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European Journal of Experimental Biology, 2012, 2 (6):2456-2464

ISSN: 2248 –9215
CODEN (USA): EJEBAU

Morphology and physicochemical properties of 40 genotypes of almond (*Amygdalus communis* L.) fruits

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ABSTRACT

In order to study morphological, physical characteristics of almond nuts and compare the chemical content of their hulls and shells, 40 almond genotypes were selected. The fruits of these almonds were collected, their hulls and shells dried, ground and then stored in room temperature. Morphological and physical characteristics such as ease of hulling, ease of harvesting, nut shape, shell colour intensity, marking of outer shell, softness of shell, kernel colour intensity, shriveling of kernel, kernel taste, kernel size, nut and kernel weight (g), length, width and thickness (mm) were determined. Total phenolic content was determined using the Folin–Ciocalteu (F–C) method by preparing methanolic extracts from these almond hulls and shells. Total protein, sugar and fat content were determined by Folin-Lowery, Dubois and Leiboritz methods, respectively. The results of this study showed that total phenolic and fat content of hulls was higher than that of shells but total protein and sugar of shells was higher than that of hulls in all Amygdalus communis L. genotypes.

Keywords: Almond (*Amygdalus communis* L.); Fruits; Genotype; Morphology; Physicochemical; Properties.

INTRODUCTION

Nuts are known as a source of nutritious food with high lipid content. Replacing half of the daily fat intake with nuts lowered total LDL cholesterol levels significantly in humans [1]. The observed blood cholesterol lowering effects of nuts were far better than what was predicted according to their dietary fatty acid profiles [2];[3]. Research also shows a connection between regular nut consumption and decreased incidence of coronary heart disease [4]. These beneficial physiological effects suggest that bioactive compounds of nuts may possess lipid altering activities due to additive/synergistic effects and/or interactions with each other [5].

Almonds (*Prunus amygdalus Batsch*), which belong to the *Rosaceae* family that also includes apples, pears, prunes, and raspberries, are one of the most popular tree nuts on a worldwide basis and rank number one in tree nut production. They are typically used as snack foods and as ingredients in a variety of processed foods, especially in bakery and confectionery products [6]. The United States is the largest almond producer in the world and most of the U.S. almonds are grown in California [7]; [8]. Almonds, when incorporated in the diet, have been reported to reduce colon cancer risk in rats [9] and increase HDL cholesterol and reduce LDL cholesterol levels in humans [10]. The peach-like almond fruit consists of the edible seed or kernel, the shell, and the outer hull. At maturity the hull splits open. When dry, it may be readily separated from the shell. The almond pit, containing a kernel or edible seed, is the nut of commerce. Shelled almonds may be sold as whole natural almonds or processed into various almond forms. The whole natural almonds have had their shells removed but still retain their brown skins; blanched whole almonds have had both their shells and skins removed [6]. The processing by-products, shells and hulls of almond fruit, account for more than 50% of dry weight of the fruit [11];[12]. Almond hulls contain triterpenoids [13], lactones [6], phenolics [14], and sterols [15]. The water extraction of hulls [16], solvent extraction of shells [17] and methanol extraction of hulls and shells [8] to produce food ingredients and antioxidants, respectively, have been studied. Almond shell is the name given to the ligneous material forming the thick endocarp or husk of the almond fruit. When the fruit is processed to obtain the edible seeds, big ligneous fragments are separated. These materials remain available as a waste product for which no important industrial use has been developed, so they are normally incinerated or dumped without control [18]. This industrial residue is the woody endocarp of the almond fruits. The high xylan content of almond shells makes them a suitable substrate for the production of xylose [19], furfural [20] or for fractionation into cellulose, pentosans and lignin [12].

The studies reporting chemical composition in different genotypes or species of almond, their hulls and shells, specifically shell portion are limited [21];[16]. Also, recent research findings are associated with characterization and identification of almond hull, shell and skin phenolic compounds to use them as natural antioxidants and antiradicals in foods and oxidative damage [5];[6];[7];[8];[13];[14];[15];[17];[22]; [23];[24];[26];[27]. This prompted us to investigate about other beneficial compounds in almond hulls and shells. The objectives of this paper were to introduce morphological and physical characteristics of almond fruits and to determine total phenolics, sugar, protein and fat contents among different genotypes of almond, their hulls and shells from Azarbaijan region (East Azarbaijan Province).

MATERIALS AND METHODS

Plant materials and sampling

This study was carried out in several orchards at "Esfahlan" located in the eastern Azarbaijan region, in Northwest Iran. Precipitation was about 400 mm per year and maximum air temperature around 35 °C during the summer months. In 2007, almond genotypes were selected. Trees representing almond (*Amygdalus communis* L.) genotypes were marked as the native population and 40 genotypes were selected from that almond population (400 trees). Almond fruits from each genotype were harvested on 25 August, and nut samples were collected from each genotype for evaluation of the following traits: ease of hulling, ease of harvesting, nut shape, shell colour intensity, marking of outer shell, softness of shell, kernel colour intensity, shriveling of kernel, kernel taste, kernel size, nut and kernel weight (g), length (mm), width (mm) and thickness (mm). The evaluation and scoring for each characteristic based on the descriptor list for almond is included in Table 1 [28]. 50 nuts were randomly chosen from the harvested almonds for fruit analyses.

