

Full Length Research Paper

Effects of moisture content on some physical properties of red pepper (*Capsicum annuum* L.) seed

Necmiye Üçer, Ahmet Kılıçkan* and İbrahim Yalçın

Department of Agricultural Machinery, Faculty of Agriculture, Adnan Menderes University, Aydin, Turkey

Accepted 27 April, 2010

The physical properties of red pepper seed were evaluated as a function of moisture content. The average length, width and thickness were 4.46, 3.66 and 0.79 mm, respectively, at 7.27% d.b. moisture content. In the moisture range of 7.27 to 20.69% dry basis (d.b.), studies on rewetted red pepper seed showed that the thousand seed mass increased from 7.97 to 8.89 g, the projected area from 8.40 to 9.09 mm², the sphericity from 0.525 to 0.555 and the terminal velocity from 4.36 to 4.51 m s⁻¹. The static coefficient of friction of red pepper seed increased linearly against surfaces of four structural materials, namely, rubber (0.394 to 0.477), aluminium (0.255 to 0.382), stainless steel (0.298 to 0.416) and galvanised iron (0.319 to 0.395) as the moisture content increased from 7.27 to 20.69% d.b. The bulk density decreased from 402.1 to 360.0 kg m⁻³, the true density from 795.2 to 746.3 kg m⁻³ and the porosity increased from 49.43 to 51.76%, respectively, with an increase in moisture content from 7.27 to 20.69% d.b.

Key words: Red pepper seed, physical properties, moisture content, terminal velocity.

INTRODUCTION

Red pepper (*Capsicum annuum* L.) as other vegetables is a good source of antioxidant substances such as carotenoids (provitamin A) and vitamin C which confer protection against carcinogenic components and delay the aging process. Dried red pepper is one of the most important vegetable spices, its quality being determined mainly by colour (Scala and Crapiste, 2008). Red pepper is eaten as a raw and cooked vegetable and also used commonly in making paste, pickle and sauce. Red ground pepper made by drying and pulverizing the hot red pepper is used as a spice and flavor

ingredient in the food industry (Doymaz and Pala, 2002). Red pepper is sensitive to aflatoxin contamination depending on atmospheric temperature, humidity, drying and processing conditions (Aydin et al., 2007).

Red pepper is one of the most widely used food colorants for culinary and industrial purposes. Because of its high colouring capacity and in some cases its peculiar pungency, red pepper is used to modify the colour and flavour of soups, stews, sausage, cheese, snacks, salad dressing, sauces, pizza and confectionary products, among others (Topuz et al., 2009).

Red pepper is one of the main agricultural products in Turkey. Turkey is one of the major red pepper producing countries together with China, Mexico and Spain (Doymaz and Pala, 2002; FAO, 2007).

To design equipment for aeration and storage, there is a need to know various physical properties as a function of moisture content (Altuntaş et al., 2005). Recently, scientists have made great efforts in evaluating basic physical properties of agricultural materials and have pointed out their practical utility in machine and structural design and in control engineering (Amin et al., 2004). Recent scientific developments have improved the handling and processing of bio-materials through mechanical, thermal, electrical, optical and other techniques, but little

*Corresponding author. E-mail: akilickan@hotmail.com. Tel: +90 256 7727023. Fax: +90 256 7727233.

Notation: A_p , Projected area, mm²; L , length of seed, mm; m_{1000} , thousand seed mass, g; M_c , moisture content, % d.b.; M_f , final moisture content of sample, % d.b.; M_i , initial moisture content of sample, % d.b.; P_f , porosity, %; Q , mass of water to added, kg; T , thickness of seed, mm; V_t , terminal velocity, m s⁻¹; W , width of seed, mm; W_i , initial mass of sample, kg; α , angle of tilt, degree; μ , static coefficient of friction; ρ_b , bulk density, kg m⁻³; ρ_t , true density, kg m⁻³; ϕ , sphericity of seed; al , aluminium; gi , galvanised iron; ru , rubber; ss , stainless steel.

is known about the basic physical characteristics of bio-materials. Such basic information is important not only to engineers but also to food scientists, processors, plant breeders and other scientists who may find new uses (Mohsenin, 1970).

