

RESEARCH PAPER

Analogy of physicochemical attributes of two grape seeds cultivars

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Abstract

S. M. Ahmadi, and B. A. Siahisar. 2011. Analogy of physicochemical attributes of two grape seeds cultivars. Cien. Inv. Agr. 38(2): 291-301. In this study, a range of physicochemical properties (dimensions, kernel volume, mass unit, bulk and true densities, porosity, terminal velocity, static friction coefficient against different surfaces, oil content and fatty acids composition) of the Bojnordi and Fakhri cultivars of grape seeds were studied. Fatty acid composition for both cultivars of grape seeds consisted of palmitic, stearic, oleic, linoleic and linolenic acid. The values for palmitic, stearic, oleic, linoleic and linolenic acid for the Bojnordi cultivar were 9.56, 4.37, 22.87, 62.85 and 0.33% and for the Fakhri cultivar were 9.22, 4.33, 19.75, 66.40 and 0.28%, respectively. All physical properties of the grape seed cultivars were significantly affected by the moisture content in the studied range (11.5 to 23.9 w.b.%). For both cultivars (Bojnordi and Fakhri), the relationships between physical properties and moisture content were linear.

Key words: Chemical properties, fatty acid, grape seed, physical properties.

Introduction

Grape (*Vitis vinifera* L.), one of the largest fruit crops worldwide, are mainly used for juice and wine production. Grape pomace is the solid waste product leftover from wine and juice processing, and generally consists of pulp, skins, and seeds. It is mainly used as animal feed, due to its high fiber content (Palma *et al.*, 2001), or in the production of alcohol. Grape seeds, however, have been traditionally sold to the oil extraction industry, and there has been a recent increase in their demand in the cosmetic and pharmaceutical sectors, given their utility as a

source of antioxidants. Depending on the conditions of the grape at harvest time and the type of press used, 13.5-14.5% of the overall volume of grapes crushed becomes grape pomace waste, with extremes of waste production as high as 20% (Russ and Meyer-Pittroff, 2004). This high-volume waste product contains several valuable components, such as tannins, phytochemicals, and oil.

The use of pomace within the food industry represents an opportunity to lower production costs and create new food sources for human consumption. Grape seeds, which comprise 20 to 26% of the pomace (Kamel *et al.*, 1985), have a high protein content (Ohnishi *et al.*, 1990). They also have an oil content of 10 to 20% (Schuster, 1992) and are rich in vitamin E, which has important health benefits. Grape seed oil consists

mainly of triglycerides (TG), which are comparatively rich in unsaturated fatty acids, such as oleic and linoleic acids, in relation to other oil-rich seeds (Barron *et al.*, 1988). The polyunsaturated fatty acids, such as linoleic and linolenic acids, are essential for human metabolism. Given the lack of enzymes responsible for synthesis of these fatty acids, they must be taken from daily foods. It has been reported that grape seed oil is rich in linoleic acid (Barron *et al.*, 1988; Schuster, 1992). As such, its oil can be used as a source of edible vegetable oil (Ohnishi *et al.*, 1990). Grape seed oil is high-quality culinary oil, possessing a high smoke point (252°C), which makes it a good choice for frying and other high-temperature food applications. Due to its stability and fluidity properties, grape seed oil spreads and mixes better with food, than other oils, such as sunflower, soybean, cotton and colza oil (Arvanitoyannis *et al.*, 2006).

In the last three decades, significant progress has been made in the development of measurement techniques and the accumulation of data concerning the physical properties of biological and agro food materials. The major moisture-dependent physical properties of biological materials are shape and size, bulk density, true density, porosity, mass unit, friction against various surfaces, terminal velocity and angle of repose (Mohsenin, 1980). These properties have been studied for various agricultural materials such as rapeseed (Çalışır *et al.*, 2005), caper (Dursun and Dursun, 2005), pomegranate (Kingsly *et al.*, 2006), safflower (Bäumler *et al.*, 2006), sunflower (Gupta and Das, 1997), cotton (Ozarlan, 2002), cumin (Singh and Goswami, 1996), canola (White and Jayas, 2001), pigeon pea (Baryeh and Mangope, 2002), lentil (Scanlon *et al.*, 2005), green soybean (Sirisomboon *et al.*, 2007), pistachio nut (Kashaninejad *et al.*, 2006), rice (Corrêa *et al.*, 2007), peanut (Aydin, 2007), and sorghum (Mwithiga and Sifuna, 2006).