Biochemical analyses

Extraction and determination of total phenolics

The green shells cover (Hulls) and inner shells of *Amygdalus communis* L. genotypes were separated, dried at room temperature and then reduced to coarse powder. This powder (3 g) was extracted with methanol (50 ml) in soxhlet apparatus for 30 min at 80 ^{o}C [7]; [8]. The total phenolics were assayed colorimetrically by means of the Folin-Ciocalteu method, as modified by Singleton and Rossi [29]. Ten-fold diluted Folin-Ciocalteu reagent (2.5 ml), 2 ml of 7.5% sodium carbonate, and 0.5 ml phenolic extract were mixed well. The absorbance was measured at 765 nm after 15 min heating at 45 ^{o}C. A mixture of water and reagents was used as a blank. The content of phenolics was expressed as mg gallic acid equivalents (GAE) in per gram extract.

Determination of total fat

The extraction with ether method was used for measuring of total fat content [30]. One gram of each sample was transferred in test tubes and 10 ml ether was added to them, twice. Each time tubes were placed in 40 ^{o}C oven for 12 hr and above solutions were transferred to balanced tubes. Tubes were placed in 40 ^{o}C oven for 4 hr so that its ether evaporated. Weight difference of tubes before and after experience was used for fat content measurement.

Determination of total protein
To measure total protein, the Lowry method was used [31]. 0.005 gram from dried samples was transferred to test tubes and 4 ml from below extraction buffer was added:
1. Tris (0.2N): 50 ml,
2. HCl (0.2N): 26.8 ml,
3. Sucrose: 17.2 gr,
4. Ascorbic acid: 1 gr.

Samples were centrifuged in 8000 rate. 1 ml from above solution was added to C solution that was prepared as follows:
A solution: $NaCO_3$: 2 gr, K.Na tartaric: 0.02 gr, NaOH: 0.4 gr and distilled water: 100 ml.
B solution: $CuSO_4.5H_2O$: 0.5 gr and distilled water: 100 ml.
C solution: A solution: 50 ml +B solution:1 ml

After 10 min, Folin indicator that was diluted the ratio of 1 to 9 before, was added. Tubes were placed in darkness location for 30 min. Light absorption of samples was measured by Spectrophotometer in wave length of 660 nm. Protein content was obtained from below formula:
Protein content (%) = $[420A - 6.9 \times 4] / 50$

Determination of total sugar
To measurement total sugar content of almond hulls and shells, the Dubois et al. [32] method was used. 0.1 gram from dried samples was transferred to test tubes and then 10 ml ethanol 70% was added to above test tubes. To liberate soluble sugars of almond hulls and shells, the test tubes were placed in refrigerator (4 °C) for a week. After a week, 0.1 ml solution was taken from these test tubes and transferred to other test tubes and the volumes of these test tubes were increased to 2 ml. 0.5 ml phenol 5% was added to the test tubes containing diluted sugars solution and then mixed well. After mixing the solutions, pure sulfuric acid 5% was added to all the test tubes. After exactly 30 minutes, the absorbance at 485 nm was measured. Sugar concentration in all samples was calculated according to prepared standard curve for glucose.

Statistical analysis
All the assays were carried out in triplicate. The results are expressed as mean values and standard error (SE) of the mean or standard deviation (SD) of the mean. The differences between the almond genotypes were analyzed using one-way analysis of variance (ANOVA). This treatment was carried out using SPSS v. 11.5 program.

