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Physical and chemical properties of some pistachio varieties (*Pistacia vera* L.) and oils grown under irrigated and non-irrigated conditions in Turkey

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RESEARCH ARTICLE

Abstract

The purpose of this study was to compare physicochemical characteristics and fatty acid profiles of two varieties (Kırmızı and Siirt) of pistachio nut (*Pistacia vera* L.) and to determine the effects of irrigation on some chemical characteristics and fatty acid composition. It was observed that while the irrigation caused an increase in Pistachio nut yield, crude fibre, ash and oil content of the nuts and decrease in protein content, it had no effect on kernel and nut sizes and dry matter contents. Variety affected primary fatty acids markedly, but irrigation did not. Total lipid levels in two varieties of pistachio were between 53.09 and 56.11%. The results showed that the most abundant fatty acid in pistachio oils was oleic acid, composing between 70.47 and 75.82% of the total fatty acids. The oil of Kırmızı pistachio variety had the highest linoleic acid content (17.72%) under irrigated conditions. Total saturated fatty acids of pistachio nuts were less than 12.02%, monounsaturated and polyunsaturated fatty acids totalled up to 77.07 and 17.99%, respectively.

Keywords: fatty acid, linoleic acid, nuts, oils, pistachio

1. Introduction

Nuts are known as a fundamental component of a healthy human diet, because of being rich in unsaturated fatty acids, proteins, phytochemicals, essential micronutrients, B vitamins, carotenoids, tocopherols and other bioactive components (Asghari *et al.*, 2017; Stuetz *et al.*, 2017). Nuts are often consumed roasted in confectionary industry (Eliseeva *et al.*, 2017; Stuetz *et al.*, 2017). Due to their lipid components, they are associated with a series of health benefit against some diseases such as high blood pressure, coronary heart disease, the risk of stroke, metabolic syndrome and some cancers (Amaral *et al.*, 2003; Song *et al.*, 2018). On the other hand, because nuts contain approximately 40-80% fat, there are some concerns about gaining weight with the consumption of nuts (Amaral *et al.*, 2003; Song *et al.*, 2018), but the previous studies showed that, the certain amount of nut consumption does not cause to gain weight (Asghari *et al.*, 2017; Stuetz *et al.*, 2017). The high polyunsaturated fatty acids (PUFA) content of the nuts reduces the heart disease risks by increasing HDL-cholesterol and decreasing the total and LDL-cholesterol (Davis *et al.*, 2007). It is known that eating nuts has beneficial effects on glycemic and lipid parameters and it can also modify the insulin resistance (Asghari *et al.*, 2017; Gulati *et al.*, 2014).

Pistachio nut is one of the most common known tree nuts in the world because of its high nutritional value, deep green kernel colour, unique flavour and texture (Gamlı and Hayoğlu, 2007; Kendirci and Onogur, 2014). The shape of the pistachio nut is generally oval and it has a hard shell around which protects the kernel in every aspect (Aliakbarkhani *et al.*, 2015). The pistachio tree is known as 'a green gold tree' due to its all beneficial health effects (Aliakbarkhani *et al.*, 2015). The nutritional properties of the pistachio nuts are mainly attributed to their richness of fatty acids (myristic, palmitic, margaric, stearic, elaidic, oleic and linoleic acids),

carotenoids (alpha-carotene, beta-carotene, trans-carotene, lutein and zeaxanthin), chlorophylls (chlorophyll a and b) and tocopherols (alpha-tocopherol, gamma tocopherol and delta-tocopherols) (Chaharbaghi *et al.*, 2017). Compared with other edible nuts, pistachios are the richest source of unsaturated fatty acids (linoleic, linolenic and oleic acids), phytosterols, phenolic and other compounds (Bartzas and Komnitsas, 2017; Mokhtarian *et al.*, 2017). They also contain mineral salts, vitamins, polysaccharides (pectin), protein and fibre (Chaharbaghi *et al.*, 2017; Gulati *et al.*, 2014). They have a high antioxidant and anti-inflammatory potential because of their phytosterols, polyphenols and tocopherols (Mokhtarian *et al.*, 2017; Ojeda-Amador *et al.*, 2018). The most common pistachio variety is 'Uzun' in Turkey (Sonmezdag *et al.*, 2018).

