for the moisture to di stribute uniformly throughout the samples. Before each test, the required quantity of samples was taken out of refrigerator and allowed to warm up to room temperature. All the physical properties were determined at the moisture contents of 6.7, 9.6, 12.1 and 15.3% (db).

Physical characteristics: In order to determine dimensions and unit mass one hundred soybeans were randomly selected and labeled for easy identification. For each soybeans, the three principal dimensions, namely length, width and height were measured using an electronic digital caliper having a least count of 0.001 mm at each moisture level. The Length (L) was defined as the distance from the tip cap to the kernel crown. Width (W) was defined as the widest point to point measurement taken parallel to the face of the kernel. Thickness (T) was defined as the measured distance between the two kernel faces as described by Pordesimo *et al*. (1990).

The geometric mean diameter D_g of the seed was calculated by using the following relationship (Mohsenin, 1980):

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

Where, L is the length, W is the width and T is the thickness in mm.

The sphericity Φ of chick pea seeds is calculated using the following formula (Mohsenin, 1980):

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

Where, L is the length, W is the width and T is the thickness in mm.

The mass of individual seeds were determined in a electronic balance to an accuracy of 0.001 g.

Bulk density, true density and porosity measurement: The bulk density is the ratio of the mass sample of soybeans to its total volume. It was determined by filling a 1000 mL container with kernels from a height of about 15 cm, striking the top level and then weighing the contents (Gupta and Das, 1997; Despande *et al*., 1993; Konak *et al*., 2002). True density of the seed was determined by the water displacement technique (Dutta *et al*., 1988). Twenty randomLy selected seeds were weighed and then coated with a thin layer of table gum and allowed to dry in order to prevent water absorption. The seeds were lowered with a metal sponge sinker into a 1.1 capacity measuring cylinder containing 500 mL of distilled water, such that the seeds did not float during immersion in water. Net volumetric water displacement by the seeds was recorded. This technique was found to be suitable, as the increase in seed mass due to the coating was about 2%, causing a negligible error in the determination. Moreover, there were no changes in the net water displacement on immersion of the coated seeds in water for 3 min, indicating the functional effectiveness of the coating. The bulk density was determined using the mass/volume relationship, by filling an empty plastic container of predetermined volume and tare weight with the seeds by pouring from a constant height, striking off the top level and weighing (Fraser *et al*., 1978).

The porosity (∈) of the bulk is the ratio of the volume of internal pores in the particle to its bulk volume and was determined using the following relationship (Mohsenin, 1980):

$$\in = \frac{\rho_t - \rho_b}{\rho_t}$$

where ρ_t is the true density and ρ_b is the bulk density.

Coefficient of static friction measurement: The coefficient of static friction of soybeans at different moisture contents were measured using a friction device modified by Tsang-Mui-Chung *et al*. (1984) and improved by Chung and Verma (1989). Also, the coefficient of static friction with an applied torque was measured and calculated using the following relationship (Aydin and Ozcan, 2002).

$$\mu = T_m/W\cdot q$$

Where μ is coefficient of friction, T_m measured value of torque, q the length of torque arm and W is the weight of fruits on the rotating surface.

Terminal velocity measurement: The terminal velocities of soybeans at different moisture content were measured using an air column. For each test, a sample (nut or kernel) was dropped from the top of a 75 mm diameter, 1 m long glass tube. The air flowed upwards in the tube from bottom to the top and the air velocity at which the sample suspended was recorded by an anemometer having at least 0.1m/s sensitivity. Ten replications were taken for each moisture content level (Aydin and Ozcan, 2002; Gezer *et al*., 2002; Joshi *et al*., 1993)

