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The Effect of Moisture of Organic Chickpea (*Cicer arietinum* L.) Grain on the Physical and Mechanical Properties

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Abstract: The physical and mechanical properties of organic chickpeas (cv. Kocabaş) grains were determined as a function of moisture content in the range of 11.31-25.03% dry basis (d.b.). The average length, width and thickness were 10.30, 8.41 and 8.33 mm, at a moisture content of 11.31% d.b., respectively. In the above moisture range, the arithmetic and geometric mean diameters and sphericity increased from 9.01 to 9.85 mm, from 8.96 to 9.80 mm and from 0.870 to 0.884, respectively. Studies on rewetted organic chickpea grains showed that the thousand seed mass increased from 432.22 to 640.00 g, the projected area from 58.30 to 71.50 mm^2, the true density from 1000 to 1200 kg m^{-3}, the porosity from 29.95 to 54.17% and the terminal velocity from 7.20 to 8.70 m sec^{-1}. The bulk density decreased from 700.50 to 550.00 kg m^{-3} with an increase in the moisture content range of 11.31-25.03% d.b. The static coefficient of friction of organic chickpea grains increased the linear against surfaces of six structural materials, namely, rubber (0.4452-0.4986), aluminum (0.3939-0.4411), stainless steel (0.3541-0.3899), galvanized iron (0.4040-0.4557), glass (0.3057-0.3541) and Medium Density Fiberboard (MDF) (0.2867-0.3249) as the moisture content increased from 11.31-25.03% d.b. The shelling resistance of organic chickpea grains decreased as the moisture content increased from 101 to 70 N.

Key words: Organic chickpea grains, physical properties, mechanical properties, moisture content

INTRODUCTION

Agricultural products such as bean, wheat, corn, sunflower and chickpea of physical and mechanical properties gain importance during harvesting with machines, separation and cleaning processes of this crop and also during the designation or improvement of this type of machines. Physical properties consist of dimensional properties such as crop width, length, thickness and technical properties such as specific gravity, bulk density and thousand grain weights. However, mechanical properties are the behavior of the crops against to applied force (Isik and Güler, 2004).

Organic chickpeas are a cultivated plant grown for dry consumption and raw material of canned food industry. It contains 21.3 g protein, 5.4 g fat, 49.6 g carbohydrates and 1339 kJ energy 100 g^{-1} (dry) (Anonymous, 2006).

Turkey had about 606,000 ha of chickpea harvesting area, 620,000 t of chickpea production per annual with a yield of 4,286 kg ha^{-1} of chickpea in 2004 (SIS, 2006). However, detailed statistic of organic chickpeas has not fount in Turkey.

The physical and mechanical properties have been studied for various crops such as green gram (Nimkar and Chattopadhyay, 2001), pigeon pea (Baryeh and Mangope, 2002), cotton

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(Özarslan, 2002), okra grain (Sahoo and Srivastava, 2002), vetch (Yalçın and Özarslan, 2004), *Balanites aegyptiaca* nuts (Aviara *et al*., 2005), caper seed (Dursun and Dursun, 2005), sweet corn seed (Coşkun *et al*., 2006), black-eyed pea (Ünal *et al*., 2006), göynük bombay bean (Tekin *et al*., 2006) and green laird lentil (Isik, 2006).

Despite some engineering properties have been studied for chick pea grain (Konak *et al*., 2002), no published literature was available on the detailed physical properties of organic chickpea grains of moisture content in the range of 11.31-25.03% dry basis and their dependency on operation parameters that would be useful for the design of processing machineries. Therefore, an investigation was carried out to determine moisture-dependent physical properties of organic chickpea grains in 11.31, 13.25, 14.96, 17.51, 21.97 and 25.03% dry basis moisture contents.

The purpose of this study was to investigate some moisture-dependent physical properties, namely, axial dimensions, arithmetic and geometric mean diameters, sphericity, thousand grain mass, surface and projected areas, bulk and true densities, porosity, terminal velocity, static coefficient of friction and shelling resistance of organic chickpea grains.

MATERIALS AND METHODS

The organic chickpea (*Cicer arietinum* L.) (cv. Kocabaþ) grains used in the study were produced by TEMA (The Turkish Foundation for Combating Soil Erosion, for Reforestation and the Protection of Natural Habitats) in Kemalpaþa, Izmir and certificated by IMO^{control} IMO-GmbH (certificate number: IMO GmbH: TR7159).

