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Physical and Chemical Grain Properties of New Registered Common Bean cv. 'Kantar-05'

(Sifat Fizikal dan Kimia Bijiran Kacang cv. Biasa Baru Berdaftar 'Kantar-05')

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ABSTRACT

Moisture-dependent physical grain properties of a new registered common bean cultivar 'Kantar-05' were determined. Some important chemical parameters of the grain were also investigated. The average length, width and thickness of the grain were 12.48, 7.92 and 5.00 mm at 7.82% db (dry basis) moisture content. The values of bulk density and true density of the grains decreased from 793.37 to 683.62 kg/m^3 (P<0.01) and from 1269.37 to 1206.55 kg/m^3 (P<0.05) with increasing moisture content. The coefficients of dynamic friction increased from 0.180 to 0.316, 0.173 to 0.276, and 0.226 to 0.331 on steel, plywood and wood friction surface, respectively with increasing moisture content. The force of rupture decreased from 121.88 to 68.93 N with increase in moisture content. Phosphorus, potassium, calcium, sodium and magnesium contents were 5020 ppm, 5576 ppm, 3562 ppm, 780 ppm and 372 ppm, respectively wb% (wet basis) at the initial moisture content. The antioxidant activity and phenolic content of the grains were found to be 56.62% and 24.82 µg GAE/mg db., respectively at the initial moisture content.

Keywords: Common bean; chemical properties; physical properties

ABSTRAK

Sifat fizikal bijiran yang bergantung kepada lembapan bagi kacang kultivar biasa yang baru didaftar 'Kantar-05' telah ditentukan. Beberapa paramater kimia bijiran yang penting juga dikaji. Purata panjang, lebar dan tebal bijiran tersebut ialah masing-masing 12.48, 7.92 dan 5.00 mm pada 7.82% db (asas kering) kandungan lembapan. Nilai ketumpatan pukal dan ketumpatan sebenar bijiran ini masing-masing menurun daripada 793.37 kepada 683.62 kg/m^3 (P<0.01) dan daripada 1269.37 ke 1206.55 kg/m^3 (P<0.05) dengan peningkatan kandungan lembapan. Pekali geseran dinamik meningkat daripada 0.180 ke 0.316, 0.173 ke 0.276, dan 0.226 ke 0.331 masing-masing di atas permukaan keluli, papan lapis dan kayu dengan peningkatan kandungan lembapan. Daya pecahan menurun daripada 121.88 ke 68.93 N dengan peningkatan kandungan lembapan. Kandungan fosforus, kalium, kalsium, natrium dan magnesium adalah masing-masing 5020, 5576, 3562, 780 and 372 ppm mw% (asas basah) pada kandungan lembapan asal. Aktiviti antioksidan dan kandungan fenolik adalah masing-masing 56.62% and 24.82 µg GAE/mg db pada kandungan lembapan asal.

Kata kunci: Kacang biasa; sifat fizik; sifat kimia

INTRODUCTION

Common beans (*Phaseolus vulgaris* L.) are 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 (Anon. 2005). Bean species and cultivars grow in a wide range of areas 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. 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 (Anon. 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 'Kantar-05' has 80-85 days vegetation period that may push the production areas in short growth period of highlands and as a second crop in the lowlands (Elkoca & Kantar 2005).

Kantar-05 is of a semi-vining growth type with a plant height of 50 cm, 3 branches per plant, 13 pods per plant, 10 cm pod length, 11 cm height to first pod and 4 seeds per pod. The seed is a typical subcompressus pinto type with brown spots on beige field (Elkoca & Kantar 2005). Despite being a short growing period cultivar, Kantar-05 yields generally exceed most of other standard cultivars by 24% (2.36 t ha^{-1}). Technological analysis show that average cooking time is 55 min, water holding capacity is 0.11 g grain^{-1}, water uptake index is 0.65%, swelling capacity is 0.10 ml grain^{-1} and swelling index is 1.18%.

In order to design the appropriate systems, machines and structures for planting, harvesting, handling, processing and storing of agricultural products, the data related to their physical properties is needed (Mirzaee et al. 2009).

