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Fatty Acid Profile and Mineral Content of Commercial Table Olives from Turkey

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Abstract

In this study, five different types of commercial table olive: Domat, Kalamata, Edremit (green), Edremit (black) and Gemlik, from Turkey, were investigated for the fatty acid composition and mineral content. Fatty acid analyses were performed by capillary gas chromatography. The fatty acid results showed that all table olives characterized by high level of were oleic acid (C18:1, 57.473-72.294%), linoleic acid (C18:2, 7.914-25.279%) and palmitic acid (C16:0, 9.735-16.441%). Moreover, in terms of the unsaturated oil content and a ratio of polyunsaturated fatty acids (PUFA) to saturated fatty acids (SFA) value, Kalamata olives were found to be more advantageous as compared to the other table olive types. The sodium (Na), magnesium (Mg), calcium (Ca), phosphorus (P), iron (Fe) and potassium (K) content of table olives were measured by inductively coupled plasma optical emission spectrometry (ICP-OES). Na was the most concentrated mineral detected (6637.722-20613.666 mg/kg), followed by K (2814.296-3386.520 mg/kg) and Ca (342.595-742.894 mg/kg). Results showed that there are differences among the fatty acid and mineral content of the commercial table olives depending on type.

Keywords: fatty acid, kalamata, minerals, oleic acid, table olive

Introduction

Olives (*Olea europea* L.) are the most widespread and valuable plant in Mediterranean countries. Table olives are the most important fermented food worldwide (Sakouhi *et al*., 2008). Turkey is one major producer of olive as a Mediterranean country. According to data from the International Olive Oil Council, the world table olive production in the 2011-2012 season was approximately 2.526.000 tons. Approximately 28.5% of the world's table olives are produced by European Union (EU) countries (Spain, France, Greece, Italy, Portugal and Slovenia). Moreover, Egypt and Turkey produce 19.8% and 15.8%, respectively, of the world's table olives.

World table olive consumption has reached 2,438,500 tons, and the EU is the largest consumer of table olives (25%; 615,500 tons) followed by Turkey (14%; 350.000 tons), Egypt (12% 300,000 tons) and the USA (8.6%; 210,000 tons) (IOOC, 2013). As known, olive oil and table olives are important components of the Mediterranean diet and become more popular in many countries that produce no olive.

One of the common components of the Mediterranean diet is fatty acids. In particular, high levels of monounsaturated fatty acids (mainly oleic acid), which have health benefits and are important for human nutrition, are among the major components of the Mediterranean diet, and they play an important role in the nutritional value of table olives (Boskou *et al*., 2006; Sakouhi *et al*., 2011; Charoenprasert and Mitchell, 2012). The major fatty acids in table olives are oleic, palmitic, stearic, linoleic and palmitoleic acids (Sakouhi *et al*., 2008; Uylaser *et al*., 2009). Because table olives are mainly composed of monounsaturated fatty acids, the consumption of table olives can prevent and reduce the risk of cardiovascular diseases, regulate cholesterol levels, stimulate transcription of LDL-cholesterol receptor mRNA and reduce breast cancer risks (Owen *et al*., 2004; Sakouhi *et al*., 2008; Kastorini *et al*., 2010).

Other important components of table olives are mineral substances. Minerals have important functions in the body, and they are essential for healthy growth and life. Mineral substances in table olives are important from nutritional and toxicological point of view. The mineral content of table olives depends on various parameters, such as location, weather conditions, environmental pollution, phytochemical product contamination, cultivar differences, maturation, processing method, packing material and chemicals used (Garcia *et al*., 2002; Soares *et al*., 2006; Lopez *et al*., 2008; Fernandez-Hernandez *et al*., 2010; Sahan, 2010).

Potassium (K) is the most abundant element in the olive fruit, followed by calcium (Ca), magnesium (Mg) and sodium (Na) (Nergiz and Engez, 2000; Biricik and Basoglu 2006). K, Na and Mg are necessary for the osmotic pressure and acid/base balance of body fluids. Many enzymes in the body depend on the presence of Mg. Ca and phosphorus (P) are especially effective in the growth and maintenance of healthy bones and teeth. In addition, Ca and P are required for blood clotting, nerve transmission

and heartbeat control through cell membrane transport. Iron (Fe) is a constituent of many enzyme systems regulating oxidation/reduction processes (Murray *et al*., 2000; Soetan *et al*. 2010), and Fe has been quantified in table olives (Sahan, 2010). Dietary intake is considered to be the major supplier of minerals for the body. Therefore, the levels of these elements in consumed food products should be investigated (Sahan *et al*., 2007).

