Australian Journal of Agricultural Engineering AJAE
AJAE 1(5):170-178 (2010) ISSN:1836-9448

# Comparison of moisture-dependent physical and mechanical properties of two varieties of corn (Sc 704 and Dc 370)

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**Abstract**

This study was carried out to determine the effect of moisture content on some physical properties and mechanical behavior of corn grains under compression load of two varieties of corn (Sc704 and Dc370) which are the most cultivated varieties by Iranian farmers. Four levels of moisture content ranging from 4.73-22% wet base (w.b.) and 5.15-22% w.b. for Sc704 and Dc370, respectively were used. The average length, width, thickness, geometric mean diameter, equivalent diameter, arithmetic diameter, sphericity, grain volume, surface area and aspect ratio were studied. The thousand grain weight increased linearly from 271.0 to 321.4 g for Sc704 and from 267.7 to 305.8g for Dc370. As the moisture content increased, bulk density was found to decrease from 710 to 649 $kgm^{-3}$ and 679 to 632 $kgm^{-3}$ for Sc704 and Dc370, respectively whereas true density and porosity were found to increase from 1250 to 1325 $kgm^{-3}$ and 43.2% to 51.02% for Sc704 and 997 to 1170 $kgm^{-3}$ and 31.90% to 45.98% for Dc370. The static coefficients of friction on various surfaces, namely, galvanized iron, plywood and plastic also increased linearly with an increase in moisture content. The linearity of coefficients of friction data of galvanized iron and plastic for Sc704 was higher with moisture content than Dc370. The results showed higher correlation with moisture content for the static angle of repose of Sc704 compared to Dc370 variety. The mechanical properties of corn were determined in terms of average rupture force and rupture energy. The rupture force decreased for compression while rupture energy of the corn grains generally increased in magnitude with an increase in moisture content. Dc370 had higher rupture force than Sc704 in all moisture content levels. The variance of rupture energy data for Sc704 was greater than those of Dc370. The results showed that the thousand grain weight had the best linear relationship with moisture content while the surface area and true density had the worst relationship with moisture content.

**Keywords:** Corn, Dc370 variety, moisture content, physical and mechanical properties, Sc 704 variety.

**Abbreviations:** L_length (mm); Q_weight of required water (g); W_width (mm); T_thickness (mm); S_surface area ($mm^2$); $R^2$_correlation coefficient; $\theta_s$_static angle of repose (deg); ε_porosity (%); $D_g$_geometric mean diameter (mm); $R_a$_aspect ratio; M_ moisture content (%); $M_i$_initial moisture content (%); $M_f$_final moisture content (%); $W_t$_total weight of sample (g); $F_a$_average rupture force (N); $D_p$_ equivalent diameter (mm); $D_a$_ arithmetic diameter (mm); V_volume, $mm^3$; $S_p$_sphericity (%); $\rho_b$_bulk density ($kgm^{-3}$); $\rho_t$_true density ($kgm^{-3}$); $E_a$_average rupture energy (N mm).

## Introduction

Corn is one of the leading food crops in the world and is one of the most important crops in Iran. Little researches concerning the effects of moisture content on physical and mechanical properties of corn grains are available in Iran. For designing equipment used in planting, transportation, storage, harvesting and processing of corn, knowledge of various physical and mechanical properties as a function of moisture content is essential. The size and shape and mechanical properties of corn are important in designing of harvesting, separating, sizing and grinding machines. Many studies have been conducted about the physical and mechanical properties of kernels, seeds and fruits, in examples Puchalski et al. (2003) for apple, Mamman et al. (2005) for desert date nuts, Kashaninejad et al. (2006) and Razavi et al. (2007) for pistachio nuts and kernels, Gezer et al. (2002) and Fathollahzadeh et al. (2008) for apricot pit and apricot kernel, Khazaei and Mann (2004) for sea buckthorn berries, Aydin (2003) for almond nut and kernel, ElMasry et al. (2006) for potato, Sessiz et al. (2007) for caper fruit and Ghadge et al. (2008) for chick pea split. Bulk density, true density, and porosity (the ratio of intergranular space to the total space occupied by the grain) can be useful in sizing grain hoppers and storage facilities. They can affect the rate of heat and mass transfer of moisture during aeration and drying processes. Grain bed with low porosity will have greater resistance to water vapor escape during the drying process, which may lead to higher power to drive the aeration fans. Cereal grain kernel densities have been of interest in breakage susceptibility and hardness studies. The static coefficient of friction is used to determine the angle at which chutes must be positioned in order to achieve consistent flow of materials through the chute. Such information is useful in sizing motor's power requirements for grain transportation and handling

(Ghasemi Varnamkhasti et al., 2007). The static angle of repose is important in designing of storage and transporting structures. Therefore, this study was conducted to investigate some moisture dependent physical and mechanical properties of corn grain namely, dimensions, geometric mean, equivalent and arithmetic diameter, sphericity, thousand grain weight (TGW), surface area, bulk density, true density, porosity, static coefficient of friction against different materials, static angle of repose, rupture force and rupture energy.