Essential fatty acids can only be taken from foods because of not being synthesised in the human body (Galedar *et al.*, 2009). These fatty acids are very important for the biological systems such as providing energy sources (Galedar *et al.*, 2009). Nuts, especially pistachio nuts, have a healthy and essential fatty acid profile with low saturated and high unsaturated fatty acids (Galedar *et al.*, 2009; Kendirci and Onogur, 2014). Some fatty acids such as oleic, linoleic and linolenic acids are present in pistachio kernels at the rate of 50-60% (Galedar *et al.*, 2009). Because of its green colour, it is mainly preferred for the production of the baklava, ice cream and nut paste (Galedar *et al.*, 2009; Kendirci and Onogur, 2014). The green hull of pistachio has antimutagenic, antimicrobial activities and high antioxidant capacity due to phenolic compounds such as catechin, naringin, 4-hydroxibenzoic acid (Galedar *et al.*, 2009). Gallic acid, which is able to scavenge free radicals, is the most predominant phenolic compound in the pistachio green hull (Galedar *et al.*, 2009). Pistachio kernel is very popular in confectionery and snack foods (Galedar *et al.*, 2009). Pistachio nuts are mainly used as dried or roasted with salt (Ling *et al.*, 2016).

With the inauguration of the South East Anatolian Project in Turkey, an increase is expected in pistachio production due to irrigation. To the best of our knowledge, there is no much study on the effects of irrigation during the growth period on the fatty acid composition of pistachio.

The purpose of this research was to investigate the effects of irrigation on some chemical characteristics and the fatty acid composition of pistachio Siirt and Kırmızı varieties.

2. Materials and methods

Materials

Kırmızı (long shape) and Siirt (round shape) varieties of pistachio nuts were grown in Research Field (36°50'46''N 40°02'56''E) of Harran University, Turkey. A calcareous, reddish brown and medium textured soil with low organic matter content was used (Anonymous, 2012). In the growing region, the lowest temperatures recorded in February were ranging from -2.6 °C to 16.4 °C. The maximum temperatures recorded in July were ranging from 26.8 °C to 46.0 °C and the average temperature was 31.8 °C. In the same year, average relative humidity was 73% in February and 32.4% in July. The highest recorded rainfall was 88.2 mm in February, but during July, August and September no rainfall was recorded (Ak and Fidan, 2012). The available moisture levels of irrigation sites are 28.42, 34.85 and 19.26 mm at 0-30, 30-60 and 60-90 cm, respectively. This value is 12 mm or less in non-irrigation sites. Some pistachio nuts in both varieties were irrigated with a drip irrigation system under controlled conditions, and some of them were grown under non-irrigation (dry) conditions. Irrigation, 250 tons in total, was carried out to pistachio nuts grown on irrigated conditions once a week between June and September. Pistachio nuts grown on dry and irrigated conditions were harvested at the last week of August and the first week of September. The pistachio samples were harvested and dried to about 4% moisture, as achieved traditionally. They were stored at room temperature until the analysis. The hard shells of pistachio samples were crushed and the inner skins of them were removed before the analysis.

All chemicals used in this study were obtained from Sigma (St. Louis, MO, USA) or Aldrich Chemical Company (Milwaukee, WI, USA) and they were of ACS-grade or better quality.

Oil extraction

To define the amount of oil in the pistachio, exhaustive extractions were performed in a Soxhlet extractor (Gerhardt Soxtherm SX-40, Königswinter, Germany). Approximately 20 g of pistachio samples were extracted in the Soxhlet for 6 h in accordance with the procedure defined in AOAC (1990), at the boiling point of the hexane (AOAC, 1990). Then, the organic phase was removed with the help of a rotary evaporator under decreased pressure; the oil was flushed with a stream of nitrogen and stored at -20 °C in sealed tubes until the analyses.

