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Full Length Research Paper

Physico-chemical grain properties of new common bean cv. 'Elkoca-05'

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The several physical properties of a new registered common bean cultivar 'Elkoca-05' were determined according to three selected moisture content namely, 7.50, 15.28, and 19.85% d.b. In addition, some chemical and color parameter of the grain were studied. The average length, width, and thickness of grain were 14.38, 6.83, and 5.86 mm at 7.50% d.b moisture content. The values of bulk density of the grains were determined as 811.57, 755.17 and 726.10 kg m^{-3} at the 7.50, 15.28 and 19.85% moisture content. The coefficients of dynamic friction increased from 0.173 to 0.353, 0.174 to 0.261, and 0.214 to 0.316 for steel, plywood, and wood with increasing moisture content. The force of rupture decreased from 138.09 to 100.65 N with increasing moisture content. The antioxidant activity and phenolic content of grains were found to be 53.53%, and 23.91 μgGAE mg^{-1} d.b.

Key words*:* Bean, physical properties, chemical properties.

INTRODUCTION

Common beans (*Phaseolus vulgaris* L.) is most widely grown legume species in the world. Its acreage is 26.778.000 ha and production 18.991.000 tons, yields being average 0.71 t ha^{-1} worldwide (FAO, 2005). Bean species and cultivars grow in a wide range of area extending from around 52° north latitude to 32° south latitude and from sea level to 3000 m above sea level, implying great variation in plant habits and length of vegetation. Vegetation period of beans ranges from 70 days to more than 200 days.

Common beans rank third after chickpea and lentils in terms of acreage (175.000 ha) and production (225.000 t) in Turkey (FAO, 2005). Yields are steadily increasing in the country. There are more than 14 bean cultivars registered in Turkey. Vegetation period of many of these cultivars is above 120 days. Recently registered national cultivar 'Elkoca-05' has 100-105 days vegetation period that may push the production areas in short growth period of highlands (Elkoca and Kantar, 2005).

Elkoca-05 is of a semi-vining growth type with a plant height of 53 cm, 4 branches per plant, 13 pods per plant, 12 cm pod length, 15 cm height to first pod and 4 seeds per pod. Seed is a typical oblong type with white testa color (Elkoca and Kantar, 2005). Despite being a short growing period cultivar, Elkoca-05 yield exceeds most of other standard cultivars by 15% (2.26 t ha^{-1}). Technological analysis shows that average cooking time is 53 min, water holding capacity is 0.21 g $grain^{-1}$, water uptake index is 1.05%, swelling capacity is 0.22 ml $grain^{-1}$ and swelling index is 1.34%.

The knowledge of physical properties of agro-materials is of importance to plant breeders, engineers, machine manufacturers, food scientists, processors, and consumers. The data on physical properties are used in designing relevant machines and equipment for harves-ting, handling, transportation, separating, aeration, sizing, storing, packing and the other processing. The data have also been used for assessing the product quality.

Physical properties have been studied for several beans such as faba beans (Altuntas and Yildiz, 2007), oil bean

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Nomenclature: ε, porosity, %; ρ_b, bulk density, kg m^{-3}; ρ_t, true density, kg m^{-3}; θ, angle of repose, deg; *H,* height of cone, mm; *D,* radius of circular plate, mm; μ_d, coefficient of dynamic friction; *F,* friction force, N; *N,* normal force, N; E_a, energy absorbed by grain, mJ; F_r, rupture force, N; D_r, deformation at rupture, mm; *P,* toughness, mJ mm^{-3}; *V,* grain volume, mm^3.

Table 1. Means and standard deviations of size distribution and mass of the grain.