**Materials and methods**

Two varieties of corn grains (Sc 704 and Dc370) shown in Figs. 1 and 2 were used for all experiments in this study. The crops were collected from Plant and Seed Institute in Karaj. For determining the initial moisture content of seeds, oven method was used and the desired water was calculated by the rewetting formula (Equation 1) to obtain moisture levels as 12, 16, and 22% w.b. then they were placed in refrigerator to allow water be absorbed by samples.

$$Q = \frac{W_t(M_f - M_i)}{(100 - M_f)} \tag{1}$$

For obtaining length, width and thickness of about 10 randomly selected grains of each sample, a digital caliper was used. The geometric mean, Dg, equivalent, Dp, and arithmetic diameter, Da, in mm were calculated by these equations respectively (Mohsenin, 1970).

$$D_g = (LDT)^{\frac{1}{3}} \tag{2}$$

$$D_p = [L\frac{(W+T)^2}{4}]^{\frac{1}{3}} \tag{3}$$

$$D_a = \frac{(L+W+T)}{3} \tag{4}$$

The ratio of surface area of the sphere having the same volume as that of grain to the surface area of grain, defined as sphericity (Sp), was determined using following formula (Mohsenin, 1970).

$$S_p = \frac{(LDT)^{\frac{1}{3}}}{L} \tag{5}$$

For obtaining thousand grain weight (TGW), 100 grains were weighted in an electronic balance with an accuracy of .001g and then multiplied by 10 to give mass of 1000 kernels. Jain and Bal (1997) have considered grain volume, V and surface area, S by:

$$V = 0.25[(\frac{\pi}{6})\, L\, (W+T)^2] \tag{6}$$

$$S = \frac{\pi B L^2}{(2L-B)} \tag{7}$$

**Fig 1.** Sc704 Seeds

**Fig 2.** Dc370 Seeds

where:

$$B = \sqrt{W\,T} \tag{8}$$

Omobuwajo et al. (1999) calculated aspect ratio (Ra) by:

$$R_a = \frac{W}{L} \tag{9}$$

Deshpande et al. (1993) used a container to determine bulk density which is the ratio of the mass sample of seeds to its total volume by filling it to a constant height, striking the top level and then weighing the container. Mohsenin (1970) measured true density which is a ratio of mass sample of seeds to its pure volume with the toluene displacement method. The following formula was used for measuring the porosity which is the ratio of free space between seeds to total of bulk grains:

$$\varepsilon = \frac{\rho t - \rho b}{\rho b} \times 100 \tag{10}$$

Three surfaces (plywood, plastic and galvanized iron) were used for measuring the static coefficient of friction. Grains at

**Table1.** Physical properties of Sc 704 variety considering moisture content ranges of 4.73-22 %

| MC (% w.b.) | 4.73 | 12 | 16 | 22 |
|---|---|---|---|---|
| L (mm) | 11.26±1.48 | 12.12±1.61 | 12.48±1.48 | 12.60±1.93 |
| W (mm) | 7.27±0.94 | 7.03±1.03 | 7.42±0.87 | 7.98±1.25 |
| T (mm) | 4.47±1.06 | 4.25±0.94 | 4.56±0.79 | 4.71±1.21 |
| $D_g$ (mm) | 7.20±0.53 | 7.10±0.66 | 7.49±0.60 | 7.77±0.72 |
| $D_p$ (mm) | 7.36±0.50 | 7.27±0.58 | 7.64±0.58 | 7.96±0.66 |
| $D_a$ (mm) | 7.79±0.48 | 7.80±0.55 | 8.15±0.52 | 8.43±0.39 |

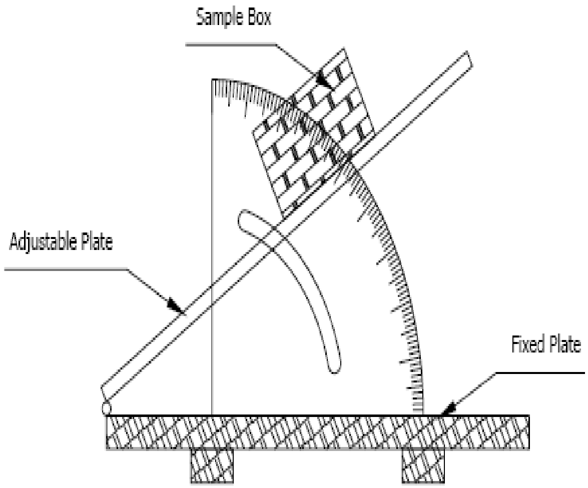


**Fig 3.** Empting angle of repose device

the desired moisture content were poured in the small rectangular frame which is open at both ends then placed on adjustable titling surface in a way that the metal rectangular did not contacts the surface. The surface was then raised gradually until the filled rectangular just started to slide down (Razavi and Milani, 2006).

Tabatabeefar (2003) measured the static angle of repose (the angle with the horizontal at which the piled material will stand) by using the apparatus shown in Fig. 3. It consists of a plywood box with 160 mm length, 140 mm width and 35mm height and two plates (fixed and adjustable). The box was filled with the sample, and then the adjustable plate was inclined gradually allowing the seeds to follow and assume a natural slope.

From forces acting on the grain with speed load of 5 mm/min, rupture strength for corn grain was determined (Fig. 4). The procedure was to put the seed on desired section and selecting speed of loading and then applying force until grain is fractured. Instron Universal Testing Machine (Model Santam STM-5), that is equipped with a 25 kg compression load cell and integrator, was used for this test. The measurement accuracy was 0.001 N in force and 0.001 mm in deformation (Mohsenin, 1980). The individual seed was loaded between two parallel plates of the machine and compressed at the present condition until rupture occurred as is denoted by a bio-yield point in the force-deformation curve. Once the bio-yield was detected, the loading was stopped. The mechanical properties of corn grain were expressed in terms of rupture force and rupture energy.