The size, shape and physical dimensions of grape seed are important in sizing, sorting, sieving and other separation processes. The densities of grape seed are necessary for the design of processing and storage equipment. Porosity affects the resistance to airflow through

bulk grape seed. Terminal velocity is critical for the design of pneumatic conveyors, which transport grape seed using air and separate grape seed from undesirable materials. During the handling, processing and storage of grape seed, the product exerts frictional forces on machinery components or storage structures. The magnitude of these frictional forces determines the amount of power required to convey the material. Static friction between the grape seed and a conveyor belt affects the maximum angle at which the conveyor transport grape seed. (Mohsenin, 1980; White and Jayas, 2001). Therefore, the determination and consideration of these properties plays an important role in the grape seed industry.

The objective of this study was to compare some physicochemical properties of two cultivars of grape seeds, Bojnordi and Fakhri, as a function of moisture content in the range of 11 to 23% (w.b.).

Materials and methods

Measured properties

In this research, two cultivars of grape seeds at five moisture content levels were investigated with respect to their dimensions, geometric mean diameter, sphericity, unit mass, kernel volume, true density, bulk density, porosity, and static coefficient of friction against various surfaces and terminal velocity. The oil content and fatty acid composition of seeds were also determined.

Sample preparation

Seventy kilograms of two cultivars of grape (Bojnodi and Fakhri) was purchased from a local market in Mashhad (province of Khorasan, Iran), and their seeds were separated from the pomace and sun-dried. The seeds were manually cleaned to remove all foreign materials, and broken seeds were eliminated. The initial moisture content of samples was determined by drying about 15 g of samples in an air convec-

tion oven at 103 ± 2 °C until a constant weight was obtained (ASAE S352.2). The process was repeated three times to determine mean values.

In order to obtain samples with higher moisture content, a calculated quantity of distilled water was added to the sample. The quantity of distilled water was calculated from the following equation:

$$W_2 = W_1 \times \left[\frac{M_1 - M_2}{100 - M_1} \right]$$

where W_1 , W_2 , M_1 , and M_2 are sample weight (g), distilled water weight (g), final moisture content (w.b.%) and initial moisture content (w.b.%), respectively. Then, the sample was sealed and kept at 4°C in a refrigerator for at least a week to enable the moisture to distribute uniformly throughout the product. It was necessary to let the samples to warm up to room temperature before starting each test (Kashaninejad *et al.*, 2006). All the physical properties of both seed cultivars were measured at five moisture contents in the range of 11-23% (w.b.).

Determination of oil content and fatty acid composition

Soxhlet extraction was employed to determine the total oil content of 20 g of milled grape seeds. Fatty acids of the grape seed oil were analyzed using gas chromatography (GC) (Agilent Chemstation, 6890N) with a flame ionization detector (FID) and a Permabond FFAP stainless steel column (120 m × 0.25 mm, BPX70, Australia, SGE). Esterification of the fatty acids was performed according to Marquard (1987). Briefly, 20 dried grape seeds were homogenized with 400 mL iso-octane/iso-propanol (9:1, v:v), and the upper phase was removed and put into 2 mL sodium methylate (5 g sodium methylate, 800 mL methanol, 200 mL iso-octane). After orbital shaking followed by a 30-minute wait, 0.7 mL of iso-octane was added to the mixture. Then, 0.5 µL of upper phase containing fatty acid methyl esters (FAME) was injected into the column of GC. The operation conditions of GC were as follows: detector temperature, 240 °C;

injector temperature, 250 °C; column temperature, 120 °C (3 minute hold) to 200 °C at 3 °C/minute (6 minute hold); split ratio, 50:1 mL/H; and helium was used as a carrier gas.