RESULTS AND DISCUSSION

Dimensions and Unit Mass Distribution of soybean: The results of soybean mass and size at different moisture content are shown in Table 1. All the dimensions increased with moisture content in the moisture range of 6.7-15.3% (db). The relationships between the axial dimensions (L,W,T and D_g) and crop moisture content (M_c) can be expressed using the regression equations as:

$$Mc = -8.47+1.45\,L+0.678\,W+0.467\,T \quad R^2 = 0.78$$
$$L = 4.22+0.434Mc \quad R^2 = 0.75$$
$$W = 4.07+0.180Mc \quad R^2 = 0.76$$
$$T = 4.02+0.0762Mc \quad R^2 = 0.72$$
$$Dg = 4.63+0.165Mc \quad R^2 = 0.98$$

All of the dimensional properties were significantly correlated to different moisture content. The results indicates that the soybeans increased in length, width, thickness, Arithmetic mean diameter, geometric diameter and 1000 seed mass within the moisture range 6.7-15.3%. Similar investigations have been made to evaluate the mass and dimensional properties and similar results were found by Desphande *et al.* (1993) for soybeans; Kashaninejad *et al.* (2005) for pistachio nuts, Carman (1996) for lentil, Baryeh (2001) for bambara groundnuts and Gezer *et al.* (2002) for apricot pits and kernels.

Bulk density, true density and porosity measurement: The bulk density of soybeans increased from 465.38 to 576.20kg/m^3, respectively as moisture content increased from 4.10 to 38.1% (db). The true density of soybean was found to deccrease from 1180.75 kg m^{-3} at a moisture content of 4.10% to 1210.50 g kg m^{-3} at a moisture content of 19.48% (Table 2). Desphande *et al.* (1993) and Aydin and Ozcan (2002) also reported the same results for soybean and terebinth (*P. terebinthus* L.) fruit. The true density, bulk density of soybean can be represented by following equations:

$$\rho_t = 1043+2.76Mc \qquad R^2 = 94.4$$

$$\rho_b = 891-13.8Mc \qquad R^2 = 91.5$$

where is the true density and is the bulk density

The porosity of soybeans at the different moisture content was found to decrease from 42.56 to 40.87% with increase in moisture content from 8.95 to 17.12%. The porosity values were similar and lower than those reported for soybeans (Desphande *et al*., 1993), karingha seeds (Suthar and Das, 1996), raw cashew nut (Balasubmarian, 2001), okra seeds (Sahoo and Srivastava, 2002), hazelnut (Aydin, 2002) and pistachio nuts (Kashaninejad *et al*., 2005). The relationship between the porosity and moisture content for soybeans can be represented by the following equation:

$$\epsilon = 55.9-0.761\,Mc \quad R^2 = 93.7$$

Coefficient of static friction: At all moisture contents, the static coefficient of friction was the highest for soybean against plywood and least for glass. As the moisture content of soybean increased, the static coefficient of friction increased linearly. At the 6.7% db moisture content, the coefficient of static friction of soybean was 0.22 on plywood, 0.21 on galvanized steel sheet and 0.19 on glass (Table 3). The coefficients of static friction were similar and lower than those reported for karingha seeds (Suthar and Das, 1996), raw cashew nut (Balasubmarian, 2001), okra seeds (Sahoo and Srivastava, 2002), hazelnut (Aydin, 2002)and pistachio nuts Kashaninejad *et al*., 2005).

Table 1: 1000 seed mass and axial dimensional properties of Soybeans (standard deviation in parentheses)

Moisture content % db	1000 seed Mass g	Length (L) mm	Width (W) mm	Thickness (T) mm	Arithmetic mean diameter $\frac{L+W+T}{3}$ mm	Geometric mean diameter $(L\times W\times T)^{1/3}$ mm	Sphericity (%)	L/W	L/T	L/D_g
6.7	121.76 (4.03)	7.41 (0.40)	5.34 (0.43)	4.50 (0.39)	5.75	5.62	75	1.38	1.64	1.30
9.6	155.45 (7.37)	8.09 (0.60)	5.55 (0.43)	4.75 (0.52)	6.13	5.97	73	1.43	1.78	1.62
12.1	193.98 (7.66)	9.29 (1.00)	6.49 (0.53)	5.21 (0.47)	7.01	6.80	73	1.40	1.70	1.36
15.3	223.65 (7.66)	9.57 (0.31)	6.75 (0.43)	5.17 (0.29)	7.16	6.94	72	1.41	1.85	1.38