Table olives are an important component in the dietary habits of Turkish people. Thus, table olive consumption is important due to the contribution of essential fatty acids and mineral substances to the body because these components are essential for nutrition. In the present study, the fatty acid profile and mineral content of five different types of commercial table olives commonly consumed in Turkey were determined.

Materials and methods

Materials

Five different types of table olives were obtained directly from the local markets in Bursa, Turkey, where olives are produced commercially. The following table olive types were studied: Domat olives, which are large, green olives stored in brine; Kalamata olives, which are large, elongated olives with a red-brown color stored in brine; Edremit (black) olives, which are small, wrinkled olives with a black color stored in oil; Edremit (green) olives, which are small, scratched olives with a green color stored in brine; and Gemlik olives, which are intermediate olives with a black color stored in brine.

Chemical analysis

The total dry matter content of the samples was determined by oven (ED115 Binder, Tuttlingen, Germany) drying at 105±5 °C until a constant weight was achieved. The determination of oil content was performed by extractions (Soxhlet method) with n-hexane for 6 h (Uylaser and Basoglu, 2011). The samples were analyzed in three replicates.

Determination of mineral contents

The homogenized olive sample (0.5 g) was placed into a burning cup, and a HNO_3/H_2O_2 (6:1 v/v) acid mixture was then added. The sample was incinerated in a Milostone Microwave oven with three different treatments as follows: 250 W for 8 min; 400 W for 5 min; and 600 W for 5 min. The solution was then diluted to 25 mL with distilled water. The mineral content of the samples was then determined with an inductively coupled plasma optical emission spectrometry ICP-OES (Tab. 1) (Yıldız *et al*., 2009). The samples were analyzed in six replicates.

Tab. 1. Operating conditions of the ICP-OES and the wavelengths used for each mineral

Instrument	Perkin Elmer Optima 2100 DV
RF Power	1300 W (Axial)
Plasma gas flow rate (Ar)	1.5 L/min
Detection wavelengths (nm)	
Na	589.592
Mg	285.213
K	766.490
Ca	317.933
P	213.617
Fe	259.940

Determination of fatty acids

For the determinations of the fatty acid compositions of olive samples, methyl esters were prepared by transesterification with methanolic potassium hydroxide. The samples were analyzed with an Agilent 6890N GC-FID instrument equipped with a DB-WAX capillary column (30 m x 0.25 mm x 0.25 µm) under the following temperature program: 120 °C for 3 min followed by an increase to 220 °C at a rate of 20 °C/min for 45 min. Hydrogen was used as the carrier gas at a flow rate of 1 mL/min. The injector and flame ionization detector temperatures were set at 250 °C. The Supelco 37 Component FAME-Mix (47885-U) was used as a reference, and the results were expressed in relative percentages of each fatty acid (***, 2000). Nine replicate measurements were performed for each sample.

Statistical Analysis

The results were analyzed using the JMP (Version 7.0, SAS Institute Inc., Cary, NC, USA) software program. Mean differences were tested with a least significant difference (LSD) test at a 5% level of significance.

Results and Discussion

The types of table olives and basic characteristics of each type are shown in Tab. 2. The table olives examined in this study had a number of fruits per kilogram ranging from 93 to 291. The largest size was observed in the Kalamata type, and the smallest size was observed in the Edremit (green) type. The total dry matter of table olives ranged between 35.18 and 53.24%. Edremit (black) olives contained the highest dry matter (53.24%) compared to the other table olive types. The highest oil content was determined in Edremit (black) olives with 16.23% and Edremit (green) olives had the lowest oil content with 7.36%. The differences in the oil content of table olives might be caused by olive cultivars, the state of ripeness at the time of harvest and processing method (Di Bella *et al*., 2007; Montano *et al*., 2010). In three different maturity stage of Memecik variety, total oil content reported by Ünal and Nergiz (2003) in green olive was 14.86%, 21.90% in Kalamata olive and 26.55% in fully ripened black olive. The average oil content

found by Lopez-Lopez (2006) in Spanish style green olive was 15.10% while untreated green table olive was 21.80%. Furthermore, the addition of oil to Edremit (black) olives for storage may increase the dry matter and oil content.

Fatty acid profiles of table olives

Fatty acid composition (especially oleic acid) of table olive and olive oil are among the most important quality parameters (Stark and Madar, 2002; Uylaser and Yıldız, 2013). The fatty acid compositions of the studied table olive samples are presented in Tab. 3.

