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Full Length Research Paper

Moisture dependent of some physical and morphological properties of dent corn (*Zea mays* var. *indentətə* Sturt) seeds

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In this study, physical properties of seeds of Simon and Goldeclat dent corn (*Zea mays* var. *indentətə* sturt) cultivars as a function of moisture content were evaluated. Three levels of moisture ranging from 12.76 to 17.0% (dry basis), and 11.09 to 16.48% (dry basis) were used for Simon and Goldeclat cv., respectively. The averaged length, width, thickness, arithmetic and geometric mean diameter of seeds ranged from 10.54, 7.26, 4.57, 116.46 and 7.04 mm for Simon cv.; 10.80, 6.89, 4.81, 119.42 and 7.09 mm for Goldeclat cv., respectively. The sphericity, volume and surface area increased linearly from 0.668 to 0.684, 125.94 to 162.51 mm^3, 131.13 to 154.37 mm^2 for Simon cv.; 0.657 to 0.670, 128.19 to 155.63 mm^3, 133.18 to 150.89 mm^2 for Goldeclat cv., respectively. The bulk densities decreased from 762.60 to 675.51 kg/m^3 and from 783.37 to 714.48 kg/m^3 and true densities decreased from 1425.07 to 1367.35 kg/m^3 and from 1455.0 to 1396.36 kg/m^3 for Simon and Goldeclat cv., respectively, whereas, the angle of repose increased from 23.50 to 26.65° band from 21.86 to 25.27°. The static coefficients for friction of dent corn seeds were determined steel, plywood, wood, glass and galvanized sheet at various moisture contents. The highest static coefficient of friction was found on the wood and the lowest on the glass sheet among the materials tested.

Key words: Dent corn, physical properties, moisture content, dimensions, density.

INTRODUCTION

Zea mays var. *indentata* sturt is the most widely grown type of corn in the world. It is higher in starch and lower in sugar than table corn. There are a wide range of uses for dent corn, which is one of the most cultivated crops around the world. In addition to being used as a source of food for humans, dent corn provides corn starch and other by products which can be processed into an assortment of things from biodegradable plastics to fuels. It has very rich in vitamin A content (Kirtok, 1998; Oktem, 2005). Dent corn is used a great deal in processed corn foods, such as breakfast cereals, corn meal, corn oil, corn syrup, hominy, posole and starch. It is also very popular to feed livestock (Sezer et al., 2007).

After wheat and rice, corn is the most widely and extensively grown crop species. Corn has been cultivated for thousands of years. During archaelogical excavations in New Mexico, grains of corn and parts of corn ears were found in caves and shelters, which are thought to be about 4500 years old (Berger, 1962). Corn's origin is believed to be in the Mexican plateau or the highlands of Guatemala (Miller-Sanford, 2010). Corn was brought to Europe by Colombus, at the end of the 15th century. It was first grown in Spain and from there spread to other parts of Europe (Arnon, 1975). The introduction of corn to Turkey went back to 1600 AD through Egypt and Syria (Ilarslan et al., 2001). It is one of the major crops in Turkey now. Presently, corn production in Turkey is about

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Table 1. Mean and standard error (SE) for dimensions of dent corn cultivars at a function of moisture contents.

Moisture content (%)	Simon			Goldeclat		
	12.76	14.30	17.00	11.09	13.00	16.48
Length (mm)	10.54 ± 0.22	10.82 ± 0.08	11.16 ± 0.13	10.80 ± 0.18	11.03 ± 0.13	11.28 ± 0.25
Width (mm)	7.26 ± 0.23	7.46 ± 0.19	7.69 ± 0.10	6.89 ± 0.63	7.08 ± 0.22	7.33 ± 0.17
Thickness (mm)	4.57 ± 0.23	4.85 ± 0.19	5.19 ± 0.15	4.81 ± 0.21	5.01 ± 0.27	5.22 ± 0.28
LWT	349.38 ± 21.78	391.01 ± 18.02	445.02 ± 15.41	358.25 ± 40.18	391.55 ± 26.54	431.05 ± 27.22
Arithmetic mean diameter (mm)	116.46 ± 7.26	130.34 ± 6.01	148.34 ± 5.14	119.42 ± 13.39	130.52 ± 8.85	143.69 ± 9.07
Geometric mean diameter (mm)	7.04 ± 0.15	7.31 ± 0.11	7.63 ± 0.09	7.09 ± 0.26	7.31 ± 0.17	7.55 ± 0.16

4.274.000 tons of grain corn from 593.785 ha (FAO, 2009). There are three types of corn (flint, dent and pop corn) which were planted in Turkey. Dent corn types are mainly grown (approximately 90% ratio) in Turkey. Dent corn was planted especially in Aegean and Marmara regions of Turkey (Ilarslan et al., 2001; Sezer et al., 2007). Nowadays, dent corn production has an increasing trend in Turkey.

Various physical properties of seeds, grains and kernels are dependent on moisture content and appear to be important in the design of planting, harvesting, handling, transportation, storing and processing equipment (Baryeh, 2002; Karababa and Coşkuner, 2007). It is necessary to determine their physical properties as a function of moisture content. Bulk density affects the structural loads. The angle of repose is important in the designing of storage and transporting structures (Kasap and Altuntaş, 2006). The coefficient of friction of dent corn seeds against the various surfaces is also necessary in designing of conveying, transporting and storing structures (Altuntas, 2007). The physical properties have been studied for various crops, such as lentil seeds by Amin et al. (2004), sweet corn seeds by Coşkun et al. (2006), grasspea and bitter vetch seeds by Altuntas and Karadag (2006); roselle seeds by Mendoza et al. (2008) in recent years. However, no published work has been carried out on the physical properties of dent corn seed and their relationship with moisture content.