**Results and discussion**

***Size and shape***

Summary results of the corn varieties' dimensions (Sc704 and Dc370) are presented in Tables 1 and 2. For Sc704, length and arithmetic diameter increased with the increase in moisture content from 4.73 to 22% but the other dimensions showed a decrease with the increase in moisture content from 4.73 to 12%. From Table 2, it can be seen that the Dc370's dimensions showed different behaviors with moisture content increase and didn't follow similar pattern.

***Sphericity***

A polynomial relationship was found for the sphercity of both varieties. Dc370 had significantly higher sphiricity values at 5% level at the two smaller moisture levels but for 16 and 22% moisture content, there was no significant difference (Fig. 5). The below equations showed the relationships between sphericity and moisture levels.

(for Sc704) $S_p = 0.0385M^2 - 1.0313M + 66.206$ $R^2 = 0.898$ (11)

(for Dc370) $S_p = 0.0474M^2 - 1.4667M + 74.052$ $R^2 = 0.998$ (12)

***Volume***

The volume of corn varieties is shown in Fig. 6. Like sphericity, polynomial relationship was obtained for volume and moisture content. Sc704 volume increased significantly (at 5% level) with an increase in moisture level from 4.73 to 22% but Dc370 grains didn't have similar trend. Deshpande et al. (1993) for soybean, Dutta et al. (1988) for gram, Altuntas and Yıldız (2007) for faba bean and Ogut (1998) for white lupin reported an increase in volume with the moisture content increase.

(for Sc704) $V = 0.0724M^2 - 1.8156M + 260.03$ $R^2 = 0.853$ (13)

(for Dc370) $V = 0.3112M^2 - 4.8864M + 224.15$ $R^2 = 0.938$ (14)

***Surface Area***

While 26.4% increase in surface area of Sc704 was obtained, there was no significant difference in surface area values of Dc370. As shown in Fig. 7, unlike 16 and 22% w.b., in the base and 12% moisture level, Dc370 had greater surface area (at 5% level) than Sc704. Linear increase in Sc704 surface area with moisture content was obtained whereas polynomial relationship was found for Dc370.

(for Sc704) $S = 1.3848M + 126.12$ $R^2 = 0.722$ (15)

(for Dc370) $S = 0.0387M^2 - 0.9652M + 158.32$ $R^2 = 0.738$ (16)

Surface area increase with the increase in moisture content reported by Baryeh (2002) for millet, Milani et al. (2007) for

**Table2.** Physical properties of Dc 370 variety considering moisture content ranges of 5.15-22 %

| MC (% w.b.) | 5.15 | 12 | 16 | 22 |
|---|---|---|---|---|
| L (mm) | 11.31±2.27 | 11.97±1.30 | 12.24±1.24 | 11.87±.88 |
| W (mm) | 8.19±0.76 | 8.20±1.24 | 7.73±0.93 | 8.09±0.95 |
| T (mm) | 4.84±1.04 | 4.42±0.72 | 4.72±1.04 | 4.73±1.12 |
| $D_g$ (mm) | 7.63±0.94 | 7.56±0.39 | 7.61±0.65 | 7.67±0.32 |
| $D_p$ (mm) | 7.82±0.82 | 7.81±0.54 | 7.78±0.66 | 7.87±0.43 |
| $D_a$ (mm) | 8.11±0.90 | 8.20±0.56 | 8.23±0.59 | 8.23±0.41 |