Moisture content (% d.b.)	7.50	15.28	19.85	Signif. Level
Length (mm)	14.38±1.01[c]	14.90±0.92[b]	15.66±0.78[a]	**
Width (mm)	6.83±0.41[c]	7.13±0.40[b]	7.53±0.38[a]	**
Thickness (mm)	5.86±0.45[c]	6.00±0.46[b]	6.14±0.40[a]	*
Arithmetic mean diameter (mm)	9.02±0.56[c]	9.34±0.51[b]	9.78±0.42[a]	**
Geometric mean diameter (mm)	8.31±0.51[c]	8.60±0.48[b]	8.97±0.40[a]	**
Mass (g)	0.43±0.07[c]	0.46±0.07[b]	0.51±0.06[a]	**

*, ** Significant levels at 5 and 1% respectively; a, b, c letters indicate the statistical difference in same rows.

(Oje and Ugbor, 1991), soybean (Deshpande et al., 1993), locust bean (Olajide and Ade-Omowaye, 1999), cocoa beans (Bart-Plange and Baryeh, 2003), barbunia bean (Cetin, 2007) and white speckled red kidney bean (Isik and Unal, 2007).

The objective of the study was to determine some moisture-dependent physical properties for example size, mass, sphericity, bulk density, true density, angle of repose, volume, porosity, coefficient of dynamic friction, terminal velocity, and rupture properties of cv. Elkoca-05 common bean grains. In addition, some chemical and color parameters also were studied.

EXPERIMENTAL PROCEDURES

Physical properties

The physical properties of the cv. Elkoca-05 bean grain were determined by the following methods.

The initial moisture content of the grain was determined using the ASAE standard oven method S352.2 (ASAE, 1997). The initial moisture content was 7.50% d.b. Three levels of moisture content of the grain were selected as 7.50, 15.28, and 19.85% d.b. The samples at the selected moisture contents were prepared by adding distilled water to sealed bags of seed and stored in a refrigerator at 5°C for 7 days to achieve certain moisture equilibrium. Before starting a test, the required quantity of grain was taken out of the refrigerator and was allowed to warm up to room temperature (Deshpande et al., 1993).

To determine the size of the grain one-hundred grains were selected at random and their three principal linear dimensions namely length, width and thickness were measured by a digital caliper reading to 0.01 mm.

Arithmetic mean diameter, geometric mean diameter, and sphericity were calculated by Mohsenin (1986). Grain mass was measured by using a digital balance with a sensitivity of 0.01 g. Grain volume and true density were determined using the liquid displacement method (Mohsenin, 1986). Bulk density was determined with a mass per hectoliter tester, which was calibrated in kg cm^{-3} (Deshpande et al. 1993). The porosity was calculated by the equation given below (Mohsenin, 1986):

$$\varepsilon = [1-(\rho_b/\rho_t)]\ 100 \qquad (1)$$

The height of cone (H) and the radius of the circular plate (D) were measured. The angle of repose (θ) was calculated using the following relationship (Kaleemullah and Gunasekar, 2002).

$$\theta = \tan^{-1}(2H/D) \qquad (2)$$

The coefficient of dynamic friction is defined as the ratio between the friction force and the normal force acting on the contact surface:

$$\mu_d = F/N \qquad (3)$$

To determine the friction force a direct shear test device was used (Kara et al., 1997). Three different frictional surfaces namely steel, plywood, and wood were used in the tests. The friction tests were repeated five times. The rupture properties of the grains were determined by a quasi-static loading device (Turgut et al., 1998). Twenty grains were used in the tests. The energy absorbed during the loading up to rupture was calculated from the area under the load-deformation curve using the following equation (Altuntas and Yildiz, 2007):

$$E_a = ½\ (F_r D_r) \qquad (4)$$

Toughness, a ratio of energy absorbed by the grain up to the rupture point to the volume of the grain, was calculated from the following formula (Olaniyan and Oje, 2002):

$$P = E_a/V \qquad (5)$$

To determine the terminal velocity a measurement setup was used (Song and Litchfield, 1991). The procedure was replicated twenty times.

Chemical analyses

In β-Carotene–linoleic acid assay, antioxidant capacity of bean grains is determined by measuring the inhibition of the volatile organic compounds and the conjugated diene hydroperoxides arising from linoleic acid oxidation (Barriere et al., 2001).