The objective of this study was to investigate the moisture dependent physical properties of dent corn seeds namely, seed dimensions, arithmetic and geometric mean diameter, sphericity, seed volume, surface area, bulk density, true density, porosity, angle of repose and static coefficient of friction against five structural surfaces (steel, plywood, wood, glass and galvanized sheet) in the moisture content range from 12.76 to 17.0% (dry basis), and 11.09 to 16.48% (dry basis) for Simon and Goldeclat cultivars, respectively.

MATERIALS AND METHODS

This study was conducted at the Faculty of Agriculture of Ondokuz Mayis University in Samsun province, Turkey. The dry seeds of dent corn cultivars, Simon and Goldeclat were used for all the experiments in this study. The seeds used were obtained from the production year of 2009 and purchased from the seed producers. The samples were manually cleaned to remove all foreign matter such as dust, dirt, stores and chaff as well as immature and broken seeds. The initial moisture content of the samples was determined by oven drying at 105 ± 1°C for 24 h (Suthar and Das, 1996; Altuntas, 2007). 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 5°C in a refrigerator for a week to obtain uniform moisture distribution throughout the samples. Before each test, the required quantities of the samples were taken out of the refrigerator and allowed to warm up at room temperature for analysis (Sing and Gaswami, 1996; Yalçin and Özarslan, 2004; Coşkun et al., 2006).

The samples of desired moisture contents were calculated from the following equation (Karababa, 2006; Altuntas and Yildiz, 2007).

$$Q = \frac{Wi\ (Mf\ - Mi\ )}{(100\ - Mf\ )} \qquad (1)$$

Where, Q is the mass of water added in kg; W_i is the initial mass of a sample in kg; M_i is the initial moisture content of a sample in % wet basis and M_f is final moisture content of the samples in % wet basis.

All the physical properties of dent corn seeds were investigated at three moisture levels in the range from 12.76 to 17.00% (dry basis) and from 11.09 to16.48% for Simon and Goldeclat seeds, respectively (Table 1). These values are within the range of moisture contents for sweet corn seed recommended for safe module storage as 14.94% (Kirtok, 1998; Coşkun et al., 2006).

The measurement of physical properties at each moisture level (12, 15, 17 w.b.%) was replicated 10 times in this study. The length, width and thickness of dent corn seeds at each moisture level were measured in 100 randomly selected dent corn seeds using a digital micrometer to an accuracy of 0.01 mm (Özarslan, 2002; Karababa and Coşkuner, 2007).

The arithmetic mean diameter (D_a) and the geometric mean diameter (D_g) of the seeds were calculated using the following relationships, respectively (Mohsenin, 1970; Milani et al., 2007).

$$D\alpha = \frac{L+W+T}{3} \tag{2}$$

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

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

Jain and Bal (1997) have stated seed volume given by:

$$V = \frac{\pi B^2 L^2}{6(2L-B)} \tag{4}$$

Where, $B = (WT)^{0.5}$ (5)

The sphericity value (Φ) of dent corn seeds is also calculated using the following formula (Mohsenin, 1970);

$$\Phi_m = \frac{LWT^{1/3}}{L} 100 \tag{6}$$

The one thousand seed mass was determined by means of digital electronic balance (Kern and Sahn Gmbh D- 72336 model) at an accuracy of 0.001 g (Baryeh, 2002). The weights of 10 samples representing each moisture content and containing 100 randomly selected seeds were averaged to evaluate 1000 seed mass (Öğüt, 1998).

Jain and Bal (1997) have stated surface area, *S* may be given by:

$$S_j = \frac{\pi B L^2}{2L-B} \tag{7}$$

The bulk density of dent corn seed was determined using standard test weight procedure (Sing and Goswami, 1996), by filling a 500 ml container with the seeds from a height of 150 mm at a constant rate and then, weighing the content (Özarslan, 2002). No separate manual compaction of seeds was done. The bulk density was calculated from the mass of the seeds and the volume of the container.

The average true density was determined using the toluene (C_7H_8) displacement method. Toluene was used in place of water because it is absorbed by the seeds to a lesser extent. The volume of toluene displaced was found by immersing a weighted quantity of dent corn seeds in the toluene (Coşkun et al., 2006; Kasap and Altuntas, 2006).

The porosity is the fraction of the space in the bulk grain which is not occupied by the grain (Thompson and Isaacs, 1967). The porosity was calculated from the following relationship (Mohsenin, 1970):

$$\varepsilon = (1 - \frac{P_b}{P_t})\, 100 \tag{8}$$

Where, ε is the porosity in %; P_b is the bulk density in kg m^{-3}, and P_t is the true density in kg m^{-3}.

The filling angle of repose is the angle with the horizontal at which the material will stand when piled. This was determined by using a topless and bottomless cylinder of 150 mm diameter and 250 mm height (Razavi and Milani, 2006). The cylinder was placed on a wooden table, filled with dent corn seeds and raised slowly until it forms a cone of a circular plate. The angle of repose was calculated from the measurement of the height (H) and diameter of the cone (D).

$$\theta = Arc\tan(2H/D) \tag{9}$$

The static coefficients of friction of dent corn seeds against five different structural materials, namely steel, plywood, wood, glass and galvanized sheet. A polyvinylchloride cylindrical pipe of 50 mm in a diameter and 50 mm in height was placed on an adjustable tilting plate, faced with the test surface and filled with the seed sample. The structural surface with the cylinder resting on it was raised gradually with a screw device until the cylinder started to slide down and the angle of tilt was read from graduated scale (Sing and Gaswami, 1996; Suthar and Das, 1996). The coefficient of friction was calculated from the following relationship (Coşkun et al., 2006):

$$\mu = \tan\alpha \tag{10}$$

Where, μ is the coefficient of friction and α is the angle of tilt in degrees.