The initial moisture content of the grains was determined by oven drying at 105±°C for 24 h (Yalçın and Özarslan, 2004) and then calibrated with 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 (Saçılık *et al*., 2003):

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

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 seed was taken out of the refrigerator and allowed to equilibrate to the room temperature for about 2 h (Singh and Goswami, 1996).

All the physical properties of the grains were determined at six moisture contents in the range of 11.31-25.03 d.b. with 10 replications at each moisture content.

To determine the average size of the seed, 100 grains were randomly picked and their three linear dimensions namely, length (L), width (W) and thickness (T) (Fig. 1) were measured using a digital compass (Minolta, Japan) with a accuracy of 0.01 mm.

The average diameter of seed 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 seed were calculated by using the following relationships (Mohsenin, 1970):

$$D_\alpha = (L+W+T)/3 \quad (2)$$

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

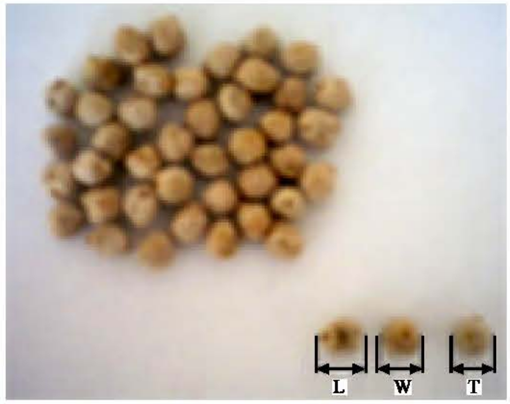

Fig. 1: Three dimensions of organic chickpea grains, length (L), width (W) and thickness (T)

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 seed mass was determined by means of an electronic balance reading to 0.001 g.

The surface area A_s in mm^2 of organic chickpea grains was found by analogy with a sphere of same geometric mean diameter, using the following relationship (Tunde-Akintunde and Akintunde, 2004):

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

The projected area A_p was determined from the pictures of organic chickpea 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) computer program (Isik and Güler, 2003).

The average bulk density of the organic chickpea grains was determined using the standard test weight procedure reported by Gupta and Das (1997) by filling a container of 500 mL with the seed 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 organic chickpea grains in the toluene (Yalçın and Özarslan, 2004). The porosity was calculated from the following relationship (Mohsenin, 1970):

$$\varepsilon = (1 - \frac{\rho_b}{\rho_t})100 \tag{6}$$

where, ε 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 seed 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 column was 28 mm in diameter. Relative opening of a regulating valve provided at blower output end was used to control the airflow rate. In the beginning, the blower output was set at minimum. For each experiment, a sample was dropped into the air stream from the top of the air column. Then airflow rate was gradually increased till the seed mass gets suspended in the air stream. The air velocity which kept the seed suspension was recorded by a digital anemometer (Thies clima, Germany) having a least count of 0.1 m sec^{-1} (Özdemir and Akıncı, 2004).

The static coefficient of friction of organic chickpea grains against 6 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 seed 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:

$$\mu = \tan\alpha \quad (7)$$

where:

μ = The coefficient of friction.

α = The angle of tilt in degrees.

Shelling resistance R_s was determined by forces applied to one axial dimension (length). The shelling resistance of seed was determined under the point load by using a penetrometer.

Statistical Design

The average size of the grain, 100 grains were randomly chosen and the other physical and mechanical properties of the grains were determined at six moisture (from 11.31 to 25.03% d.b.) content with 10 replications at each moisture content level and the results obtained were subjected to analysis of variance (ANOVA) and DUNCAN test using SPSS 13.0 software and analysis of regression using Microsoft Excel.

RESULTS AND DISCUSSION

Seed Dimensions

The mean values and standard errors of the axial dimensions of the organic chickpea grains at different moisture contents are shown in Fig. 2. The three axial dimensions increased with increase in moisture content from 11.31-25.03% d.b. The mean dimensions of 100 grains measured at a moisture content of 11.31% d.b. are: length, 10.304±0.030 mm and width 8.4118±0.062 mm and thickness 8.333±0.051 mm.

The average diameter calculated by the arithmetic mean and geometric mean are also shown in Fig. 2. The average diameters increased with the increase in moisture content as axial dimensions. The arithmetic and geometric mean diameter ranged from 9.01 to 9.85 mm and 8.96 to 9.80 mm as the moisture content increased from 11.31-25.03% d.b., respectively.