Physicochemical characteristics

The 100-kernel weight and the 100-dehulled nut weight was determined with three replications, weighed randomly and counted out according to (AOAC, 1990). To determine the kernel to nut ratio, 10 g of the whole pistachio nuts were manually and carefully broken in triplicate. They were weighed with their shells removed. After this, the kernel weight to the total pistachio nut weight was determined. To determine the dry matter, oven drying was performed at 105 °C to constant weight (AOAC, 1990). The ash content was ascertained according to the (AOAC, 1990). Nitrogen

was determined by the Kjeldahl procedure and the crude protein was calculated as N×6.25 (AOAC, 1990). Pistachio samples were analysed for crude fibre using AACC Method 32-10.01 described in (AACC, 2000). The refractive index in pistachio oil was determined by an Abbe refractometer (WYA-2WAJ, Ningbo Yuda Import & Export Co. Ltd, Beijing, China) at 20 °C (AOAC, 1990).

The degree of unsaturation (DU) was determined according to Porzucek (1990) and the equation was stated below:

$$DU = \frac{1\times(wtMUFA\%) + 2\times(wtDUFA\%) + 3\times(wtPUFA\%)}{100}$$

MUFA, DUFA and PUFA represent monounsaturated, diunsaturated and polyunsaturated fatty acids, respectively.

Fatty acid composition of the oil samples

Fatty acid methyl esters (FAMEs) analysis were performed by the following procedure. (Lutterodt *et al.,* 2011; Parry *et al.,* 2005). In brief, 1 mg oil and 0.1 M NaOH-MeOH reacted with each other for 5 min and this mixture reacted with 4% HCl-MeOH for 5 min, at environmental temperature. To stop this reaction, it was added some water and then fatty acid methyl esters were extracted by using iso-octane. Gas chromatography (GC) analysis was carried out with a Shimadzu GC-2010 equipped with a flame ionization detector and a Shimadzu AOC-20Si auto sampler (Shimadzu, Columbia, MD, USA). A fused silica capillary column SP™ -2380 (30 mm 0.25 mm with a 0.25 µm film thickness) from Supelco (Bellefonte, PA, USA) was used in GC analyses. Helium was used as the carrier gas at a flow rate of 0.8 ml/min whereas 1 µl was as selected as an injection volume. The split ratio was 10/1. Initial temperature of 142 °C was increased at 6 °C/min to 184 °C, held for 3 min, and then increased at 6 °C/min to 244 °C. Identification of individual fatty acid methyl esters were performed by comparing their retention times with those of FAME standards. Ratio of the area under each fatty acid peak to the total area of all fatty acid peaks was used to quantify the fatty acids identified. All samples were analysed in duplicate.

Statistical analysis

The experiment was designed according to 2 (irrigation)×2 (variety) factorial design with triplicate. The results obtained were subjected to analyse statistically (SAS System for Windows v6.12, SAS Institute, Inc., Cary, NC, USA) and evaluated. Analysis of variance by the general linear model (PROC GLM) procedure and comparison of means by Duncan's test were performed using Statistical Analysis System (SAS, 2001).

3. Results and discussion

Some properties of Kırmızı and Siirt pistachio varieties grown under non-irrigated and irrigated conditions were determined and the mean values were shown in the Table 1.

Irrigation increased the yield by 33.91% in Kırmızı, and 53.96% in Siirt pistachio variety. The kernel and nut weights of Siirt variety were higher than that of Kırmızı. The kernels and nuts of Siirt variety are larger, plump and oval, while the kernels and nuts of Kırmızı are thin and long. The effect of irrigation on 100-kernel weight, 100-nut weight, and

Table 1. Physicochemical characteristics of Turkish pistachio nut varieties (Kırmızı and Siirt).[1]