Data analysis

All measurements were obtained in 10 replicates at the three moisture contents selected. In order to determine physical dimensions, 100 seeds were randomly selected and analyzed at each moisture level for each cultivar. Mean, maximum, minimum and standard deviation of data were determined using a computerized statistical program called 'SAS-JMP', version 5.01. The effect of moisture level on the different physical properties of dent corn seed was determined using the regression equations and coefficients (R^2). Each one of the variables analyzed regression curves of linear type was obtained.

$$Y = \beta_1 x + \beta_0 \tag{11}$$

RESULTS AND DISCUSSION

Seed dimension and size distribution

Simon seeds have length, width and thickness range of about 82% 10.27 to 10.89 mm, 92% 8.98 to 7.55 mm, 79% 4.39 to 4.86 mm, respectively, at 12.76% moisture content on dry basis (Figure 1). Goldeclat seeds have about 82% of length range 10.55 to 10.90 mm, 72% of width range of 6.05 to 7.47 mm, 93% of thickness range of 4.56 to 5.02 mm at 11.09% moisture content on dry

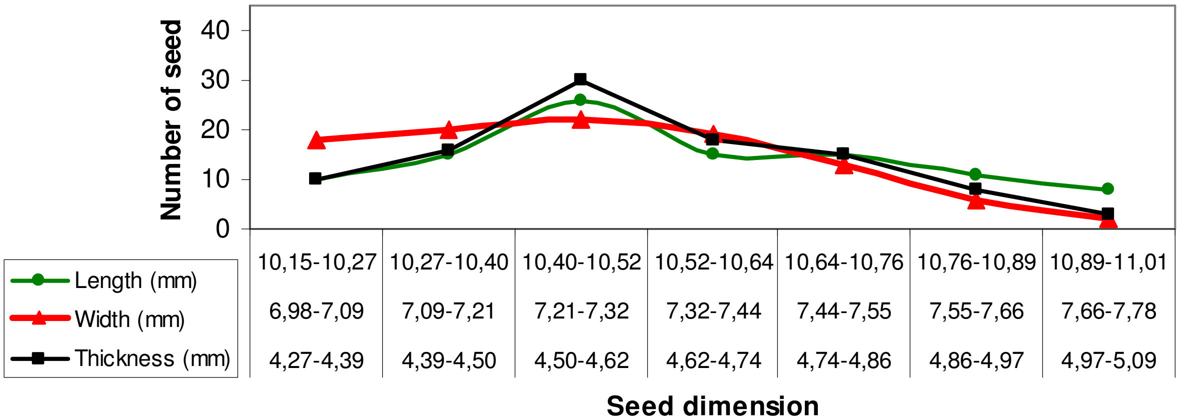

Figure 1. Frequency distribution curves of dent corn seeds (cv. Simon) length, width and thickness at 12.76% moisture content.

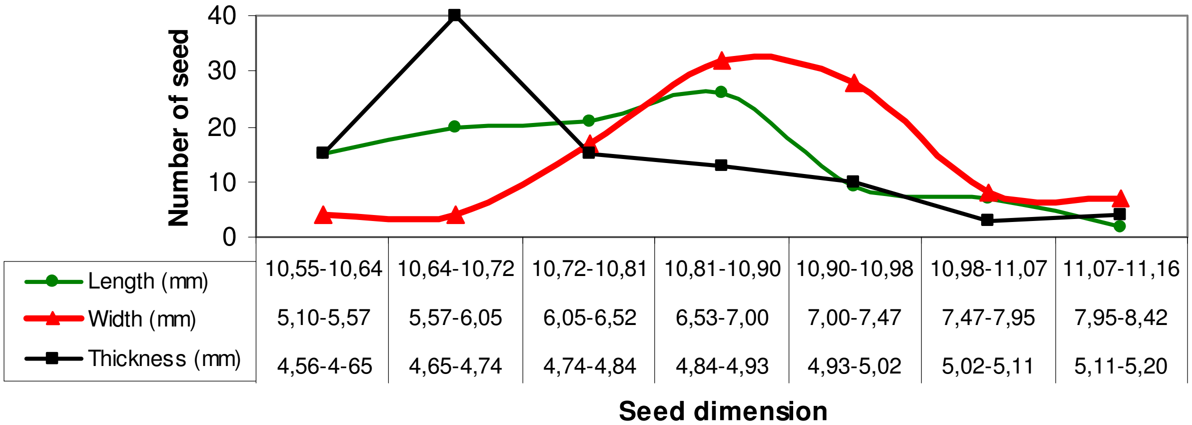

Figure 2. Frequency distribution curves of dent corn seeds (cv. Goldeclat) length, width and thickness at 11.09% moisture content.

basis (Figure 2).

The average seeds length, seed width, seed thickness, arithmetic and geometric mean diameter of Simon cv. range was 10.54 to 11.16 mm, 7.26 to 7.69 mm, 4.57 to 5.19 mm, 116.46 to 148.34 mm and 7.04 to 7.63 mm as the moisture content increased from 12.76 to 17.00 % wet basis, respectively (Table 1). The average seed length, seed width, seed thickness, arithmetic and geometric mean diameter of Goldeclat cv. range was 10.80 to 11.28 mm, 6.89 to 7.33 mm, 4.81 to 5.22 mm, 119.42 to 143.69 mm, 7.09 to 7.55 mm as the moisture content increased from 11.09 to 16.48% wet basis, respectively (Table 1).

All the dimensions were significantly and positively correlated to seed moisture content. This result indicates that the seeds expand in length, width and thickness within the moisture contents 12.76 to 17.00% and 11.09 to 16.48% for Simon and Goldeclat, respectively. Similar results have been reported by some researchers (Coşkun et al., 2006; Karababa, 2006). The length, width and thickness values are important in development of sizing and grading machines (Altuntas and Karadağ, 2006).