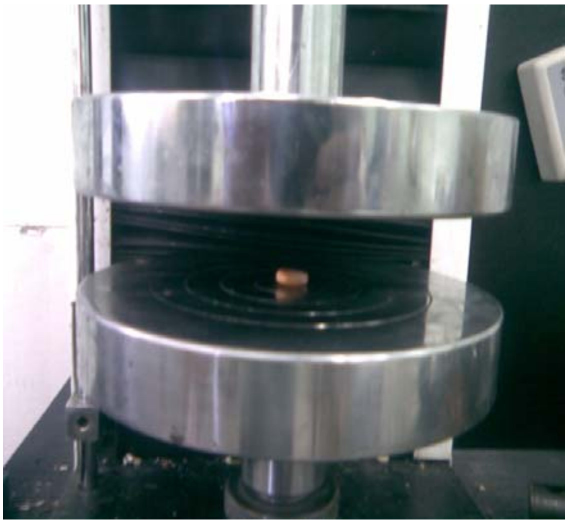

**Fig 4.** Apparatus for testing rupture strength

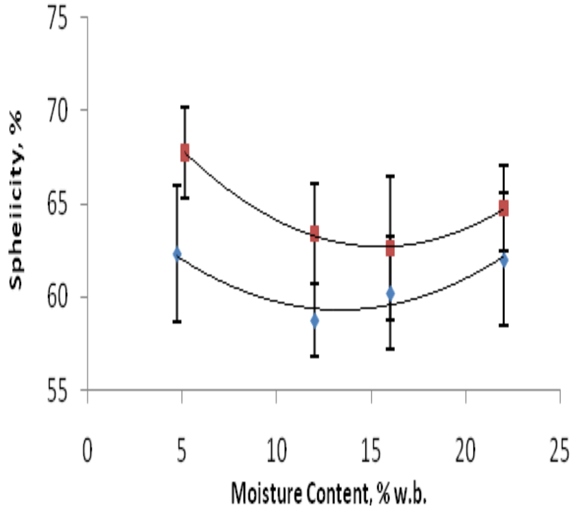


**Fig 5.** Effect of moisture content on sphericity, Dc370 (□) and Sc704 (◊)

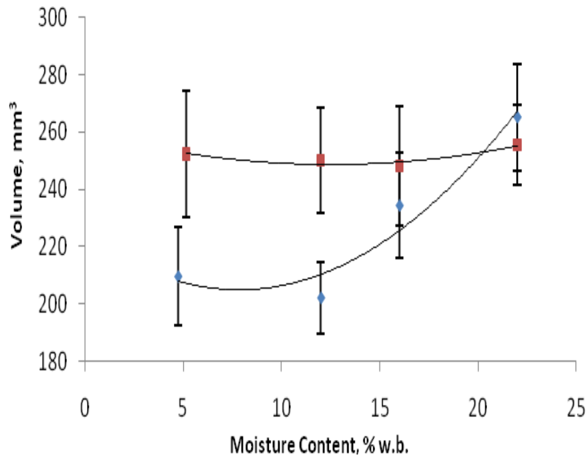


**Fig 6.** Effect of moisture content on volume, Dc370 (□) and Sc704 (◊)

cucurbit, Altuntas and Yıldız (2007) for faba bean and Akinci et al. (2004) for Juniperus drupacea fruits.

***Aspect Ratio***

The aspect ratios of Sc704 and Dc370 were polynomially related with moisture content (Fig. 8). Dc370 had higher values of aspect ratio than Sc704. The correlation coefficient of Sc704 aspect ratio values was much greater than Dc370.

(for Sc704) $R_a = 0.0628M^2 - 1.6253M + 69.243$ $R^2 = 0.981$ (17)

(for Dc370) $R_a = 0.0611M^2 - 1.9798M + 81.732$ $R^2 = 0.777$ (18)

***Thousand Grain Weight***

Increases in moisture content, resulted 18.60 % and 14.23 % increase in the thousand grain weight for Sc704 and Dc370, respectively. Fig. 9 shows high linear correlation for the thousand grain weight of both varieties with moisture content. The relationship for one thousand grain weight with moisture content was determined as follows:

(for Sc704) $TGW = 2.924M + 256.0$ $R^2 = 0.996$ (19)

(for Dc370) $TGW = 2.240M + 254.6$ $R^2 = 0.985$ (20)

Similar results were found by Nimkar and Chattopadhyay (2001) for green gram, by Baryeh (2002) for millet, by Özarslan (2002) for cotton seed, by Gezer et al. (2002) for apricot kernel, by Deshpande et al. (1993) for soybean and by Altuntas and Yıldız (2007) for faba bean.

***Bulk and true densities and porosity***

According to the results shown in Fig. 10, as the moisture content increased, the values of Sc704 bulk density decreased greater than Dc370 (8.50 % versus 5.95 %). The bulk density of