Total soluble phenolics in the bean extracts were determined with Folin-Ciocalteu reagent according to the method of Slinkard and Singleton (1977) using gallic acid as a standard. Results were expressed as milligrams of gallic acid equivalent (GAE) per 100 g of fresh weight (FW).

Mineral elements were determined according to Kacar and Kovanci (1982).

RESULTS AND DISCUSSIONS

Mean values of grain length, width, thickness, arithmentic and geometric diameter and mass are given in Table 1. The average length, width and thickness of the grains increased from 14.38 to 15.66 mm, 6.83 to 7.53 mm and

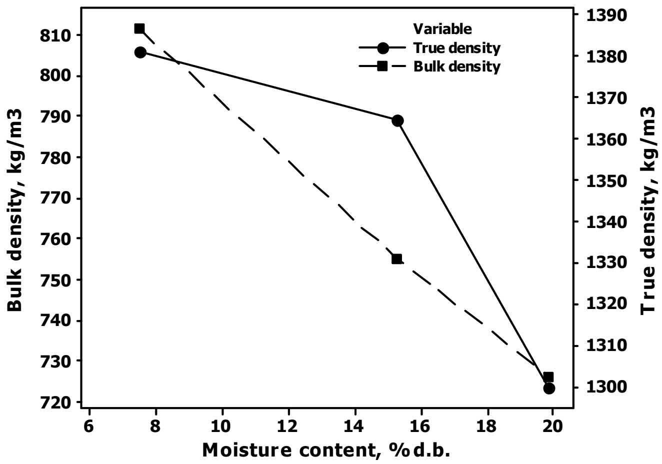

Figure 1. Effect of moisture content on the bulk and true densities of the grain.

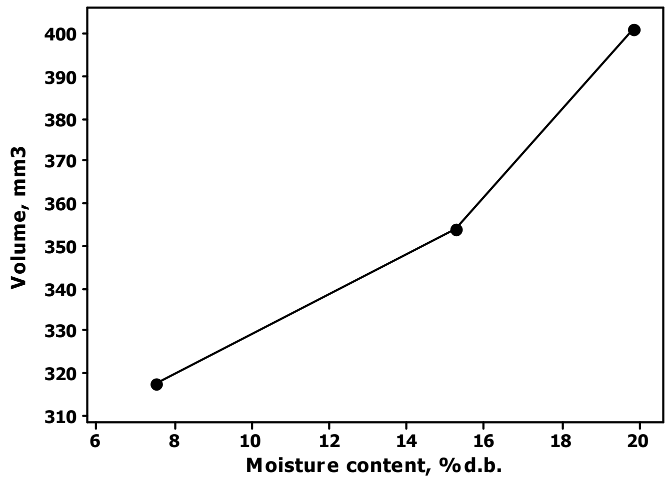

Figure 3. Effect of moisture contents on the volume of the grain.

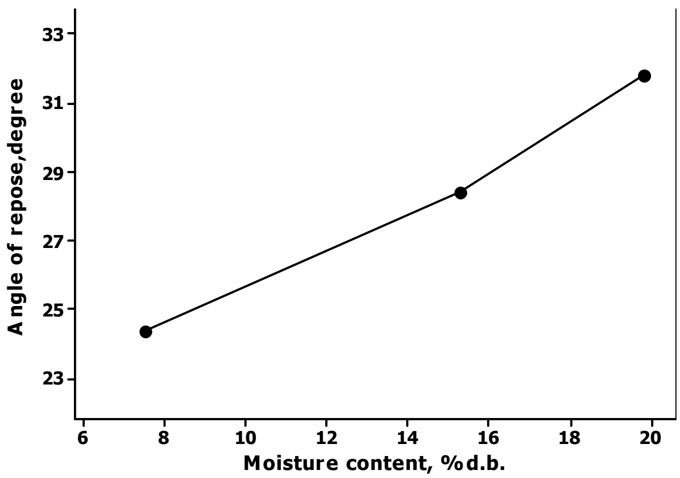

Figure 2. Effect of moisture content on the angle of repose of the grain.