RESULTS AND DISCUSSION

Selected important nut and kernel characteristics have been investigated in this study. Obtained data have been given separately for each almond genotype in Tables 2 and 3. Ease of hulling is an important characteristic for almonds. In these genotypes, ease of hulling changed from intermediate to high. Ease of harvesting generally intermediate except for E2-1, E2-2, E3-5, E4-3, E4-4, E4-5, E5-4, E5-5, E6-1, E6-3, E6-5, E7-1, E7-3, E7-4, E8-1, E8-2, E8-4 and E8-5. Most of genotypes have oblong (19 genotypes) and ovate (12 genotypes) nuts. E2-1, E4-5, E6-1, E6-2, E6-5, E7-4, E8-1 and E8-4 genotypes have cordate nut shape. The nut shape of E4-1 is extremely narrow. Round nut shape was not found among almond nuts. Shell colour intensity changed from intermediate to dark among different collected nuts of almond genotypes. Most genotypes of almond nut are identified with intermediate to densely pore on their outer shell. The nuts of E1-3, E4-3, E4-4 and E3-3, E7-1 is scribed and sparsely pore, respectively. Also without pore nut are not seen among almond fruits. Softness of shell in the 32 genotypes consisted of generally hard but E1-2, E1-3, E2-2, E2-3, E4-4, E4-5, E7-2 and E8-4 had intermediate shell types. There was not hard and extremely hard shells among almond nuts. Most of genotypes in the populations had light (21 genotypes) and intermediate (12 genotypes) colour kernels. Kernel colour of E1-2, E1-3, E2-2, E4-3, E6-3, E7-1 and E8-2 is dark. Also most of the almond genotypes had intermediate or slightly wrinkled kernels. But the kernels of E1-2, E1-4, E2-1, E3-5, and E6-1 were wrinkled. In addition, all genotypes of almonds have sweet kernel taste but E4-3 and E4-4 are bitter. The mean values of length, width, thickness, weight of nut and kernel in 40 almond genotypes differed statistically ($P \leq 0.05$). Nut weight of the almond genotypes ranged between 3.23 to 8.34 g, length from 30.5 to 43.6 mm, width from 18.3 to 29.4 mm, and thickness 15.00 to 22.33 mm. Kernel weight ranged between 0.89 to 1.39 g, length from 20.0 to 32.0 mm, width from 11.6 to 18.2 mm, and thickness 6.12 to 9.86 mm (Table 4).

Contents of total phenolics, protein, sugar and fat in almond hulls and shells also differed statistically ($P \leq 0.05$) (Table 5). The mean value of total phenplics content in 40 almond hull phenolic extracts was 77.1±1.99 mg gallic acid equivalents/g extract. Maximum total phenolics content in hull extract was 115.4±5.32 mg/g for E3-2 and minimum total phenolics content was 45.3±1.22 mg/g for E1-2. The content of total phenolics in almond hull extract reported by Siriwardhana and Shahidi [22], Wejerante et al. [7], Subhashinee et al. [23] and Jahanban Esfahlan et al. [8] were 71.1±1.74 mg catechin equivalents/g extract, 71±2 mg quercetin equivalents/g extract and 78.2±3.41 mg gallic acid equivalents/g extract, respectively. The mean value of total phenolics content in different almond shells phenolics extract was 35.2±1.91 mg gallic acid equivalents/g extract. Highest total phenolics content of shell extract 59.6±0.32 mg/g for E5-4 and lowest phenolics content of shell extract 11.9±0.65 for E8-5 mg/g was obtained. Total phenolics content for almond shell extract recorded as 2.2 g gallic acid equivalents/ 100 g shell by Moure et al. [24] and 38.0±3.30 mg gallic acid equivalents/g extract by Jahanban Esfahlan et al. [8]. In this study, although the genotypes showed similar findings to related references with respect to total phenolics content, some genotypes contained higher total phenolics than identified almond varieties or genotypes. Also values of hulls total phenplics content were higher than that of their shells in all almond genotypes. This study shows that the mean value of total phenolics content in 40 almond hulls extract (77.1±1.99 mg/g) was two-fold higher than that of their shell extract (35.2±1.91 mg/g). This indicates that total phenolic of almond hull extract was higher than of its shell in different genotypes of almond.

1. Ease of hulling	2. Ease of harvesting	3. Kernel size	4. Nut shape
Low	Low	3 Small	1 Round
Intermediate	Intermediate	5 Medium	2 Ovate
High	High	7 Large	3 Oblong
		9 Extremely large	4 Cordate
			5 Extremely narrow

5. Shell colour intensity	6. Marking of outer shell	7. Softness of shell
1 Extremely light	0 Without pores	1 Extremely hard
3 Light	3 Sparsely pored	3 Hard
5 Intermediate	5 Intermediate	5 Intermediate
7 Dark	7 Densely pored	7 Soft
	9 Scribed	9 Paper

8. Kernel colour intensity	9. Shrivelling of kernel	10. Kernel taste
1 Extremely light	3 Slightly wrinkled	3 Sweet
3 Light	5 Intermediate	5 Intermediate
5 Intermediate	7 Wrinkled	7 Bitter
7 Dark		
9 Extremely dark		

Table 1: Evaluation and scoring for each characteristic

The mean value of almond hulls total fat content in different genotypes was 4.0±0.91%. Maximum total fat content in almonds hull was 5.7±1.32% for E4-3 and minimum value was 2.3±0.57 for E5-5. The mean value of shell total fat content 2.3±0.67% was obtained. Highest shell total fat content was 3.8±1.32% in E7-2 genotype and lowest value of shell total fat content was 0.8±0.54% for E4-5 genotype. The results of this study for almond hulls and shells total fat content shows that the mean value of almond genotype hull total fat content (4.0±0.91%) was higher than that of their shells mean value (2.3±0.67%). Therefore, this indicates that fat content of almond hull was higher than that of its shell in different genotypes of almonds.