The most abundant fatty acids in each type of table olive were oleic acid (C18:1, 57.473 to 72.294%), linoleic acid (C18:2, 7.914 to 25.279%) and palmitic acid (C16:0, 9.735 to 16.441%), which was also stated in previous studies Lopez *et al*., 2006; Sakouhi *et al*. 2008; Lopez-Lopez *et al*., 2009; Uylaser *et al*., 2009; Sousa *et al*., 2011; Tofala *et al*., 2012.

Tab. 2. Basic characteristics of table olives

Type	Characteristics	Number of fruits per kg	Total dry matter (%)	Oil (%)
Domat	Big, green color in brine	126[d]	35.18[c]	8.78[d]
Kalamata	Big, long, red-brown color in brine	93[e]	35.36[c]	10.34[c]
Edremit (black)	Small, black color with oil	273[b]	53.24[a]	16.23[a]
Edremit (green)	Small, scratched, green color in brine	291[a]	37.28[c]	7.36[c]
Gemlik	Middle, black color in brine	203[c]	45.67[b]	13.27[b]

[-e] Means superscript with different alphabets in the same column differ significantly (P < 0.05)

On the other hand, the stearic acid (C18:0, 2.068 to 2.852%), palmitoleic acid (C16:1, 0.520 to 1.988%), linolenic acid (C18:3, 0.583 to 1.015%), arachidic acid (C20:0, 0.238 to 0.528%) and cis-11-eicosanoic acid (C20:1, 0.194 to 0.519%) were found less amount for all types of table olives. Behenic acid (C22:0, 0.030 to 0.128%) was the least abundant fatty acid in all samples. There were significant differences (P < 0.05) among the table olive types for all of the fatty acids analyzed. The highest content of oleic acid, the most characteristic fatty acid in olive, was found in Gemlik (72.294%), followed by Edremit (green, 64.032%), Edremit (black, 63.539%), Domat (61.542%) and Kalamata (57.473%). Ünal and Nergiz (2003) reported that Kalamata olives have oleic acid contents between 70.64 and 74.03% depending on storage time, and these values were higher than the oleic acid values determined for the commercial table olives in the present study, except for Gemlik.

Gemlik olives had the highest levels of oleic acid, but they had the lowest levels of linoleic acid (7.914%). Linoleic and palmitic acids were significantly higher (P < 0.05) in the Kalamata (25.279%) and Domat (16.441%) table olives, respectively.

Compared to previous studies, differences were observed in fatty acid content of table olives. These variations could be from olive varieties, maturation and processing method of olives (Ünal and Nergiz, 2003; Lopez *et al*., 2006; Lopez-Lopez *et al*., 2009).

Ünal ve Nergiz (2003) noted that Memecik green table olives have 67.26-69.33% oleic acid, 9.12-11.89% linoleic acid and 16.42-17.38% palmitic acid, and they also reported that Memecik black table olives have 72.85-76.30% oleic acid, 8.27-10.48% linoleic acid and 10.48-12.71% palmitic acid. Lopez *et al*. (2006) reported the following oleic, linoleic and palmitic acid contents data for green Spanish olive as 6.91-10.65, 0.52-1.05 and 1.17-2.53%, respectively, and 11.38-19.20, 1.65-3.64 and 2.14-5.06% for directly brined olive and similarly 5.53-13.77%, 0.42-1.03%, and 1.21-2.91% for ripe olive. The oleic, linoleic and palmitic acid content found by Sakouhi *et al*. (2008) with ranged from 47.70 to 60.50, 4.50 to 23.20 and 7.40 to 12.20%, respectively, for three different olive cultivars processed according to Spanish style.

Currently, it is suggested that the energy from fat should not exceed 30%, and it is desirable to have oil containing unsaturated fatty acids (Jequier, 1999). According to a current dietary guidance for healthy nutrition, polyunsaturated fatty acids (PUFA) are recommended to constitute up to 7-10% of the total energy intake (Ribarova *et al*., 2003). An overall evaluation of commercial olives sold in Turkey has indicated that they contain, on average, 15.60% PUFA (Tab. 3). In addition, evaluation of the nutritional value of fat composition a ratio of PUFA to saturated fatty acids (SFA) is commonly used (Alonso *et al*., 2002; Serrano *et al*., 2005) and according to current dietary guidance for healthy nutrition, PUFA/SFA ratio above 1.5 is associated with good health (Ribarova *et al*., 2003).

PUFA/SFA ratios of table olive samples were 0.85, 2.15, 0.77, 0.99 and 0.60, respectively for Domat, Kalamata, Edremit (black), Edremit (green) and Gemlik olives. Based on the PUFA/SFA ratio results, Kalamata table olives is healthier product compared to the other olive types.