Sphericity

The sphericity changes with the increase in moisture content. The relation between sphericity and moisture content of dent corns are shown in Figure 3. The sphericity of Simon and Goldeclat seeds was 0.668 to 0.684 and 0.657 to 0.670, respectively. With the increase; the moisture content M_c in the % d.b. can be represented

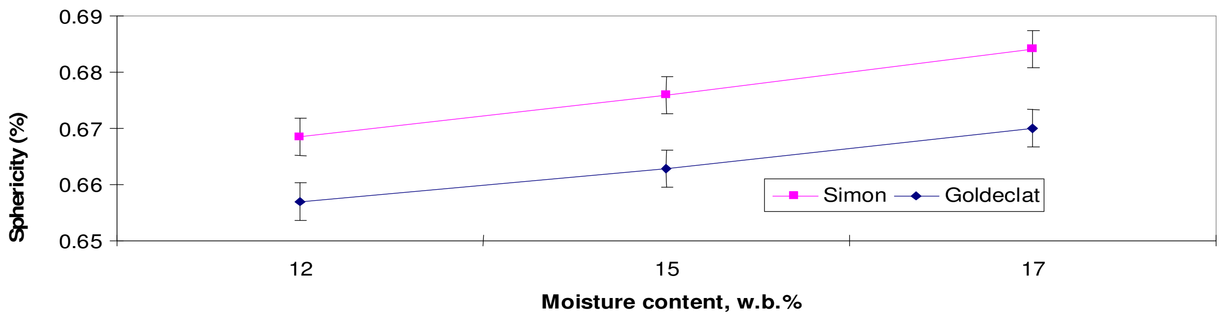

Figure 3. Effect of moisture content on sphericity of dent corns.

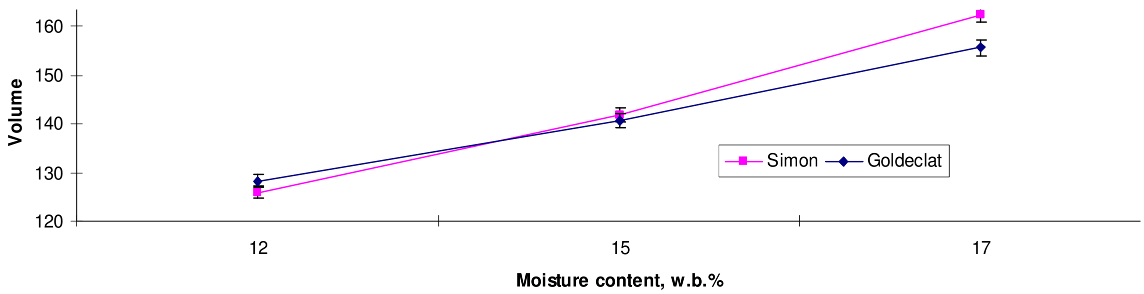

Figure 4. Effect of moisture content on volume of dent corns.

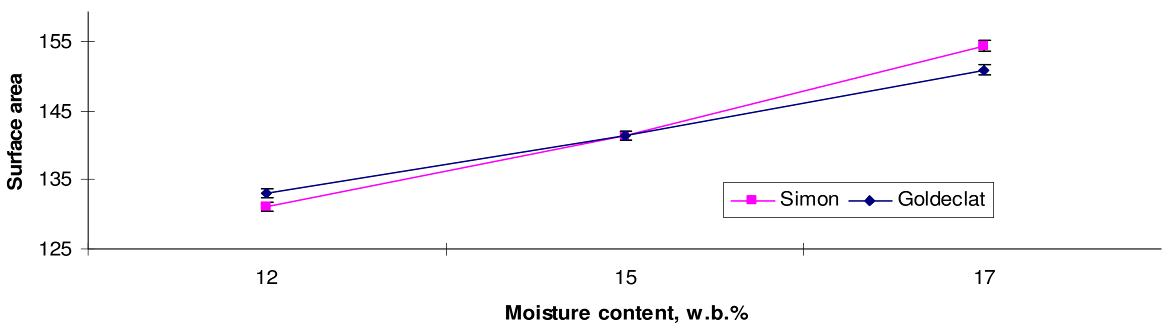

Figure 5. Effect of moisture content on surface area of dent corns.

by the following equation;

$$m = 0.6206 + 0.0035\ M_c \qquad (R^2 = 0.946)$$

Similar results have been founded by Yalçin (2007) for cowpea seeds, Karababa and Coşkuner (2007) for dried corn seeds and Karababa (2006) for popcorn seeds.

Seed volume

The seed volume variations with seed moisture content are shown in Figure 4. The seed volume increased linearly with moisture contents for Simon cv., similar results were obtained for Goldeclat seeds (Figure 4). This relationship can be written as:

$$V = 58.4231 + 5.9604\ M_c \qquad (R^2 = 0.924)$$

Similar results have been reported by Karababa (2006) for popcorn kernels, Kasap and Altuntas (2006) for sugar beet and Milani et al. (2007) for cucurbit seeds.