Characteristics	Pistachio varieties			
	Kırmızı		Siirt	
	Non-irrigated	Irrigated	Non-irrigated	Irrigated
Yield (kg per tree, FW)	24.27^{d}	32.50^{c}	33.97^{b}	52.30^{a}
100-nut weight (g, DW)	92.62^{b}	93.48^{b}	142.30^{a}	141.83^{a}
100-kernel weight (g, DW)	38.82^{b}	39.60^{b}	57.84^{a}	58.02^{a}
Kernel to nut ratio (%, DW)	41.91^{a}	42.36^{a}	40.65^{b}	40.91^{b}
Dry matter (%)	96.06^{a}	96.06^{a}	96.05^{a}	96.06^{a}
Ash (%)	3.13^{b}	3.15^{a}	3.12^{b}	3.16^{a}
Protein (%)	27.45^{a}	26.21^{b}	27.09^{a}	26.77^{b}
Crude fibre (%)	7.63^{d}	8.19^{b}	8.04^{c}	8.39^{a}
Oil (%)	53.09^{d}	53.86^{c}	54.96^{b}	56.11^{a}
Refractive index in oil (at 20 °C)	1.462^{a}	1.463^{a}	1.463^{a}	1.463^{a}
Degree of unsaturation	1.038^{b}	1.078^{a}	1.029^{c}	1.027^{c}

[1] Values are mean of triplet determination; DW: dry weight, FW: fresh weight; means in a same line in different letters are significantly different (P<0.05).

the kernel to nut ratio was not significant (P<0.05) in both varieties. Monastra *et al.* (1995) reported that, although yield increased in parallel with irrigation, the average weight of fruit in shell and dry did not change significantly.

Although irrigation increased the ash content slightly, values are very close to each other. The significance between these results may be attributed to the fact that the differences between replications were very small.

In the same way, the crude fibre content increased with irrigation significantly (P<0.05). The protein contents of both pistachio varieties were significantly (P<0.05) higher under non-irrigated conditions than in irrigated conditions. But irrigation increased the oil content of both varieties. The oil content of Siirt variety was higher in both non-irrigated and irrigated conditions. Satil reported that, Siirt pistachio contained the higher level of oil than other varieties investigated (Satil *et al.,* 2003).

Total lipid levels were between 53.09 and 56.11% in two varieties (Kırmızı and Siirt) of pistachio. The fatty acid compositions (%) were characterised in Kırmızı and Siirt pistachio varieties (Table 2) under non-irrigated (dry) and irrigated conditions.

The major fatty acids characterised of both pistachio varieties were, oleic acid (70.47-75.82%), linoleic acid (12.37-17.72%), palmitic acid (7.25-8.10%), stearic acids (2.17-3.31%). Similar results were reported by earlier research (Agar *et al.,* 1994; Aslan *et al.,* 2002; Satil *et al.,* 2003).

The oleic acid content of Siirt was higher than Kırmızı variety. The effect of irrigation on the oleic acid content was insignificant (P<0.05) in Siirt pistachio variety. Agar reported a clear inverse correlation between oleic and linoleic acids, and considered them as complementary (Agar *et al.,* 1994).

Linoleic acid was the most abundant polyunsaturated fatty acid in pistachio. Contrary to oleic acid, the linoleic acid content of Kırmızı was higher than Siirt. The effect of irrigation was insignificant on Siirt, but it increased the linoleic acid content of Kırmızı pistachio. Oleic acid is known more stable against oxidative alterations than linoleic and linolenic acids, the higher level of oleic acid than them make pistachio more stable for oxidation.

The Kırmızı variety had higher amount of stearic acid under both dry and irrigated conditions. The palmitic acid content of pistachio followed the same pattern as linoleic acid. It

Table 2. Fatty acid composition (%) of the oils of Turkish pistachio nut varieties.[1]

