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The Effect of Moisture Content on Physical Properties of Wheat

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Abstract: Physical properties often required for designing the equipments for planting, harvesting and postharvesting operations of seeds. Several physical properties of three popular wheat varieties (Shiraz, Karoun and Shiroudy) were determined and compared for moisture content in 8, 12 and 18% w.b in 2007 in University of Tehran. The average length, width and thickness were 6.75, 3.26 and 2.77 mm at a moisture content of 8% w.b., respectively. studies on rewetted wheat seeds showed that the thousand-kernel weight increased from 18.38 to 22.43g. The geometric and equivalent mean diameter, surface area, sphericity and aspect ratio at a moisture content of 8% w.b were 3.93, 3.94 mm, 48.68 mm^2, 0.58, 0.48, respectively. The porosity increased from 0.43 to 0.45 %. Whereas the bulk density decreased from 0.72 to 0.66kg m^{-3} and the true density from 1.25 to 1.19 kg m^{-3}, with an increasing in the moisture content range of 8B18% w.b. The static and dynamic angle of repose varied from 37.28 to 47.33 and 29.89 to 36.5^o. The mean of static friction coefficient of three wheat varieties increased the linearly against surfaces of three structural materials, namely, compressed plastic (0.43 - 0.53), galvanized iron (0.33 - 0.53) and plywood (0.35 - 0.41) as the moisture content increased from 8 to 18% w.b.

Key words: Physical property, wheat, moisture content, equipment design

Introduction

The total wheat farmland in Iran is 6.41 million hectares, that Khorasan province has the most of that (10.85%). The annual wheat production is 13.44 million tons that Fars province includes the maximum of that (Anonymous, 2003). In the design of machines, structures, processing and controls to be used in productions, handling and processing of food and agricultural products, certain physical characteristics and engineering properties of the materials should constitute important and essential engineering data (Mohsenin, 1986).

To design a machine for handling, cleaning, conveying, storing and milling, the physical properties of wheat at different moisture contents must be known (Tabatabaeefar, 2003).

Principal axial dimensions of rough rice grains are useful in selecting sieve separators and in calculating power during the seed milling process. They can also be used to calculate surface area and volume of kernels which are important during modeling of grain drying, aeration, heating and cooling (Ghasemi Varnamkhasti *et al.,* 2007). The rate of heat transfer to the material also significantly depends on the heat transfer surface. The smaller the volume of material per unit surface, the better its condition for rapid heat transfer. The effects of size and surface area on drying rates of particulate materials can also be characterized by using the surface to volume ratio. When diffusion of water within the particle limits drying rate, larger particles dry more slowly than smaller particles of the same shape. Also, the ratio of surface area to volume affects drying time and energy requirements (Stroshine and Hamann, 1998).

Bulk density can indicate the degree of kernel filling during growth and therefore an indicator of quality and predicated in breakage susceptibility and hardness studies, milling and baking qualities (Chang, 1988). Kernel and bulk density data have been used in research on determining the dielectric properties of cereal grains (Nelson and You, 1989) and for determining volume fractions for use in dielectric mixture equations (Nelson, 1992). Porosity, on the other hand, allows gases, such as air and liquids to flow through a mass of particles in aeration, drying, heating, cooling and distillation operations.

The static coefficient of friction and angle of repose is necessary to design conveying machine and hopers used in planter machines.

The objective of current study was to determine some physical properties of wheat seeds at 8% moisture content such as dimensions, equivalent and geometric diameter, sphericity surface area, volume and then other properties under effect of moisture content variation such as true and bulk density, thousand grain kernel, porosity, static coefficient of friction against deferent materials and angle of repose.

Materials and Methods

Three popular varieties of cleaned wheat (Shiraz, Karoun and Shiroudy) were obtained from Plant and Seed Institute in Tehran, capital of Iran. The initial moisture content of seeds was determined by oven method (Tabatabaeefar, 2003). And in order to approach the desired moisture level as 8, 12 and 18% w.b., the rewetting formula was used Eq (1) and to allow the

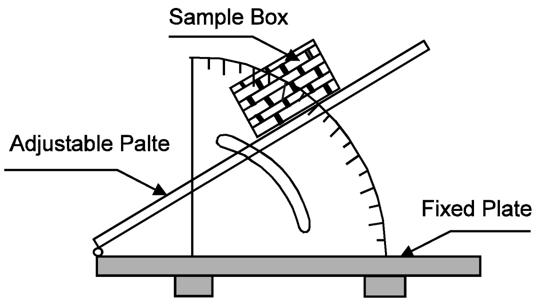

Fig. 1: Apparatus to determine empting angle of repose.