Surface area

The dent corn seeds surface area, *S*, are shown in Figure 5. The surface area of Simon cv. increased from 131.13 to 154.37 mm^2 when the moisture content of seed increased from 12.76 to 17.0%. Similar results were

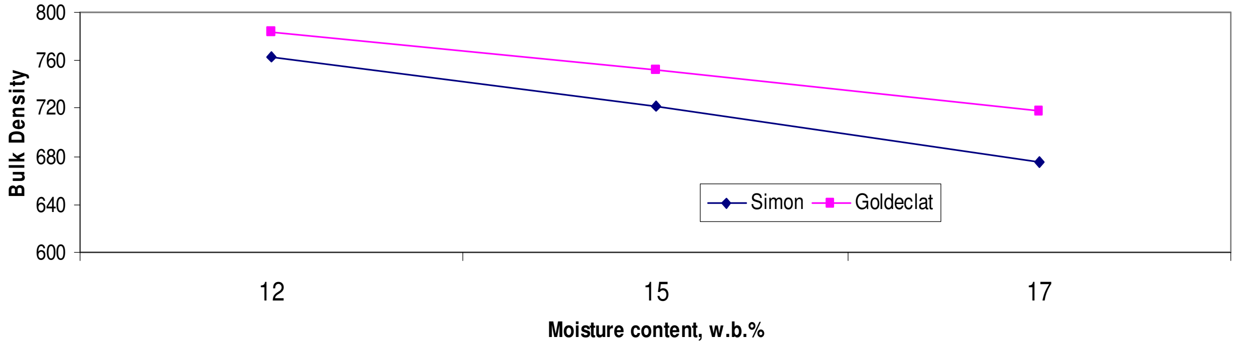

Figure 6. Effect of moisture content on bulk density of dent corns.

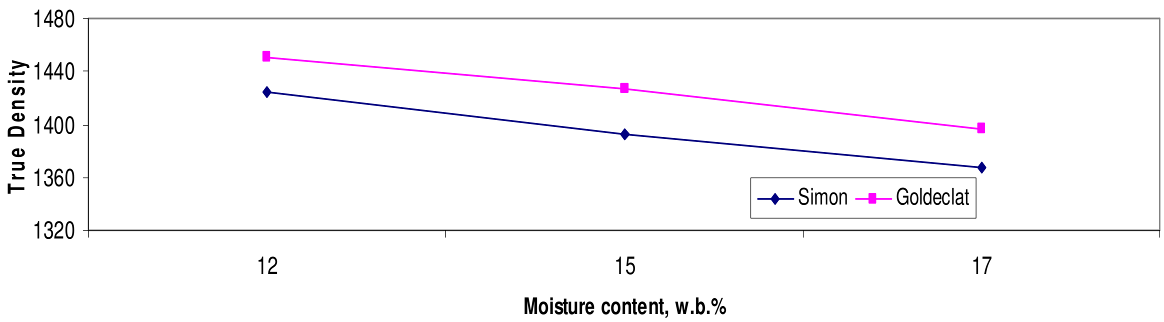

Figure 7. Effect of moisture content on true density of dent corns.

obtained from Goldeclat seeds. The surface area of Goldeclat cv. increased from 133.18 to 150.89 mm^2 when the moisture content of seed increased from 11.09 to 16.48%. Similar trends have been reported by Coşkun et al. (2006) for sweet corn, Karababa (2006) for popcorn, kernel and Yalçin (2007) for cowpea seed. The variation in surface area with the moisture content of dent corn kernel can be represented by the following equation:

$$S_j = 89.1259 + 3.7563\ Mc \qquad (R^2 = 0.945)$$

Bulk density

The bulk density of dent corn seeds at different moisture levels for Simon and Goldeclat cvs. varied from 762.60 to 675.51 kg/m^3 and from 783.37 to 714.48 kg/m^3, respectively (Figure 6). Bulk density of dent corn values decreased for both cultivars as moisture increased. Values were higher in Goldeclat cv. than those in Simon cv. The relationship can be expressed by the following equation:

$$P_b = 962.7169 - 16.1717\ M_c \qquad (R^2 = 0.992)$$

The decrease in bulk density of dent corn seed is similar to both cultivars because of its increase in size with moisture content, resulting in a decrease in quantity of seeds occupying the same bulk volume (Coşkun et al., 2006; Karababa and Coşkuner, 2007).

True density

The true density of dent corn seeds at different moisture levels for Simon and Goldeclat cvs. varied from 1425.07 to 1367.35 kg/m^3 and from 1455.0 to 1396.36 kg/m^3, respectively (Figure 7). The effect of moisture content on the true density of dent corn seed showed a decrease with increasing moisture content and the true density of dent corn seed decreased as moisture content increased for both cultivars and values were higher in Goldeclat cv. than those in Simon cv. A decrease in the true density of 4.04% for Simon and 4.03% for Goldeclat was recorded for dent corn seeds in moisture content range from 12.76 to 17.0% for Simon and 11.09 to 16.48% for Goldeclat. The linear relationship between moisture content (M_c) and true density (p_t) was described by the regression equations:

$$P_t = 1592.3120 - 12.8107\ M_c \qquad (R^2 = 0.957)$$

The effect of cultivar and moisture content on the true density was found significant in this study. The negative linear relationship was also observed by Kasap and

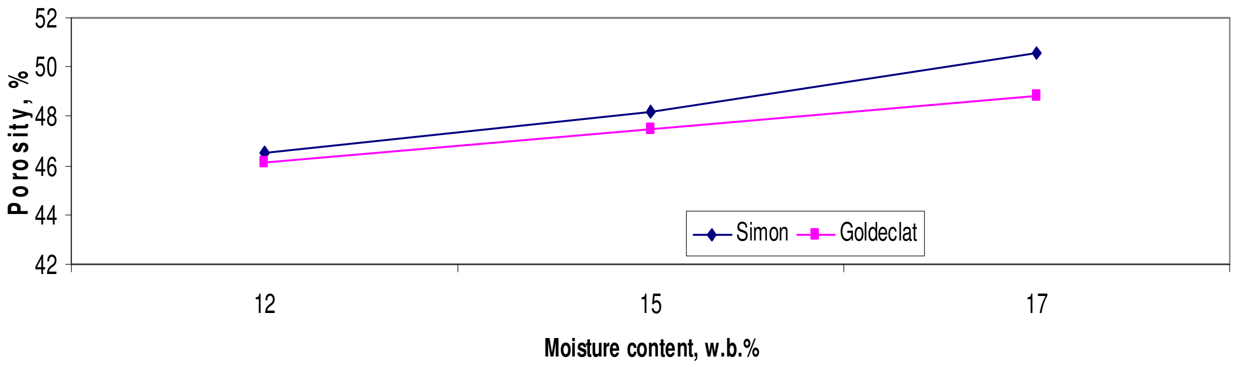

Figure 8. Effect of moisture content on porosity of dent corns.