Dimensions, sphericity and mass unit

In order to determine dimensions, sphericity, and unit mass, one hundred grape seeds at each moisture level were randomly selected, and three principal dimensions, namely, minor diameter (thickness), intermediate diameter (width) and major diameter (length), were measured for each using an electronic digital caliper (GUANGLU), which was accurate to 0.01 mm. To obtain the unit mass, each seed was weighed on a precision electronic balance (Sartorius, TE313S) with a reading to 0.001 g. Geometric mean diameter and degree of sphericity were calculated at each moisture level using following equations (Mohsenin, 1980):

$$D = (LWT)^{1/3} \quad \phi = \frac{(LWT)^{1/3}}{L} \times 100$$

where D , ϕ , LWT , L , W , and T are geometric mean diameter (mm), sphericity (%), seed volume, seed length (mm), seed width (mm) and seed thickness (mm), respectively.

Volume, bulk density, true density and porosity

Bulk density was calculated from the mass and volume of the circular container with known volume (0.5 L) that was filled with the grape seeds. After filling the circular container, excess seeds were removed by passing a stick across the top surface using five zigzag motions. The samples were not compacted in any way.

The true density, defined as the ratio of the mass of the seed to the true volume occupied by the sample, was determined using an electronic balance reading to 0.001 g and a pycnometer (Bäumler *et al.*, 2006). Grape seed volume was determined using the liquid displacement method. Toluene (C₇H₈) was used instead of water because it is less readily absorbed by seeds

and because its low surface tension allows it to feel even shallow seed depressions (Mohsenin, 1980). The porosity (ε) of the bulk is the ratio of spaces in the bulk to its bulk volume and was determined by the following equation (Mohsenin, 1980):

$$\varepsilon = \frac{\rho_t - \rho_b}{\rho_t} \times 100$$

where ε , μ , ρ and ρ_t are porosity (%), coefficient of static friction, bulk density (kg m^{-3}) and true density (kg m^{-3}), respectively.

Coefficient of static friction

Coefficient of static friction for grape seeds was determined against surfaces of galvanized iron, plywood, concrete, fiberglass and rubber at different moisture contents. A wooden box of 100 mm length, 100 mm width and 40 mm height without a base or lid was filled with the sample and placed on an adjustable tilting plate faced with the test surface. The sample container was raised slightly (5–10 mm) so that it did not touch the surface. The inclination of the test surface was increased gradually with a screw device until the box started to slide downward, and then, the angle of tilt (α) was read from a graduated scale. For each iteration, the sample in the container was emptied and refilled with a new sample (Joshi *et al.*, 1993; Olajide *et al.*, 2000; Kashaninejad *et al.*, 2006). The coefficient of static friction was calculated from the following relationship:

$$\mu = \text{tg}\alpha$$

where μ is coefficient of static friction and $\text{tg}\alpha$ is tangent of repose angle.

Terminal velocity

The terminal velocity of grape seeds at different moisture content were measured using an air column. For each test, a sample was dropped from the top of a 100-mm-diameter, 2-m-long glass tube. The air flowed upwards in the tube, from bottom to the top, and the air velocity at which the sample suspended was recorded by a hot wire anemometer with at least 0.01 m s^{-1} sensitivity. Ten iterations were performed for each moisture content level (Joshi, *et al.*, 1993; Aydin and Ozcan, 2002; Gezer *et al.*, 2002; Kashaninejad *et al.*, 2006).

Data analysis

Unless otherwise noted, all these experiments were replicated three times, and the average values are reported. The effects of moisture content on different physical properties of grape seed were determined using analysis of variance (ANOVA), and significant differences of means were compared using Duncan's test at the 1% significance level. The optimal relationship between moisture content and physical properties of grape seeds was determined using regression analysis. Analysis of data was performed using SAS 9.2 software.

Results and discussion

Oil content and fatty acid composition

The oil contents and some oil quality properties of grape seeds obtained from the two cultivars are given in Table 1. The values for oil content obtained are 16 and 14.7% for the Bojnordi and Fakhri cultivars, respectively. These results were

Table 1. Oil contents and selected oil quality properties of the two cultivars of grape seeds.