The mean value of total protein content for different genotypes of almond hulls 2.6±0.71% was obtained. Highest hull total protein content was 4.5±0.74% in E7-2 genotype and lowest value was 1.2±0.94% for E3-4 genotype. Almond hull protein content was reported as 2-5% by Weir [33]. The mean value of almond shell total protein content was 3.5±0.68%. Maximum total protein of shells was 5.4±1.32% for E8-2 and minimum value was

1.8±0.33% for E6-5 genotype. Values of shells total protein content were higher those that of their hull values in all almond genotypes. Also the mean value of almond shells total protein content (3.5±0.68%) was higher than that of hulls mean value (2.6±0.71%). This shows that almond shell total protein content was higher than that of its shell.

Genotype	Ease of hulling	Ease of harvesting	Nut shape	Shell colour intensity	Marking of outer shell	Softness of shell
E1-1	Intermediate	Intermediate	Oblong	Intermediate	Densely pores	Hard
E1-2	Intermediate	Intermediate	Oblong	Intermediate	Intermediate	Intermediate
E1-3	High	Intermediate	Ovate	Intermediate	Scribed	Intermediate
E1-4	High	Intermediate	Oblong	Dark	Densely pores	Hard
E1-5	High	Intermediate	Ovate	Dark	Densely pores	Hard
E2-1	High	High	Cordate	Intermediate	Densely pores	Hard
E2-2	High	High	Oblong	Dark	Intermediate	Intermediate
E2-3	Intermediate	Intermediate	Ovate	Dark	Intermediate	Intermediate
E2-4	High	Intermediate	Oblong	Intermediate	Densely pores	Hard
E2-5	High	Intermediate	Ovate	Intermediate	Densely pores	Hard
E3-1	Intermediate	Intermediate	Ovate	Intermediate	Densely pores	Hard
E3-2	High	Intermediate	Oblong	Intermediate	Densely pores	Hard
E3-3	High	Intermediate	Ovate	Dark	Sparsely pores	Hard
E3-4	High	Intermediate	Ovate	Dark	Intermediate	Hard
E3-5	High	High	Oblong	Intermediate	Densely pores	Hard
E4-1	High	Intermediate	Extremely narrow	Dark	Densely pores	Hard
E4-2	Intermediate	Intermediate	Ovate	Intermediate	Densely pores	Hard
E4-3	High	High	Oblong	Intermediate	Scribed	Hard
E4-4	High	High	Oblong	Intermediate	Scribed	Intermediate
E4-5	High	High	Cordate	Dark	Intermediate	Intermediate
E5-1	High	Intermediate	Oblong	Dark	Densely pores	Hard
E5-2	Intermediate	Intermediate	Oblong	Intermediate	Intermediate	Hard
E5-3	High	Intermediate	Ovate	Dark	Densely pores	Hard
E5-4	Intermediate	High	Ovate	Dark	Intermediate	Hard
E5-5	High	High	Oblong	Intermediate	Densely pores	Hard
E6-1	Intermediate	High	Cordate	Intermediate	Densely pores	Hard
E6-2	High	Intermediate	Cordate	Intermediate	Intermediate	Hard
E6-3	High	High	Oblong	Dark	Intermediate	Hard
E6-4	High	Intermediate	Oblong	Dark	Intermediate	Hard
E6-5	High	High	Cordate	Intermediate	Intermediate	Hard
E7-1	High	High	Oblong	Dark	Sparsely pores	Hard
E7-2	High	Intermediate	Oblong	Dark	Intermediate	Intermediate
E7-3	High	High	Oblong	Intermediate	Intermediate	Hard
E7-4	Intermediate	High	Cordate	Dark	Densely pores	Hard
E7-5	High	Intermediate	Oblong	Intermediate	Densely pores	Hard
E8-1	High	High	Cordate	Intermediate	Densely pores	Hard
E8-2	High	High	Oblong	Intermediate	Densely pores	Hard
E8-3	Intermediate	Intermediate	Ovate	Dark	Densely pores	Hard
E8-4	High	High	Cordate	Intermediate	Intermediate	Intermediate
E8-5	High	High	Ovate	Intermediate	Intermediate	Hard

Table 2: Morphological characterizes of different genotypes of almond fruits.

