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SOME PHYSICAL PROPERTIES AND NUTRITIONAL COMPOSITIONS OF COWPEA (*Vigna sinensis* L.) SEEDS

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ABSTRACT

In this study, nutrient contents for human diet and some physical properties that are important for the design of equipments for sowing, harvesting, processing, transportation, sorting, separation and packaging of cowpea cv. Poyraz grown in Turkey were determined. The physical properties were evaluated as functions of moisture content in the moisture range from 13 to 35% d.b. for the rewetted cowpea seed. As a result, the average length, width, thickness, the geometric mean diameter, sphericity, unit mass and volume were 8.9, 6.2, 5.1, 6.61 mm, 73.9%, 0.27 g and 0.18 cm^3, respectively. The bulk density decreased from 727.2 to 678.8 kg/m^3, true density decreased from 1428.5 to 1000 kg/m^3, porosity decreased from 48.8 to 32.1%, projected area increased from 0.5 to 0.73 cm^2, terminal velocity increased from 7.2 to 8.5 m/s, one thousand seed mass increased from 230.7 g. to 327.4 g, the rupture strength of cowpea seed decreased from 88.2 to 37.6 N, the sphericity of cowpea seed decreased from 73.9 to 71.5% while the moisture content of cowpea seed increased from 13 to 35% d.b.. Mineral contents of cowpea seeds including K, P, Ca, Na, Zn and Fe were determined 1.09%, 0.2%, 5.8%, 0.03%, 30ppm, 63ppm, respectively.

Key words: *Cowpea seed, physical properties, chemical composition, mineral contents*

BÖRÜLCE TOHUMLARININ BAZI FİZİKSEL ÖZELLİKLERİ VE BESİNSEL BİLEŞİMLERİ

ÖZET

Bu çalışmada, Türkiye'de yetiştirilen Poyraz börülce çeşidinin ekim, hasat, işleme, taşımacılık, ayıklama, ayırma paketleme gibi işlemlerin yapılması için gerekli olan aletlerin projelendirilmesinde önemli olan bazı fiziksel özelliklerve insan beslenmesinde önemli olan besin maddesi içerikleri tespit edilmiştir. Börülce tohumlarının söz konusu fiziksel özellikleri %13 ile %35 arasında değişen değerlerde nemlendirilerek, bu aralıktaki nem değerlerinin fonksiyonlarına göre değişimleri belirlenmiştir. Araştırma sonucunda uzunluk, genişlik, kalınlık ortalaması, geometrik ortalama, küresellik, kütle ve hacim sırasıyla 8.9, 6.2, 5.1, 6.61mm, %73, 0.27g ve 0.18cm^3 bulunmuştur. Börülce tohumlarının nem değerleri %13 den %35 e yükselirken, yığın yoğunluğu değerleri 727.2 kg/m^3'den 678.8 kg/m^3'e, dane yoğunluğu 1428.5'den 1000 kg/m^3'e, porozite %48.8'den %32.1'e ve küresellik ise %73.9'dan %71.5'e, kırılma indeksi 88.2 N'dan 37.6 N'a düşmüştür. Bunun yanında izdüşüm alanı 0.5 cm^2'den 0.73 cm^2'ye, terminal hız 7.2 m/s'den 8.5 m/s'ye, bin dane ağırlığı 230.7 g'dan 327.4g'a, artmıştır. Yapılan araştırmada kullanılan börülce tohumlarının K, P, Ca, Na, Zn ve Fe gibi, bazı mineral madde içerikleri sırasıyla %1.09, %0.2, %5.8, %0.3, 30ppm ve 63ppm bulunmuştur.

Anahtar kelimeler: *Börülce tohumu, fiziksel özellikler, kimyasal bileşimler, mineral madde içerikleri*

INTRODUCTION

Cowpea (*V. sinensis* L.) is grown a legume vegetable. In general, it is well-known green plant in Aegean and Mediterranean regions in Turkey. The annual production of cowpea seed in Turkey is 16 077 ton (Tuik, 2006).

