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www.agri.ankara.edu.tr/journal

TARIM BİLİMLERİ DERGİSİ — JOURNAL OF AGRICULTURAL SCIENCES 22 (2016) 566-575

# The Effect of Harvesting Time on Seed Oil Content and Fatty Acid Composition of Some Lemon and Mandarin Cultivars Grown in Turkey

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**ARTICLE INFO**
Research Article DOI: 10.1501/Tarimbil_0000001415
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Received: 04 December 2014, Received in Revised Form: 04 March 2015, Accepted: 14 April 2015

**ABSTRACT**

Citrus fruits usually processed into juice. The main residues are peel and seeds for citrus fruits after juice production. In order to evaluate the seeds for alternative usages; the oil content and fatty acid compositions of four mandarin (*Citrus reticulata*) and three lemon cultivars (*Citrus limon*) were determined with respect to their harvesting times. Oil content and fatty acid compositions of the samples were significantly ($P<0.05$) varied depends on cultivars and their harvesting times for each citrus species. Oil content ranged from 21.66 to 37.75% for these seeds. These results revealed that citrus seeds contain much more oil than many oil seeds. The citrus seeds oil combined from eight different fatty acids. The highest fatty acid was determined as linoleic acid (35.64-37.39%) for mandarin and oleic acid (32.99-36.39%) for lemon seed oil. These results revealed that citrus seeds could be valued as an edible oil source and other industrial area with respect to fatty acid composition.

Keywords: Citrus seed; Fatty acid; Cultivar; Harvesting time

# Türkiye'de Yetiştirilen Bazı Limon ve Mandalina Çeşitlerinin Çekirdek Yağları ve Yağ Asidi Bileşimleri Üzerine Hasat Zamanının Etkisi

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Geliş Tarihi: 04 Aralık 2014, Düzeltmelerin Gelişi: 04 Mart 2015, Kabul: 14 Nisan 2015

**ÖZET**

Turunçgiller endüstriyel olarak genellikle meyve suyuna işlenmektedir. Turunçgillerin meyve suyuna işlenmesi sonucunda ortaya atık olarak önemli miktarda kabuk ve çekirdek çıkmaktadır. Bu çalışmanın amacı bazı turunçgil çekirdeklerinin alternatif değerlendirme yöntemlerine yol gösterecek veriler ortaya koymaktır. Bu amaçla dört mandalina (*Citrus reticulata*) ve üç limon (*Citrus limon*) çeşidine ait çekirdeklerde hasat zamanına bağlı yağ miktarı ve yağ asitleri bileşenlerinin değişimi incelenmiştir. Örneklerin yağ miktarları ve yağ asitleri bileşimleri her bir tür için çeşit ve hasat zamanına göre önemli oranda ($P<0.05$) farklılık göstermiştir. Analiz edilen örneklerin yağ içerikleri % 21.66-37.75 arasında dağılım göstermektedir. Bu veriler turunçgil çekirdeklerinin birçok yağlı tohuma göre daha zengin yağ içeriğine sahip olduğunu göstermektedir. Örneklere ait yağlarda sekiz farklı yağ asidinin varlığı tespit edilmiştir. Mandalina çekirdek yağları için oransal en yüksek yağ asidi linoleik asit (% 35.64-37.39) iken limonlar için oleik asit (% 32.99-36.39) olmuştur. Araştırma sonuçları turunçgil çekirdek yağlarının yağ asitleri bileşimi bakımından başta alternatif yemeklik yağ kaynağı olmak üzere farklı endüstriyel alanlarda değerlendirilebilecek önemli bir kaynak olduğunu göstermiştir.

Anahtar Kelimeler: Turunçgil çekirdeği; Yağ asidi; Çeşit; Hasat zamanı



# 1. Introduction

Citrus species are recognized as one of the major cultivated fruit crops. They are cultivated in tropical or subtropical climate regions of the world (Liu et al 2012). The main producers for citrus are Brazil, China, Japan, Mexico, Pakistan, USA and the Mediterranean countries. The citrus fruit production of the world was 131,283,333 tons in 2012. Turkey has an important place in the world citrus production by 3,556,407 tons in 2012. Lemon and mandarin production amounts of Turkey were 759,711 tons and 889,293 tons in 2012, respectively (FAO 2013).