Several investigators determined the physical properties of seeds at various moisture contents such as Shepherd and Bhardwaj (1986) for pigeon pea, Amin et al. (2004) for lentil seed, Ogunjimi et al. (2002) for locust bean seed and Konak et al. (2002) for chickpea seeds. However, no published work seems to have been carried out on the physical properties of red pepper seed and their relationship with moisture content. The objective of this study was to investigate some moisture-dependent physical properties of red pepper seed namely, linear dimensions, thousand seed mass, projected area, sphericity, bulk density, true density, porosity, terminal velocity and static coefficient of friction against different materials.

MATERIALS AND METHODS

The dry seeds of red pepper cultivar, local variety were used for all the experiments in this study. The seeds were cleaned manually to remove all foreign matter such as dust, dirt, stones and chaff as well as immature, broken seeds. The initial moisture content of the seeds was determined by oven drying at $105 \pm 1^\circ\text{C}$ for 24 h (Gupta and Das, 1997; Özarlan, 2002). The initial moisture content of the seeds was 7.27% dry basis (d.b.).

The samples of the desired moisture contents were prepared by adding an amount of distilled water as calculated from the following relation (Yalçın, 2007; Kılıçkan et al., 2010).

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

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 warm up to room temperature for about 2 h (Yalçın and Özarlan, 2004; Baumler et al., 2006). All the physical properties of the seeds were assessed at moisture levels of 7.27, 10.98, 15.45 and 20.69% d.b. with ten replications at each moisture content.

To determine the average size of the seed, 100 seeds were randomly picked and their three linear dimensions namely, length L , width W and thickness T were measured using a micrometer reading to 0.01 mm (Özarlan, 2002).

The sphericity of seeds ϕ was calculated by using the following relationship (Mohsenin, 1970):

$$\phi = \frac{(LWT)^{1/3}}{L} \quad (2)$$

The one thousand seed mass was determined by means of an electronic balance reading to 0.001 g (Baryeh, 2002). The projected area of a seed was measured by a scanner connected to a computer. For this purpose, a special computer program was used (Özarlan, 2002; Yalçın and Özarlan, 2004). The average bulk

density of the red pepper seed was determined using the standard test weight procedure (Singh and Goswami, 1996) 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. 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 (Yalçın, 2007).

The true density defined as the ratio between the mass of red pepper seed and true volume of seed was determined using the toluene displacement method. Toluene was used in place of water because it is absorbed by seeds to a lesser extent. The volume of toluene displaced was found by immersing a weighed quantity of red pepper seed in toluene (Singh and Goswami, 1996).

The porosity of red pepper seed at various moisture contents was calculated from bulk and true densities using the relationship given by Mohsenin (1970) as follows:

$$P_f = (1 - \rho_b / \rho_t) \times 100 \quad (3)$$

Where, P_f 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 seeds at different moisture contents were measured using a cylindrical air column (Joshi et al., 1993; Baryeh, 2002; Yalçın, 2007). For each experiment, a sample was dropped into the air stream from the top of the air column, up which air was blown to suspend the material in the air stream. The air velocity near the location of the seed suspension was measured by a hot wire anemometer having a least count of 0.01 m s^{-1} .

The static coefficient of friction of red pepper seed against four different structural materials, namely rubber, aluminium, stainless steel and galvanised iron was determined. These are common material used for handling and processing of grains and construction of storage and drying bins. A polyvinylchloride cylindrical pipe of 50 mm diameter and 50 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 α was read from a graduated scale. Other researchers have used this method for other grains and seeds (Singh and Goswami, 1996; Dutta et al., 1988; Baryeh, 2002). The coefficient of friction was calculated from the following relationship:

$$\mu = \tan \alpha \quad (4)$$

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

RESULTS AND DISCUSSION

Seed dimensions and size distribution

The mean dimensions of 100 seeds measured at 7.27% d.b. moisture content are: length $4.46 \pm 0.23 \text{ mm}$, width $3.66 \pm 0.26 \text{ mm}$ and thickness $0.79 \pm 0.08 \text{ mm}$. About 88% of the seeds have a length ranging from 4.2 to 4.8 mm; about 84%, a width ranging from 3.4 to 4.0 mm; and about 86%, a thickness ranging from 0.7 to 0.9 mm at 7.27% d.b. moisture content.