The leaf of cowpea is often confused with other bean varieties. It has some forms similar to beans. However cowpea leaf doesn't have feathers just like that of beans, so that the surface of leaf is more smooth and bright and the veins are less evident. The flower is positioned in cluster form the top of flower stalk which appears from leaves. The cluster stalks are mostly longer than flower stalks. Pods are flat, cylinder, thin, filled and long in shape. As ripened, the pods turn yellow while fresh they are dark green in color. Some varieties turn brown or violet (Şehirali, 1988; Günay, 2005; Vural, Eşiyok & Duman, 2000).

The seed germination starts at 8-10 ^{o}C and optimum germination temperature is between 10 and 20^{o}C; germination rate range from 85 to 90%. The duration of germination is about 10-20 days (Günay, 2005). Cowpea is a warm climate green plant which well adapted to moderate humidity conditions. In growing season, it requires high temperatures and also susceptible to frost occurring in spring and fall. Cowpea is suitable for various soil textures and pH of 5.5-6.5. The seeds are sown by planting machine and manually in row. The crop is an important source of protein in human nutrition.

Seeds exhibit a wide range of differences in terms of size, color and shape. The shapes are associated with their pods shape. If carpel's in pods are separated themselves during growth, they appear in ''kidney''

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shape. They approach to sphere as their close position in pod increase. Testa might be flat or wrinkled the color of seed and hilum may be white, beige, brown, red or black in color. There are exist 80-85% of water and 15-20% of dry matter in fresh cowpea. Majority of dry matter consists of carbohydrates and proteins. The cowpea contains 20.42-34.60% protein, 1.3% oil, 3.9% cellulose and 50-67% carbohydrates. Oil rates are low in fresh cowpea (Şehirali, 1988; Günay, 2005; Vural, Eşiyok & Duman, 2000).

Cowpea, a kind of legumes, used for fodder and human nutrition, improves the soil nitrogen. It is accounted for 8.9% of world's edible seed legumes planting area and 2.86% of production. Cowpea's phosphorus needs are enormous. In case of well inoculation by soil nitrogen bacteria, nitrogen content of soil will be enriched (Anonymous, 2006).

The 1000 seed mass of cowpea varies from 100 to 400 g (Günay, 2005). Deshpande, Bal, and Ojha (1993) found a linear decrease in true density, bulk density and porosity as the moisture content increased at 8.7-25% d.b. in soybeans. Çarman (1996) assessed some physical properties such as bulk density, porosity, projected area, terminal velocity and static and dynamic coefficients in lentil seeds. Ige (1977) measured the size and rupture strength of seeds of five cowpea varieties and determined relationship between rupture strength and the size of seeds. However, limited studies have been carried out on physical properties of cowpea.

The physical properties of cowpea are important for the design of equipments for sowing, harvesting, processing, transporting, sorting, separating and also packing. The currently used system has been designed without taking these criteria into consideration; the resulting designs lead to inadequate applications. This results in a reduction in work efficiency and an increase in product loss. The determination and consideration of these criteria therefore have an important role in making these machines.

The objective of this study is to investigate physical properties of cowpea seed namely, linear dimensions, unit mass and volume, sphericity, densities, projected area, 1000 seed mass, terminal velocity and rupture strength depending on the moisture. In addition, some chemical compositions and mineral contents were determined.

MATERIAL AND METHODS

Materials

The dry seeds of cowpea (*V. sinensis* L. cv. Poyraz) were used for all the experiments in this study. The cowpea grown in Konya province was harvested in September 2005. After this transaction the cowpea seeds were desiccated and they were cleaned manually to remove all foreign matter such as dust, dirt, stones and chaff as well as immature, broken seeds.

Notation

D_p	geometric mean diameter, mm
R^2	coefficient of determination
F	axis of force, N
V	terminal velocity, $m s^{-1}$
L	length, mm
T	thickness, mm
W	width, mm
M_c	moisture content, % d.b.
E	porosity, %
P_a	projected area, mm^2
ρ_y	bulk density, kgm^{-3}
ρ_d	true density, kgm^{-3}
F_r	rupture strength, N
Φ	sphericity, %
M_{1000}	1000 seed mass, g

Methods

The moisture content was determined by drying the seeds at 70 C° until a constant weight was obtained (AOAC, 1984). The initial moisture content of the seeds was 13 % dry basis (d.b.). The cowpea samples of the desired moisture levels were prepared by adding calculated amounts of distilled water, thorough mixing and then sealing in separate polyethylene bags. The samples were kept at 278 K° in a refrigerator for 7 days for the moisture to distribute uniformly throughout the sample. Before starting the test, the required quantities of the seed were allowed to warm up to room temperature (Deshpande, Bal & Ojha, 1993; Çarman, 1996). All the physical properties of the cowpea seeds were assessed at moisture levels of 13, 15, 20, 25 and 35% d.b. with three replications at each level.