Citrus fruits have great economic value because of their varied uses. Although many citrus fruits, such as orange, mandarin, and grapefruit could be eaten fresh, about one third of citrus fruit is utilized in food industry in the worldwide (Liu et al 2012). The residues of the juice industry are peels and seeds. These residues, represent about 50% of the raw processed fruit, are potential sources of valuable by-products (Matthaus & Özcan 2012). The peels could be processed into jam, marmalade, essential oil, pectin, food additive (Baker 1994, Kim et al 2004; Saidani et al 2004; Shahidi & Zhong 2005; Yoshikawa et al 2006; Avula et al 2007; Yalçin et al 2011). On the other hand, citrus seeds generally are not valued in food industry.

There are a lot of cultivars for each citrus species in the world. The composition of each citrus seeds could be significantly varied depends on their species, cultivar, environmental conditions and other cultural practices. The main chemical component is oil for citrus seeds (Gorinstein et al 2001; Moufida & Marzouk 2003; Mathhaus & Özcan 2012). Citrus fruits are not grown for their seed oils. Conventional vegetable oil sources are sunflower, soybean, peanut, palm, rapeseed, corn and olive oils (Flickinger & Matsuo 2003). These sources are unable to meet demands of domestic and industrial sectors. Therefore, the need exists to investigate new alternative oil sources to supplement the supplies from natural sources. Citrus fruit seeds could be a good alternative to conventional edible oil sources (Kulkarni et al 2012).

Citrus seeds contain 20.0-78.9% oil according to the species, cultivar, and growing area (Habib et al 1986; Ajewole & Adeyeye 1993; Saidani et al 2004; Anwar et al 2008; Waheed et al 2009; Habila et al 2012). Fatty acid composition is the main quality parameter for edible oil. Mathhaus & Özcan (2012) were stated that oleic, linoleic and palmitic acids in 17 different citrus seeds oils ranged between 12.8-70.1%, 19.5-58.8%, 5.1-28.3%, respectively. Saidani et al (2004) were also found differences in fatty acid composition in seed oils of five varieties of Tunisian citrus fruits. Palmitic (21.40-39.40%), oleic (14.90-36.60%) and linoleic acids (23.80-40.30%) were detected as major fatty acids in all samples. To the best of our knowledge, there are no reports on the oil content and fatty acid composition of lemon and mandarin cultivars studied in this research. Additionally, there are comparative studies on the effects of harvesting time on oil content and composition of citrus seeds oil. Generally, harvesting time of these citrus fruits could be changed according to the marked demand. And, harvesting time could lead to significant changes in chemical composition of these fruits and their seeds.

The aim of this study was to compare oil content and fatty acid composition of seeds obtained from four mandarins and three lemons cultivars during their harvesting time.

## 2. Material and Methods

### *2.1. Material*

Four mandarin (Batem Göral, Yerli Apireno, Nova and Klemantin Fina) and three lemon cultivars (Batem Pınarı, Interdonato, Meyer) were selected for this experiment. For each replication, 20 fruits, from all mandarin and lemon cultivars, were collected by hand from citrus trees growing in Bati Akdeniz Agricultural Research Institute citrus orchard in Antalya. The same amount of samples were collected for three harvesting times. Samples harvesting time were given in Table 1.

### *2.2. Methods*

In order to determine some physical properties of the samples; fruit weight, seed content, seed weight were measured. The fruits were firstly peeled by hand. After that their seeds were removed from the fruit pulps. The seeds were washed and removed excess water from the seeds. After that the moisture content of the seeds were determined by drying them up to reach constant weight in an oven at 72 °C. And, the dried seeds were milled with a laboratory type miller (Retch GM200) than oil of seeds was extracted successively with petroleum ether using a soxhlet extractor (Gerhardt, Soxtherm 2000) for 3 h. Oil content was calculated as % on dry matter bases.