One Thousand Grains Mass

The one thousand organic chickpea grains mass M_{1000} increased logarithmic from 432.22 to 640.00 g as the moisture content increased from 11.31-25.03% d.b. (Fig. 3).

The logarithmic equation for one thousand seed mass can be formulated to be:

$$M_{1000} = 272.03\ \mathrm{Ln}\,(M_c)-224.07 \quad (R^2 = 0.9516) \quad (8)$$

A logarithmic increase in the one thousand organic chickpea grains mass as the seed moisture content increases has been noted by Sahoo and Srivastava (2002) for okra seed.

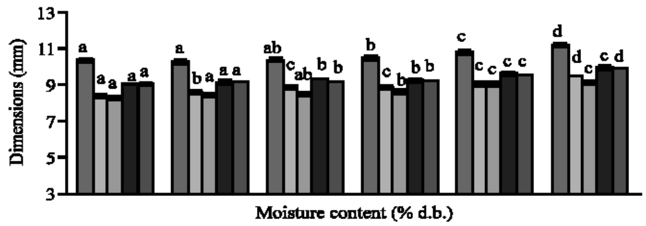

Fig. 2: Dimensions of organic chickpea grains, ([a-d] Values followed by different letter(s) are significant, $p<0.05$)

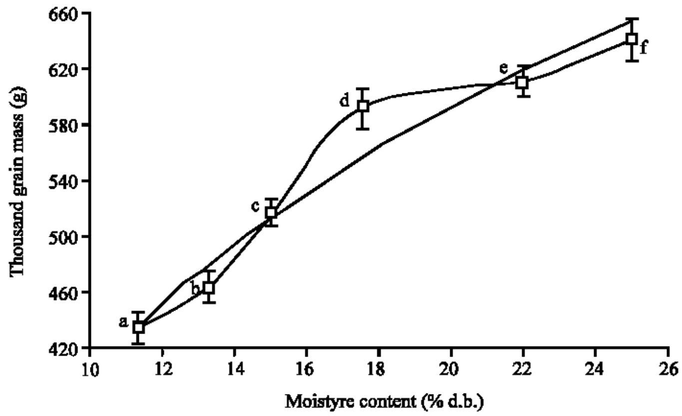

Fig. 3: Effect of moisture content on thousand grains mass of organic chickpea grains, ([a-f]Values followed by different letter(s) are significant, $p<0.05$)

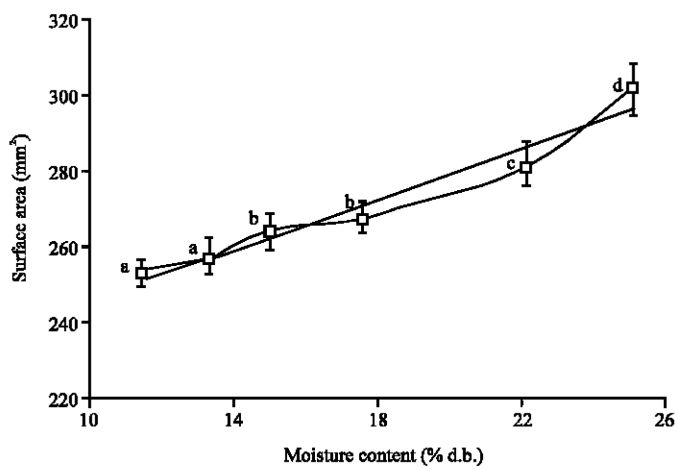

Fig. 4: Effect of moisture content on surface area of organic chickpea grains, ([a-] Values followed by different letter(s) are significant, $p<0.05$)

Surface Area of Seed

The variation of the surface area with the organic chickpea grains moisture content is plotted in Fig. 4. The figure indicates that the surface area increases linearly with increase in seed moisture content. The surface area of organic chickpea grains increased from 252.588 to 302.383 mm^2 when the moisture content increased from 11.31-25.03% d.b.

The variation of moisture content and surface area can be expressed mathematically as follows:

$$A_s = 212.36+3.3705M_c \quad (9)$$

with a value for the coefficient of determination R^2 of 0.9495.

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

Projected Area of Grains

The projected area of organic chickpea grains increased from 58.30 to 71.50 mm^2, when the moisture content of seed increased from 11.31-25.03% d.b. (Fig. 5).