5.86 to 6.14 mm respectively as the moisture content increased from 7.50 to 19.85% d.b. The arithmetic and geometric mean diameter ranged from 9.02 to 9.78 mm and 8.31 to 8.97 mm as the moisture content increased from 7.50 to 19.85% ($P < 0.01$) (Table 1).

The effect of moisture content on the sphericity values of the grain was not significant. Sphericity did not vary as the moisture content increased from 7.50 to 19.85% d.b and its value was found 58% at the moisture contents of 7.50 and 15.28% and 57% at the moisture content of 19.85%. It can be said that the cv. Elkoca-05 bean grain is quite far from a spherical shape. Bart-Plange and Baryeh (2003) found similar results for category B cocoa beans.

The values of bulk and true densities of the grains decreased from 811.57 to 726.10 kg m^{-3} ($P<0.01$) and from 1380.82 to 1299.50 kg m^{-3} ($P<0.05$) as the moisture content increased from 7.50 to 19.85% d.b. Both bulk density and true density decreased with increasing mois-ture content (Figure 1). Cetin (2007) also reported the si-milar results for barbunia bean.

The variation of the angle of repose with the moisture content of the grain is plotted in Figure 2. An increase was observed between 24.34 and 31.81^{o} in line with increasing moisture range. The similar trend was reported by Altuntas and Yildiz (2007) for faba bean.

The volume of the grain increased from 317.54 to 401.30 mm^3 with increasing moisture content from 7.50 to 19.85% d.b. ($P<0.05$) (Figure 3). Altuntas and Yildiz (2007) reported similar trend for faba bean.

The values of porosity of the grain increased from 41.18 to 46.74% with increase in moisture content ($P<0.05$) (Figure 4). Similar results also were reported by Cetin (2007) for barbunia bean, and Isik and Unal (2007) for white speckled red kidney bean.

The effect of moisture content of the grain on the coefficient of dynamic friction against the two friction surfaces, namely, steel, plywood and wood is presented in Figure 5. The coefficients of dynamic friction increased linearly with moisture content for both frictional surfaces due to increased adhesion between contact surfaces. The coefficients of dynamic friction ranged from 0.173 to 0.353, 0.174 to 0.261 and 0.214 to 0.316 respectively for steel, plywood, and wood as the moisture content increased from 7.50 to 19.85% d.b. (Figure 5).

Chung and Varma (1989) reported the similar values of coefficients of dynamic friction for soybean and red kidney beans on sheet metal.

The values of the terminal velocity of the grain at the three moisture contents are shown in Figure 6. The terminal velocity increased from 9.47 to 10.14 m s^{-1} with increasing moisture content ($P<0.01$). Cetin (2007) reported the similar trend for barbunia seed.

The values of the rupture properties of the grain, namely rupture force, deformation at rupture, energy absorbed

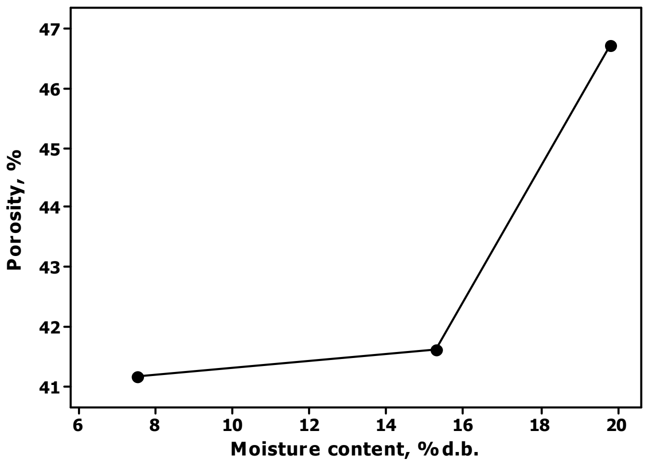

Figure 4. Effect of moisture contents on the porosity of the grains.