Determination of physical properties:

To determine the average size of the seed, a sample of 100 cowpea seed was randomly selected. Measurement of the three major perpendicular dimensions of the cowpea was carried out with a micrometer to an accuracy of 0.01 mm.

The geometric mean diameter D_p of the seed was calculated by using the following relationship (Mohsenin, 1970):

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

Where L is the length, W is the width and T is the thickness (Fig.1). According to (Mohsenin, 1970), the degree of sphericity Φ can be expressed as follows:

$$\Phi = [\,(LWT)^{1/3} / L] \times 100$$

This equation was used to calculate the sphericity of both the cowpea seed in the present investigation. To obtain the mass, each cowpea was weighed by a chemical balance reading to 0.0001 g. The true density is defined as the ratio of the mass of a sample to its solid volume (Deshpande, Bal & Ojha, 1993). The cowpea seed volume was determined using the liquid displacement method. Toluene (C_7H_8) was used in place of water because it is absorbed by cowpea seeds to a lesser extent. Also, its surface tension is low so that it fills even shallow dips in a cowpea seed and its dissolution power is low (Sitkei, 1986; Ögüt, 1998). The bulk density is the ratio of the mass of a sample of a cowpea seed to its total volume. It is a moisture-dependent property. The bulk density was determined with a weight per hectoliter tester which was calibrated in kilogram per hectoliter (Deshpande, Bal, and Ojha, 1993). The porosity of cowpea seed at various moisture contents was calculated from bulk and true densities using the relationship given by Mohsenin (1970) as follows:

$$\varepsilon = [\ (\rho_d - \rho_y)\ / \rho_d\ ]\ x\ 100$$

Where ε is the porosity in %, ρ_y is the bulk density in kg/m^3 and ρ_d is the true density in kg/m^3.

To determine the projected area of cowpea seeds, a digital camera has been used to take pictures of the cowpea seeds which were placed on a white paper. After these pictures were transferred to the computer, they were used to calculate the projected area of the cowpea seeds.

The terminal velocities of cowpea seed of different moisture contents were measured using an air column. For each test, a small sample was dropped into the air stream from the top of the air column, which air was blown to suspend the material in the air stream. The air velocity near the location of the cowpea seed suspension was measured by an electronic anemometer having an accuracy of 0.1 m/s (Joshi, Das & Mukherjee 1993). Three replications were made for each cowpea seeds.

To determine the rupture strength of cowpea seed, a biological material test device was used. The device developed by Aydın and Ögüt (1992) has three main components which are a fixed base plate and an upper moving platen, a driving unit and the data acquisition system. The cowpea seed was placed on the base plate and pressed with the moving platen. The rupture force of the cowpea seed was measured by the data acquisition system.

Determination of chemical properties:

The chemical properties of the cowpea seeds were analyzed according to AOAC (1984). The moisture content was determined by drying the seeds at 70 ^{o}C until a constant weight was obtained. Crude protein content was calculated by converting the nitrogen content, determined by Kjeldahl's method (6,25×N). Fat was determined by the method described by the using the Soxhlet system. Ash content was determined in a muffle furnace at 550 ^{o}C for 5 h. Crude fibre was determined in a Tecator Fibertec System M1020 Hot extractor (AOAC, 1984). Vitamin C content was determined using the HPLC method described by Rückemann (1980). Carbohydrates were calculated as "Nitrogen free extract" according to the formula: Carbohydrates = 100 – (% moisture + %protein + %crude fibre + % fat + %ash). Energy (kcal) was calculated according to the formula: Energy = (% protein × 4) + (% carbohydrates×4) + (% fat × 9). Organic matter (%) was calculated according to the formula: Organic matter = 100 - %ash.