One thousand seed mass

The one thousand seed mass m_{1000} increased linearly

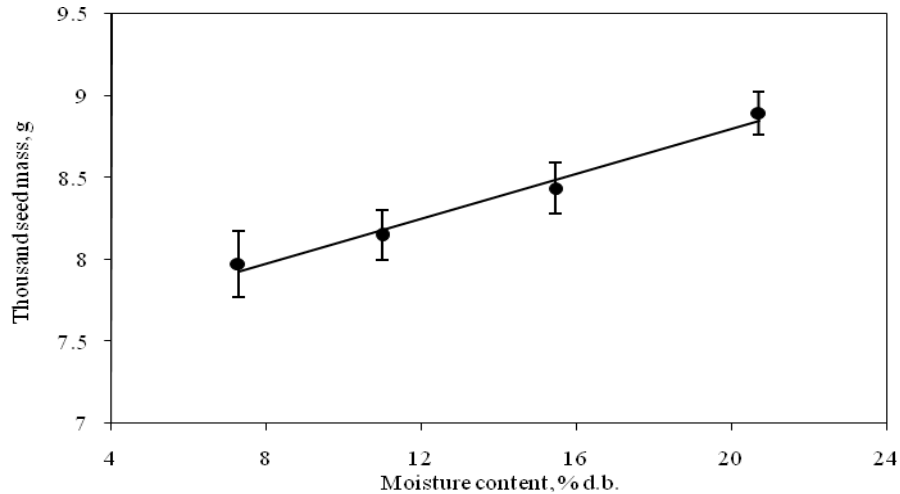


Figure 1. Effect of moisture content on thousand seed mass.

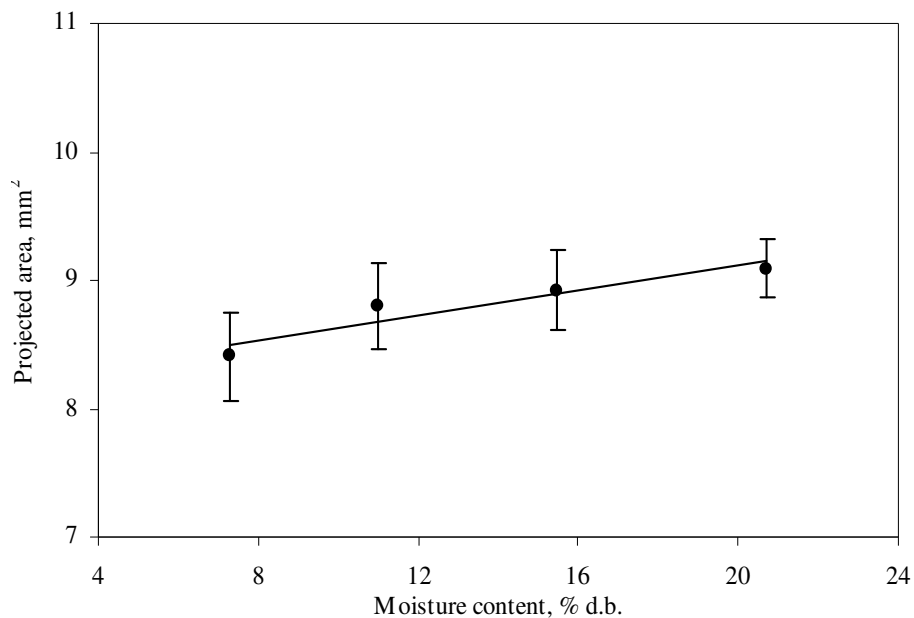


Figure 2. Effect of moisture content on projected area.

from 7.97 to 8.89 g as the moisture content increased from 7.27 to 20.69% d.b. (Figure 1). An increase of 11.54% in the one thousand seed mass was recorded within the above moisture range. The linear equation for one thousand seed mass can be formulated to be:

$$m_{1000} = 7.4275 + 0.687M_c \quad (R^2 = 0.9834) \quad (5)$$

A linear increase in the one thousand red pepper seed mass as the seed moisture content increases has been noted by Sacilik et al. (2003) for hemp, Singh and Goswami (1996) for cumin and Ixtaina et al. (2008) for chia.