Various researchers studied the physical properties of bean grains such as Fraser et al. (1978), and Altuntas and Yildiz (2007) for faba bean, Ozturk et al. (2009) for common bean, Olajide and Ade-Omowaye (1999) and Ogunjimi et al. (2002) for locust bean, Oje and Ugbor (1991) for oil bean, Deshpande et al. (1993) for soybean, Bart-Plange and Baryeh (2003) for cocoa beans, Cetin (2007) for barbunia bean and Isik and Unal (2007) for white speckled red kidney bean.

This study was carried out to determine some moisture-dependent physical properties of cv. Kantar common bean grain namely, size, mass, sphericity, bulk density, true density, angle of repose, volume, porosity, coefficient of dynamic friction, terminal velocity, and rupture properties. In addition, some chemical and color parameters of the grain also were investigated.

Experimental Details

General

The initial moisture content of the grain was obtained by keeping the sample in the oven at 105 ± 1°C for 24 h (Suthar & Das 1996) and it was found 7.82% db (dry basis). Three levels of moisture content of the grain selected were as 7.82%, 15.68%, and 19.39% db. The desired moisture contents for higher levels were obtained by adding the distilled water of mass calculated by the following equation:

$$M_w = W_i\,(M_f - M_i)/\,(100 - M_f), \tag{1}$$

where M_w is the mass of water added to sample, W_i the initial mass of sample, M_i and M_f the initial and final moisture content of sample, respectively.

The prepared sample was sealed in separate bags and kept in a refrigerator at 5°C for 7 days to enable the moisture to diffuse uniformly throughout the sample. Just before starting the test, the required amount of grain was taken out of the refrigerator and was allowed to warm up to room temperature (Carman 1996).

In order to measure the size dimensions of the grain one-hundred grains were selected randomly and their length (L), width (W) and thickness (T) were measured by a digital caliper reading to 0.01 mm.

The arithmetic mean diameter (D_a) , geometric mean diameter (D_g) , and sphericity (ϕ) of the grain were calculated from the following three equations given by Mohsenin (1986), respectively:

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

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

$$\phi = \frac{D_g}{L}100. \tag{4}$$

Toluene (C_7H_8) displacement method was used to determine the volume and true density (ρ_τ) of the grain. A known mass of grains was immersed into the toluene; the volume of toluene displaced was read from the graduated scale of the cylinder (Mohsenin 1986). Bulk density (ρ_b) was determined by using a mass per hectoliter tester, which was calibrated in kg/cm^3 (Desphane et al. 1993).

The porosity (ε) was calculated by the following equation given by Mohsenin (1986):

$$\varepsilon = [1-(\rho_b/\rho_t)]\ 100. \tag{5}$$

The angle of repose, an angle between horizontal and natural slope of the grain when it piled, was determined by using a topless and bottomless cylinder in 150 mm diameter and 250 mm height. A removable circular plate was placed under the cylinder, the sample was poured into a cylinder and then the cylinder was slowly raised up allowing the sample to form a cone on a circular plate. The height of cone was measured and the angle of repose was calculated by dividing the height of the cone by the radius of the circular plate (Kaleemullah & Gunasekar 2002).

The coefficient of dynamic friction (μ_d) was calculated by dividing the friction force (F) by the normal force (N) acting on the contact surface:

$$\mu_d = F/N. \tag{6}$$

In order to measure the friction force a direct shear test device was used (Kara et al. 1997). The rupture force of the grains (F_r) was determined by a quasi-static loading device (Turgut et al. 1998).

The deformation of the grain (D_r) occurred during the loading up to rupture was determined from the fixed loading speed and time. The energy absorbed by the grain (E_a) during the loading up to rupture was calculated from the triangular area under the load-deformation curve by the following relationship (Altuntas & Yildiz 2007):

$$E_a = ½\ (F_r D_r). \tag{7}$$

The terminal velocity was measured by using a measurement device (Song & Litchfield 1991). In β-Carotene–linoleic acid assay, antioxidant capacity of the bean grains was determined by measuring the inhibition of the volatile organic compounds and the conjugated diene hydroperoxides arising from linoleic acid oxidation. The synthetic antioxidant, butylated hydroxyanisole (BHA) which is commonly used in processed foods was used as a control (Barriere et al. 2001).

The 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 μgGAE/mg db.

The mineral compositions were determined according to Kacar and Kovanci (1982).

PLANT MATERIAL

Common bean cv. Kantar-05 was grown in the Experimental Station of Ataturk University in Erzurum of Turkey.