Determination of mineral contents of cowpea seeds: About 0,5 g. dried and ground sample was put into burning cup and 10 ml pure HNO_3 was added . The sample was incinerated in (CEM, Mars 5) Microwave oven under the 170 psi at 200 ^{o}C temperature and solution diluted to the certain volume (25 ml) with water. Samples were filtered in filter paper, and were determined with an ICP-AES (Varian-Vista Model Axial Simultaneous) (Skujins, 1998).

RESULTS AND DISCUSSION

Physical properties

The values for the mass and volume of an individual, dimensions, geometric mean diameter and sphericity of cowpea seeds are given in Table 1. The frequency distribution curves for the mean values of the dimensions show a trend towards a normal distribution (Fig 2). About 80% of the cowpea seed has a length ranging from 7.95 to 9.84 mm, about 80% a thickness ranging from 4.51 to 5.68 mm and about 80% a width ranging from 5.63 to 6.76 mm.

Table 1. Means and standard errors of the cowpea seed dimensions at 13 % d.b.

Properties	Values
Length, mm	8.9 ± 0.72
Width, mm	6.2 ± 0.43
Thickness, mm	5.1 ± 0.45
Geometric mean diameter, mm	6.6 ± 0.40
Sphericity, %	73.9 ± 3.50
Mass, g	0.3 ± 0.03
Volume, cm^3	0.2 ± 0.016

The length of cowpea seeds increased from 8.9 mm to 11 mm, the width of cowpea seeds increased from 6.2 mm to 7.3 mm, the thickness of cowpea seeds increased from 5.2 mm to 5.9 mm while the moisture content of cowpea seeds increased from 13 to 35% d.b. (Fig. 3).

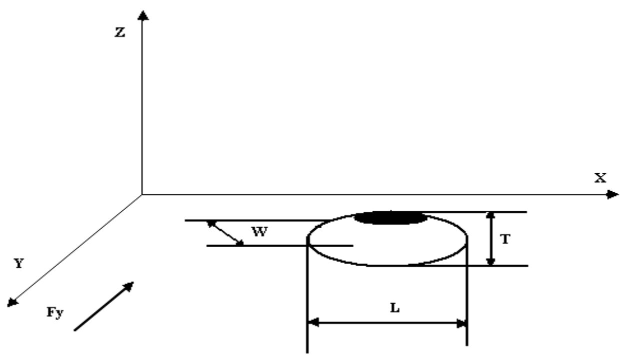

Fig. 1. Axis and three major perpendicular dimensions of cowpea seeds.

The values of bulk density of cowpea seeds at moisture levels of 13-35% d.b. varied from 727.2 to 678.8 kg/m^3 (Fig. 4) and indicated a decrease in bulk density with an increase in moisture content. The negative linear relationship of bulk density with moisture content was also observed by Shepherd and Bhardwaj (1986) for pigeon pea. The statistical analysis of experimental data showed that the relation between bulk density and moisture content was significant. Similar results have been reported by Dursun and Dursun (2005) for caper, Abalone, Cassinera, Gaston and Lara (2004) for amaranth.

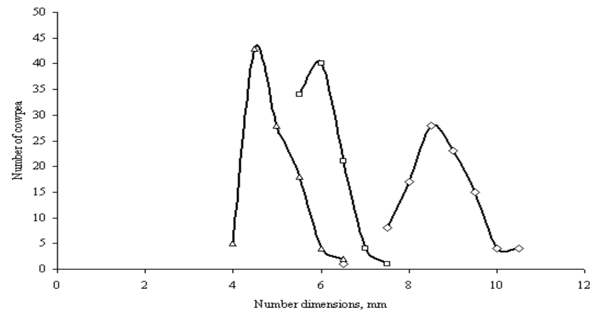

Fig. 2. Frequency distribution curves of cowpea seeds at moisture levels of 13% d.b. (◊), length; (□), width; (Δ), thickness.