The variation in projected area with moisture content of organic chickpea grains can be represented by the following equation:

$$A_p = 24.574 \operatorname{Ln} (M_c) \quad (R^2 = 0.9218) \quad (10)$$

However, linear increasing trends have been reported by Tang and Sokhansanj (1993) for lentil, Öğüt (1998) for white lupine, Özarslan (2002) for cotton and Dursun and Dursun (2005) for caper seed.

Sphericity

The sphericity of organic chickpea grains increased from 0.870 to 0.884 with the increase in moisture content (Fig. 6). The relationship between sphericity and moisture content M_c in % d.b. can be represented by the following equation:

$$\phi = 0.8199+0.0064(M_c)-0.0002(M_c^2) \quad (R^2 = 0.8795) \quad (11)$$

Although this increasing trend is polynomial, linear trends have been reported by Baryeh and Mangope (2002) for pigeon pea and Saçılık *et al*. (2003) for hemp seed.

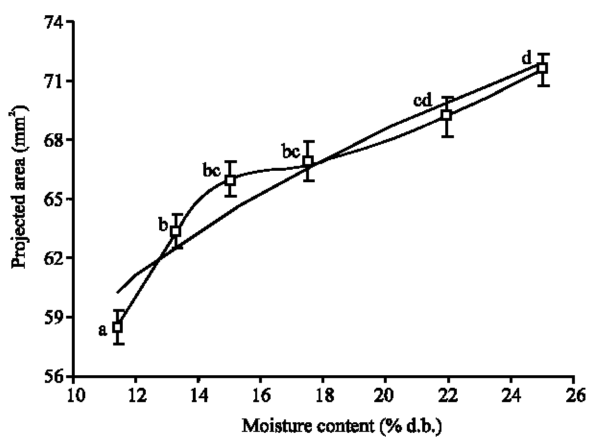

Fig. 5: Effect of moisture content on projected area of organic chickpea grains, ([a-d] Values followed by different letter(s) are significant, $p<0.05$)

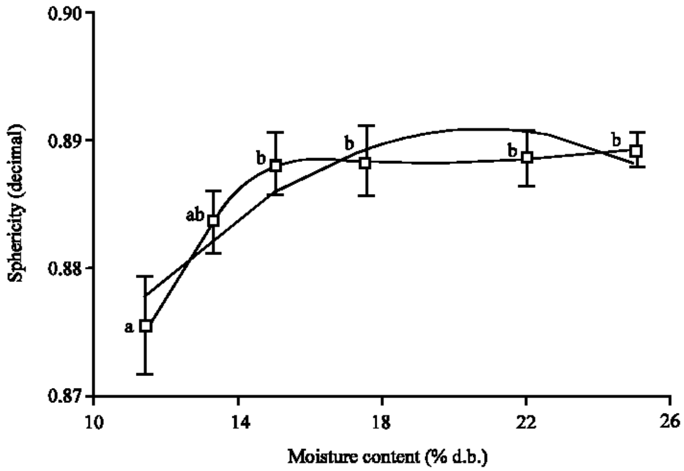

Fig. 6: Effect of moisture content on sphericity of organic chickpea grains, ([a-b] Values followed by different letter(s) are significant, $p<0.05$)

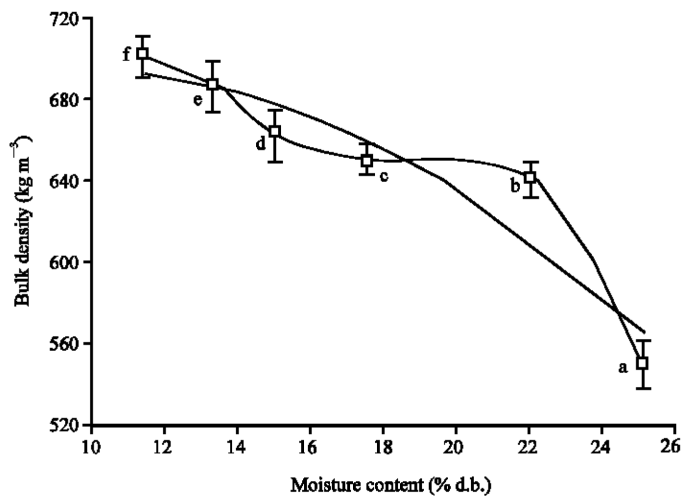

Fig. 7: Effect of moisture content on bulk density of organic chickpea grains, ([a-f] Values followed by different letter(s) are significant, $p<0.05$)

Bulk Density

The values of the bulk density for different moisture levels varied from 700.50 to 550.00 kg m^{-3} (Fig. 7). The bulk density of grains was found to bear the following relationship with moisture content:

$$\rho_b = 643.12-0.5377(M_c^2)+10.333(M_c) \quad (12)$$

with a value for R^2 of 0.8953.