Mineral composition of table olives

The mineral contents of the studied table olive samples are shown in Tab. 4. The Na contents of the table olives ranged from 6637.722 mg/kg in Edremit (green) olives to 20613.666 mg/kg in Gemlik olives, and there was no significant difference in the Na contents between Domat (11975.259 mg/kg) and Kalamata (10883.443 mg/kg) olives (P > 0.05). Compared to the other analyzed minerals, Na had the highest content in table olives and also

Tab. 3. Fatty acid profile of table olives (%)

Fatty acids	Domat	Kalamata	Edremit (black)	Edremit (green)	Gemlik
Palmitic C16:0	16.441±0.147^{a}	9.735±0.184^{c}	12.766±0.385^{b}	12.293±1.296^{b}	12.493±0.202^{b}
Palmitoleic C16:1	1.331±0.014^{b}	0.520±0.056^{c}	1.988±0.105^{a}	1.252±0.227^{b}	1.228±0.406^{b}
Stearic C18:0	2.852±0.013^{a}	2.556±0.190^{c}	2.273±0.086^{c}	2.068±0.218^{d}	2.317±0.258^{c}
Oleic C18:1	61.542±0.288^{c}	57.473±1.658^{d}	63.539±1.840^{bc}	64.032±4.377^{b}	72.294±1.592^{a}
Linoleic C18:2	15.303±0.199^{b}	25.279±1.921^{a}	10.676±0.437^{d}	13.382±1.121^{c}	7.914±3.407^{c}
Linolenic C18:3	0.658±0.007^{b}	1.015±0.030^{a}	0.607±0.027^{c}	0.583±0.034^{c}	0.700±0.102^{b}
Arachidic C20:0	0.528±0.139^{a}	0.414±0.021^{b}	0.341±0.014^{bc}	0.238±0.192^{c}	0.361±0.077^{b}
Cis-11-eicosanoic C20:1	0.246±0.007^{b}	0.519±0.027^{a}	0.234±0.045^{b}	0.194±0.148^{b}	0.248±0.023^{b}
Behenic C22:0	0.128±0.022^{a}	0.117±0.030^{a}	0.098±0.015^{a}	0.030±0.049^{b}	0.043±0.041^{b}
Total	99.030±0.313^{a}	97.628±0.426^{a}	92.523±2.603^{b}	94.073±5.365^{b}	97.607±2.325^{a}
ΣPUFA/ΣSFA	0.85	2.15	0.77	0.99	0.60

$^{a-d}$ Means superscript with different alphabets in the same column differ significantly (P < 0.05)

daily recommended value of Na is maximum 2400 mg/day (CFR, 2003). This high Na concentration may be because Na is the only element habitually added during processing (Garrido Fernandez *et al*., 1997). Lopez *et al*. (2008) reported the following average content of Na: 16200, 7400 and 13956 mg/kg, respectively, for green Spanish, ripe olives and directly brined olives. Na levels reported also by Biricik and Basoglu (2006) in green table olives were ranged from 15640 to 20510 mg/kg.

The Mg values in Edremit (green) and Kalamata olives were 156.015 and 82.781 mg/kg, respectively, and the Mg differences were significant for only these olive types (P < 0.05). Previous studies have reported Mg contents of table olives in the following range: 37.64 and 197.30 mg/kg (Biricik and Basoglu, 2006; Sahan *et al*., 2007; Lopez *et al*., 2008).

The amount of Ca in table olives ranged from 342.595 to 742.894 mg/kg. There were no significant differences in Ca contents among the Domat, Kalamata, Edremit (black) and Edremit (green) olives (P > 0.05), but the Ca content of Gemlik olives was the lowest compared to the other table olives (P < 0.05). Ca is responsible for the prevention of olive softening (De Castro *et al*., 2007). Olive flesh can absorb and retain Ca (Garrido Fernandez *et al*., 2007). Several authors have reported the following amounts of Ca in table olives: 422–850 mg/kg for green Turkish olives Biricik and Basoglu, 2006, 270–450 mg/kg in Kalamata olives, 110–230 mg/kg in natural black olives Ünal and Nergiz, 2003, 476-850 mg/kg in green Spanish style olives, 363-731 mg/kg in ripe olives and 337-691 mg/kg in directly brined olives (Lopez *et al*., 2008).

Among all olive types analyzed, Edremit (green) olives (249.770 mg/kg) had the highest P content, and Domat olives (116.082 mg/kg) had the lowest P content (P < 0.05). Lopez *et al*. (2008) reported that the P content of green, ripe and directly brined olives ranges from 68.8 to 118, 57 to 93.3 and 99 to 129.4 mg/kg, respectively.