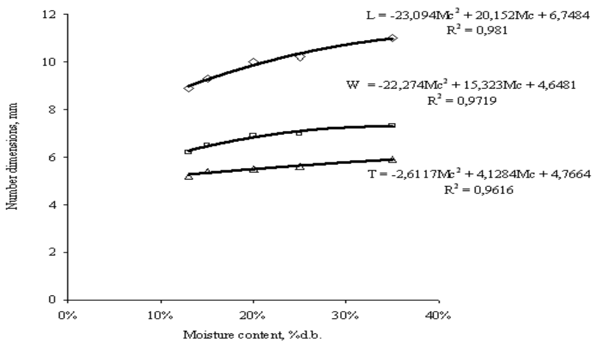

Fig. 3. Effect of moisture content on dimensions (◊), length; (□), width; (Δ), thickness.

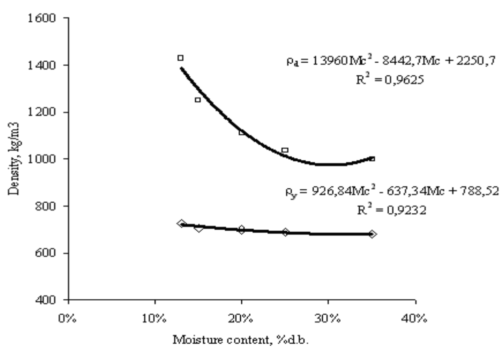

Fig. 4. Effect of moisture content on density: (□), true density; (◊), bulk density.

The true density of cowpea seeds at different moisture levels in the experimental range varied from 1428.5 to 1000 kg/m^3. The effect of moisture content on the true density of cowpea seeds showed a decrease with moisture content (Fig. 4). Deshpande, Bal and Ojha (1993) also observed the linear decrease in true density with increase in grain moisture in the range 8.7-25% d.b. for J.S.-7244 soybean. The similar results have been reported by Karababa (2006) for popcorn, Sacilik, Öztürk and Keskin (2003) for hemp seed, Aydın (2002) for hazelnuts.

Since the porosity depends on the bulk and true densities, the magnitude of variation in porosity depends on these factors only. The porosity of cowpea seed was found to slightly decrease with increase in moisture content from 13 to 35% d.b. (Fig. 5).

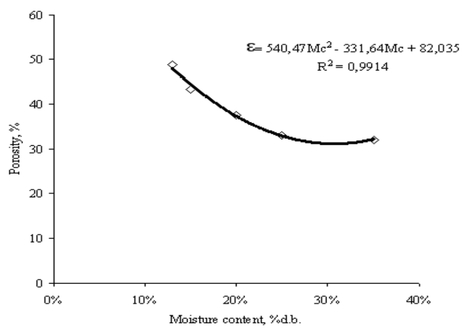

Fig. 5. Effect of moisture content of porosity.

The projected area of cowpea seed (Fig. 6) increased from 0.5 cm^2 to 0.73 cm^2, while the moisture content of cowpea seed increased from 13 to 35% d.b.. The relationship between projected area and moisture content was found to be significant similar trends were also reported for many other seeds (Mohsenin, 1970; Sitkei, 1986). Deshpande, Bal and Ojha (1993) found that the surface area of soybean grain increased from 0.813 to 0.952 cm^2 when the moisture content was increased from 8.7 to 25 % d.b.. Tang and Sokhansanj (1993) for lentil, Ögüt (1998) for white lupin, Paksoy and Aydın (2004) for edible squash, Abalone, Cassinera, Gaston and Lara (2004) for amaranth have been reported similar trends.

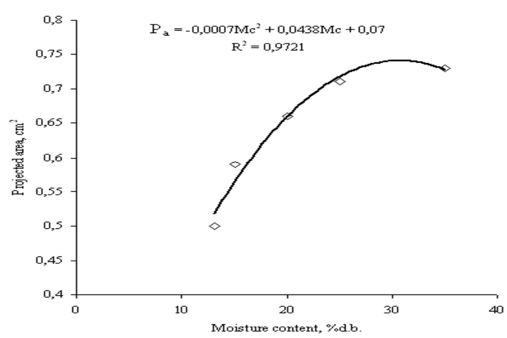

Fig. 6. Effect of moisture content on projected area.