The fatty acid composition of the samples was analyzed by gas chromatography (Agilent 5975C) coupled to flame ionization detector and mass spectrometry (Agilent 5975C) (GC-MS-FID). Firstly, fatty acid methy esters (FAMEs ) were prepared (Garces & Mancha 1993) and then injected in to GC-MS/FID. Separations were performed using an HP innowax capillary column (60 m, 0.25-mm i.d., 0.25 µm film thickness). Helium was used as carrier gas at a flow rate of 0.8 mL $min^{-1}$. Injector and detector temperatures were 250 and 260 $^{o}$C, respectively. The temperature programming for the column was applied as follow; started from 150 °C and raised to 200 °C with an increment of 10 °C/minute, hold at 200 °C for 5 minute, then increased to 250 °C with 5 °C/minute increments and hold 250 °C at 10 minute (totally 30 minutes). Sample of 1 µL was injected by auto sampler with a split mode (1:50). The content (percentage by weight) of fatty acids was calculated from their corresponding integration data. MS spectra were monitored between 35-450 amu and the ionization mode used was electronic impact at 70 eV. The relative percentage of the components was calculated from GC-FID peak areas. FAMEs were identified by comparison of their retention times with those of the reference standards. FAMEs were further identified by using WILEY and NIST libraries of the GC-MS system.

### *2.3. Statistical analysis*

Statistical analysis were performed using SAS program to evaluate the significance of differences in the analyzed quality parameters between cultivars and their harvesting times at the level of $P<0.05$.

**Table 1- Citrus cultivars and their harvesting times**

*Çizelge 1- Turunçgil çeşitleri ve hasat zamanları*

| | *Cultivars* | *1st harvesting* | *2nd harvesting* | *3rd harvesting* |
|---|---|---|---|---|
| Mandarin | Batem Göral | 25 October 2013 | 10 November 2013 | 25 November 2013 |
| | Klemantin Fina | 25 October 2013 | 10 November 2013 | 25 November 2013 |
| | Nova | 5 November 2013 | 20 November 2013 | 5 December 2013 |
| | Yerli Apireno | 5 January 2014 | 20 January 2014 | 4 February 2014 |
| Lemon | Batem Pınarı | 15 September 2013 | 30 September 2013 | 15 October 2013 |
| | Interdonato | 15 September 2013 | 30 September 2013 | 15 October 2013 |
| | Meyer | 10 October 2013 | 25 October 2013 | 10 November 2013 |

The experiment was conducted in randomized design with three replications (the fruit was picked from five different trees for each replication). Data were expressed as means ± standard error (SE).

## 3. Results and Discussion

In order to evaluate samples, some basic parameters of the samples were analyzed. These physical and chemical properties of each lemon and mandarin fruits, depends on cultivars and harvesting time, are presented in Table 2 and Table 3.

Seed content was significantly affected by cultivars and their harvesting time for mandarin. Not only amount of seeds but also total seeds' weight per fruit were found as the highest level for Yerli Apireno, which is well known characteristic for this cultivar, followed by Klemantin Fina, Nova and Batem Göral in descending order. The dry matter content of these seeds ranged between 38.57% (Nova) and 49.06%

**Table 2- Some physical and chemical properties of mandarin depending on cultivars and harvesting time (mean±SE)**

*Çizelge 2- Mandalina çeşitlerinin hasat zamanlarına göre bazı fiziksel ve kimyasal özellikleri (ortalama±SH)*