Genotype	Kernel colour intensity	Shrivelling of kernel	Kernel taste	Kernel size
E1-1	Light	Wrinkled	Sweet	Small
E1-2	Dark	Intermediate	Sweet	Medium
E1-3	Dark	Slightly wrinkled	Sweet	Large
E1-4	Light	Wrinkled	Sweet	Medium
E1-5	Intermediate	Intermediate	Sweet	Medium
E2-1	Intermediate	Wrinkled	Sweet	Small
E2-2	Dark	Slightly wrinkled	Sweet	Medium
E2-3	Light	Slightly wrinkled	Sweet	Medium
E2-4	Intermediate	Slightly wrinkled	Sweet	Medium
E2-5	Intermediate	Slightly wrinkled	Sweet	Small
E3-1	Light	Slightly wrinkled	Sweet	Large
E3-2	Intermediate	Slightly wrinkled	Sweet	Large
E3-3	Light	Slightly wrinkled	Sweet	Large
E3-4	Intermediate	Intermediate	Sweet	Small
E3-5	Light	Wrinkled	Sweet	Large
E4-1	Light	Slightly wrinkled	Sweet	Small
E4-2	Light	Slightly wrinkled	Sweet	Medium
E4-3	Dark	Slightly wrinkled	Bitter	Medium
E4-4	Light	Slightly wrinkled	Bitter	Large
E4-5	Intermediate	Intermediate	Sweet	Large
E5-1	Light	Slightly wrinkled	Sweet	Medium
E5-2	Intermediate	Intermediate	Sweet	Medium
E5-3	Light	Intermediate	Sweet	Medium
E5-4	Light	Slightly wrinkled	Sweet	Medium
E5-5	Intermediate	Slightly wrinkled	Sweet	Medium
E6-1	Light	Wrinkled	Sweet	Medium
E6-2	Light	Slightly wrinkled	Sweet	Large
E6-3	Dark	Slightly wrinkled	Sweet	Medium
E6-4	Light	Slightly wrinkled	Sweet	Large
E6-5	Intermediate	Intermediate	Sweet	Small
E7-1	Dark	Slightly wrinkled	Sweet	Medium
E7-2	Light	Slightly wrinkled	Sweet	Large
E7-3	Light	Intermediate	Sweet	Large
E7-4	Light	Intermediate	Sweet	Large
E7-5	Light	Slightly wrinkled	Sweet	Small
E8-1	Light	Slightly wrinkled	Sweet	Medium
E8-2	Dark	Intermediate	Sweet	Small
E8-3	Intermediate	Slightly wrinkled	Sweet	Large
E8-4	Intermediate	Intermediate	Sweet	Medium
E8-5	Light	Slightly wrinkled	Sweet	Large

Table 3: Morphological characterizes of different genotypes of almond kernels.

Genotype	Nut				Kernel			
	Length (mm)	Width (mm)	Thickness (mm)	Weight (g)	Length (mm)	Width (mm)	Thickness (mm)	Weight (g)
E1-1	35.6	27.2	17.32	6.92	27.0	16.2	6.55	1.21
E1-2	35.5	23.0	16.71	6.05	23.0	14.1	8.05	1.20
E1-3	30.5	23.6	15.10	5.45	20.0	13.3	8.55	0.94
E1-4	34.4	19.8	18.44	4.20	24.5	13.4	8.10	1.27
E1-5	37.3	25.5	17.15	4.88	30.1	16.7	6.12	0.89
E2-1	39.6	31.1	16.72	7.23	25.6	15.7	7.11	1.23
E2-2	31.0	24.8	20.31	6.10	20.7	13.3	8.85	1.11
E2-3	36.2	22.8	16.54	4.45	26.4	14.0	8.10	1.28
E2-4	36.8	26.3	17.57	5.88	24.4	15.7	7.10	1.23
E2-5	42.5	20.3	16.11	5.87	31.0	11.6	8.05	1.10
E3-1	33.8	18.3	15.03	3.76	23.9	12.2	9.30	0.97
E3-2	35.6	24.1	16.23	5.83	26.1	17.1	7.47	1.11
E3-3	33.5	26.1	17.65	5.12	24.2	15.3	9.04	1.10
E3-4	31.4	18.7	19.51	3.23	25.4	14.5	7.13	1.17
E3-5	31.1	25.9	21.22	7.14	21.8	12.4	9.67	1.01
E4-1	35.4	23.8	17.61	5.55	25.6	13.3	7.13	0.89
E4-2	34.7	25.4	18.42	6.87	23.9	14.4	8.14	1.13
E4-3	40.4	21.2	17.22	6.74	28.0	12.7	9.22	1.20
E4-4	32.7	25.8	17.33	7.67	22.4	15.5	9.30	1.17
E4-5	34.2	19.2	16.11	4.89	25.4	12.3	6.43	0.99
E5-1	37.7	25.0	18.76	8.03	25.0	16.3	9.66	1.11
E5-2	35.3	20.3	17.23	5.96	26.5	13.4	7.54	1.11
E5-3	37.8	29.4	19.50	7.96	29.0	18.4	8.77	1.02
E5-4	41.5	22.3	18.34	7.85	29.0	13.8	9.33	1.30
E5-5	35.8	26.5	19.53	7.87	24.0	15.5	9.25	1.24
E6-1	36.5	24.9	18.71	6.44	26.7	14.5	8.24	0.99
E6-2	32.2	26.0	22.33	8.15	22.9	13.5	9.78	1.11
E6-3	32.5	19.8	20.65	4.34	26.5	15.6	8.24	1.28
E6-4	34.6	27.2	18.78	6.13	25.3	16.4	9.50	1.20
E6-5	36.6	24.0	17.69	7.06	24.0	15.2	7.06	1.30
E7-1	31.6	24.7	16.20	6.56	21.3	14.4	9.55	1.28
E7-2	35.5	20.9	19.56	5.30	25.6	14.5	9.20	1.37
E7-3	38.4	26.6	18.23	5.99	31.2	17.8	7.13	1.09
E7-4	40.7	32.1	17.81	8.34	26.7	16.8	8.12	1.34
E7-5	32.0	25.9	21.43	7.20	21.8	14.4	9.86	1.22
E8-1	37.3	23.9	17.64	5.56	27.5	15.0	9.20	1.39
E8-2	43.6	21.4	17.25	6.98	32.0	12.7	9.06	1.20
E8-3	34.9	19.4	16.00	4.87	24.0	13.3	9.42	1.07
E8-4	36.7	25.2	17.37	6.94	27.2	18.2	8.58	1.22
E8-5	40.6	23.9	18.38	8.11	26.1	16.6	7.08	1.14