Projected area of seed

The projected area of red pepper seed (Figure 2) increased from 8.40 to 9.09 mm², while the moisture content of seed increased from 7.27 to 20.69% d.b. The variation in projected area A_p in mm² with moisture content of red pepper seed can be represented by the following equation

$$A_p = 8.1548 + 0.0478M_c \quad (R^2 = 0.8953) \quad (6)$$

Similar trends have been reported by Abalone et al. (2004) for amaranth, Işik (2008) for sira bean grains and Tang

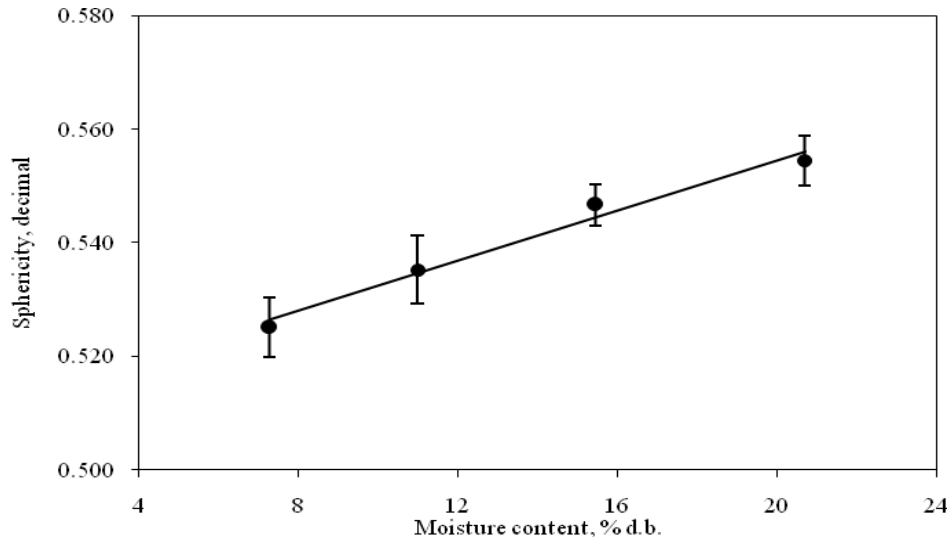


Figure 3. Effect of moisture content on sphericity.

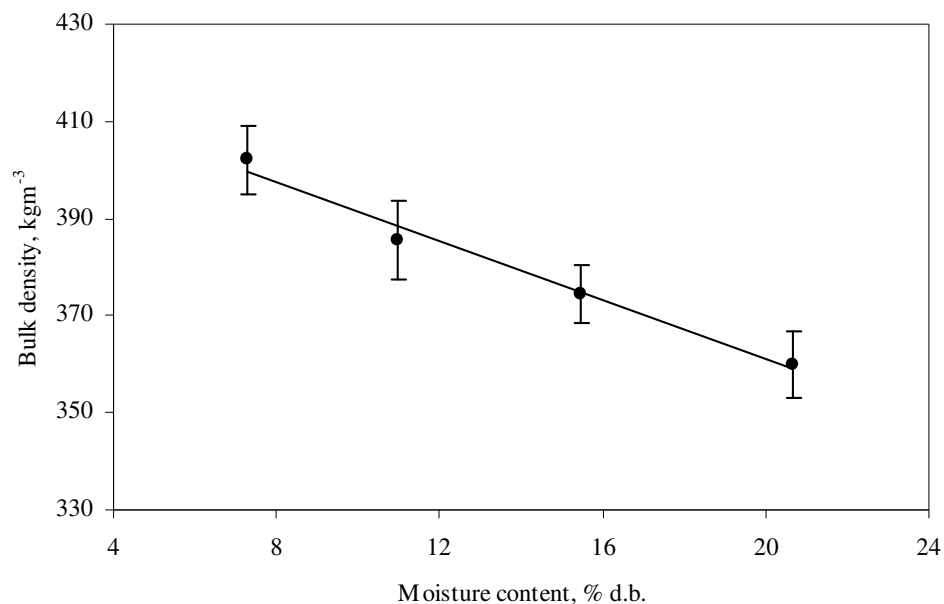


Figure 4. Effect of moisture content on bulk density.

and Sokhansanj (1993) for lentil.

Sphericity

The sphericity of red pepper seed increased from 0.525 to 0.555 with the increase in moisture content (Figure 3). The relationship between sphericity and moisture content M_c in % d.b. can be represented by the equation

$$\phi = 0.5104 + 0.0022M_c \quad (R^2 = 0.9808) \quad (7)$$

Similar trends have been reported by Altuntaş et al. (2005) for fenugreek seed, Baumler et al. (2006) for safflower and Solomon and Zewdu (2009) for niger seed.