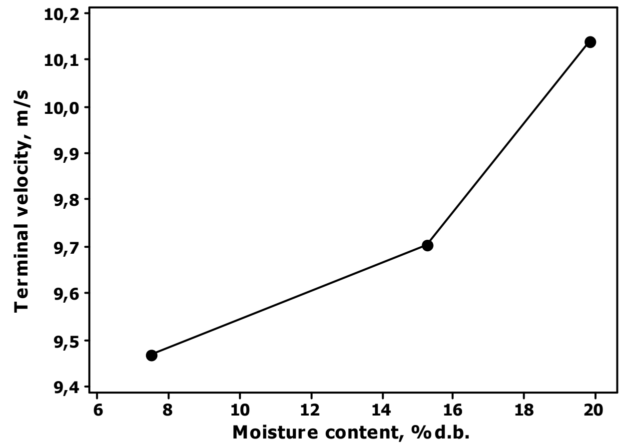

Figure 6. Effect of moisture content on the terminal velocity of the grain.

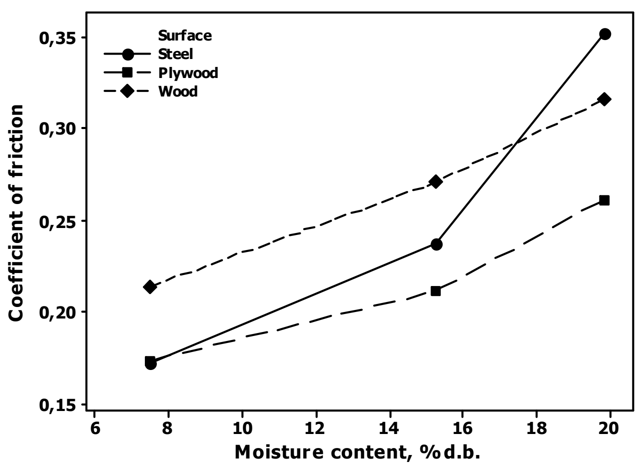

Figure 5. Effect of moisture content on the dynamic coefficients of friction of the grains on steel, plywood and wood surface.

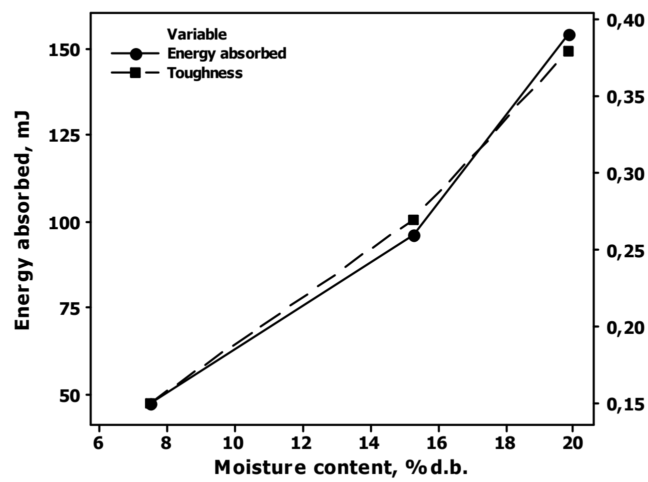

Figure 7. Effect of moisture content on energy absorbed up to rupture and toughness of the grain

up to rupture, and toughness are summarized in Table 2 as a function of moisture content. As the moisture content increased from 7.50 to 19.85% the rupture force decreased from 138.09 to 100.65 N ($P<0.05$) and the deformation at the rupture point increased from 0.68 to 3.04 mm ($P<0.01$) (Figure 7). The results are in agreement with these reported by Paulsen (1978) for soybean. As the moisture content increased from 7.50 to 19.85%, energy absorbed up to the rupture point and toughness increased from 47.56 to 154.14 mJ and 0.15 to 0.38 mJ mm^{-3}, respectively ($P<0.01$) (Figure 7).

The results are similar to these reported by Paulsen (1978) for soybean and Vursavus and Ozguven (2004) for apricot pit.