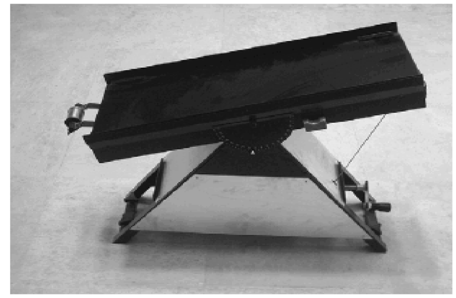

Fig. 2: Apparatus to determine coefficient of static friction.

moisture be absorbed by samples were placed in refrigerator.

$$\Delta W_w = W_t \frac{(M_f - M_i)}{(100 - M_f)} \quad (1)$$

Where ΔW_w, mass of water added, W_t, total seeds mass, M_i, initial moisture content, Mf, final moisture content.

A vernier caliper was used to determine length, width and thickness of about 50 randomly selected seeds of each sample. The geometric mean, Dg and equivalent diameter, Dp, in mm was calculated by considering prolate spheroid shape for a wheat grain and hence Eq (2) and Eq (3) respectively (Mohsenin, 1986).

$$Dp = \left[L\frac{(W+T)^2}{4}\right]^{\frac{1}{3}} \quad (2)$$

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

The sphericity (Sp) defined as the ratio of the surface area of the sphere having the same volume as that of the grain to the surface area of the grain, was determined using following formula (Mohsenin, 1986).

$$\Phi = \frac{(LDT)^{1/3}}{L} \quad (4)$$

Thousand kernel wheat (TKW) was measured by counting 100 seeds and weighing them in an electronic balance to an accuracy of .001g and then multiplied by 10 to give mass of 1000 kernels.

Jain and Bal (1997) have considered seed volume, V and surface area, S may be given by:

$$V = 0.25\left[\left(\frac{\pi}{6}\right)L(W+T)^2\right] \quad (5)$$

$$S = \frac{\pi BL^2}{(2L - B)} \quad (6)$$

Where

$$B = \sqrt{WT} \quad (7)$$

The aspect ratio (Ra) was calculated by (Omobuwajo *et al.,* 1999).

$$R_a = \frac{W}{L} \quad (8)$$

The true density is the ratio of the mass sample of seeds to its pure volume. It was determined by the toluene displacement method (Mohsenin, 1986). And the bulk density is the ratio of the mass sample of the seeds to its total volume. It was determined by filling a predefined container with from a constant high, striking the top level and then weighing the constants (Deshpande *et al.,* 1993; Gupta and Das, 1997; Konak *et al.,* 2002; Paksoy and Aydin, 2004).

The porosity is the ratio of free space between kernels to the total of bulk seeds. That was computed as:

$$\varepsilon = \frac{\rho_k - \rho_b}{\rho_k} x100 \quad (9)$$

The coefficient of static friction was determined with respect to different surfaces: Plywood, compressed plastic and galvanized iron. A hollow metal cylinder (Fig. 1) of diameter 75mm and depth 50mm and open at both ends was filled with the seeds at the desired moisture content and placed on adjustable titling surface such that the metal cylinder did not touche the surface. Then the surface was raised gradually until the filled cylinder just started to slide down (Razavi and Milani, 2006). The emptying angle of repose is the angle with the horizontal at which the material will stand when piled. This was determined by using the apparatus (Fig. 2) consisting of a plywood box of 140-160-35 mm and two plates: fixed and adjustable (Tabatabaeefar, 2003). 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.