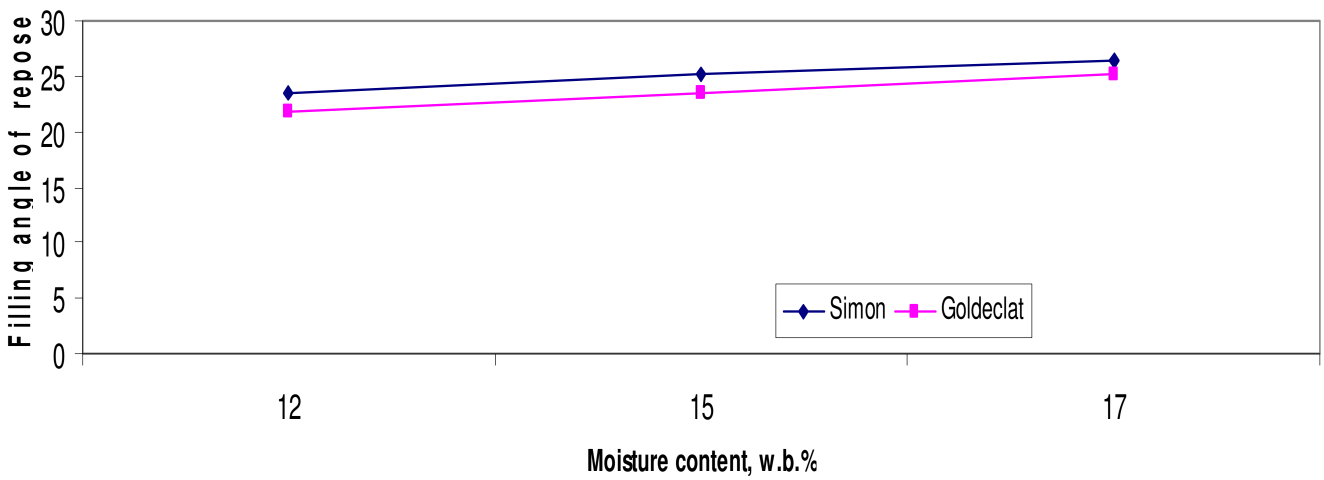

Figure 9. Effect of moisture content on filling angel of repose of dent corns.

Altuntas (2006) for sugar beet seed and Karababa (2006) for popcorn seeds.

Porosity

The porosity was calculated from the bulk density and true density of the seeds. The porosity of Simon seeds was determined to increase from 46.5 to 50.6% with increase in moisture content from 12.76 to 17.0%. Similar results were obtained for Goldeclat seeds. It was found to increase from 46.1 to 48.8% with increase in moisture content from 11.09 to 16.48% (Figure 8). The relationship between porosity and moisture content can be represented by the following equation:

$$\epsilon = 38.5029 + 0.6720\ M_c \qquad (R^2 = 0.963)$$

The results were similar to those reported by Karababa (2006) and Karababa and Coşkuner (2007) for dried corn and popcorn seeds, respectively.

Angle of repose

The results obtained for the angle of repose for Simon and Goldeclat cvs. with respect to the moisture content are shown in Figure 9. A linear increase was observed from 23.50 to 26.65° and from 21.86 to 25.27° with increasing moisture content from 12.76 to 17.0% and from 11.09 to 16.48% in Simon and Goldeclat, respectively (Figure 9). Angle of repose of dent corn values increased with moisture content for Simon and Goldeclat cvs. A considerable increase of 15.58% for Goldeclat and a lower increase of 13.38% for Simon occurred in the angle of repose for dent corn seeds in the moisture contents studied. This may be because of the rough surface of dent corn seeds that provides resistance to them sliding onto one another.

The relationship between the moisture content (M_c) and the angle of repose (θ) were represented by following regression equations:

$$\theta = 14.2790 + 0.7119\ M_c \qquad (R^2 = 0.977)$$

Table 2. Mean and standard error (SE) for variables of Simon and Goldeclat dent corns with varying moisture contents.

Coefficient of friction	Moisture content (%)					
	Simon			Goldeclat		
	12.76	14.30	17.00	11.09	13.00	16.48
Steel	0.224±0.011	0.255±0.010	0.282±0.009	0.199±0.010	0.228±0,008	0.257±0,004
Plywood	0.359±0,008	0.394±0.013	0.425±0,004	0.353±0.007	0.379±0,010	0.408±0.007
Wood	0.394±0.011	0.455±0.010	0.523±0,007	0.382±0,006	0.439±0,010	0.475±0.009
Glass	0.154±0.005	0.185±0.007	0.214±0.004	0.151±0.003	0.183±0,005	0.213±0.011
Galvanized sheet	0.267±0.006	0.285±0.024	0.316±0.003	0.245±0.012	0.271±0,008	0.299±0,005