EXTRACTION

A sample of 100 g was extracted in a soxhlet with methanol (MeOH) at 60°C for 6 h. The extract was then filtered and concentrated in vacuum at 45°C. Finally, the extracts were then lyophilized and kept in the dark at 4°C until antioxidant capacity and total soluble phenolic tests.

RESULTS AND DISCUSSION

The mean values of the dimensions and mass of the grains for different levels of moisture content are presented in Table 1. According to the moisture content increasing from 7.82 to 19.39% db. the average length, width, thickness, and mass of the grain increased from 12.48 to 13.47 mm, 7.92 to 8.44 mm, 5.00 to 5.54 mm, 0.34 to 0.40 g, respectively (Table 1). The dimensions of grains increased between 6.6% and 10.8% while the moisture content increased from 7.82 to 19.39% db. The value of mass increased about 17.6% with increasing moisture content. Similar trend was reported by Ozturk et al. (2009) for common bean, Altuntas and Yildiz (2007) for faba bean, Cetin (2007) for barbunia bean and Isık and Unal (2007) for white speckled red kidney bean. However, these increases in the dimensions and mass of the cv Kantar-05 grains as affected by moisture content were lower than those of the works by Altuntas and Yildiz (2007) and Cetin (2007).

The arithmetic and geometric mean diameter increased from 8.47 to 9.15 mm and 7.90 to 8.56 mm as the moisture content increased ($P<0.01$) (Table 1). The values of geometric mean diameter were similar to those of Ozturk et al. (2009), but lower than those reported by Altuntas and Yildiz (2007) and Cetin (2007).

The relationship between the moisture content and the sphericity values of the grains was not significant. Sphericity did not vary as the moisture content increased from 7.82% to 19.39% d.b and its average value was found 64% for all levels of the moisture content (Table 2). This value means that the cv. Kantar-05 bean grains are far from a spherical shape. The sphericity values of cv Kantar-05 grains were similar to those of Altuntas and Yildiz (2007) and Cetin (2007), but lower than those by speckled red kidney bean (Isık & Unal 2007) and higher than common bean (Ozturk et al. 2009).

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

Some physical properties	Moisture content, % db (dry basis)			Sign. Level
	7.82	15.68	19.39	
Length, mm	12.48±0.85^{c}	12.91±0.84^{b}	13.47±0.70^{a}	**
Width, mm	7.92±0.53^{c}	8.17±0.46^{b}	8.44±0.43^{a}	**
Thickness, mm	5.00±0.45^{c}	5.21±0.52^{b}	5.54±0.49^{a}	**
Arithmetic mean diameter, mm	8.47±0.52^{c}	8.76±0.50^{b}	9.15±0.41^{a}	**
Geometric mean diameter, mm	7.90±0.49^{c}	8.18±0.49^{b}	8.56±0.39^{a}	**
Mass, g	0.34±0.06^{c}	0.37±0.05^{b}	0.40±0.05^{a}	**

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

TABLE 2. Means and standard deviations of some physical properties of the grain

Some physical properties	Moisture content, % db (dry basis)			Sign. Level
	7.82	15.68	19.39	
Sphericity, %	63±0.02	64±0.03	64±0.02	Ns
Volume, mm^3	269.06±19.35^{c}	289.42±7.00^{b}	335.17±36.75^{a}	*
True density, kg/m^3	1269.37±56.12^{a}	1234.29±15.15^{ab}	1206.55±12.84^{b}	*
Bulk density, kg/m^3	793.37±0.81^{a}	716.17±2.04^{b}	683.62±5.06^{c}	**
Porosity, %	37.10±0.91^{c}	40.43±0.63^{b}	46.07±2.12^{a}	**
Angle of repose, ^{o}	25.58±0.61^{c}	29.62±0.78^{b}	31.02±0.78^{a}	*
Terminal velocity, m/s	9.26±0.36^{b}	9.58±0.33^{a}	9.77±0.33^{a}	*

*, ** Significant levels at 5% and 1% respectively; NS: Not significants; a, b, c letters indicate the statistical difference in column

Both bulk density and true density of the grains decreased from 793.37 to 683.62 kg/m^3 (P<0.01) and from 1269.37 to 1206.55 kg/m^3 (P<0.05) as the moisture content increased (Table 3). The values of bulk density and true density decreased about 13.83% and 4.95% with increasing moisture content, respectively. Similar relationships were found by some previous works for common bean (Ozturk et al. 2009), barbunia bean (Cetin 2007), sweet corn (Karababa and Coskuner 2007), popcorn (Karababa 2006), and chick pea (Konak et al. 2002). But, some researchers (Isık and Unal 2007; Altuntas and Yildiz 2007; Baryeh 2002) reported that true density increased with increasing moisture content in contrary with our results.