Table 1: Several dimensional properties of three wheat varieties

Variety	L	W	T	Dg	Dp	Sp	Ra	V	S
Shiraz	6.78±0.38	3.45±0.24	2.84±0.21	4.05±0.23	4.06±0.23	0.60±0.02	0.51±0.03	35.39±5.84	51.58±5.80
Karoun	6.37±0.42	3.10±0.34	2.78±0.26	3.80±0.30	3.80±0.30	0.60±0.03	0.49±0.04	29.30±6.61	45.53±6.99
shiroudi	7.10±0.58	3.22±0.35	2.69±0.31	3.94±0.29	3.95±0.30	0.56±0.05	0.46±0.05	32.81±7.13	48.92±7.16

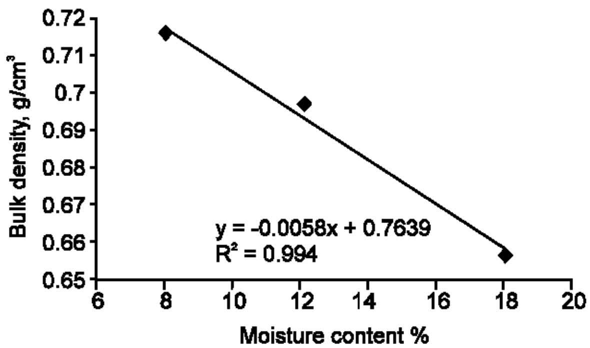

Fig. 3: Effect of moisture content on the bulk density.

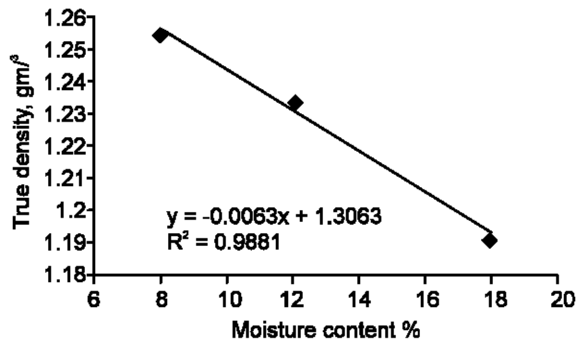

Fig. 4. Effect of moisture content on the true density.

Results and Discussion

The mean and standard deviations of 50 measurements of the dimensions of each wheat variety at moisture content of 8 % is presented in Table 1. Wheat width and thickness values practically did not present significant differences among the cultivars, but there were significant differences between the cultivars at the 5% level of probability among the lengths of the studied varieties. It also indicated that the length of the Shiroudi variety was the longest but the sphericity and aspect ratio of that were the least of all.

The grain volume values for Shiraz, Karoun and Shiroudi cultivars were 35.39, 29.30 and 32.81 mm^3, respectively. The highest geometric and equivalent mean diameter and Surface area values were obtained for Shiraz variety. Bulk density at different moisture levels varied from 0.72 to 0.66gcm^{-3} and indicated a decrease in bulk density with an increasing in moisture content with significant (probability < 0.01) variations as shown in Fig. 3. The bulk density of seed was found to bear the following relationship with moisture content:

$$\rho b = -0.0059M + 0.7639 \quad R^2=0.99$$

This decreasing relation is due to the fact that an increasing in mass owing to moisture gain in the grain sample was lower than the accompanying volumetric expansion of the bulk (Tabatabaeefar, 2003). The negative relationship of bulk density with moisture content was also observed by various other research works (Carman, 1996; Duttas *et al.*, 1988; Gupta and Prakash, 1990; Shepherd and Bhardwaj, 1986). Mohsenin (1986) has shown that bulk density at 11.9% moisture content for wheat was higher, 767 kgm^{-3}, than the value found in this study, at 18% moisture content (715.29kg m^{-3}).

The true density of the wheat was measured at different moisture levels and was found to be negatively correlated and varied from 1.25 to 1.19gcm^{-3} (Fig. 4). The variation in true density with the increasing in moisture content was significant with a value for:

$$\rho_t = -0.0063M + 1.3063, \quad R^2 = 0.99$$

The average value for true density of winter wheat was reported (Nelson, 1980), as 1.34 gcm^{-3} at 11.4% moisture content higher than the value found in this study, 1.23gcm^{-3} at 18% moisture content. However, there is the results were similar to that in this study reported by Ozarslan (2002) for cotton, Gupta and Prakash, 1992 for sofflower and Singh and Goswami (1996) for cumin seed. But Ogut, 1998 reported the reverse result and stated an increase in true density with an increase in moisture content for white Lupin (varied from 980 to 1103 kg/m^3). This result may be due to the biological differences between wheat and white Lupin grains.