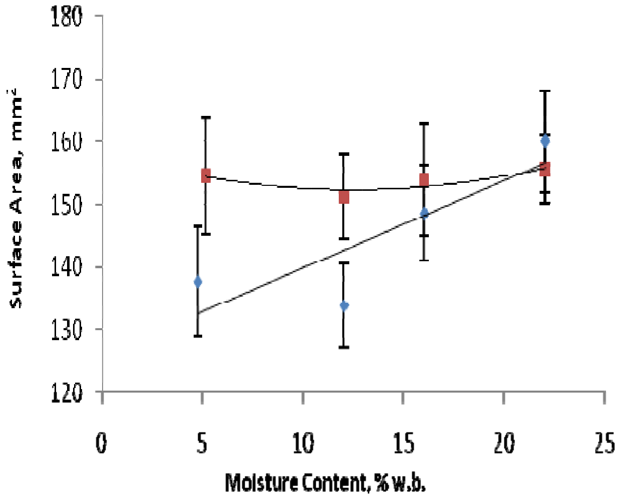


**Fig 7.** Effect of moisture content on surface area, Dc370 (□) and Sc704 (◊)

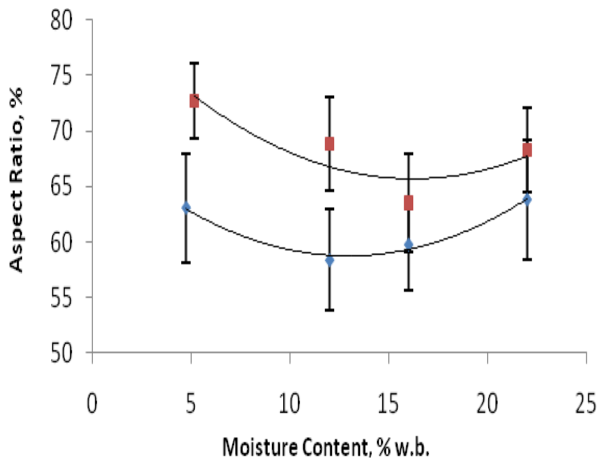


**Fig 8.** Effect of moisture content on aspect ratio, Dc370 (□) and Sc704 (◊)

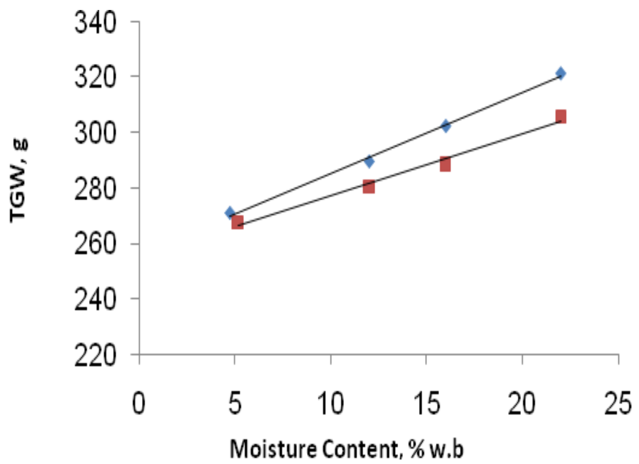


**Fig 9.** Effect of moisture content on thousand grain weight, Dc370 (□) and Sc704 (◊)

grains was found to bear the following relationship with moisture content:

| | | | |
|---|---|---|---|
| (for Sc704) | $\rho_b = -3.357M + 723.6$ | $R^2 = 0.948$ | (21) |
| (for Dc370) | $\rho_b = -2.971M + 689.2$ | $R^2 = 0.851$ | (22) |

The above equations show that the decrease in bulk density for Sc704 grains is more linear than Dc370 (R2eq1> R2eq2). A similar decreasing trend in bulk density has been reported by Gupta and Das (1997) for sunflower seed, Parde et al. (2003) for koto buckwheat, Aydin (2002) for hazel nut, Özarslan (2002) for cotton grain, Joshi et al. (1993) for pumpkin seed and Altuntas and Yıldız (2007) for faba bean.
The true density and the moisture content of grain can be correlated as follows:

| | | | |
|---|---|---|---|
| (for Sc704) | $\rho_t = 4.389M + 1246$ | $R^2 = 0.711$ | (23) |
| (for Dc370) | $\rho_t = 9.833M + 993.6$ | $R^2 = 0.620$ | (24) |

Increase of Sc704 true density is more linear than Dc370 but the correlation coefficient of both equations is relatively lower than other physical properties. The values of true density in different moisture content levels are shown in Fig. 11. Similar results was obtained by Altuntaş and Yildiz (2007) for faba bean grains, Garnayak et al. (2008) for jatropha seed and Pradhan et al. (2008) for karanja kernel but different trend was reported by Sacilik et al. (2003) for hemp seed, Yalçin et al. (2007) for pea seed, Tavakoli et al. (2009) for soybean grains, Cetin (2007) for barbunia bean seed and Altuntaş and Demirtola (2007) for legumes seeds. Dc 370 with 44.14% increase in porosity showed greater dependency to moisture content change than Sc704 with 18.10% increase (Fig. 12). The porosity increase for Dc370 with $R^2 = 0.721$ is not as much as linear of Sc704. The relationship between porosity and moisture content can be represented by the following equations:

| | | | |
|---|---|---|---|
| (for Sc704) | $\varepsilon = 0.441M + 42.01$ | $R^2 = 0.897$ | (25) |
| (for Dc370) | $\varepsilon = 0.827M + 30.78$ | $R^2 = 0.721$ | (26) |

The results were similar to those reported by Suthar and Das (1996), Baumler et al.(2004), Aviara et al. (1999), Gupta and Das (1997) for karingda kernel, safflower seed, guna seeds and sunflower kernel, respectively.

***Static Coefficient of Friction***

The static coefficient of friction of corn grains on three surfaces (plastic, plywood and galvanized metal) against different levels of moisture content are presented in Fig. 13. It was observed that the static coefficient of friction increased with increase in moisture content for all the surfaces. This is due to the adhesion increase between the grains and the material surfaces at higher moisture values. Increases of 56.8%, 25.9% and 69.4% were recorded in the case of plastic, plywood and galvanized iron for Sc704 but for Dc370 the values of 70.0%, 55.0% and 43.85% were obtained, respectively for moisture content increase of 4.73% to 22% w.b. for Sc704 and from 5.15 to 22% for Dc370. For Sc704, the least static coefficient of friction occurred for plastic whereas plywood had the lowest static coefficient of friction for Dc370. Sc704 data showed more linear correlation with moisture content than Dc370. The relationships between static coefficient of friction and moisture content on plastic, plywood and galvanized iron can be represented by following