Bulk density

The values of the bulk density for different moisture levels varied from 402.1 to 360.0 kg m⁻³ (Figure 4). The bulk density of seed was found to bear the following relationship with moisture content.

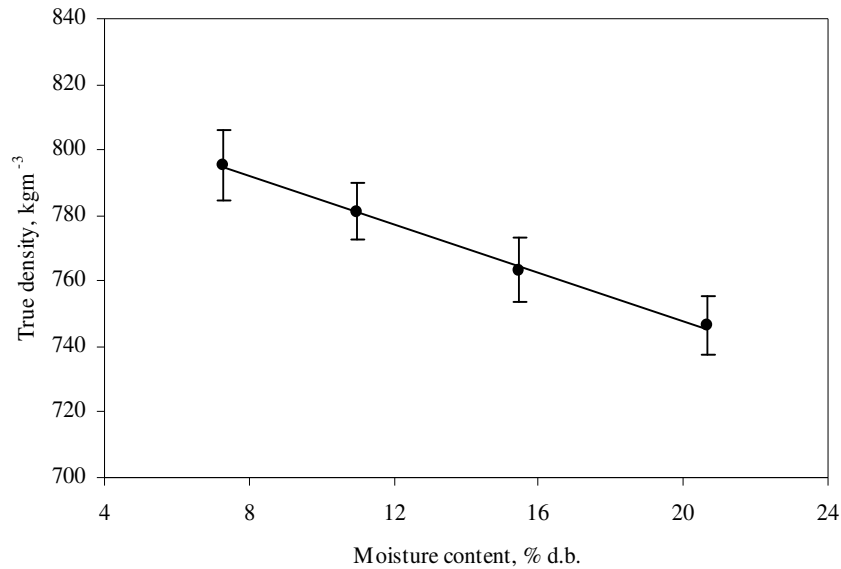


Figure 5. Effect of moisture content on true density.

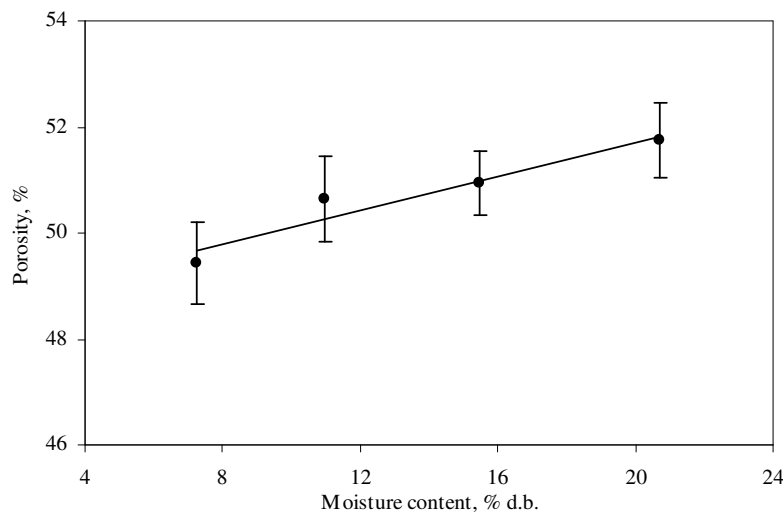


Figure 6. Effect of moisture content on porosity.

$$\rho_b = 421.98 - 3.0462M_c \quad (R^2 = 0.9837) \quad (8)$$

$$\rho_t = 821.48 - 3.6736M_c \quad (R^2 = 0.998) \quad (9)$$

A similar decreasing trend in bulk density has been reported by Dursun and Dursun (2005) for caper, Abalone et al. (2004) for amaranth, Kiani et al. (2008) for red bean seed.

The results were similar to those reported by Abalone et al. (2004) for amaranth, Shepherd and Bhardwaj (1986) for pigeon pea, Nimkar et al. (2006) for horse gram and Sacilik et al. (2003) for hemp seed.