L/W, Length/Width; L/T, Length/Thickness; L/D_g, Length/Geometric mean diameter

Table 2: Bulk density, true density and porosity of soybean at the different moisture content

Moisture content % d.b.	True Density ($g\ kg\ m^{-3}$)	Bulk Density ($g\ kg\ m^{-3}$)	Porosity (%)
6.7	1062.6	804.8	51.0
9.6	1069.2	756.5	48.1
12.1	1076.5	708.6	46.8
15.3	1086.4	689.3	44.2

Table 3: Static coefficient of friction of soybean at different moisture content

Moisture content % d.b.	Glass	Galvanized iron	Plywood
6.7	0.19	0.21	0.22
9.6	0.29	0.31	0.32
12.1	0.32	0.33	0.35
15.3	0.33	0.34	0.35

Table 4: The relationship between moisture content and static coefficients of friction

Surfaces	Equations	Coefficient of determination (R^2)
Glass	$\mu = 0.105+0.0167$ Mc	0.78
Galvanized iron	$\mu = 0.118+0.0161$ Mc	0.86
Plywood	$\mu = 0.174+0.0128$ Mc	0.72

Table 5: Aerodynamic properties of soybean at diffrerent different moisture content

Moisture content % d.b.	Terminal velocity (m/s)	SD
6.7	7.13	0.31
9.6	7.49	0.62
12.1	8.88	0.50
15.3	9.24	0.56

The relationships between Static coefficient of friction of soybean at different moisture content were found to be as Table 4.

Terminal velocity: The terminal velocity was found to increase from 7.13 to 9.14 m/s for soybean respectively in the moisture range of 6.7-15.3% (db). As the moisture content increased, the terminal velocity of soybean was found to increase linearly (Table 5).

Kashaninejad *et al*. (2005) for pistachio nuts, Carman (1996) for lentil, Gezer *et al*. (2002) for apricot pits and kernels and Aydin (2002) for hazel nuts found similar results. The relationship between moisture content and terminal velocity was found to be as follows:

$$V = 5.27+0.268\ Mc \quad R^2 = 94.8$$

CONCLUSIONS

The various properties of soybean measured will serve as a useful tool in process and equipment design and this will go a long way in assisting to improve yield and quality of soybean. The following conclusions are drawn from this investigation into the properties of soybean:

- All the physical properties of soybean to be dependent on their moisture contents.
- At the moisture content of 6.7% (db), the average length, width and thickness soybean were 7.41, 5.34 and 4.50 mm, respectively, while the corresponding values at the moisture content of 15.3% (db) were 8.09, 5.55 and 4.75 mm. At the moisture content of 6.7 and 15.3% (db) the average unit mass of soybean for 1000 seed mass was 121.76 and 223.65 g, respectively.
- An increasing relationship was found between sphericity as well as geometric mean diameter and moisture content in soybean. Geometric mean diameter of soybean also increased with increase in moisture content. But sphericity of soybean decreased with increase in moisture content.
- As the moisture content increased from 6.7 to 15.3% (db), bulk density of soybean increased, but true density of soybean decreased.
- The porosity of soybean decreased with increase in moisture content.
- The static coefficient of friction of soybean increased linearly with moisture content for all the surfaces. At all moisture contents, the static coefficient of friction was the highest for soybean against plywood and the least for glass.
- As the moisture content increased from 6.7 to 15.3% (d.b.), the terminal velocity of soybean was found to increase linearly.

REFERENCES

Anonymous, 2001. http://www.unitedsoybean.org/soystats2001/page_33.htm.