A different decreasing trend in bulk density has been reported by Gupta and Das (1997) for sunflower seed, Öğüt (1998) for white lupin, Konak *et al.* (2002) for chick pea and Coşkun *et al.* (2006) for sweet corn seed.

True Density

The true density varied from 1000 to 1200 kg m^{-3} when the moisture level increased from 11.31-25.03% d.b. (Fig. 7).

The true density and the moisture content of seed can be correlated as follows:

$$\rho_b = 709.54\text{-}0.5152\ M_c^2)+32.143(M_c) \tag{13}$$

with a value for R^2 of 0.9807.

However, linear increasing trends were reported by Singh and Goswami (1996) for cumin seed, Özarslan (2002) for cotton, Yalçın and Özarslan (2004) for vetch seed, Aviara *et al.* (2005) for Balanites aegypticiaca nuts and Coşkun *et al.* (2006) for sweet corn seed.

Porosity

The porosity of organic chickpea grains increased from 29.95 to 54.17% with the increase in moisture content from 11.31-25.03% d.b. (Fig. 9).

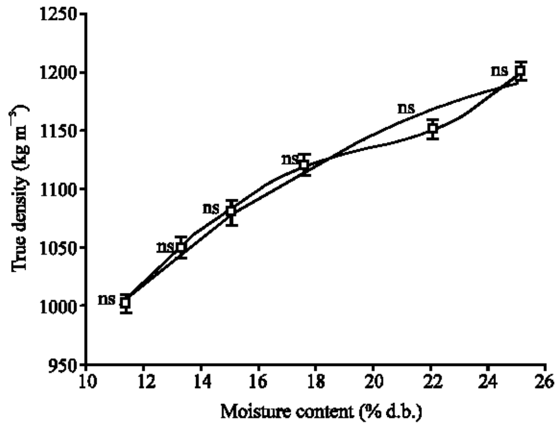

Fig. 8: Effect of moisture content on true density of organic chickpea grains, ns: not significant

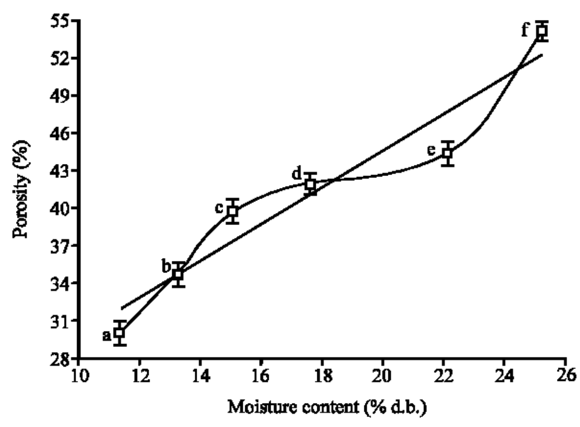

Fig. 9: Effect of moisture content on porosity of organic chickpea grains, ($^{a\text{-}f}$ Values followed by different letter(s) are significant, $p<0.05$)

The relationship between porosity and moisture content can be represented by the following equation:

$$\varepsilon = 14.4416+1.5225\ M_c \qquad (14)$$

with a value for R^2 of 0.9273.

Gupta and Das (1997), Öğüt (1998), Nimkar and Chattopadhyay (2001), Nimkar *et al*. (2005), Aviara *et al*. (2005) and Coşkun *et al*. (2006) reported similar trends in the case of sunflower seed, white lupine, green gram, moth gram, Balanites aegyptiaca nuts and sweet corn seed, respectively; however, logarithmic increasing trend was reported by Konak *et al*. (2002) for chick pea.

Terminal Velocity

The experimental results for the terminal velocity of organic chickpea grains at various moisture levels are shown in Fig. 10.