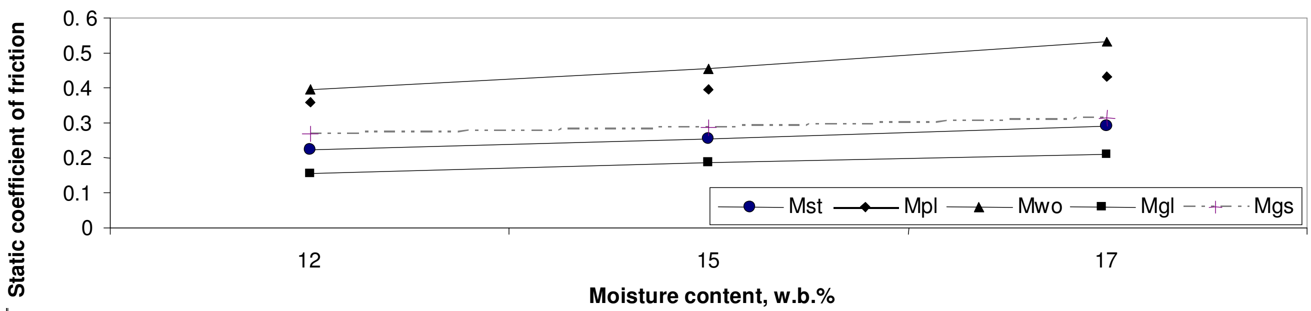

Figure 10. Effect of moisture content on static coefficient of friction of dent corns (cv. Simon).

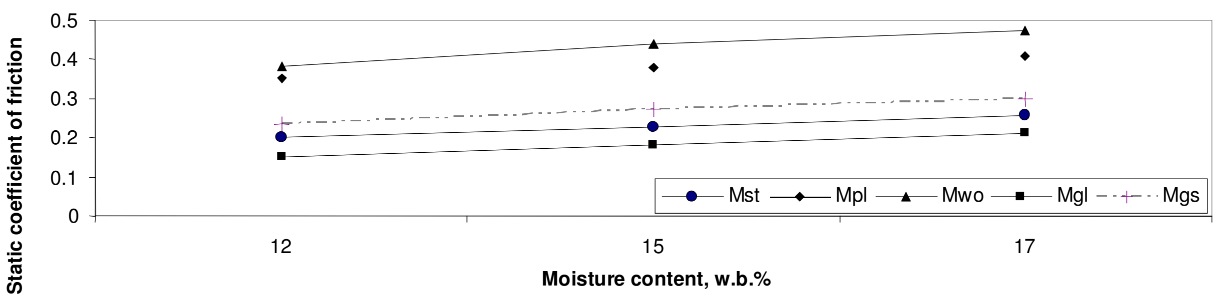

Figure 11. Effect of moisture content on static coefficient of friction of dent corns (cv. Goldeclat).

These results were similar to those reported by Karababa (2006) for popcorn kernel and Karababa and Coşkuner (2007) for sweet corn seeds.

Static coefficient of friction

As the moisture content of seed increased, the static coefficients also increased significantly. Increases of 6.8%, 6.6%,12.9%,6% and 4.9% were recorded. In the case of steel, plywood, wood, glass and galvanized sheet, respectively, as the moisture content increased from 12.76 to 17.00% for Simon seeds (Table 2). The static coefficients of friction for Goldeclat ranged from 0.199 to 0.257 for steel, from 0.353 to 0.408 for plywood, from 0.382 to 0.475 for wood, from 0.151 to 0.213 for glass and from 0.245 to 0.299 for galvanized sheet with moisture contents of 11.09 to 16.48%, respectively (Table 2). The static coefficient of friction was the greatest for wood. At all moisture contents, the least static coefficient of friction was for glass (Figures 10 and 11). This may be owing to smoother and more polished surface of glass than the other surfaces (Gupta and Das, 1997; Altuntas et al., 2005, Coşkun et al., 2006).

The relationships between static coefficients of friction and moisture content on steel (M_{st}), plywood (M_{pl}), wood (M_{wo}), glass (M_{gl}) and galvanized sheet (M_{gs}) can be represented by following equations:

$M_{st} = 0.0681 + 0.01225\ M_c$ ($R^2 = 0.918$)
$M_{pl} = 0.2199 + 0.0118\ M_c$ ($R^2 = 0.919$)
$M_{wo} = 0.1428 + 0.0214\ M_c$ ($R^2 = 0.973$)
$M_{gl} = 0.1110 + 0.0119\ M_c$ ($R^2 = 0.932$)
$M_{gs} = 0.0233 + 0.0114\ M_c$ ($R^2 = 0.952$)

Similar results were determined by Kasap and Altuntas (2006), Coşkun et al. (2006), and Karababa and Coşkuner (2007) for sugarbeet, sweet corn and dry sweet corn kernels, respectively.

Conclusions

Some physical properties of seeds for Simon and Goldeclat cvs. were evaluated in the range of different moisture contest in this study. All the dimensions of dent corn seeds, such as length, width, thickness, increased with increase in moisture contents for both cultivars. Arithmetic and geometric mean diameter, surface area of dent corn seeds increased linearly with increase in the seed moisture content with high correlation. The sphericity of Simon seeds changed from 0.668 to 0.684 and that for Goldeclat seeds changed from 0.657 to 0.670 with the increase in the moisture content. The porosity was found to increase with the increase in the moisture content. The porosity started at 46.5 and 46.1% and increased to 50.6 and 48.8% for cultivars Simon and Goldeclat, respectively. The bulk and true density for different moisture levels decrease with the increase in moisture content. In the moisture content range studied, the seed volume and angle of repose values increased for both cultivars. The static coefficients of friction for dent corn seeds increased with the increase in the moisture content. Therefore, the highest static coefficient of friction was found on wood surface and the lowest on glass among the materials tested. The cultivars evaluated showed a comparable behavior in relation with the static coefficient of friction. In this current study, the physical parameters of dent corn seeds are explained in the form of regression equations as a function of moisture content. Once the moisture is known, the physical parameters can be obtained from these equations. High correlation coefficients were found with a significance level of 91%.