Table 4: Physical characterizes of different genotypes of almond fruits and kernels.

The mean value of total sugar content in almond hulls 18.1±1.04% was obtained. Highest total sugar content of hull was 28.3±0.99% in E8-3 genotype and lowest value was 10.3±0.70% for E1-3 genotype. Almond hull sugar contents were reported as 18-30% by Weir [33] and as 25% by Sequeira and Lew [21]. The mean value of almond shells total sugar content was 27.1±0.89%. Maximum total sugar of shells was 33.4±0.78% for E7-4 and minimum value was 17.5±0.65% for E8-3 genotype. Some genotypes of this work had higher sugar content in their hulls or shells than cultivars or genotypes reported in references. Values of shells total sugar content were higher than that of their hulls values in all almond genotypes. On the other hand, the mean value of almond shells total sugar content (27.1±0.89%) was higher than that of hulls mean value (18.1±1.04%). This indicates that almond shell total sugar content was higher than that of its hull.

	Phenol content (mg/g)		Fat content (%)		Protein content (%)		Sugar content (%)	
Genotype	Hull	Shell	Hull	Shell	Hull	Shell	Hull	Shell
E1-1	78.2±0.41	34.2±0.87	5.2±0.38	1.7±0.44	2.8±0.71	3.2±0.91	19.8±1.11	24.7±1.41
E1-2	45.3±1.22	25.3±2.32	4.0±0.87	2.5±0.22	1.9±1.31	2.3±0.43	11.5±0.87	28.8±1.20
E1-3	54.6±3.36	44.6±1.23	3.2±0.74	3.1±0.94	1.6±1.50	3.4±0.23	10.3±0.70	27.9±0.91
E1-4	49.5±4.12	32.5±1.36	5.4±0.35	3.6±0.78	2.4±1.32	3.6±0.57	26.7±1.31	32.4±0.42
E1-5	75.2±0.65	45.6±2.63	4.6±0.51	2.8±1.11	1.9±1.05	2.3±0.11	15.1±1.50	25.3±1.11
E2-1	98.4±0.98	26.8±4.51	5.6±1.32	3.3±0.57	3.2±1.20	4.1±0.75	24.3±1.33	31.2±0.57
E2-2	109.5±2.32	46.3±0.69	4.2±1.05	1.6±1.24	2.9±0.93	3.4±0.31	10.4±1.05	24.4±1.21
E2-3	75.9±1.25	12.6±0.25	3.5±0.98	1.5±0.75	2.5±0.61	2.9±0.33	11.2±1.20	24.3±0.75
E2-4	85.4±3.02	49.6±2.31	5.3±0.91	1.9±0.25	2.3±1.52	2.7±0.14	12.3±0.92	27.3±1.00
E2-5	80.3±1.11	56.6±3.35	4.5±0.61	1.4±0.33	2.5±1.20	3.6±0.85	23.4±0.61	32.4±1.30
E3-1	67.2±1.36	33.3±2.14	4.5±1.51	2.3±0.47	3.1±0.55	3.2±0.78	16.8±1.50	18.5±1.40
E3-2	115.4±5.32	47.5±1.25	3.1±1.24	1.6±0.85	2.5±1.22	2.7±0.46	22.4±1.22	27.4±0.85
E3-3	88.1±0.95	25.6±1.35	4.3±0.52	2.5±0.78	2.8±0.61	3.3±0.68	19.5±0.50	33.4±0.78
E3-4	49.7±0.54	35.1±4.21	2.7±1.22	1.2±0.46	1.2±0.94	1.9±0.65	23.4±1.22	32.5±0.46
E3-5	66.3±2.54	32.1±0.58	4.5±0.66	2.7±0.68	2.1±1.11	2.3±0.81	18.3±0.66	24.3±0.68
E4-1	78.4±1.36	45.6±1.23	5.2±0.99	2.7±0.65	2.8±1.32	3.5±0.58	17.2±0.91	28.1±0.65
E4-2	58.1±5.61	13.5±2.36	4.1±1.11	2.4±0.81	2.4±0.28	3.6±0.36	24.2±1.11	25.5±0.81
E4-3	66.3±1.32	21.3±1.32	5.7±1.32	1.3±0.58	2.6±0.35	4.1±0.71	23.3±1.31	28.1±0.58
E4-4	70.5±3.32	33.2±1.24	4.2±1.36	2.5±0.31	3.1±0.69	3.6±0.32	10.4±1.05	24.4±1.11