True density

The true density varied from 795.2 to 746.3 kg m⁻³ when the moisture level increased from 7.27 to 20.69% d.b. (Figure 5). The true density and the moisture content of seed can be correlated as follows

Porosity

The porosity of red pepper seed increased from 49.43 to 51.76% with the increase in moisture content from 7.27 to 20.69% d.b. (Figure 6). The relationship between porosity and moisture content can be represented by the equation

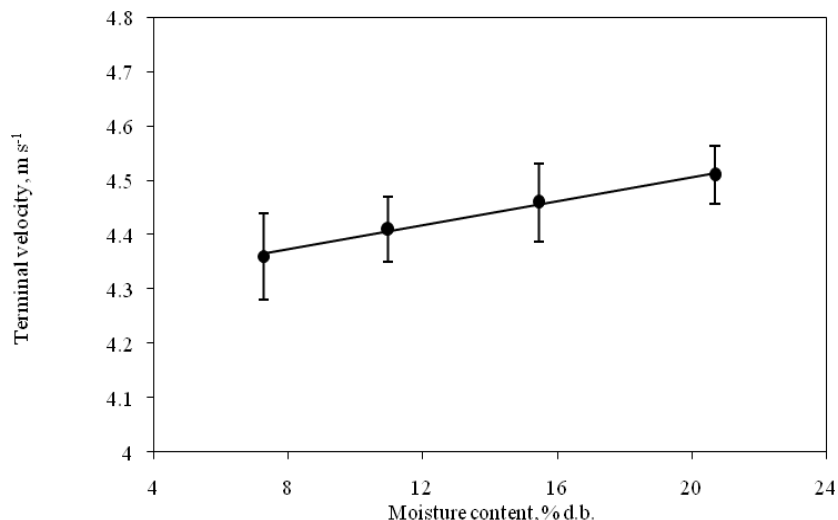


Figure 7. Effect of moisture content on terminal velocity.

$$P_f = 48.515 + 0.1601M_c \quad (R^2 = 0.924) \quad (10)$$

Singh and Goswami (1996), Gupta and Das (1997) and Yalçın and Özarslan (2004) reported similar trends in the case of cumin, sunflower and vetch, respectively. Since the porosity depends on the bulk and true densities, the magnitude of variation in porosity depends on these densities only.

Terminal velocity

The experimental results for the terminal velocity of red pepper seed at various moisture levels are shown in Figure 7. The terminal velocity was found to increase linearly from 4.36 to 4.51 m s⁻¹ as the moisture content increased from 7.27 to 20.69% d.b. The relationship between terminal velocity and moisture content can be represented by

$$V_t = 4.2839 + 0.0111M_c \quad (R^2 = 0.9942) \quad (11)$$

Similar results were reported by Suthar and Das (1996), Singh and Goswami (1996), Yalçın et al. (2009), Nimkar et al. (2005) and Ramakrishna (1986) in the case of karingda, cumin, onion, moth gram and melon seeds, respectively.

Static coefficient of friction

The static coefficient of friction of red pepper seed on four surfaces (rubber, aluminium, stainless steel and galvanised iron) against moisture content in the range 7.27 to 20.69% d.b. are presented in Figure 8. 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 21.06, 49.80, 39.59 and 23.82% were recorded in the case of rubber, aluminium, stainless steel and galvanised iron, respectively, as the moisture content increased from 7.27 to 20.69% d.b. As the moisture content of the seed increased, the static coefficients increased significantly. This is due to the increased adhesion between the product and the surface at higher moisture values. The relationships between static coefficients of friction and moisture content on rubber μ_{ru} , wood μ_{wo} , stainless steel μ_{ss} and galvanised iron μ_{gi} , can be represented by the following equations:

$$\mu_{ru} = 0.3448 + 0.0062M_c \quad (R^2 \text{ of } 0.9866) \quad (12)$$

$$\mu_{al} = 0.1994 + 0.009M_c \quad (R^2 \text{ of } 0.9645) \quad (13)$$

$$\mu_{ss} = 0.2331 + 0.009M_c \quad (R^2 \text{ of } 0.9948) \quad (14)$$

$$\mu_{gi} = 0.2875 + 0.0053M_c \quad (R^2 \text{ of } 0.9466) \quad (15)$$

Similar results were found by Sahoo and Srivastava (2002), Singh and Goswami (1996), Çarman (1996), Gurhan et al. (2009) and Garnayak et al. (2008) for okra, cumin, lentil, black kabuli chickpea and jatropha seeds, respectively.