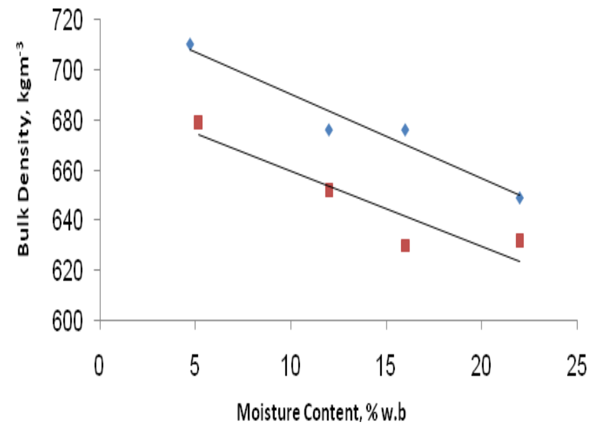


**Fig 10.** Effect of moisture content on bulk density, Dc370 (□) and Sc704 (◊)

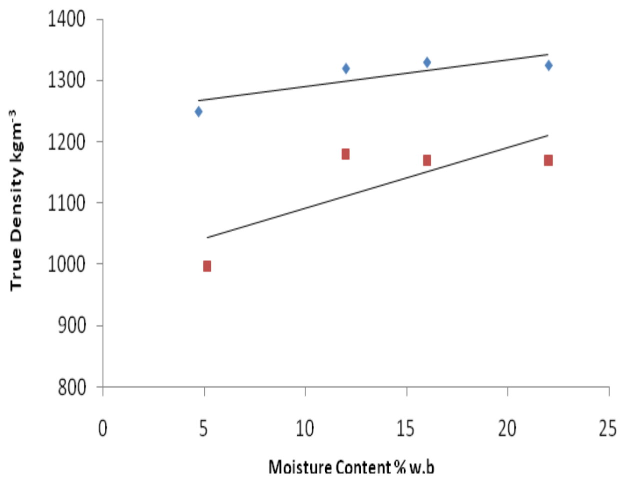


**Fig 11.** Effect of moisture content on true density, Dc370 (□) and Sc704 (◊)

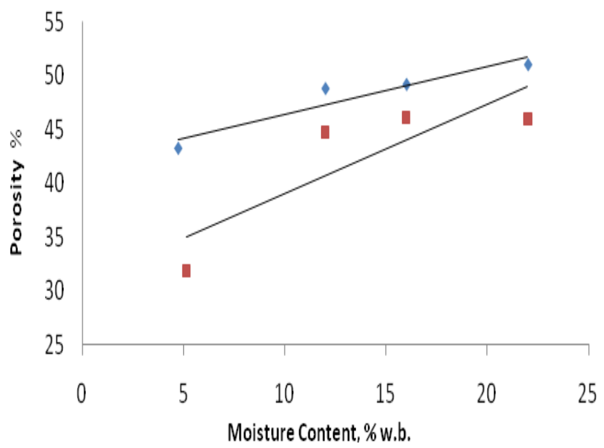


**Fig 12.** Effect of moisture content on porosity, Dc370 (□) and Sc704 (◊)

equations:

| | | | |
|---|---|---|---|
| For Sc704 | $\varphi_{\text{plyw}} = 0.007M + 0.422$ | $R^2 = 0.828$ | (27) |
| | $\varphi_{\text{galv}} = 0.015M + 0.307$ | $R^2 = 0.998$ | (28) |
| | $\varphi_{\text{plas}} = 0.010M + 0.284$ | $R^2 = 0.975$ | (29) |
| For Dc370 | $\varphi_{\text{plyw}} = 0.013M + 0.264$ | R2 = 0.871 | (30) |
| | $\varphi_{\text{galv}} = 0.011M + 0.298$ | $R^2 = 0.882$ | (31) |
| | $\varphi_{\text{plas}} = 0.020M + 0.245$ | $R^2 = 0.852$ | (32) |

Similar results were found by Sahoo and Srivastava (2002), Amin et al. (2004); Carman (1996); Gupta & Das (1997); konak et al. (2002) and Nimkar & Chattopadhyay (2001).

***Static Angle of Repose***

The experimental results for the static angle of repose with respect to moisture content are shown in Fig. 14. As it can be seen, changes in moisture content resulted 35.71% and 18.37% increase in the static angle of repose for Dc370 and Sc704, respectively. Like other physical properties, Sc704 had more linear data. The static angle of repose for corn varieties has the following relationships in terms of moisture content.

| | | | |
|---|---|---|---|
| (for Sc704) | $\theta_{st} = 0.546M + 46.27$ | $R^2 = 0.963$ | (33) |
| (for Dc370) | $\theta_{st} = 0.858M + 35.91$ | $R^2 = 0.872$ | (34) |

The results were similar to those reported by Singh and Goswami (1996) for cumin seed, Nimkar and Chattopadhyay (2001) for green gram, Baryeh (2002) for millet, Amin et al. (2004) for lentil.

***Rupture force***

The force required to initiate grain rupture at different moisture contents is presented in Fig. 15. The rupture force values ranged from 298.11 to 198.44 N for Sc704 and from 321.67 to 218 N for Dc370. The results showed that for both Dc370 and Sc704, the rupture force is highly dependent on moisture content. For the curves, greater force was necessary to rupture the grains at low moisture content. The small rupturing force at higher moisture content might have resulted from the fact that the corn grain might have soft texture at high moisture content. As seen in the Fig., rupture force decreased to a minimum value at a moisture content of 16% for both of them and later increased as moisture content was increased further from 16% to 22%. This was so because, when the corn grains were compressed, further absorption of water by shell made grain interior to swell up and fill the clearance between the inside of grain and the shell. Thereby, they formed structurally turgid and this resulted in an increase of rupture force again. The results are similar to those reported by Vursavus and Özguven (2004) for apricot pit, Altuntas and Yıldız (2007) for faba been, Guner at el. (2003) and Olaniyan and Oje (2002) for shea nut. The relationship between moisture content and rupture force of corn grain compressed can be expressed mathematically as follows:

| | | | |
|---|---|---|---|
| (for Sc704) | $F_a = -6.327M + 310.1$ | $R^2 = 0.718$ | (35) |
| (for Dc370) | $F_a = -6.601M + 345.7$ | $R^2 = 0.854$ | (36) |