The experimental results for the terminal velocity of the cowpea seed at various moisture levels are plotted in Fig. 7. As moisture content increased, the terminal velocity was found to increase linearly. The increase in terminal velocity with increase in moisture content can be attributed to the increase in mass of an individual seed per unit frontal area presented to the air stream. The results are similar to those reported by Kural and Çarman (1997).

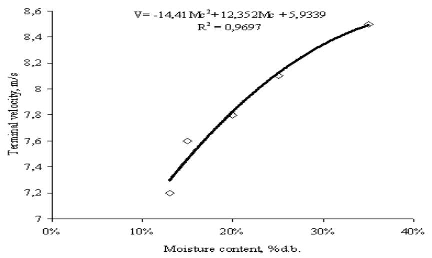

Fig. 7. Effect of moisture content on terminal velocity.

The results of the rupture strength tests are presented in Fig. 8. The rupture strength of cowpea seed decreased from 88.2 to 37.6 N while the moisture content of cowpea seed increased from 13 to 35% d.b.. The force was obtained for cowpea seeds loaded along the Y-axis (F_y). Similar results were reported by Konak *et al* (2002) for chick pea seeds. In this study, the results show that the rupture strength is highly dependent on moisture content of cowpea. The rupture strength of cowpea seed decreased with increasing in moisturecontent.

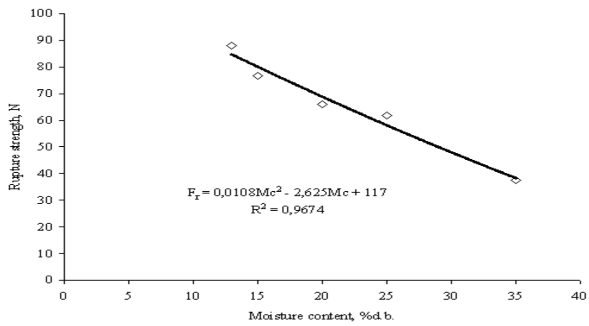

Fig. 8. Effect of moisture content on rupture strength of cowpea seed.

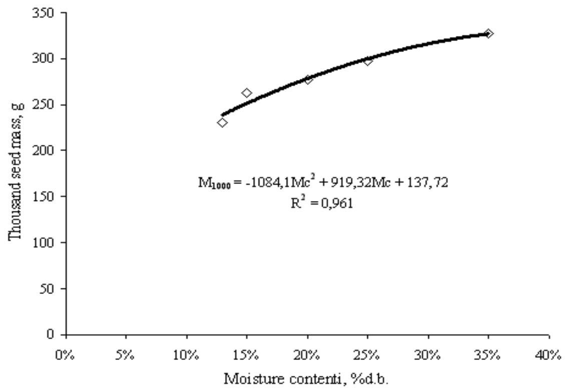

Fig. 9. Effect of moisture content on 1000 seed mass

The experimental results for the one thousand seed mass of cowpea seeds at various moisture levels are plotted in Fig. 9. The one thousand seed mass of cowpea increased from 230.7 g. to 327.4 g while the moisture content of cowpea seed increased from 13 to 35% d.b.. The one thousand seed mass of cowpea increased by 41.91% in the high moisture content (Fig.9).

The sphericity is a measure of a particle is the ratio of the surface area of a sphere (with the same volume as the given particle) to the surface area of the particle. The sphericity of cowpea seed decreased from 73.9% to 71.5 % while the moisture content increased from 13% to 35% d.b. (Fig.10).

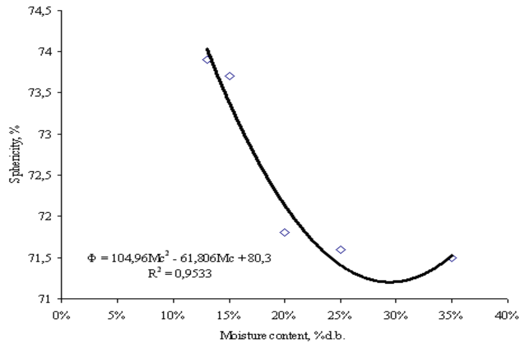

Fig. 10. Effect of moisture content on sphericity.