The content of Fe in table olives ranged between 4.880 and 13.678 mg/kg. Differences in Fe contents were observed between the black and green olives. The samples with significantly higher Fe contents were obtained from Edremit (black) (13.678 mg/kg) and Gemlik (8.298 mg/kg) olives, but significantly lower Fe contents were found in green and Kalamata (4.880 mg/kg) olives (P < 0.05). The higher Fe contents in black table olives may be related to the use of Fe salts, such as ferrous lactate and ferrous gluconate, for fixing the final color of these table olives (Brenes *et al*., 1995). In addition, the presence of Fe in green olives is unfavorable due to browning as a result of formation of complexes with the olive polyphenols (Garrido Fernandez *et al*., 1997).

Edremit (black) and Gemlik olives may be a good source of Fe, for which the daily recommended value is 18 mg (Lopez *et al*., 2008). Furthermore, the significantly lower Fe content in Gemlik olives compared to Edremit (black) olives may be related to the water soluble property of Fe. In Gemlik olives, Fe in the olive flesh can be dissolved and transported into the brine during process-

Tab. 4. Mineral content of table olives (mg/kg)

Minerals	Domat	Kalamata	Edremit (black)	Edremit (green)	Gemlik
Na	11975.259±114.472^{c}	10883.443±1467.551^{c}	14836.658±4606.359^{b}	6637.722±476.146^{d}	20613.666±659.640^{a}
Mg	96.502±7.593^{ab}	82.781±0.934^{b}	104.865±21.317^{ab}	156.015±128.781^{a}	116.861±5.459^{ab}
Ca	742.894±189.214^{a}	618.406±452.688^{a}	655.641±34.947^{a}	623.155±137.403^{a}	342.595±3.398^{b}
P	116.082±5.511^{c}	216.123±28.610^{b}	222.052±24.735^{ab}	249.770±45.587^{a}	246.537±2.267^{ab}
Fe	6.163±0.623^{c}	4.880±0.041^{c}	13.678±0.654^{a}	5.242±1.188^{c}	8.298±2.243^{b}
K	2846.351±363.676^{b}	3386.520±141.965^{a}	3038.703±181.594^{ab}	3011.761±531.683^{ab}	2814.296±398.651^{b}

$^{a-d}$ Means superscript with different letters in the same column differ significantly (P < 0.05)

ing and storage (Ünal and Nergiz, 2003). Several authors have reported Fe content values of table olives as follows: 6.11-180.06 mg/kg in black olives (Ziena *et al*., 1997; Ünal and Nergiz, 2003; Sahan *et al*., 2007), 4.45-12.27 mg/kg in green olives (Ünal and Nergiz, 2003; Sahan *et al*., 2007), and 6.5 mg/kg for Kalamata olives (Ünal and Nergiz, 2003).

K was the second most abundant element in the table olives. The K content of olive samples varied between 2814.296 and 3386.520 mg/kg. This monovalent metal is not as strongly fixed as Ca in the olive flesh, and it is progressively lost during processing (Garrido Fernandez *et al*., 1997). Previous studies have reported the following K contents in table olives: 902-1176 mg/kg in directly brined olives (Lopez *et al*., 2008), 560-1130 mg/kg (Ünal and Nergiz, 2003) and 4230-7401 mg/kg (Biricik and Basoglu, 2006) in green olives, 1140-1820 mg/kg in Kalamata olives, and 3260-3760 mg/kg in black olives (Ünal and Nergiz, 2003).

The present results indicated that the mineral content of table olives varies depending on cultivars and processing methods (Ünal and Nergiz, 2003; Lopez *et al*., 2008). Na was the most abundant mineral in the table olives, followed by K, Ca, P, Ma and Fe.

Conclusions

The present study provided information regarding the fatty acid composition and minerals of five different commercial Turkish table olives. Turkey is both a producer and consumer of table olives. In addition, most of the commercialized olives at the international level are from Turkey. The results obtained in the present work showed that there are differences among the fatty acid and mineral compositions according to the table olive types. The major fatty acids found in studied Turkish table olives were oleic acid, linoleic acid and palmitic acid, respectively. Kalamata olives presented the highest PUFA contents with the best PUFA/SFA ratio that widely used to evaluate the nutritional value of fat for human diet. Na was the most abundant mineral, followed by K and Ca. Consumption of table olives is important from a nutritional point of view due to their contribution of essential fatty acids and mineral substances to the body.

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