The chemical and color properties of bean are given in Table 3. As shown in Table 3, the lightness (*L*), apparent color (*a, b)* and hue angle (α) of skin of the Elkoca-05 bean grain was found to be 77.24, 0.69, 9.83 and 85.98 respectively. Grain skin color and brightness are one of the most important quality parameters of common bean. Stoilova et al. (2005) reported that most of the grains of common bean cultivars from Bulgaria and Portugal have white color which supports our findings. The concentrations of the different analyzed elements are shown in Table 3. Among mineral elements, K (7872 ppm), Ca (4660) and P (4062) were the most abundant. Previously K, Ca and P content of different common bean cultivars were found between 14782-16271; 1466-3207 and 3684-6044 ppm, respectively (Beebe et al., 1999). Such differences may be due to cultivar and environmental effect. It is well known that cultivar, soil characteristics, climate and sample preparation method affects nutrient concentrations in agricultural crops. The antioxidant activity and total phenolic content of the cultivar was 53.53% and 23.

Table 2. Effect of moisture content on rupture force, deformation, energy absorbed, and toughness.

Moisture content, (%d.b.)	Rupture force (N)	Deformation at rupture (mm)	Energy absorbed (mJ)	Toughness (mJ mm^{-3})
7.50	138.09[a]	0.68[c]	47.56[c]	0.15[c]
15.28	114.37[b]	1.69[b]	96.31[b]	0.27[b]
19.85	100.65[c]	3.04[a]	154.14[a]	0.38[a]
Sign. Level	*	**	**	**

*, ** Significant levels at 5 and 1% respectively; a, b, c letters indicate the statistical difference in same column.

Table 3. The summary of the chemical and color properties of the grain determined.

Chemical parameters	Elkoca-05	
Dry matter (%w.b.)	93.02	
P (ppm)	4062.00	
K (ppm)	7872.00	
Na (ppm)	806.00	
Mg (ppm)	390.00	
Ca (ppm)	4660.00	
Fe (ppm)	32.50	
Mn (ppm)	16.00	
Cu (ppm)	18.00	
Zn (ppm)	36.00	
Antioxidant activity (%)	53.53	
Phenolic content (µgGAE mg^{-1} d.b.)	23.91	
Color parameters	**External Color**	**Internal Color**
Lightness, L	77.24	75.66
green to red, a	0.69	1.74
blue to yellows, b	9.83	17.67
Hue angle, α	85.98	84.33
Chroma, C	9.86	17.75

91 µgGAE mg^{-1} d.b. (Table 3). The antioxidant activity of BHA was 75.10%. The average values of antioxidant activity and total phenolic content of bean cultivars were found between 28.26-54.34% and 2.08-78.24 µgGAE mg^{-1} d.b. (Cardador-Martinez et al., 2002).

Conclusion

The results from this work have clearly shown the following

1. The average length, width, thickness, geometric mean diameter, and arithmetic mean diameters of the grains increased from 14.38 to 15.66 mm, 6.83 to 7.53 mm, 5.86 to 6.19 mm, 8.31 to 8.97 mm, 9.02 to 9.78 mm respecttively as the moisture content increased from 7.50 to 19.85% d.b. Sphericity did not vary with moisture content.
2. The terminal velocity increased from 9.47 to 10.14 m s^{-1} with increase in moisture content from 7.50 to 19.85% d.b.
3. As the moisture content increased the rupture force decreased from 138.09 to 100.65 N and the deformation at the rupture point increased from 0.68 to 3.04 mm. Energy absorbed up to the rupture point, and toughness increased from 47.56 to 154.14 mJ and from 0.15 to 0.38 mJ mm^{-3}, respectively.
4. Dry matter was measured about 93.02% at the initial moisture content of 7.50% d.b. The antioxidant activity and phenolic content were found to be about 53.53%, and 23.91 µgGAE mg^{-1} d.b.

REFERENCES

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

ASAE Standards (1997). S352.2 Moisture measurement. – unground grain and seeds. America Society of Agricultural Engineers. St Joseph, Michigan, USA.