There was a variation from 42.93 to 44.87% for the porosity at the moisture levels. This variation was presented in the equation as:

$$\varepsilon = 0.193M + 41.415, \quad R^2 = 1.00$$

Baumler *et al.*, 2004, reported an increase in porosity against moisture content variations and have then evaluated the relationship between porosity and moisture content for safflower seed as:

$$\varepsilon = 39.53 + 0.34M, \quad R^2 = 0.93$$

One thousand kernel weight (TKW) was increased significantly at 5% level of probability from 18.38 to

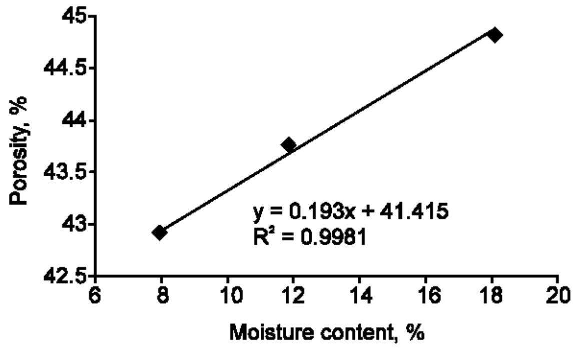

Fig. 5: Effect of moisture content on the porosity.

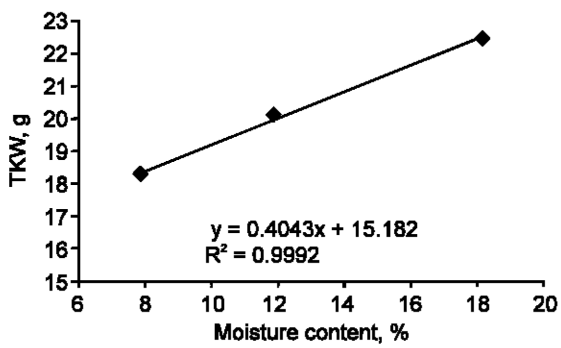

Fig. 6: Effect of moisture content on the TKW.

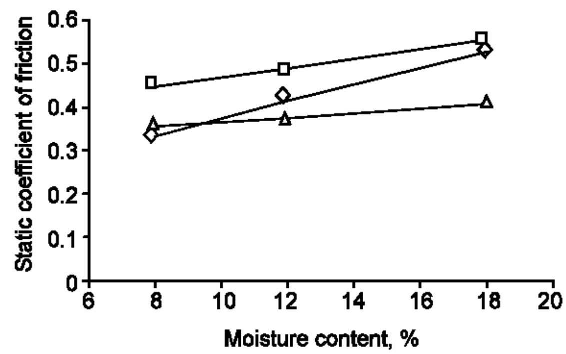

Fig. 7: Effect of moisture content on static coefficient of friction: (Δ) plywood; (◇) compressed plastic and (□) galvanized iron.

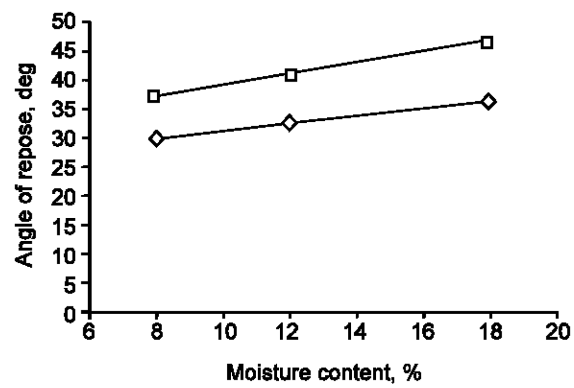

Fig. 8: Effect of moisture content on dynamic (◇) and static (□) angle of repose.