The relationship between terminal velocity and moisture content can be represented by the following equation:

$$V = 4.1408-0.0067(M_c^2)+0.3493\ (M_c) \quad (R^2 = 0.9948) \qquad (15)$$

The terminal velocity was found to increase polynomial from 7.20 to 8.70 m s^{-1} as the moisture content increased from 11.31-25.03% d.b. However, linear increase of terminal velocity with increase of moisture content was reported by Joshi *et al*. (1993), Suthar and Das (1996), Gupta and Das (1997) in the case of pumpkin grains, sunflower and karingda, respectively.

Static Coefficient of Friction

The static coefficient of friction of organic chickpea grains on six surfaces (rubber, stainless steel, aluminum, glass, MDF(medium density fiberboard) and galvanized iron) against moisture content in the range 11.31-25.03% 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 seed and the material surfaces at higher moisture values. Increases of from 0.4452 to 0.4986, 0.3541 to 0.3899, 0.3939 to

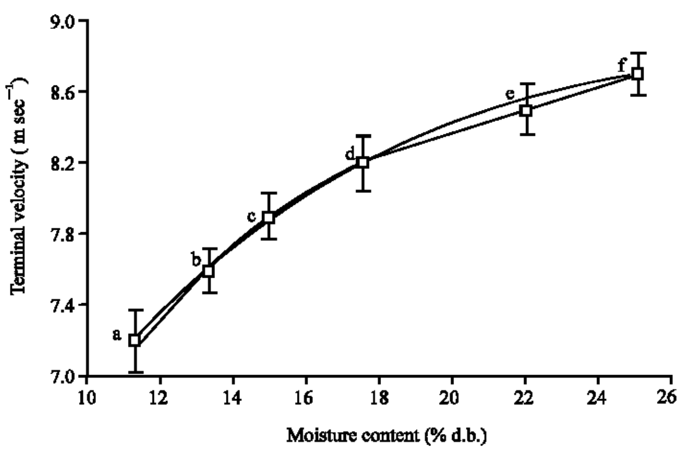

Fig. 10: Effect of moisture content on terminal velocity of organic chickpea grains, ([a-f]Values followed by different letter(s) are significant, $p<0.05$)

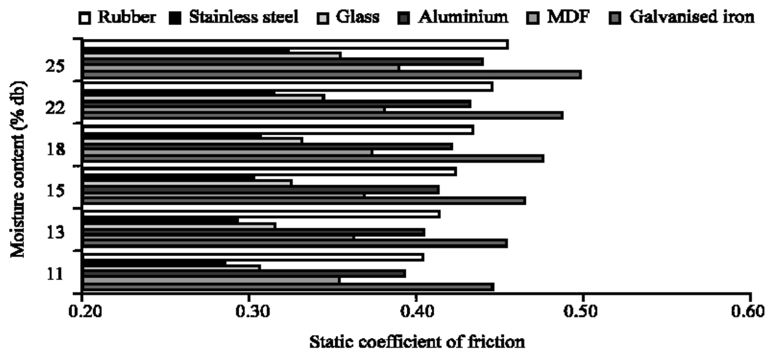

Fig. 11: Effect of moisture content on static coefficient of friction of organic chickpea grains against various surface

0.4411, 0.3057 to 0.3541, 0.2867 to 0.3249 and 0.4040 to 0.4557 were recorded in the case of rubber, stainless steel, aluminum, glass, MDF and galvanized iron, respectively, as the moisture content increased from 11.31-25.03% d.b.

At all moisture contents, the least static coefficient of friction were on MDF. This may be owing to smoother and more polished surface of the MDF sheet than the other materials used. The relationships between static coefficients of friction and moisture content on rubber (μ_{rub}), aluminum (μ_{al}), galvanized iron (μ_{gi}), stainless steel (μ_{ss}), MDF (μ_{mdf}) and glass (μ_{gl}) can be represented by the following equations:

$$\mu_{ru} = 0.4071+0.0037(M_c) \qquad (R^2 = 0.9725) \tag{16}$$

$$\mu_{1a} = 0.3611+0.0033(M_c) \qquad (R^2 = 0.9648) \tag{17}$$

$$\mu_{gi} = 0.3671+0.0036(M_c) \qquad (R^2 = 0.9723) \tag{18}$$

$$\mu_{22} = 0.3313+0.0024(M_c) \qquad (R^2 = 0.9612) \tag{19}$$

$$\mu_{mdf} = 0.2596+0.0026(M_c) \qquad (R^2 = 0.9269) \tag{20}$$

$$\mu_{gi} = 0.2709+0.0033(M_c) \qquad (R^2 = 0.9798) \tag{21}$$

Similar results were found by Singh and Goswami (1996) for cumin seed, Özarslan (2002) for cotton, Yalçın and Özarslan (2004) for vetch seed, Aviara *et al.* (2005) for Balanites aegypticiaca nuts and Coşkun *et al.* (2006) for sweet corn seed.