Fatty acids	Pistachio varieties			
	Kırmızı		Siirt	
	Non-irrigated	Irrigated	Non-irrigated	Irrigated
Myristic acid ($C_{14:0}$)	0.12±0.3^{a}	0.08±0.2^{a}	0.09±0.4^{a}	0.08±0.3^{a}
Palmitic acid ($C_{16:0}$)	8.10±0.1^{a}	7.81±0.1^{a}	7.41±0.2^{b}	7.25±0.2^{b}
Palmitoleic acid ($C_{16:1}$)	0.60±0.2^{a}	0.50±0.3^{b}	0.45±0.1^{c}	0.44±0.1^{c}
Heptadecanoic acid ($C_{17:0}$)	0.05±0.0^{a}	0.04±0.1^{a}	0.05±0.1^{a}	0.05±0.1^{a}
Heptadecenoic acid ($C_{17:1}$)	0.06±0.1^{b}	0.06±0.2^{b}	0.08±0.1^{a}	0.08±0.1^{a}
Stearic acid ($C_{18:0}$)	3.31±0.3^{a}	2.17±0.2^{a}	2.68±0.2^{b}	2.53±0.3^{c}
Oleic acid ($C_{18:1}$)	71.33±0.1^{b}	70.47±0.3^{b}	74.98±0.1^{b}	75.82±0.2^{a}
Linoleic acid ($C_{18:2}$)	15.08±0.2^{b}	17.72±0.1^{a}	12.88±0.2^{c}	12.37±0.1^{c}
Linolenic acid ($C_{18:3}$)	0.35±0.1^{a}	0.27±0.1^{d}	0.31±0.2^{b}	0.29±0.1^{c}
Arachidic acid ($C_{20:0}$)	0.30±0.3^{a}	0.21±0.2^{c}	0.25±0.3^{b}	0.25±0.1^{b}
Eicosenoic acid ($C_{20:1}$)	0.56±0.3^{b}	0.55±0.1^{b}	0.72±0.2^{a}	0.73±0.1^{a}
Behenic acid ($C_{22:0}$)	0.14±0.1^{a}	0.12±0.1^{a}	0.10±0.2^{a}	0.11±0.1^{a}
∑ SFA	12.02	10.43	10.58	10.27
∑ MUFA	72.55	71.58	76.23	77.07
∑ PUFA	15.43	17.99	13.19	12.66
∑ Unsaturated fatty acid	87.98	89.57	89.42	89.73

[1] Means in a same column with different letters are significantly different (P<0.05); data are expressed as means (n=3). SFA, MUFA and PUFA stand for saturated, monounsaturated and polyunsaturated fatty acids, respectively.

was higher in Kırmızı than in Siirt variety. Although it was higher under non-irrigated grown varieties than irrigated ones, the difference was statistically insignificant ($P<0.05$). The fatty acid levels determined in the present study were generally lower than those reported by (Küçüköner and Yurt, 2003). Higher temperature is reported to decrease the palmitic acid level in pistachio (Satil *et al.,* 2003). Neither irrigation nor variety affected myristic and behenic acids, which were below 1%, significantly.

Of the characterised fatty acids, the amounts of saturated fatty acids were determined as 12.02 and 10.43% in Kırmızı and 10.58% and 10.27% in Siirt in dry and irrigated conditions, respectively. In general, the amount of saturated fatty acids increased in dry conditions. Polyunsaturated fatty acids (PUFA) content of Kırmızı pistachio was much higher than that in the Siirt variety.

The results indicated that oleic acid was the most abundant fatty acid in pistachio oils, contributing between 70.47 and 75.82% of total fatty acids. Oil of Kırmızı pistachio variety had the highest linoleic acid content (17.72%) under irrigated conditions. Other fatty acids present consist of palmitic acid (7.25-8.10%) and stearic acid (2.17-3.31%). Total saturated fatty acids were less than 12.02%, monounsaturated and polyunsaturated fatty acids totalled up to 77.07 and 17.99%, respectively.

4. Conclusions

The fatty acid composition affected the oil quality of oilseed crops. The nutritional, pharmaceutical and industrial suitability of a vegetable oil is evaluated by the determination of its fatty acid composition. This fatty acid composition varies according to plant species and variety.

It can be concluded that irrigation increased Pistachio nut yield, ash, oil, crude fibre, but decreased protein content while it did not affect kernel and nut sizes, and dry matter contents. In general, variety effected the major fatty acid composition, but irrigation did not, markedly.

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