Cultivar	Oil content (%)	Fatty acid composition (%)					Degree of unsaturation (%)
		Palmitic	Stearic	Oleic	Linoleic	Linolenic	
Bojnordi	16.0	9.56	4.37	22.87	62.85	0.33	86.07
Fakhri	14.7	9.22	4.33	19.75	66.40	0.28	86.45

similar to those obtained by Ohnishi *et al.* (1990), Schuster (1992) and Baydar and Akkurt (2001). They reported that the seeds of the different grape cultivars contained 9.9 to 20.0% oil. Fatty acid composition of grape seeds consisted of palmitic, stearic, oleic, linoleic, and linolenic acids for both cultivars. The values for palmitic, stearic, oleic, linoleic, and linolenic acids in the Bojnordi cultivar were 9.56, 4.37, 22.87, 62.85 and 0.33% and for the Fakhri cultivar were 9.22, 4.33, 19.75, 66.40 and 0.28%, respectively. Other researchers have also reported that grape seed oil contains mainly palmitic, stearic, oleic, and linoleic acids (Baydar and Akkurt, 2001; Barron *et al.*, 1988; Schuster, 1992). Baydar and Akkurt (2001) reported that the ranges of fatty acids in the seeds of 18 grape cultivars were 6.5 to 9.7% for palmitic acid, 3.5 to 7.3% for stearic acid, 17.8 to 26.5% for oleic acid, 60.1 to 70.1% for linoleic acid and less than 1% for linolenic acid. The fatty acid composition of grape seed oil is similar to that of safflower, sunflower, soybean, maize and cotton seed oils, which are of the linoleic type (Weiss, 1983). The fatty acid composition of grape seed oil is similar to that of sunflower oil. Sunflower oil generally comprises 60% linoleic, 25% oleic, 8% palmitic and 5% stearic acid (Weiss, 1983).

The degree of unsaturation in the grape seed oil (Table 1) was over 86% due to unsaturated fatty acid. High levels of unsaturation play an important role in lowering high blood cholesterol and also in the treatment of atherosclerosis (Axtell, 1981). Poly-unsaturated fatty acids, such as linoleic and linolenic acids, are essential for the human body because they cannot be synthesized in the body. As such, grape seed oil, which is very rich in linoleic acid, may be

a valuable source of dietary fat. Grape seed oil was rather poor in linolenic acid. Low levels of linolenic acid are desirable in edible oils because high levels of this fatty acid can result in undesirable odors and tastes. Furthermore, because linolenic acid is easily oxidized due to its having three double bonds on its hydrocarbon chain, the stability or shelf-life of an oil rich in linolenic acid would be too short. Because of its low quantities of linolenic acid, grape seed oil also has advantages in terms of human health and shelf-life.

Dimensions and unit mass

Table 2 shows the dimensions and mass of two grape seeds cultivars at various moisture contents in the range of 11.5 to 23.9 (w.b.%). Significant differences were observed among the measured parameters with increases in moisture content. Increases of moisture content caused an increase in grape seed size. The dimensions of both seed cultivars increased linearly with increasing moisture content. Similar results were found by Deshpande *et al.* (1993) for soybeans, Gezer *et al.* (2002) for apricot pits and kernels and Carman (1996) for lentil seeds. The relationship between length, width, thickness and unit mass and moisture content of grape seeds for the Bojnordi and Fakhri cultivars are given by the following equations:

$$L_b = 2.4107 M_c + 7.3696 \quad (R^2 = 0.94)$$

$$L_f = 0.6167 M_c + 7.6744 \quad (R^2 = 0.95)$$

$$W_b = 1.3187 M_c + 4.3538 \quad (R^2 = 0.98)$$

Table 2. Dimensions and unit mass of the two cultivars of grape seeds.

Cultivar	Moisture content (w.b.%)	Length (mm)	Width (mm)	Thickness (mm)	Mass (g)
Fakhri	11.5	7.74±0.43	4.39±0.30	2.95±0.26	0.047±0.005
	16.8	7.78±0.40	4.46±0.25	2.97±0.30	0.052±0.052
	19.8	7.80±0.38	4.51±0.32	3.05±0.24	0.054±0.006
	23.8	7.81±0.43	4.55±0.31	3.09±0.25	0.055±0.006
Bojnordi	11.6	7.62±0.58	4.49±0.19	2.92±0.25	0.048±0.005
	15.9	7.78±0.56	4.58±0.30	2.97±0.26	0.053±0.006
	19.7	7.84±0.38	4.61±0.26	3.03±0.26	0.054±0.006
	23.9	7.91±0.46	4.67±0.26	3.08±0.31	0.058±0.008