| *Cultivar** | *Harvesting time* | *Fruit weight (g)* | *Seed weight (g fruit⁻¹)* | *Seed number fruit⁻¹* | *Seed dry matter (%)* | *Seed oil content (%, DM)* |
|---|---|---|---|---|---|---|
| Batem Göral | 1st | 85.99$^{e}$±1.46 | 2.84$^{a}$±0.10 | 11.30$^{d}$±0.90 | 46.88$^{b}$±0.08 | 35.79b$^{c}$±1.29 |
| | 2nd | 87.21$^{e}$±1.47 | 2.07$^{c}$±0.12 | 12.00$^{cd}$±0.80 | 49.50$^{ab}$±0.11 | 37.79$^{ab}$±0.27 |
| | 3rd | 88.43$^{e}$±0.58 | 1.29$^{d}$±0.01 | 11.80$^{cd}$±1.00 | 50.81$^{a}$±0.96 | 39.67$^{a}$±2.03 |
| Klemantin Fina | 1st | 94.81$^{cd}$±1.12 | 2.41$^{b}$±0.07 | 15.20$^{cb}$±0.40 | 47.15$^{b}$±0.22 | 31.22$^{d}$±1.20 |
| | 2nd | 95.96$^{c}$±2.69 | 2.43$^{b}$±0.11 | 15.20$^{cb}$±0.80 | 47.26$^{b}$±0.99 | 35.92$^{bc}$±0.54 |
| | 3rd | 104.21$^{b}$±1.70 | 2.69$^{a}$±0.07 | 15.20$^{cb}$±1.00 | 49.40$^{ab}$±0.17 | 36.37$^{abc}$±1.22 |
| Nova | 1st | 125.70$^{a}$±0.67 | 2.11$^{c}$±0.05 | 18.50$^{ab}$±1.30 | 37.45$^{c}$±0.23 | 32.17$^{d}$±0.74 |
| | 2nd | 122.71$^{a}$±3.75 | 2.10$^{c}$±0.05 | 17.40$^{ab}$±0.60 | 39.51$^{c}$±0.64 | 30.67$^{d}$±0.66 |
| | 3rd | 126.93$^{a}$±2.57 | 2.11$^{c}$±0.03 | 18.30$^{ab}$±1.10 | 38.75$^{c}$±0.67 | 33.35$^{cd}$±0.04 |
| Yerli Apireno | 1st | 90.97$^{cde}$±1.55 | 2.87$^{a}$±0.11 | 20.60$^{a}$±1.00 | 39.87$^{c}$±0.40 | 30.15$^{d}$±1.67 |
| | 2nd | 95.10$^{cd}$±1.81 | 2.89$^{a}$ ±0.02 | 20.60$^{a}$±0.80 | 40.19$^{c}$±1.81 | 30.26$^{d}$±0.13 |
| | 3rd | 92.17$^{cde}$±3.02 | 2.75$^{a}$±0.10 | 20.10$^{a}$±2.10 | 39.69$^{c}$±1.25 | 29.89$^{d}$±1.17 |

*, mean in the same column with different letters are significantly different (P<0.05); DM, dry matter

**Table 3- Some physical and chemical properties of lemon depending on cultivars harvesting time (mean±SE)**

*Çizelge 3- Limon çeşitlerinin hasat zamanlarına göre bazı fiziksel ve kimyasal özellikleri (ortalama±SH)*