Conclusions

From the study, it was found that the thousand seed mass

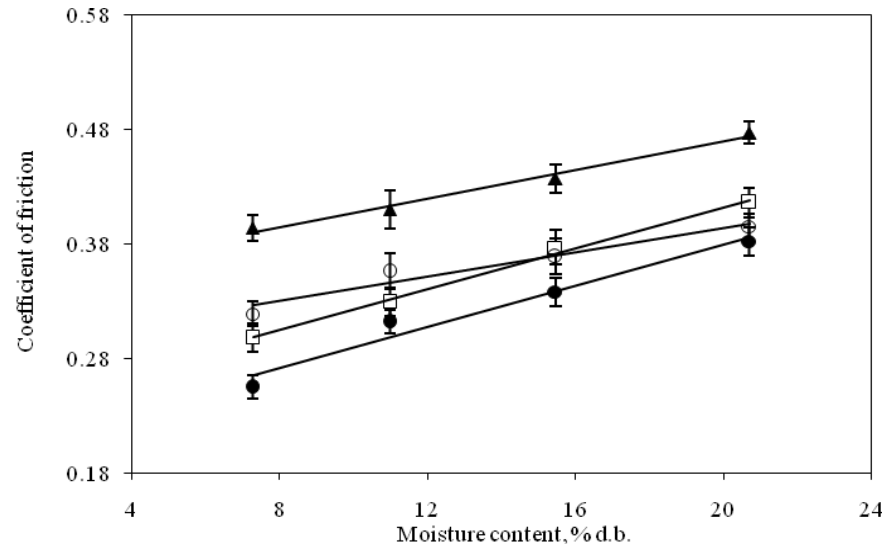


Figure 8. Effect of moisture content on static coefficient of friction; ▲, rubber; ●, aluminium; ○, galvanized iron; □, stainless steel.

increased from 7.97 to 8.89 g and the sphericity increased from 0.525 to 0.555 with increase in moisture content from 7.27 to 20.69% d.b. Also, the projected area increased from 8.40 to 9.09 mm². The bulk density decreased linearly from 402.1 to 360.0 kg m⁻³, the true density decreased from 795.2 to 746.3 kg m⁻³ and the porosity increased from 49.43 to 51.76%. Finally, the terminal velocity increased from 4.36 to 4.51 m s⁻¹ and static coefficient of friction increased for all four surfaces, namely, rubber (0.394 to 0.477), aluminium (0.255 to 0.382), stainless steel (0.298 to 0.416) and galvanised iron (0.319 to 0.395).