$$W_f = 1.2881 M_c + 4.2555 \quad (R^2 = 0.98)$$

$$T_b = 1.360 M_c + 2.756 \quad (R^2 = 0.99)$$

$$T_f = 0.046 M_c + 2.894 \quad (R^2 = 0.95)$$

$$M_b = 0.072 M_c + 0.0405 \quad (R^2 = 0.95)$$

$$M_f = 0.0652 M_c + 0.0407 \quad (R^2 = 0.92)$$

Geometric mean diameter and sphericity

Table 3 shows the sphericity and geometric mean diameter of grape seeds at different moisture contents. The sphericity and geometric mean diameters of both cultivars increased with increasing moisture content. When the moisture content increased, the sphericity of the grape seeds increased from 31.10 to 32.32% and from 32.11 to 32.20% for the Bojnordi and Fakhri cultivars, respectively. Calculated values of the geometric mean diameter varied from 2.479 to 2.492 and from 2.477 to 2.487 mm for the Bojnordi and Fakhri cultivars, respectively. The relationship between sphericity and moisture content and the relationship between geometric mean diameter and moisture content were found to have the following values for the Bojnordi and Fakhri cultivars, respectively:

$$\phi_b = 8.8195 M_c + 30.122 \quad (R^2 = 0.96)$$

$$\phi_f = 0.7831 M_c + 32.014 \quad (R^2 = 0.95)$$

$$D_b = 0.0955 M_c + 2.4671 \quad (R^2 = 0.89)$$

$$D_f = 0.0866 M_c + 2.4672 \quad (R^2 = 0.98)$$

Bulk density

The experimental results of the bulk density for grape seeds at different moisture levels are presented in Figure 1. As the moisture content increased from 11.5 to 23.9%, the bulk density of the Fakhri and Bojnordi cultivars decreased from 603 to 590 and from 587 to 570 kg m⁻³, respectively. The decrease in the bulk density of both grape seed cultivars following an increase in moisture content indicates that the increase in mass owing to moisture gain in the sample is less than the accompanying volumetric expansion of the bulk. The negative linear relationship between bulk density and moisture content was observed by Deshpande *et al.* (1993) with respect to soybean, by Carman (1996) with respect to lentil, by Gupta and Das (1997) with respect to sunflower and by Konak *et al.* (2002) with respect to chick pea. The following equations were obtained to show the relationship between moisture content and bulk density of the Bojnordi and Fakhri cultivars, respectively:

$$\rho_{bf} = -1.3882 M_c + 600.88 \quad (R^2 = 0.90)$$

$$\rho_{bb} = -1.0789 M_c + 615.14 \quad (R^2 = 0.99)$$

Table 3. Sphericity and geometric mean diameter of the two grape seeds cultivars. w.b.:wet basis.

Cultivar	Moisture Content (w.b.%)	Sphericity (%)	Geometric mean diameter (mm)
Fakhri	11.5	32.11±1.55	2.477±0.030
	16.8	32.13±1.35	2.480±0.030
	19.8	32.16±1.53	2.485±0.024
	23.8	32.20±1.83	2.487±0.035
Bojnodi	11.6	31.10±2.23	2.479±0.045
	15.9	31.56±1.68	2.481±0.034
	19.7	31.75±1.26	2.483±0.029
	23.9	32.32±1.92	2.492±0.039

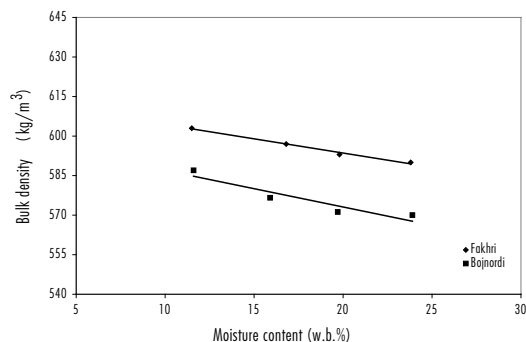


Figure 1. Effect of moisture content on the bulk density of the grape seeds cultivars. w.b.:wet basis.