Chemical Properties

The chemical composition of cowpea seeds analyzed is given in Table 2. Vitamin C, crude oil, crude protein, crude fiber, crude energy, ash, organic matter, moisture, water- soluble extract, ether-soluble extract, alcohol-soluble extract, carbohydrate content were found 1.04 mg/100g, 1.91%, 21.8%, 3.45%, 330.35 kcal, 3.35%, 96.65%, 13%, 14%, 1.24%, 2.73%, 56.49% respectively. Prinyawiwatkul, McWatters, Beuchat and Phillips (1996) reported that crude protein, crude fat, crude fiber, ash and carbohydrate of eight cowpea varieties were respectively, 24.1-25.4%, 1.1-3.0%, 5.0-6.9%, 3.4-3.9% and 60.8-66.4%. Iqbal, Khalil, Ateeq and Khan (2006) reported that moisture, crude protein, crude fat and ash of cowpeas were, respectively, 9.4±0.07 g/100g, 24.7±0.10 g/100g, 4.8±0.07 g/100g and 4.2±0.05 g/100g. Deshpande and Damodaran (1990) reported that crude energy, moisture, crude protein, crude fat, carbohydrates and ash of beans (*Phaseolus vulgaris* L.) were, respectively, 343 cal/100g, 11.0%, 22.0%, 1.6%, 57.8% and 3.6%. Prinyawiwatkul, McWatters, Beuchat and Phillips (1996) reported that vitamin C was respectively 1.5 mg/100 g. Çalışır, Özcan, Hacıseferoğulları and Yıldız (2005) reported that water-soluble extract, and ether-soluble extract of okra (*Hibiscus esculenta* L.) seeds were respectively, 2.6% and 8.7%. In other study, water-soluble extract, alcohol-soluble extract and ether-soluble extract contents of strawberry fruits were determined as 35.6±2.30%, 19.16±3.20%, 3.0±0.40%, respectively (Özcan & Hacıseferoğulları, 2007).

Table 2. Chemical properties of cowpea seed (Dry Weight Basis)

Properties	Values
Moisture (%)	13
Crude Protein (%)	21.8
Crude oil (%)	1.9
Crude cellulose (%)	3.5
Ash (%)	3.3
Organic matter (%)	96.5
Vitamin C (mg/100g)	1.04
Carbohydrate (%)	56.9
Crude energy (kcal.)	330.3
Water-soluble extract (%)	14
Alcohol-soluble extract (%)	2.7
Ether-soluble extract (%)	1.2

(Protein = N × 6,25)

Mineral contents of cowpea seeds are presented in Table 3. Bergmann (1992), reported that P, Ca, Mg, B, Cu, Zn were the minerals present in the cowpea seeds with the levels of 0.12-0.15%, 5.00-5.50%, 0.50-0.80%, 15-20 ppm, 5-7 ppm and 40-50 ppm, respectively. In other study, Prinyawiwatkul, McWatters, Beuchat and Phillips (1996) modified from Phillips (1991), reported that Cu, Fe, Mg, P, K, Na, Zn were the minerals present in cowpea seeds with the amounts of 8 ppm, 83 ppm, 0.18%, 0.42%, 1.11%, 0.016% and 34 ppm, respectively.

Table 3. Mineral content of cowpea seed

Minerals	Values
B (ppm)	18.3
Ca (%)	5.8
Cd (ppm)	0.03
Cr (ppm)	0.004
Cu (ppm)	8.5
Fe (ppm)	63
K (%)	1.09
Mg (%)	0.12
Mn (ppm)	14.2
Na (%)	0.03
P (%)	0.2
Zn (ppm)	30

REFERENCES

Abalone, R., Cassinera, A., Gaston, A., Lara, M. A. 2004. Some physical properties of amaranth seeds. Biosystems Engineering, 89(1), 109-117.

Anonymous 2006. Available from http://www. gencbilim.com

AOAC 1984. Official methods of analysis (14th ed.). VA, USA: Associaton of Official Analytical chemists, Arlington.

Aydın, C. 2002. Physical properties of hazel nuts. Biosystems Engineering, 82, 297-303.

Aydın, C., Ögüt, H. 1992. Determination of deformation energy in some biological materials. National Symposium on Mechanization in Agriculture, Samsun, Turkey, pp. 254—264.