22.43g as the moisture content increased from 8% to 18% w.b. (Fig. 6). Linear Relationship for one thousand kernel weight based on moisture content, M, was determined as follow:

$TKW = 0.4043M + 15.182 \; R^2 = 1.00$

A linear increase in the one thousand kernel weight as the seed moisture content increases has been noted by Sacilik *et al.* (2003) for hemp and Karababa (2006), for popcorn. And Tabatabaeefar (2003) for wheat represented that the TKW increased linearly from 23.2g to 39.7g when the moisture content increased from 0 to 22% d.b.

The static coefficient of friction of wheat grain on three surfaces (compressed plastic, plywood and galvanized iron) against moisture content in the range 8% to 18% w.b. are presented in Fig. 7. It was observed that the static coefficient of friction increased against compressed plastic, plywood with 5% probability level and galvanized iron with 1% probability level with increase in moisture content. This is due to the increased adhesion between the grains and the material surfaces at higher moisture values. Increases of 22.94%, 16.01% and 58.9% were recorded in the case of compressed plastic, plywood and galvanized iron, respectively, as the moisture content increased from 8% to 18% w.b. At all moisture contents, the highest static coefficient of friction were on compressed plastic. This may be owing to more unpolished surface of the compressed plastic than the other materials used. The relationships between static coefficient of friction and moisture content on compressed plastic, plywood and galvanized iron can be represented by the following equations, respectively:

$\phi_{gla} = 0.0105M + 0.3593, \; R^2 = 0.97$

$\phi_{galv} = 0.019M + 0.1778, \; R^2 = 1.00$

$\phi_{plyw} = 0.0058M + 0.3037, \; R^2 = 0.96$

Similar results were found by Sahoo and Srivastava (2002), Ozarslan (2002), Tabatabaeefar (2003), Bulent Coskun *et al.* (2005) and Shepherd and Bhardwaj (1986) for okra, cotton, lentil, wheat, sweet corn and pigeon pea seeds, respectively.

Parde *et al.* (2003) reported that the friction coefficient against plywood, galvanized steel and concrete surfaces for the Koto buckwheat cultivar increased significantly 0.26 to 0.31, 0.25 to 0.29 and 0.38 to 0.43 respectively, with increase in moisture content from 14.8% to 17.9%.

The experimental results for the static and dynamic angle of repose with respect to moisture content are shown in Fig. 8. The values of the static and dynamic angle of repose were found to increase significantly at the 1% level of probability from 37.28 to 47.33 1 and from 29.89 to 36.51, respectively in the moisture range of 8 to 18 % w.b. The static and dynamic angle of repose for wheat has the following relationships with its moisture content:

$$\theta_s = 1.0022M + 29.361, R^2 = 1.00$$

$$\theta_d = 0.663M + 24.528, R^2 = 1.00$$

Tabatabaeefar (2003) found that the values of dynamic angle of repose for wheat increased from 34.7 to 45E in the moisture range of 0 to 22% d.b. Parde *et al.* (2003) reported that the emptying angle of repose for Koto buckwheat cultivar remained constant at about 23.5E from 14.8 to 15.8% moisture content and then increased significantly and the filling angle of repose did not differ significantly at 14.8 to 16.6% but increased significantly to 28.4E at 17.9%.

Conclusion: 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 wheat grains. The following conclusions are drawn from this investigation into the properties of wheat grains:

In this work some dimensional properties of three wheat varieties were determined and compared on their 8% moisture content. By investigation the effect of moisture content on other physical properties of those, were concluded that the porosity, static and dynamic angle of repose and static friction coefficient of all three wheat varieties against different materials (compressed plastic, galvanized iron and plywood) were increased with increase in moisture content. Whereas the bulk and true density were decreased with an increase in moisture content in wheat grains.

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Notations

L	length, mm	Φ	static coefficient of friction
W	width, mm	θ_s	static angle of repose, deg
T	thickness, mm	θ_d	dynamic angle of repose, deg
TKW	thousand kernel weight, g	S	surface area, mm^2
D_g	geometric mean diameter, mm	R^2	correlation determination
D_p	equivalent diameter, mm	R_a	aspect ratio
V	volume, mm3	M	moisture content, %
S_p	sphericity, %	M_i	initial moisture content, %
ρ_b	bulk density, kgm^{-3}	M_f	final moisture content, %
ρ_t	true density, kgm^{-3}	W_t	total weight of sample, g
ε	porosity, %	ΔW_t	weight of required water, g