Kernel volume

Figure 2 presents kernel volume changes of grape seeds at different moisture contents. When the moisture content increased from 11.5 to 23.9% (w.b.%), the kernel volume of both cultivars of grape seeds were observed to increase linearly from 0.047 to 0.053 and from 0.048 to 0.052 cm³ for the Bojnordi and Fakhri cultivars, respectively. The moisture content had no significant effect on the kernel volume of either grape seed cultivar. The following equations were shown to represent the relationship between moisture content and kernel volume of the Bojnordi and Fakhri cultivars:

$$V_b = 0.0005M_c + 0.0418 \quad (R^2 = 0.96)$$

$$V_f = 0.0003M_c + 0.0446 \quad (R^2 = 0.89)$$

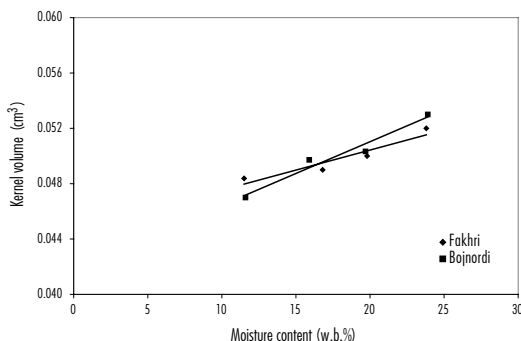


Figure 2. Effect of moisture content on the kernel volume of the two grape seed cultivars. w.b.:wet basis.

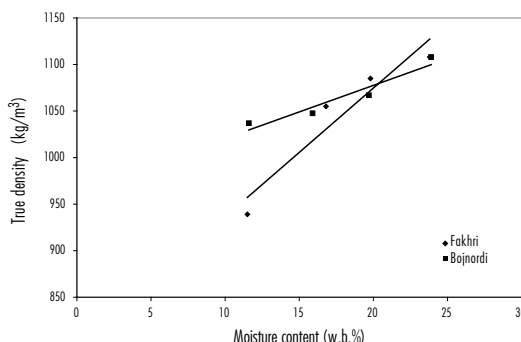


Figure 3. Effect of moisture content on the true density of the two grape seeds cultivars. w.b.:wet basis.

True density

The variation in true density with respect to moisture content for both cultivars of grape seeds is shown in Figure 3. The true density of grape seeds at different moisture levels varied from 1037 to 1108 and from 939 to 1108 kg m⁻³ for the Bojnordi and Fakhri cultivars, respectively. The increasing trend of the true density of grape seeds may be attributed to the higher moisture gain of the seeds compared to their volumetric expansion. An increase in true density in response to an increase in moisture content has been reported for cumin (Singh and Goswami, 1996), sunflower (Gupta and Das, 1997), pigeon pea (Baryeh and Mangope, 2002), and pistachio nut (Kashaninejad *et al.*, 2006); however, Deshpande *et al.* (1993) and Ozarslan and Konak *et al.* (2002) found the true densities of soybean, cotton and chickpea to decrease as the moisture content increased. The relationship between moisture content and true density appears to be linear for both cultivars, which can be represented by the following equations:

$$\rho_b = 5.7049M_c + 963.5 \quad (R^2 = 0.92)$$

$$\rho_f = 13.834M_c + 798.08 \quad (R^2 = 0.91)$$

Porosity

Because porosity depends on the bulk as well as true densities, the magnitude of variation in porosity depends only on these factors. The values of porosity were calculated using the data on bulk and true densities of the grape seeds, and the results are presented in Figure 4. Porosity increased from 43.4 to 48.5 % and from 35.8 to 46.8% for the Bojnordi and Fakhri cultivars, respectively. A similar trend was reported with for sunflower (Gupta and Das, 1997), lentil (Scanlon *et al.*, 2005) and pigeon pea (Baryeh and Mangope, 2002), but a different trend was reported for pistachio nut (Kashaninejad *et al.*, 2006) and soybean (Sirisomboon *et al.*, 2007). The relationship between moisture content and porosity appears to be linear for both cultivars, which can be represented by the following equations:

$$\epsilon_b = 0.4175M_c + 38.424 \quad (R^2 = 0.99)$$

$$\epsilon_f = 0.8983M_c + 26.675 \quad (R^2 = 0.91)$$

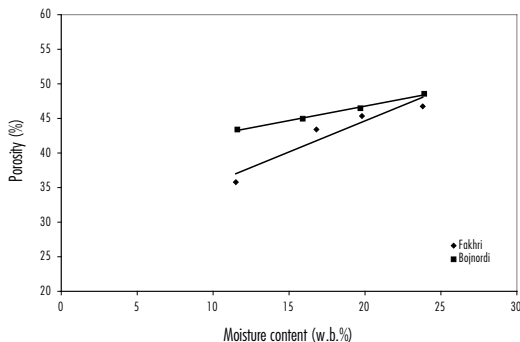


Figure 4. Effect of moisture content on the porosity of the two grape seeds cultivars. w.b.:wet basis.

Static coefficient of friction

Table 4 shows the static coefficient of friction for the Bojnordi and Fakhri cultivars as determined with respect to galvanized iron, plywood, fiberglass, concrete and rubber surfaces at different moisture contents. At all of the moisture contents, the static coefficient of friction was highest for both cultivars with respect to rubber. It was observed that the static coefficient of friction for grape seeds on all surfaces increased linearly with increasing moisture content. The relationships between these coefficients against various

surfaces and moisture contents of grape seeds cultivars are shown in Table 5. The reason for the increased friction coefficient at higher moisture content may be because the water present in the seeds acts as a cohesive force on the contact surface. As the moisture content of seeds increases, the surface of the samples becomes stickier. Water tends to adhere to surfaces, and the water on the moist seed surface would be attracted to the surface across which the sample is being moved. Other researchers have also found that, as the moisture content increased, the static coefficient of friction increased (Kashaninejad *et al.*, 2006; Joshi *et al.*, 1993; Gezer *et al.*, 2002; Carman, 1996; Gupta and Das, 1997).

Terminal velocity

The variation in terminal velocity of grape seed cultivars (Bojnordi and Fakhri) with respect to moisture content of the sample is presented in Figure 5. The terminal velocity was found to increase from 7.51 to 8.28 and from 7.40 to 8.83 m s⁻¹ for the Bojnordi and Fakhri cultivars, respectively, in the moisture range of 11.5 to 23.9% (w.b.%). As the moisture content increased, the terminal velocity was found to increase linearly. The increase in terminal velocity following an increase in moisture content can be attributed to the increase in mass of an individual sample per unit frontal area facing the air stream. The other reason for this increase is that the drag force is affected by the moisture content of particle. Joshi *et al.* (1993), Carman

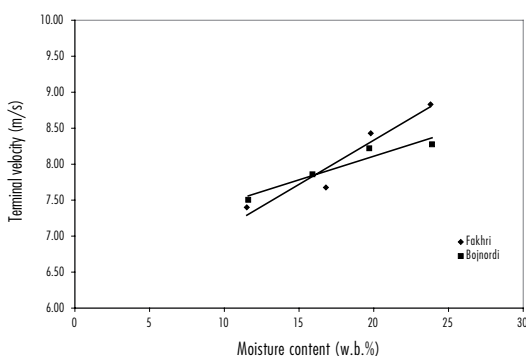
Table 4. Static coefficient of friction of the two grape seeds cultivars at different moisture contents.

Cultivar	Moisture Content (w.b.%)	Galvanized iron	Plywood	Fiberglass	Concrete	Rubber
Fakhri	11.5	0.40	0.39	0.38	0.48	0.48
	16.8	0.52	0.53	0.54	0.55	0.59
	19.8	0.53	0.56	0.59	0.57	0.62
	23.8	0.57	0.57	0.62	0.59	0.65
Bojnordi	11.6	0.32	0.44	0.33	0.49	0.52
	15.9	0.49	0.50	0.50	0.56	0.58
	19.7	0.52	0.51	0.53	0.57	0.60
	23.9	0.59	0.56	0.59	0.61	0.62

w.b.:wet basis.

Table 5. Relationships between the static coefficient of friction against different surfaces and the moisture content of the two grape seed cultivars.