***Rupture energy***

Fig. 16 shows that just in 22% w.b., Sc704 rupture energy is significantly at 5% level greater than Dc370 and the variance of

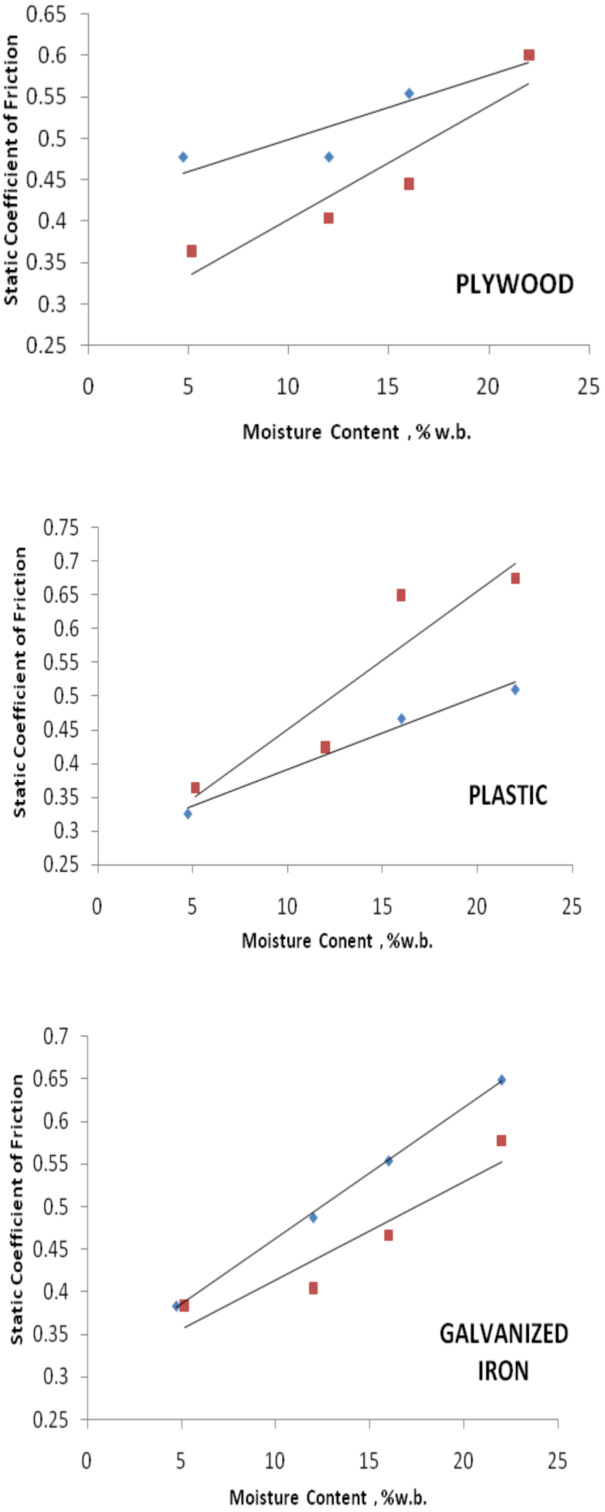


**Fig 13.** Effect of moisture content on static coefficient of friction, Dc370 (□) and Sc704 (◊)

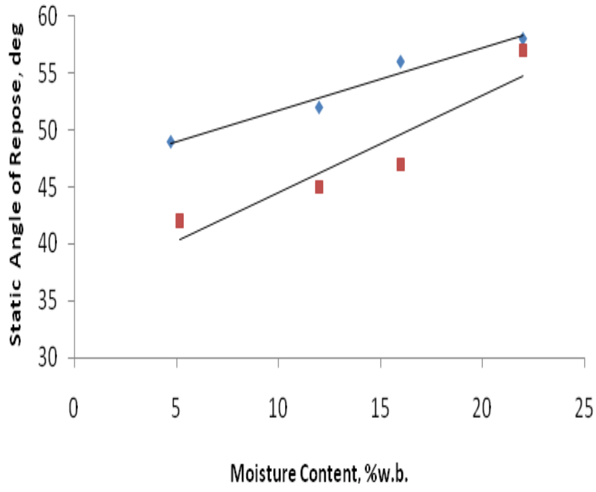


**Fig 14.** Effect of moisture content on static angle of repose, Dc370 (□) and Sc704 (◊)

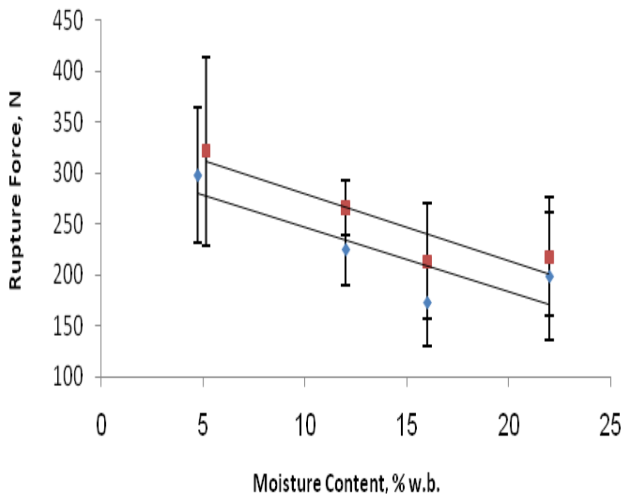


**Fig 15.** Effect of moisture content on rupture force, Dc370 (□) and Sc704 (◊)

Sc704 data is greater than Dc370.The rupture energy values ranged from 64.67 to 130.8 N.mm and from 72.71 to 80.33 N.mm for Sc704 and Dc370, respectively. Polynomial relationship was found between both rupture energy values and moisture content. The highest rupture energy was at the moisture content of 22% while the lowest was at a moisture content of 12% for both Sc704 and Dc370. It may be because of the fact that the corn grain might have soft texture at high moisture content and needed the greater rupture energy. Equations (37) and (38) showed that Sc704 was highly more correlated with moisture content than Dc370. The relationship between moisture content and rupture force of corn grain can be expressed mathematically as follows:

(for Sc704) $E_a = 0.727M^2 - 15.80M + 124.4$ $R^2 = 0.979$ (37)

(for Dc370) $E_a = 0.081M^2 - 1.696M + 78.88$ $R^2 = 0.893$ (38)

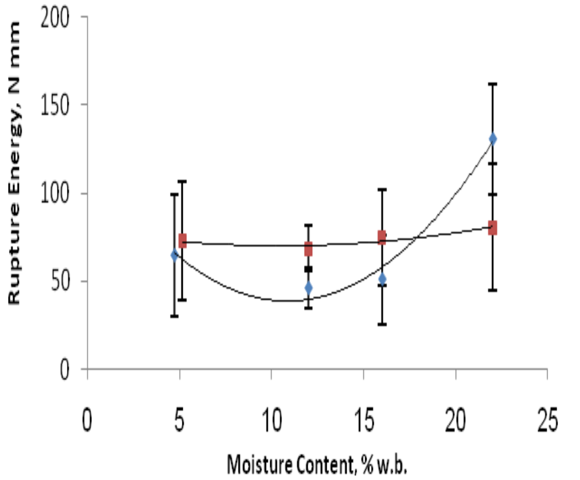


**Fig 16.** Effect of moisture content on rupture energy, Dc370 (□) and Sc704 (◊)

The results are similar to these reported by Oloso and Clarke (1993), Guner et al. (2003) and Altuntas and Yildiz (2007).

**Conclusions**

The various properties measured will serve as a useful tool in process and equipment design and this will go a long way in assisting to improve yield and quality of corn grains. All the studied physical and mechanical properties of corn grains depend on their moisture contents. The following conclusions are drawn from the investigation on physical and mechanical properties of two varieties of corn grains. For moisture content range of 4.73% to 22% w.b. for Sc704 The average length, width, thickness, geometric mean diameter, equivalent diameter, arithmetic