E4-5	102.6±2.33	49.9±3.54	3.6±1.54	0.8±0.54	3.1±0.35	3.2±0.36	11.2±1.21	24.3±0.75
E5-1	87.7±0.87	52.6±2.32	3.5±1.67	2.4±0.31	3.6±0.35	4.2±0.36	12.3±0.95	27.3±1.00
E5-2	55.2±1.65	42.5±3.33	3.2±0.65	2.2±0.32	2.8±0.69	3.1±0.39	19.8±1.10	24.7±1.41
E5-3	71.2±0.65	25.6±0.57	4.3±0.32	2.6±0.21	1.6±0.57	3.5±0.64	11.5±0.87	28.8±1.21
E5-4	90.5±2.33	59.6±0.32	3.3±0.35	2.3±0.12	1.3±0.98	2.6±1.32	13.3±0.77	27.9±0.90
E5-5	58.7±1.21	36.1±0.65	2.3±0.57	1.8±0.54	2.6±0.65	2.8±0.35	26.7±1.32	32.4±0.43
E6-1	46.8±3.03	21.3±0.54	3.3±0.98	2.3±0.35	2.5±0.23	3.6±0.32	15.1±1.50	25.3±1.11
E6-2	64.2±0.65	22.2±0.98	5.2±1.24	3.1±0.98	2.8±0.35	3.5±0.98	24.3±1.31	31.2±0.57
E6-3	89.6±1.02	31.5±1.54	4.1±0.32	3.1±0.87	3.1±0.47	3.2±0.78	10.4±1.05	24.4±1.11
E6-4	73.5±3.01	25.6±2.36	3.3±1.35	2.3±0.35	2.4±0.58	2.7±0.68	11.2±1.20	24.3±0.75
E6-5	88.9±4.33	45.9±2.35	2.8±0.87	2.3±0.65	1.9±0.65	1.8±0.33	12.3±0.94	27.3±1.00
E7-1	99.1±0.43	45.9±5.61	3.5±0.65	2.2±0.32	2.5±0.69	5.1±1.23	23.4±0.61	32.4±1.31
E7-2	112.3±0.25	58.9±2.31	4.3±1.54	3.8±1.32	4.5±0.74	5.1±1.54	16.8±1.55	18.5±1.41
E7-3	96.3±3.21	43.6±3.21	4.1±0.85	3.7±0.35	2.1±0.36	3.6±1.36	27.4±1.23	29.2±0.85
E7-4	56.3±2.22	16.3±2.31	3.3±0.68	3.3±1.35	2.6±0.31	5.3±0.32	19.5±0.55	33.4±0.78
E7-5	63.8±1.11	48.9±0.69	2.6±0.35	1.3±0.44	3.3±0.41	4.6±1.35	10.4±1.05	24.4±1.11
E8-1	89.6±1.23	18.6±1.32	3.4±0.45	1.7±0.78	3.9±0.93	5.2±0.36	23.4±1.22	31.1±0.46
E8-2	75.2±0.33	26.3±0.35	5.1±1.23	1.6±1.54	3.5±0.36	5.4±1.32	18.3±0.66	24.3±0.68
E8-3	84.6±2.63	44.5±4.32	2.9±1.25	1.8±1.32	2.5±0.31	3.2±0.35	28.3±0.99	17.5±0.65
E8-4	98.2±3.04	21.3±2.31	3.3±1.65	3.2±0.98	2.1±0.12	2.3±0.32	24.2±1.11	25.6±0.81
E8-5	68.5±3.35	11.9±0.65	2.8±0.39	2.2±1.11	2.9±0.39	3.9±0.54	23.3±1.32	28.1±0.58
Mean	77.1±1.99	35.2±1.91	4.0±0.91	2.3±0.67	2.6±0.71	3.5±0.68	18.1±1.04	27.1±0.89

The values are means of three replicates with standard errors (mean ± S.E, n =3), $p<0.05$.

Table 5: Chemical composition of different genotypes of almonds fruits hulls and shells of Esfahlan, East Azarbaijan province of Iran.

CONCLUSION

Nutritional value of almond fruit is related to its kernel. Other parts of this tree nut such as brown skin, shell and hull (55% of fruit weight) are discarded as agricultural by-products. There is no investigation or literature about almond hull and shell total fat, protein and sugar content. In addition, present references are not new either. Therefore, our obtained results for the first time shows that almond hull and shell specifically shell potion can be a potential source of useful foods, food additives, pharmaceuticals, and feed additives, over and above low value usage as animal feed and heating. Therefore, it is necessary to investigate more about almond hull and shell chemical content to produce beneficial compounds.