Barriere C, Centeno D, Lebert A, Leroy-Setrin S, Berdague JL, Talon R (2001). ''Roles of superoxide dismutase and catalase of *Staphylococcus xylosus* in the inhibition of linoleic acid oxidation''. FEMS

Microbiol. Lett. 201: 181-185.
Bart-Plange A, Baryeh EA (2003). ''The physical properties of Category B cocoa beans''. J. Food Eng. 6: 219-227.
Beebe S, Gonzalez AV, Rengifo J (1999). ''Research on trace minerals in common beans. Proceedings of International Workshop Improving Human Nutrition Through Agriculture: The Role of International Agricultural Research.
Cardador-Martinez A, Loarca-Pina G, Oomah BD (2002). ''Antioxidant activity in common beans (*Phaseolus vulgaris* L.)''. J. Agric. Food Chem. 50: 6975-6980.
Cetin M (2007). ''Physical properties of barbunia bean (*Phaselous vulgaris* L. cv. 'Barbunia') seed''. J. Food Eng. 80: 353-358.
Chung JH, Verma LR (1989). ''Determination of friction coefficients of beans and peanuts''. Transactions of the ASAE, 32: 745-750.
Deshpande SD, Bal S, Ojha TP (1993). ''Physical properties of soybean. J. Agric. Eng. Res. 56: 89-98.
Elkoca E, Kantar F (2005). ''Early maturing and high yielding two new common bean cultivar: Kantar-05 and Elkoca-05. Proceedings of 2th Turkey Tohumculuk Seed Congress, 9-11 Kasım 2005, Adana, pp. 226-229.
FAO (2005). http://www.fao.org/
Isık E, Unal H (2007). ''Moisture-dependent physical properties of white speckled red kidney bean grains''. J. Food Eng. 82: 209-216.
Kacar B, Kovanci I (1982). ''Chemical phosphorus analysis in plant, soil and fertilizers and evaluation of results''. Ege University, Agricultural Faculty, Izmir, Turkey. p. 352.
Kaleemullah S, Gunasekar J (2002). ''Moisture-depent physical properties of arecanut kernels''. Biosyst. Eng. 82: 331-338.
Kara M, Turgut N, Erkmen Y, Guler İE (1997). ''Determination of coefficient of friction of some granules''. Proceedings of 17th Agricultural Mechanization National Congress, 17-19 Sept. 1997, Tokat, Turkey, pp. 609-614.
Mohsenin NN (1986). ''Physical Properties of Plant and Animal Materials*''*. New York: Gordon and Breach Science Publisher.
Oje K, Ugbor EC (1991). ''Some physical properties of oilbean seed. J. Agric. Eng. Res. 50: 305-313.
Olajide JO, Ade-Omowaye BIO (1999). ''Some physical properties of locust bean seed''. J. Agric. Eng. Res. 74: 213-215.
Olaniyan AM, Oje K (2002). ''Some aspect of the mechanical properties of shea nut''. Biosyst. Eng. 81: 413-420.
Paulsen MR (1978). ''Fracture resistance of soybeans to compressive loading''. Transactions of the Amer. Soc. Agric. Eng. 21: 1210-1216.
Slinkard K, Singleton VL (1977). ''Total phenol analyses: automation and comparison with manual methods''. Amer. J. Enol. Vit. 28: 49–55.
Song H, Litchfield JB (1991). ''Predicting method of terminal velocity for grains. Trans. Am. Soc. Agric. Eng. 34: 225-230.
Stoilova T, Pereira G, Tavares de Sousa MM, Carnide V (2005). ''Diversity in common bean landraces (*Phaseolus vulgaris* L.) from Bulgaria and Portugal''. J. Central Eur. Agric. 6: 443-448.
Turgut N, Kara M, Erkmen Y, Guler IE (1998). ''Determination of static particle strength of granular fertilizer''. Proceedings of 18th Agricultural Mechanization National Congress, Tekirdag, Turkey, pp. 785-794.
Vursavus K, Ozguven F (2004). ''Mechanical behaviour of apricot pit under compression loading''. J. Food Eng. 65: 255–261.