Cultivar	Moisture content (w.b.%)	Surface	Equation	R ²
Fakhri	11.5- 23.8	Concrete	$\mu = 0.0086 Mc + 0.3915$	0.92
		Galvanized iron	$\mu = 0.0135 Mc + 0.2611$	0.92
		Fiber glass	$\mu = 0.0183 Mc + 0.1963$	0.89
		Plywood	$\mu = 0.0151 Mc + 0.2414$	0.87
		Rubber	$\mu = 0.0139 Mc + 0.3333$	0.95
Bojnordi	11.6- 23.9	Concrete	$\mu = 0.0085 Mc + 0.4048$	0.85
		Galvanized iron	$\mu = 0.0204 Mc + 0.1135$	0.90
		Fiber glass	$\mu = 0.0196 Mc + 0.1386$	0.88
		Plywood	$\mu = 0.0092 Mc + 0.3403$	0.92
		Rubber	$\mu = 0.0081 Mc + 0.4353$	0.89

**Figure 5.** Effect of the moisture content on the terminal velocity of the two grape seeds cultivars. w.b.:wet basis.

(1996), Gupta and Das (1997), Gezer *et al.* (2002) and Kashaninejad *et al.* (2006) found similar results for pumpkin, lentil, sunflower, apricot pit and kernel and pistachio nut, respectively. The relationship between moisture content and terminal velocity can be represented by the following equations:

$$V_{tb} = 0.0656M_c + 6.7992 \quad (R^2 = 0.93)$$

$$V_{tf} = 0.1227M_c + 5.8791 \quad (R^2 = 0.93)$$

This study revealed that the seeds of two cultivars of grape (Fakhri and Bojnordi) contain 14.7 to 16.0% oil. Baydar and Akkurt (2001) showed that the oil concentration of 18 grape cultivar seeds ranged from 11.6 to 19.6%. The presence

of fatty acids, such as linoleic and linoleic acids in grape seed oil, both of which have important health benefits, can be considered to be valuable in edible oils. Baydar and Akkurt (2001) showed that oleic and linoleic acids of grape seeds range from 17.8 to 26.5% and from 60.1 to 70.1%, respectively. Several engineering properties of the two cultivars of grape seeds were also investigated with respect to moisture content in the range of 11.5 to 23.9 (w.b.%). The results indicated that the modifications of moisture content of grape seed caused a linear variation on several different physical properties. Razavi and Fathi (2009) showed that the average values of seed length, width, thickness, geometric mean diameter, surface area, filling angle of repose, and terminal velocity decreased linearly with a decrease in the moisture content. This study also found that there is a difference in the physiochemical properties of the Bojnordi and Fakhri cultivars of grape seeds. In addition, all physical properties of the two cultivars depend on their moisture contents. In particular, these properties are very useful in the design of equipment involved in processing, transportation, and storage. Given that Khorasan is the main grape-producing region in Iran (15.42%) and that Bojnordi and Fakhri are the most-cultivated grape cultivars in Khorasan (FAO 2005), taking advantage of the difference in the seed properties of these cultivars will assist in the design of more versatile machinery for the processing of grapes in Khorasan.

Resumen

S. M. Ahmadi y B. A. Siahshar. 2011. Analogía de los atributos físico-químicos de dos cultivares de semillas de uva. *Cien. Inv. Agr.* 38(2):291-301. En este estudio fueron estudiadas una serie de propiedades físico-químicas (dimensiones, el volumen del núcleo, unidad de masa, volumen y densidad real, porosidad, la velocidad terminal, coeficiente de fricción estática con materiales diferentes, contenido de aceite y composición de ácidos grasos) en los cultivares de semillas de uva Bojnordi y Fakhri. Composición de ácidos grasos de los dos cultivares de semillas de uva consistió de ácido palmítico, esteárico, oleico, linoleico y linolénico. Los valores de ácido palmítico, esteárico, oleico, linoleico y linolénico, para el cultivar Bojnordi fueron 9.56, 4.37, 22.87, 62.85 y 0.33% y para el cultivar Fakhri fueron 9.22, 4.33, 19.75, 66.40 y 0.28%, respectivamente. Todas las propiedades físicas de los cultivares de semilla de uva se afectado significativamente por el contenido de humedad en el rango estudiado (11,5 a 23,9 w.b.%). Para los dos cultivares (Bojnordi y Fakhri), las relaciones entre las propiedades físicas y contenido de humedad fueron lineales.

Palabras clave: Ácidos grasos, propiedades físicas, propiedades químicas, semilla de uva.

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