Bergmann, W. 1992. Nutritional Disorders of Plants ISBN: 3-334-60422-5, New York, USA.

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

Çarman, K. 1996. Some physical properties of lentil seeds. Journal of Agricultural Engineering Research, 63, 87-92

Deshpande, S. S., Damodaran, S. 1990. Advanced in Cereal Science and Technology, Vol X Chapter3:156.

Deshpande, S. D., Bal, S., Ojha, T. P. 1993. Physical properties of soya bean. Journal of Agricultural Engineering Research, 56, 89-98.

Dursun, E., & Dursun, I. 2005. Some physical properties of caper seed. Biosystems Engineering, 92(2), 237-245.

Günay, A. 2005. Sebze Yetiştiriciliği. Cilt: 2, ISBN: 975-00725-0-2 (Tk), İzmir, Turkey.

Ige, M. T. 1977. Measurement of some parameters affecting the handling losses of some varieties of cowpea. Journal of Agricultural Engineering Research, 22, 127-133.

Iqbal, A., Khalil, I. A., Ateeq, N., Khan, M. S. 2006. Nutritional quality of important food legumes. Food Chemistry 97 331-335.

Joshi, D. C., Das, S. K., Mukherjee, R. K. 1993. Physical properties of pumpkin seeds. Journal of Agricultural Engineering Research, 54, 219-229.

Karababa, E. 2006. Physical properties of popcorn kernels. Journal of Food Engineering, 72, 100-107.

Kural, H., Çarman, K. 1997. Aerodynamic properties of seed crops. National Symposium on Mechanization in Agriculture, Tokat, Turkey, pp. 615-623.

Konak, M., Çarman, K., Aydın, C. 2002. Physical Properties of Chick Pea Seeds. Biosystems Engineering, 82(1), 73-78.

Mohsenin, N. N. 1970. Physical properties of plant and animal materials. Gordon and Breach Science Publishers, New York.

Ögüt, H. 1998. Some physical properties of white lupin. Journal of Agricultural Engineering Research, 56, 273-277.

Özcan, M. M., Hacıseferoğulları, H. 2007. The strawberry (*Arbutus unedo* L.) fruits: Chemical composition, physical properties and mineral content. Journal of Food Engineering, 78, 1022-1028.

Paksoy, M., Aydın, C. 2004. Some physical properties of edible squash (*Cucurbita pepo* L.) seeds. Journal of Food Engineering, 65, 225-231.

Prinyawiwatkul, W., McWatters, K. H., Beuchat, L. R., Phillips, R. D. 1996. Cowpea flour: a potential ingredient in food products. Critical Reviews in Food Science and Nutrition, 36(5), 413-436.

Rückemann, H. 1980. Methoden zur bestimmung von L-askorbinsaure mittelshochleistungs flüssigchromatographie (HPLC) II. Bestimmung von L-askorbinsaure in milchauschfuttermitteln Z. Lebensm. Unters. Forsch. 171,446-448.

Sacilik, K., Öztürk, R. Keskin, R. 2003. Some physical properties of hemp seed. Biosystems Engineering, 86(2), 191-198.

Sitkei, G. 1986. Mechanics of Agricultural Materials. Akademia Kiado, Budapest.

Shepherd, H., Bhardwaj, R. K. 1986. Moisture-dependent physical properties of pigeon pea. Journal of Agricultural Engineering Research, 35, 227-234.

Skujins, S. 1998. Handbook for ICP-AES (Varian-Vista). A short guide to Vista Series ICP-AES operation. Varian Int. AG, Zug, Version 1.0, Switzerland.

Şehirali, S. 1988. Yemeklik Dane Baklagiller [Pulses.]. Ankara, Ankara University Press Turkey .

Tang, J., Sokhansanj, S. 1993. Geometric changes in lentil seeds caused by drying. Journal of Agricultural Engineering Research, 56(4), 3 13-326.

Tuik, 2006. www.tuik.gov.tr

Vural, H., Eşiyok, D., Duman, İ. 2000. Kültür Sebzeleri (Sebze Yetiştirme) Ege Üniversitesi Ziraat Fakültesi Bahçe Bitkileri Bölümü, İzmir, Turkey.