Abbreviations

A, B regression coefficients; **B,** diameter of the spherical part of the seed, mm; ***D_a*,** arithmetic mean diameter, mm; **Dg,** geometric mean diameter, mm; **L,** length, mm; **M_i**, initial moisture content of sample, % d.b.; **M_f**, final moisture content of sample, % d.b.; **S_j**, surface area, mm^2; **T,** thickness, mm; **V,** seed volume, mm^3; **W,** width, mm; **W_i,** initial mass of sample, kg; **Є,** porosity, %; **μ,** static coefficient of friction; ***pb,*** bulk density, kg m^{-3}; ***Q,*** mass of water to added, kg; **Φ_m,** sphericity, %; ***pt,*** true density, kg m^{-3}; **θ,** angle of repose (degree); **M_{gl}**, glass; **M_{gs}**, galvanized sheet; **M_{pl}**, plywood; **M_{st}**, steel; **M_{wo}**, wood.

REFERENCES

Altuntas E, Özgöz E, Taşer ÖF (2005). Some physical properties of fenugreek (*Trigonella foenumgraceum* L.) seeds. J. Food Eng. 71: 37-43.

Altuntas E, Karadag Y (2006). Some physical and mechanical properties of sainfoin (*Onobrychis sativa* Lam.), grasspea (*Lathyrus sativus* L.) and bitter vetch (*Vicia ervilia* (L.) Willd.) seeds. J. Appl. Sci. 6(6): 1373-1379.

Altuntas E (2007). Some physical properties of pumpkin (*Cucurbita pepo* L.) and watermelon (*Citrullus lanatus* L.) seeds. Tarım Bilimleri Dergisi. 14(1): 62-69.

Altuntas E, Yıldız 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.

Amin MN, Hossain MA, Roy KC (2004). Effects of moisture content on some physical properties of lentil seeds. J. Food Eng. 65: 83-87.

Arnon I (1975). Mineral Nutrition of Maize. International Potash Institute, Bern/ Switzerland. p. 452.

Baryeh EA (2002). Physical properties of millet. J. Food Eng. 51: 39-46.

Berger J (1962). Maize Production and the Manuring of Maize. Centre D'etude De L'azote Geneva. p. 315.

Coşkun MB, Yalçın İ, Özarslan C (2006). Physical properties of sweet corn seed (*Zea mays saccharata* Sturt.). J. Food Eng. 74: 523-528.

FAO (2009). Statistical data of Turkey (available on-line at: http://apps.fao.org/faostat).

Gupta RK, Das SK (1997). Physical propertes of sunflower seeds. J. Food Agric. Eng. Res. 66: 1-8.

Ilarslan R, Kaya Z, Tolun AA, Bretting PK (2001). Genetic variability among Turkish pop, flint and dent corn (*Zea mays* L. spp. *Mays*) races: Enzyme polymorphism. Euphytica, 122: 171-179.

Jain RK, Bal S (1997). Properties of pearl millet. J. Agric. Eng. Res. 66: 85-91.

Karababa E (2006). Physical properties of popcorn kernels. J. Food Eng. 72: 100-107.

Karababa E, Coşkuner Y (2007). Moisture dependent physical properties of dry sweet corn kernels. International J. Food Properties, 10: 549-560.

Kasap A, Altuntas E (2006). Physical properties of monogerm sugarbeet (*Beta vulgaris* var. *altissima*) seeds. New Zealand J. Crop Hortic. Sci. 34: 311-318.

Kırtok Y (1998). Mısır Üretimi ve Kullanımı. Koca oluk Basım ve Yayın Eviron. pp. 8-10.

Mendoza JS, Lopez AD, Galindo SN, Sandoval JAL (2008). Some physical properties of Roselle (*Hibiscus sabdariffa* L.) seeds as a function of moisture content. J. Food Eng. 87: 391-397.

Milani E, Seyed M, Razavi A, Koocheki A, Nikzadeh V, Vahedi N, Moeinfard M. Gholamhosseinpour A (2007). Moisture dependent physical properties of cucurbit seeds. Int. Agrophys. 21: 157-168.

Mıller-Sanford B (2010). A history of corn. (available on-line at: http://www. Ontariocorn.org).

Mohsenin NN (1970). Physical properties of chickpea seeds. Biosyst. Eng. 82: 73-78.

Oktem A (2005). Response of sweet corn (*Zea mays saccharata* Sturt) to nitrojen and intra row spaces in semi-arid region. Pak. J. Biol. Sci. 8(1): 160-163.

Öğüt H (1998). Some physical properties of white lupin. J. Agric. Eng. Res. 69(3): 273-277.

Özarslan C (2002). Some physical properties of cotton seed. Biosyst. Eng. 83: 169-174.

Razavi SMA, Milani E (2006). Some physical properties of the watermelon seeds. Afr. Agric. Res. 1(3): 65-69.
Sezer İ, Mut Z, Öner F, Sirat A, Gülümser A (2007). Bafra ovasında ana ürün olarak yetiştirilebilecek mısır çeşitlerinin (*Zea mays indentata L.*) belirlenmesi üzerine araştırma. Türkiye VII. Tarla Bitkileri Kongresi, 25-27 Haziran 2007 Erzurum.
Sing KK, Gaswami KK (1996). Physical properties of cumin seed. Journal of Food Agric. Eng. Res. 64: 93-98.
Suthar SH, Das SK (1996). Some physical properties of karingda (*Citrullus lanatus* (Thumb) Mansf) seeds. J. Agric. Eng. Res. 65: 15-22.
Thompson RA, Isaacs GW (1967). Porosity determination of grains and seeds with air comparison pycnometer. Trans. ASAE. 10: 693-696.
Yalçın İ (2007). Physical properties of cowpea (*Vigna sinensis* L.) seed. J. of Food Engineering. 79:57-62.
Yalçın İ, Özarslan C (2004). Physical properties of vetch seed. Biosystems Engineering. 88(4): 507-512.