| *Cultivar** | *Harvesting time* | *Fruit weight (g)* | *Seed weight (g fruit⁻¹)* | *Seed number fruit⁻¹* | *Seed dry matter (%)* | *Seed oil content (%, DM)* |
|---|---|---|---|---|---|---|
| Batem Pınarı | 1st | 139.61$^{a}$±4.88 | 1.77$^{c}$±0.00 | 10.00$^{b}$±1.00 | 44.91$^{ef}$±0.51 | 22.00$^{b}$±1.95 |
| | 2nd | 142.70$^{a}$ ±2.22 | 1.70$^{c}$±0.06 | 10.20$^{b}$±0.40 | 46.34$^{e}$±0.81 | 21.73$^{b}$±1.18 |
| | 3rd | 134.24$^{ab}$±3.28 | 1.71$^{c}$±0.03 | 8.90$^{b}$±0.30 | 48.47$^{d}$±0.59 | 21.26$^{b}$±0.78 |
| Interdonato | 1st | 96.57$^{d}$±1.78 | 1.28$^{d}$±0.08 | 9.20$^{b}$±0.20 | 43.16$^{f}$±0.15 | 22.76$^{b}$±0.70 |
| | 2nd | 100.53$^{d}$±3.26 | 1.39$^{d}$±0.10 | 9.15$^{b}$ ±0.05 | 45.57$^{e}$±1.13 | 21.38$^{b}$±1.10 |
| | 3rd | 99.95$^{d}$±0.68 | 1.29$^{d}$±0.05 | 9.40$^{b}$±0.40 | 49.05$^{cd}$±0.18 | 23.65$^{b}$±1.11 |
| Meyer | 1st | 117.25$^{c}$±5.65 | 2.95$^{a}$±0.03 | 20.70$^{a}$±1.10 | 50.69$^{bc}$±0.30 | 36.26$^{a}$±0.85 |
| | 2nd | 122.40$^{bc}$±4.04 | 2.72$^{b}$±0.11 | 19.00$^{a}$±1.20 | 51.69$^{b}$±0.46 | 37.62$^{a}$±0.88 |
| | 3rd | 123.45$^{bc}$±5.99 | 2.62$^{b}$±0.06 | 20.40$^{a}$±1.20 | 53.66$^{a}$±0.14 | 37.17$^{a}$±0.46 |

*, mean in the same column with different letters are significantly different (P<0.05); DM, dry matter

(Batem Göral). Average total dry matter content of Batem Göral and Klemantin Fina were higher than the other mandarin cultivars. Additionally, small differences in dry matter content were observed between each harvesting time for the same cultivars. Dry matter content of the seeds slightly increased from first harvesting to third harvesting time in Batem Göral and Klemantin Fina. On the other hand, differences in dry matter content of Yerli Apireno and Nova were not statistically important between their harvesting times. Total oil contents were varied with respect to cultivars and their harvesting time on dry matter base. The highest oil content was determined in Batem Göral (37.75%) and followed by Klemantin Fina (34.50%), Nova (32.06%) and Yerli Apireno (30.10%) in descending order. Total oil content of the seeds increased steadily from first harvesting to third harvesting time for Batem Göral and Klemantin Fina. Total oil contents of the other two cultivars were similar between their harvesting times. As a consequence, the oil content of mandarin seeds (30.10-37.75%) was higher than cotton (15-24%) and soybean (17-21%) (Pritchard 1991). Anwar et al (2008) were analyzed oil content and fatty acid composition of four different citrus species. One of them was mandarin (Kinnow cultivar) and it's oil content was determined as 31.15%. Oil contents of Nova and Yerli Apireno seeds were similar with this literature finding.

Both amount of seeds and total seeds weight per fruit of Meyer cultivar were extremely higher than other two lemon cultivars. The dry matter content of the lemon seeds ranged from 43.16% (Interdonato) to 53.66% (Meyer). The total oil content of the seeds changed significantly with respect to cultivars and their harvesting times. The average highest oil content was determined in Meyer (37.02%) and followed by Interdonato (22.59%), Batem Pınarı (21.66%) in descending order. Total dry matter content of the lemon seeds steadily increased from first harvesting to third harvesting time in all lemon cultivars. Oil content of the seeds was not affected by harvesting time for each cultivar. Reda et al (2005) determined the oil content of lemon as 38.30%. This value showed similarity with Meyer seed oil content in this study. On the other hand, this value was higher than Interdonato and Batem Pınarı samples. This could be sourced by mainly cultivar differences. Growing condition could also affect their composition.