REFERENCES

- Abalone R, Cassinera A, Gaston A, Lara MA (2004). Some physical properties of amaranth seeds. *Biosyst. Eng.* 89(1): 109-117.
- Altuntaş E, Özgöz E, Taşer ÖF (2005). Some physical properties of fenugreek (*Trigonella foenum-graceum* L.). *J. Food Eng.* 71: 37-43.
- Amin MN, Hossain MA, Roy KC (2004). Effects of moisture content on some physical properties of lentil seeds. *J. Food Eng.* 65(1): 83-87.
- Aydin A, Erkan ME, Başkaya R, Ciftcioglu G (2007). Determination of Aflatoxin B₁ levels in powdered red pepper. *Food Control*, 18(9): 1015-1018.
- Bäumler E, Cuniberti A, Nolasco SM, Riccobene IC (2006). Moisture dependent physical and compression properties of safflower seed. *J. Food Eng.* 73: 134-140.
- Baryeh EA (2002). Physical properties of millet. *J. Food Eng.* 51: 39-46.
- Çarman K (1996). Some physical properties of lentil seeds. *J. Agric. Eng. Res.* 63(2): 87-92.
- Doymaz İ, Pala M (2002). Hot-air drying characteristics of red pepper. *J. Food Eng.* 55: 331-335.
- Dutta SK, Nema VK, Bhardwaj RK (1988). Physical properties of gram. *J. Agric. Eng. Res.* 39: 259-268.
- Dursun E, Dursun I (2005). Some physical properties of caper seed. *Biosyst. Eng.* 92(2): 237-245.
- FAO (2007). Statistical database. Available: <http://faostat.fao.org/sita/567/desktopDefault.aspx?PageID=567#ancor>.
- Garnayak DK, Pradhan RC, Naik SN, Bhatnagar N (2008). Moisture-dependent physical properties of jatropha seed (*Jatropha curcas* L.). *Ind. Crops Prod.* 27(1): 123-129.
- Gupta RK, Das SK (1997). Physical properties of sunflower seeds. *J. Agric. Eng. Res.* 66: 1-8.
- Gurhan R, Özarslan C, Topuz N, Akbaş T, Simsek E (2009). Effects of moisture content on physical properties of black kabuli chickpea (*Cicer arietinum* L.) seed. *Asian J. Chem.* 21(4): 3270-3278.
- Işık E (2008). Effect of moisture content on some physical and mechanical properties of sira bean grains. *Transactions of the ASABE.* 51(2): 573-579.
- Ixtaina V, Nolasco SM, Tomas MC (2008). Physical properties of chia (*Salvia hispanica* L.) seeds. *Ind. Crops Prod.* 28: 286-293.
- Joshi DC, Das SK, Mukherjee RK (1993). Physical properties of pumpkin seeds. *J. Agric. Eng. Res.* 54(3): 219-229.
- Kiani MKD, Minaei S, Maghsoudi H, Varnamkhasti MG (2008). Moisture dependent physical properties of red bean (*Phaseolus vulgaris* L.) grains. *Int. Agrophys.* 22(3): 231-237.
- Kılıçkan A, Üçer N, Yalçın I (2010). Some physical properties of spinach (*Spinacia oleracea* L.) seed. *Afr. J. Biotechnol.* 9(5): 648-655.
- Konak M, Çarman K, Aydın C (2002). Physical properties of chick pea seeds. *Biosyst. Eng.* 82(1): 73-78.
- Mohsenin NN (1970). Physical properties of plant and animal materials. Gordon and Breach Science Publishers. New York.
- Nimkar PM, Mandwe DS, Dudhe RM (2005). Physical properties of moth gram. *Biosyst. Eng.* 91(2): 183-189.
- Nimkar PM, Gurjar RL, Kaul NT, Namrata CW (2006). Physical properties of horse gram (*Dolichos biflorus*). *J. Food Sci. Technol.* 43(2): 133-136.
- Ogunjimi LAO, Aviara NA, Aregbesola OA (2002). Some engineering properties of locust bean seed. *J. Food Eng.* 55(2): 95-99.
- Özarslan C (2002). Physical properties of cotton seed. *Biosyst. Eng.* 83(2): 169-174.
- Ramakrishna P (1986). Melon seeds-evaluation of the physical characteristics. *J. Food Sci. Technol.* 23: 158-160.
- Sacilik K, Öztürk R, Keskin R (2003). Some physical properties of hemp seed. *Biosyst. Eng.* 86(2): 191-198.
- Sahoo PK, Srivastava AP (2002). Physical properties of okra seed. *Biosyst. Eng.* 83(4): 441-448.
- Scala KD, Crapista G (2008). Drying kinetics and quality changes during drying of red pepper. *LWT-Food Sci. Technol.* 41: 789-795.
- Singh KK, Goswami TK (1996). Physical properties of cumin seed. *J. Agric. Eng. Res.* 64(2): 93-98.
- Shepherd H, Bhardwaj RK (1986). Moisture dependent physical properties of pigeon pea. *J. Agric. Eng. Res.* 35: 227-234.

- Suthar SH, Das SK (1996). Some physical properties of karingda [*Citrullus lanatus* (thumb) mansf] seeds. J. Agric. Eng. Res. 65(1): 15-22.
- Solomon WK, Zewdu AD (2009). Moisture-dependent physical properties of niger (*Guizotia abyssinica* Cass.) seed. Ind. Crops Prod. 29: 165-170.
- Tang J, Sokhansanj S (1993). Geometric changes in lentil seeds caused by drying. J. Agric. Eng. Res. 56(4): 313-326.
- Topuz A, Feng H, Kushad M (2009). The effect of drying method and storage on color characteristics of paprika. LWT-Food Sci. Technol. 42: 1667-1673.
- Yalçın İ, Özarıslan C (2004). Physical properties of vetch seed. Biosyst. Eng. 88(4): 507-512.
- Yalçın İ (2007). Physical properties of cowpea (*Vigna sinensis* L.) seed. J. Food Eng. 79: 57-62.
- Yalçın İ, Çetin M, Özarıslan C (2009). Physical properties of onion (*Allium cepa* L.) seed. Asian J. Chem. 21(2): 1341-1349.