Arslan, M. and N. Isler, 2002. Yeni Soya Hatlarinin Amik Ovasinda Ikinci Ürün Olarak Yetiþtirilebilme Olanaklarinin Belirlenmesi. University of Mustafa Kemal. J. Agric. Fac., 7: 51-57.

Aydin, C. 2002. Physical properties of hazel nuts. Biosyst. Eng., 82: 297-303.

Aydin, C. and M. Ozcan, 2002. Some physico-mechanic properties of terebinth fruits. J. Food Eng., 53: 97-101.

Balasubramanian, D., 2001. Physical properties of raw cashew nut. J. Agric. Eng. Res., 78: 291-297.

Baryeh, E.A.B., 2001. Physical properties of bambara groundnuts. J. Food Eng., 47: 321-326.

Carman, K.C., 1996. Some physical properties of lentil seeds. J. Agric. Eng. Res., 63: 87-92.

Chung, J.H. and L.R. Verma, 1989. Determination of friction coefficients of beans and peanuts. Trans. ASAE, 32: 745-750.

Denis, J.M., 1994. Designer Oil Crops. Breeding, Processing and Biotechnology. vch, weinheim, pp: 15-21.

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

Dutta, S.K., V.K. Nema and R.K. Bhardwaj, 1988. Physical properties of gram. J. Agric. Eng. Res., 39: 259-268.

FAO, 2002. Production Yearbook.

Fraser, B.M., S.S. Verma and W.E. Muir, 1978. Some physical properties of fababeans. J. Agric. Eng. Res., 22: 53-57.

Gezer, I., H. Haciseferogullari and F. Demir, 2002. Some physical properties of hacihaliloglu apricot pit and kernel. J. Food Eng., 56: 49-57.

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

Hymowitz, T., C.A. Newell, 1981. Taxonomy of the genus Glycine, domestication and uses of soybeans. Econom. Bot., 35: 272-288.

Hymowitz, T., 1990. Advances in New Crops. Proceedings of the First National Symposium New Crops: Research, Development, Economics. Janick, J., Simon, J.E. Eds. Timber Press, Portland, Oregon. USA, pp: 310-321.

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

Karababa, E., 2005. Physical properties of popcorn kernels. J. Agric. Eng. Res., 54: 100-107.

Kashaninejad, M., L.G. Tabil, A. Mortazavi and A. Safe Kordi, 2003. Effect of drying methods on quality of pistachio nuts. Drying Technol., 21: 821-838.

Kashaninejad, M., A. Mortazavi, A. Safekordi and L.G. Tabil, 2005. Some Physical Properties of Pistachio (Pistachia Vera L.) Nut and Its Kernel. J. Food Eng., 72: 30-38.

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

Mohsenin, N.N., 1980. Physical Properties of Plants and Animal Materials, Gordon and Breach Science Publishers, NW, New York.

Olajide, B.I.O., Ade-Omowaye and E.T. Otunola, 2000. Some physical properties of shea kernel. J. Agric. Eng. Res., 76: 419-421.

Pordesimo, L.O., R.C. Anantheswaran, A.M. Fleischmann, Y.E. Lin and M.A. Hanna, 1990. Physical properties as indicators of popping characteristics of microwave popcorn. J. Food Sci., 55: 1352-1355.

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

Singh, U.B., 1992. Tropical grain legumes as important human foods. Singh. Econom. Bot., 46: 310-321.

Smith, K.J. and W. Huyser, 1987. Soybean Improvement, Production and Uses, Wilcox, J.R. (Ed.), Agronomy Monograph 16. American Society of Agronomy, Madison, Wisconsin. USA. 2nd Edn., pp: 1-22.

Suthar, S.H. and S.K. Das, 1996. Some physical properties of karingda seeds. J. Agric. Eng. Res., 65: 15-22.

Tsang-Mui-Chung, M., L.R. Verma and M.E. Wright, 1984. A device for friction measurement of grains. Trans. ASAE, 27: 11938-11941.