Acknowledgments
The authors would like to thank Hasan Jahanban Esfahlan for proofreading the manuscript. Also, the help and advice from Dr. Mehdi Shah Virdi Alamdari and Dr. Yousef Shiri are greatly appreciated.

REFERENCES

[1] Abbey, M., Noake, M., Belling, G. B., Nestel, P. J., **1994**. *Am J Clinical Nutr* 59: 995-999.
[2] Kris-Etherton, P. M., Yu-Poth, S., Sabate, J., Ratcliffe, H. E., Zhao, G., Etherton, T. D., **1999**. *Am J Clin Nutr* 70: 504-511.
[3] Kendall, C. W. C., Jenkins, D. J. A., Marchie, A., Parker, T., Connelly, P. W., **2002**. *Am J Clin Nutr* 75: 384.
[4] Dreher, M. L., Maher, C. V., Kearney, P., **1996**. *Nutr Rev* 54: 241-245.
[5] Jahanban Esfahlan, A., Jamei, R., Jahanban Esfahlan, R., **2010**. *Food Chem* 120: 349-360.
[6] Sang, S., Lapsley, K., Jeong, W. S., Lachence, P. A., Ho, C. T., Rosen, R. T., **2002**. *J Agric Food Chem* 50: 2459-2463.
[7] Wijeratne, S. S. K., Abou-zaid, M. M., Shahidi, F., **2006**. *J Agric Food Chem* 54: 312-318.
[8] Jahanban Sfahlan, A., Mahmoodzadeh, A., Hasanzadeh, A., Heidari, R., Jamei R., **2009**. *Food Chem* 115, 529–533.
[9] Davis, P. A., and Iwahashi, C. K., **2001**. *Cancer Lett* 165: 27-33.
[10] Hyson, D., Schneeman, B. O., Davis, P. A., **2002**. *J Nutr* 132: 703-707.
[11] Fadel, J. G., **1999**. *Anim Feed Sci Tech* 79: 255–268.
[12] Martinez, J. M., Granado, J. M., Montane, D., Salvado, J., Farriol, X., **1995**. *Bioresource Technol* 52: 59–67.
[13] Takeoka, G., Dao, L., Teranishi, R., Wong, R., Flessa, S., Harden, L., Edwards, R., **2000**. *J Agric Food Chem* 48: 3437-3439.
[14] Sang, S., Lapsley, K., Rosen, R. T., Ho, C. T. **2002**. J Agric Food Chem 50, 607-609.
[15] Takeoka, G. R., and Dao, L. T., **2003**. *J Agric Food Chem* 51: 496-501.
[16] Rabinowitz, I. N., **2004**. US Patent US 0018255.
[17] Pinelo, M., Rubilar, M., Sineiro, J., Nunez, M. J., **2004**. *Food chem* 85: 267-273.
[18] Urrestarazu, M., Martinez, G. A., Salas, M. C., **2005**. *Sci Hort* 103: 453–460.
[19] Pou-Ilinas, J., Canellas, J., Driguez, H., Excoffier, G., Vignon, M. R., **1990**. *Carbohyd Res* 207: 126–130.
[20] Quesada, J., Teffo-Bertaud, F., Croue, J. P., Rubio, M., **2002**. Holzforschung 56: 32–38.
[21] Sequeira, R. M., and Lew, R. B., **1950**. *J Agric Food Chem* 18: 950.
[22] Siriwardhana, S. S. K. W., Shahidi, F., **2002**. *J Am Oil Chem Soc* 79: 903-908.
[23] Subhashinee, S. K. W., Amarowicz, R., Shahidi F., **2006**. *J Am Oil Chem Soc* 83: 223-230.
[24] Moure, A., Pazos, M., Medina, I., Domınguez, H., Parajo, J. C., **2007**. *Food Chem* 101: 193–201.
[25] Jahanban Isfahlan, A., Heidari, R., Hasanzadeh, A., Jamei R., **2010**. *Turk J Biol* 34: 165-173.
[26] Jahanban Esfahlan, A., and Jamei R., **2011**. *NUCIS* 15: 26-30.
[27] Jahanban Esfahlan, A., and Jamei, R., **2012**. *Turk J Biol* 36: 201-209.
[28] Gülcan, R., Askin, M. A., Misirli, A., **1990**. *Reur Technical Series* 13: 357-364.
[29] Singleton, V. L., Rossi, J. A., **1965**. *Am J Enol Vitic* 16: 144-158.
[30] Leiboritz, H. D., Bengrson, A., Mougle, P. D., Simposon, K. L., **1987**. (Eds: Sorgeloss, P., Begtson, D. A., Deeiier, W., Japers E.,), Universa, Wetteven, Belgium, pp. 469-479
[31] Lowry, O. H., Rosebroug, N. J., Farr, A. L., Randall, R. J., **1951**. *J Biol Chem* 93: 265-275.
[32] Dubois, M., Gilles, K., Hamilton, J. K., **1951**. *Nature* 168: 167.
[33] Weir, W. C., **1951**. *California Agric* 5: 9-12.