diameter, sphericity, angle of repose, grain volume, bulk density, true density, porosity, surface area, aspect ratio, rupture force and rupture energy for corn grains ranged from 11.62 to 12.60 mm, 7.27 to 7.98 mm, 4.47 to 4.71 mm, 7.20 to 7.77 mm and 7.63 to 7.96 mm, 7.77 to 8.43 mm, 62.31% to 62.00%, 49° to 58°, 209.66 to 265.00 $mm^3$, 710 to 649 $kgm^{-3}$, 1250 to 1325 $kgm^{-3}$, 43.2% to 51.02%, 137.69 to 160.09 $mm^2$, 63.05% to 63.77%, 298.11 to 172.67 N and 64.67 to 130.80 N.mm and for Dc370 in the moisture content increase from 5.15% to 22%, the values were 11.31 to 12.24 mm, 8.19 to 8.09 mm, 4.84 to 4.73 mm, 7.63 to 7.67 mm, 7.82 to 7.87 mm, 8.11 to 8.23 mm, 67.73% to 64.74%, 42° to 57°, 525.29 to 255.54 $mm^3$, 679 to 632 $kgm^{-3}$, 997 to 1170 $kgm^{-3}$, 31.90% to 45.98%, 154.62 to 155.53 $mm^2$, 72.70% to 68.29%, 321.67 to 218 N and 72.71 to 80.33 N.mm. The change in moisture content had greater impact in the bulk density of Sc704 and it was highly more correlated with moisture content than Dc370. But for true density, porosity and static angle of repose, Dc370 had higher correlation with moisture content. The static coefficients of friction on various surfaces increased linearly with increase in moisture content. For Sc704, the galvanized metal as a surface for sliding offered the maximum friction followed by plywood and plastic but for Dc370 plastic showed a maximum friction while the static coefficients of friction for galvanized metal and plywood were almost the same. The parameters used to indicate corn grain mechanical behavior were dependent on the shell moisture content for along the principal axis. Rupture energy of the corn grain generally increased for compression along the principal axis, while rupture force decreased for compression along the principal axis with an increase in moisture content. As moisture content increased, the rupture force values ranged from 298.11 to 198.44 N and 265.89 to 218 N for Sc704 and Dc370, respectively. The rupture energy values ranged from 64.67 N mm to 13.0.8 N mm and 72.71 N mm to 80.33 N mm, as the moisture content increased from 4.73% to 22% w.b. for Sc704 and from 5.15% to 22% for Dc370, respectively.

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