The fatty acid composition of the samples was depicted in Table 4, 5 for mandarin and Table 6,

**Table 4- Unsaturated fatty acid composition of mandarin seed oils depending on cultivars and harvesting time (%, mean±SE)**

*Çizelge 4- Mandalina çekirdek yağlarının hasat zamanlarına göre doymamış yağ asitleri bileşimi (%, ortalama±SH)*

| *Cultivar** | *Harvesting time* | *Palmitoleic* | *Oleic* | *Linoleic* | *Linolenic* | *Gadoleic* |
|---|---|---|---|---|---|---|
| Batem Göral | 1st | $0.55^{b}\pm0.000$ | $25.56^{h}\pm0.040$ | $35.65^{d}\pm0.010$ | $3.87^{f}\pm0.005$ | $0.17^{b}\pm0.025$ |
| | 2nd | $0.49^{f}\pm0.000$ | $25.58^{h}\pm0.010$ | $35.99^{d}\pm0.035$ | $4.35^{b}\pm0.005$ | $0.24^{ab}\pm0.050$ |
| | 3rd | $0.45^{h}\pm0.000$ | $27.73^{e}\pm0.080$ | $35.28^{e}\pm0.165$ | $3.88^{f}\pm0.005$ | $0.28^{a}\pm0.050$ |
| Klemantin Fina | 1st | $0.43^{\imath}\pm0.000$ | $27.76^{d}\pm0.045$ | $35.10^{e}\pm0.095$ | $3.90^{e}\pm0.010$ | $0.22^{ab}\pm0.015$ |
| | 2nd | $0.48^{g}\pm0.000$ | $26.39^{f}\pm0.050$ | $37.12^{c}\pm0.270$ | $4.22^{d}\pm0.005$ | $0.17^{b}\pm0.030$ |
| | 3rd | $0.54^{c}\pm0.000$ | $25.93^{g}\pm0.025$ | $36.87^{c}\pm0.030$ | $4.23^{d}\pm0.010$ | $0.22^{ab}\pm0.015$ |
| Nova | 1st | $0.58^{a}\pm0.010$ | $23.18^{j}\pm0.045$ | $37.06^{c}\pm0.160$ | $4.29^{c}\pm0.010$ | $0.22^{ab}\pm0.050$ |
| | 2nd | $0.52^{d}\pm0.050$ | $24.27^{\imath}\pm0.005$ | $37.12^{c}\pm0.025$ | $4.36^{b}\pm0.005$ | $0.17^{b}\pm0.015$ |
| | 3rd | $0.50^{e}\pm0.000$ | $24.17^{\imath}\pm0.020$ | $37.98^{a}\pm0.000$ | $4.55^{a}\pm0.010$ | $0.23^{ab}\pm0.015$ |
| Yerli Apireno | 1st | $0.31^{j}\pm0.000$ | $28.99^{b}\pm0.010$ | $34.95^{e}\pm0.050$ | $3.06^{h}\pm0.000$ | $0.30^{a}\pm0.015$ |
| | 2nd | $0.30^{k}\pm0.000$ | $29.18^{a}\pm0.010$ | $35.64^{d}\pm0.020$ | $2.97^{\imath}\pm0.005$ | $0.23^{ab}\pm0.025$ |
| | 3rd | $0.29^{l}\pm0.000$ | $27.97^{c}\pm0.015$ | $37.61^{b}\pm0.020$ | $3.26^{g}\pm0.015$ | $0.24^{ab}\pm0.020$ |

*, mean in the same column with different letters are significantly different ($P<0.05$)

**Table 5- Saturated fatty acid composition of mandarin seed oils depending on cultivars and harvesting time (%, mean±SE)**

*Çizelge 5- Mandalina çekirdek yağlarının hasat zamanlarına göre doymuş yağ asitleri bileşimi (%, ortalama±SH)*