The effect of the moisture content on the angle of repose of the grain is given in Table 3. The values of angle of repose increased from 25.58 to 31.02^o with increase in the moisture range selected. Similar values were reported by Ozturk et al. (2009) for common bean, Karababa (2006) for popcorn and Konak et al. (2002) for chick pea. The values of angle of repose were lower than those of millet (Baryeh 2002) and sweet corn (Karababa & Coskuner 2007), but higher than that of faba bean seeds (Altuntas & Yildiz 2007).

The volume of the grain increased from 269.06 to 335.17 mm^3 while the moisture content increased from 7.82% to 19.39% db. (P<0.05) (Table 3). These values are close to those of common bean cv Elkoca (317.54 – 401.30 mm^3) reported by Ozturk et al. (2009).

The values of porosity of the grain increased from 37.10 to 46.07% with increasing moisture content (P<0.01) (Table 3). Similar results also were reported by Ozturk et al. (2009) for common bean, Cetin (2007) for barbunia bean and Isik & Unal (2007) for white speckled red kidney bean. These values were lower than those reported for faba bean (Altuntas & Yildiz 2007), rape seed (Calisir et al. 2005) and millet (Baryeh 2002).

The effect of moisture contents on the terminal velocity of the grain is shown in Table 3. The terminal velocity increased from 9.26 to 9.77 ms^{-1} with increasing moisture content (P<0.05). Similar results have been reported for common bean (Ozturk et al. 2009) and white speckled red kidney bean (Isık & Unal 2007). However, the results were lower than reported for barbunia bean by Cetin (2007).

The values of coefficient of dynamic friction of the grain on the three friction surfaces namely, steel, plywood and wood at three moisture content levels of the grain are given in Figure 1. The coefficients of dynamic friction increased as the moisture content increased for all frictional surfaces due to increased adhesion between contact surfaces. The coefficients of dynamic friction increased from 0.180 to 0.316, 0.173 to 0.276, and 0.226 to 0.331 respectively for steel, plywood, and wood as the moisture content ranged from 7.82% to 19.39% db. (P<0.01) (Figure 1). Wood had the highest coefficient of dynamic friction followed by steel and plywood. Similar results were obtained with steel for barbunia bean (Cetin

TABLE 3. Effect of moisture content on rupture force, deformation and energy absorbed

Moisture content, % db (dry basis)	Rupture force, N	Deformation at rupture, mm	Energy absorbed, mJ
7.82	121.88^a	0.70^c	43.02^c
15.68	82.55^b	1.93^b	77.69^b
19.39	68.93^c	3.91^a	134.34^a
Sign. Lev.	*	**	*

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

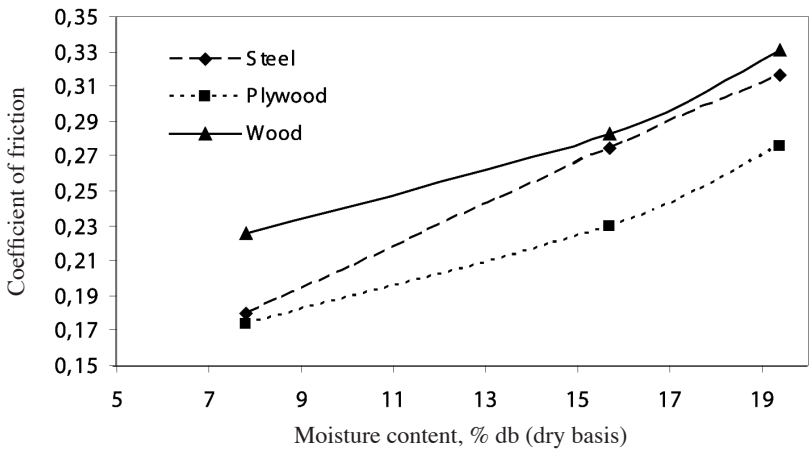

FIGURE 1. Effect of moisture content on the coefficients of dynamic friction on steel, plywood and wood surface

2007) and plywood for soybean (Tunde-Akintunde et al. 2005).