Shelling Resistance

The shelling resistance of organic chickpea grains 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 organic chickpea grains R_s in N with moisture content can be represented by the following equation:

$$R_s = 134.56 + 0.0329(M_c^2) - 3.3579M_c \tag{22}$$

with value for R^2 of 0.9824.

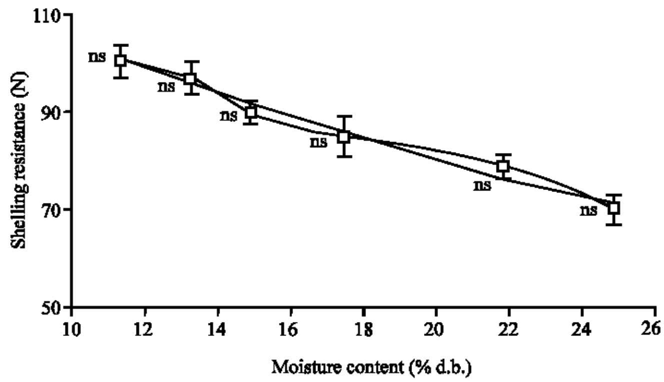

Fig. 12: Effect of moisture content on shelling resistance of organic chickpea grains, (□) length, ns: not significant

Özarslan (2002) and Konak *et al.* (2002) reported as different decrease in shelling resistance when the moisture content was increased for cotton and chick pea grains, respectively.

CONCLUSIONS

The average length, width and thickness of grains ranged from 10.30 to 11.11 (7.86%), 8.41 to 9.42 (12%) and 8.33 to 9.02 (8.23%) mm as the moisture content increased from 11.31-25.03% d.b., respectively. The arithmetic and geometric mean diameters were found to increase from 9.01 to 9.85 mm (9.32%) and 8.96 to 9.80 mm (9.37%), respectively. The thousand seed mass increased from 432.22 to 640.00 g (48.07%) and the sphericity increased from 0.870 to 0.884 (1.6%) with the increase in moisture content from 11.31-25.03% d.b. The bulk density decreased from 700.50 to 550.00 kg m^{-3} (28.5%), whereas the true density increased from 1000 to 1200 (20%) kg m^{-3}. The terminal velocity increased logarithmic from 7.20 to 8.70 m sec^{-1} as the moisture content increased from 11.31-25.03% d.b. The static coefficient of friction of organic chickpea grains increased the linear against surfaces of six structural materials, namely, rubber (11.99%), aluminum (11.98%), galvanized iron (12.79%), stainless steel (10.11%), MDF (13.32%) and glass (15.83%) as the moisture content increased from 11.31-25.03% d.b. The shelling resistance decreased as the moisture content increased from 101 to 70 N (30.69%).

NOMENCLATURE

A_p :	Projected area (mm^2)	W :	Width of seed (mm)
A_s :	Surface area (mm^2)	W_i :	Initial mass of sample (kg)
D_a :	Arithmetic mean diameter of seed (mm)	ε :	Porosity (%)
D_g :	Geometric mean diameter of seed (mm)	α :	Angle of tilt (degree)
L :	Length of seed (mm)	μ :	Static coefficient of friction
M_{1000} :	Thousand seed mass (g)	ρ_b :	Bulk density (kg m^{-3})
M_i :	Initial moisture content of sample (% d.b.)	ρ_t :	True density (kg m^{-3})
M_f :	Final moisture content of sample (% d.b.)	ϕ :	Sphericity of seed (decimal)
M_c :	Moisture content (% d.b.)	**Subscripts**	
R_s :	Shelling resistance (N)	al	Aluminum
R^2 :	Coefficient of determination	gi	Galvanized iron
Q :	Mass of water to added (kg)	gl	Glass
T :	Thickness of seed (mm)	mdf	Medium density fiberboard
V_t :	Terminal velocity (m sec^{-1})	ru	Rubber
		ss	Stainless steel

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