The values of rupture force, deformation at rupture and energy absorbed up to rupture, are summarized in Table 3 as a function of moisture content.

The rupture force decreased from 121.88 to 68.93 N ($P<0.05$) and the deformation at rupture increased from 0.70 to 3.91 mm ($P<0.01$) while the moisture content increased from 7.82 to 19.39%. The value of rupture force decreased about 43.44% and the deformation value at rupture increased 5.58 times with increasing moisture content. The small rupture forces at higher moisture content might have resulted from the fact that the grain became more sensitive to cracking at high moisture. The results are in agreement with these reported by Paulsen (1978) for soybean.

The values of energy absorbed up to the rupture point increased from 43.02 to 134.34 mJ as the moisture content increased from 7.82 to 19.39%, respectively ($P<0.05$). The results are similar to those reported by Paulsen (1978) for soybean and Vursavus and Ozguven (2004) for apricot pit.

The color properties of bean are given in Table 4. As shown in Table 4, the lightness (*L*), apparent color (*a, b)* and hue angle (α) of skin of the Kantar-05 bean grain was found to be 63.72, 4.93, 14.84 and 71.19 respectively. Grain skin color and brightness are one of the most important quality parameters of common bean. Stoilova et al. (2005) reported that of the grains of some common bean cultivars from Bulgaria and Portugal has brown spots color which supports our findings.

TABLE 4. The summary of the color properties of the grain determined

Color parameters	External Color	Internal Color
Lightness, L	63.72	77.69
Green to red, a	4.93	1.53
Blue to yellows, b	14.84	14.93
Hue angle, α	71.19	84.16
Chroma, C	15.31	15.01

The concentrations of the different analyzed elements are shown in Table 5. Among mineral elements, K (5576 ppm), Ca (3562 ppm) and P (5020 ppm) 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 effects. It is well known that cultivar, soil characteristics, climate and sample preparation method affect nutrient concentrations in agricultural crops.

The antioxidant capacity and total phenolic content of the cultivar was 56.62% and 24.82 μgGAE/mg db. (Table 5). The antioxidant capacity of synthetic antioxidant, butylated hydroxyanisole (BHA) which is commonly used in processed foods was 75.10%. The average values of antioxidant capacity and total phenolic content of bean cultivars were found between 28.26-54.34% and 2.08-78.24 μgGAE/mg db. (Cardador-Martinez et al. 2002) within the range of our results.

TABLE 5. The summary of the chemical properties of the grain determined

Chemical parameters	Kantar-05
Dry matter, % wb (wet basis)	92.74
P, ppm	5020,00
K, ppm	5576.00
Na, ppm	780.00
Mg, ppm	372.00
Ca, ppm	3562.00
Fe, ppm	19.50
Mn, ppm	12.00
Cu, ppm	16.20
Zn, ppm	21.60
Antioxidant capacity %	56.62
Total phenolic content, μgGAE/mg db	24.82

CONCLUSIONS

The values of length, width, thickness, arithmetic and geometric mean diameter increased about 7.9%, 6.6%, 10.8%, 8% and 8.3% while the moisture content increased from 7.82 to 19.39%. Sphericity did not vary as the moisture content increased and its average value was found 64% for all levels of the moisture content. The mass and volume of the grain increased by about 17.6% and 24.6% with increasing moisture content respedively. The bulk density and true density decreased from 793.37 kg m^{-3} to 683.62 kg m^{-3} and from 1269.37 kg m^{-3} to 1206.55 kg m^{-3}, respectively, the porosity increased about 24.2% while the moisture content increased. The angle of repose varied between 25.58^{o} – 31.02^{o} in the moisture range. Terminal velocity increased about 5.5% with increasing moisture content. As moisture content increased from 7.82% to 19.39%, the rupture force decreased about 43.4%, but deformation at rupture increased 6 times, and energy absorbed up to the rupture point increased 3 times, approximately. Phosphorus, potassium, calcium, sodium and magnesium content of grains were 5020 ppm, 5576 ppm, 3562 ppm, 780 ppm and 372 ppm, respectively wb% (wet basis) at the initial moisture content. The antioxidant activity and phenolic content of grains were found to be 56.62% and 24.82 μg GAE/mg db. at the initial moisture content.

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