| *Cultivar** | *Harvesting time* | *Palmitic* | *Margaric* | *Stearic* | *Arachidic* | *Behenic* |
|---|---|---|---|---|---|---|
| Batem Göral | 1st | $26.51^{a}\pm0.005$ | $0.40^{c}\pm0.005$ | $6.52^{e}\pm0.020$ | $0.61^{e}\pm0.015$ | $0.19^{fg}\pm0.005$ |
| | 2nd | $25.81^{b}\pm0.065$ | $0.38^{cd}\pm0.010$ | $6.18^{f}\pm0.000$ | $0.64^{d}\pm0.000$ | $0.36^{b}\pm0.005$ |
| | 3rd | $24.61^{d}\pm0.020$ | $0.36^{e}\pm0.000$ | $6.76^{c}\pm0.005$ | $0.72^{c}\pm0.005$ | $0.45^{a}\pm0.000$ |
| Klemantin Fina | 1st | $24.94^{c}d\pm0.030$ | $0.35^{e}\pm0.000$ | $6.58^{d}\pm0.010$ | $0.56^{fg}\pm0.000$ | $0.18^{g}\pm0.015$ |
| | 2nd | $24.00^{e}\pm0.370$ | $0.37^{de}\pm0.005$ | $6.51^{e}\pm0.010$ | $0.55^{gh}\pm0.005$ | $0.21^{ef}\pm0.005$ |
| | 3rd | $25.28^{c}\pm0.000$ | $0.35^{e}\pm0.000$ | $5.88^{g}\pm0.005$ | $0.53^{h}\pm0.005$ | $0.19^{fg}\pm0.010$ |
| Nova | 1st | $26.82^{a}\pm0.270$ | $0.47^{a}\pm0.000$ | $6.58^{d}\pm0.005$ | $0.62^{de}\pm0.010$ | $0.19^{fg}\pm0.000$ |
| | 2nd | $26.54^{a}\pm0.030$ | $0.45^{b}\pm0.005$ | $5.78^{h}\pm0.000$ | $0.58^{f}\pm0.005$ | $0.25^{d}\pm0.005$ |
| | 3rd | $25.78^{b}\pm0.005$ | $0.44^{b}\pm0.000$ | $5.59^{i}\pm0.005$ | $0.56^{fg}\pm0.005$ | $0.22^{de}\pm0.010$ |
| Yerli Apireno | 1st | $23.35^{f}\pm0.015$ | $0.48^{a}\pm0.005$ | $7.59^{a}\pm0.015$ | $0.70^{c}\pm0.010$ | $0.29^{c}\pm0.010$ |
| | 2nd | $22.96^{f}\pm0.030$ | $0.46^{ab}\pm0.005$ | $7.21^{b}\pm0.005$ | $0.77^{b}\pm0.015$ | $0.31^{c}\pm0.015$ |
| | 3rd | $21.73^{g}\pm0.050$ | $0.46^{ab}\pm0.015$ | $7.23^{b}\pm0.000$ | $0.86^{a}\pm0.005$ | $0.37^{b}\pm0.000$ |

*, mean in the same column with different letters are significantly different (P<0.05)

7 for lemon seeds oils. Ten different fatty acids were examined in all samples. Statistical analysis of the data showed fatty acid composition varied significantly (P<0.05) with in the cultivars and their harvesting time of the samples.

The main fatty acids determined as linoleic and oleic acids as unsaturated and palmitic acid as saturated fatty acid in the mandarin seed oils. Linoleic acid, is an essential fatty acid, was the most abundant fatty acids in all mandarin cultivars and ranged between 34.95 (Yerli Apireno)-37.98% (Nova). Significant differences determined between cultivars and their harvesting time. Small increasing was observed in linoleic acid content of the samples from first harvesting to third harvesting time in each mandarin cultivar. But these differences were small according to differences between mandarin and lemon species. The relatively few researches were reported for fatty acids composition of citrus seeds oil to date. El-Adawy et al (1999) analyzed the fatty acid composition of the mandarin seed oil. They detected eight different fatty acids, palmitic

**Table 6- Unsaturated fatty acid composition of lemon seed oils depending on cultivars and harvesting time (%, mean±SE)**

*Çizelge 6- Limon çekirdek yağlarının hasat zamanlarına göre doymamış yağ asitleri bileşimi (%, ortalama±SH)*

| *Cultivar** | *Harvesting time* | *Palmitoleic* | *Oleic* | *Linoleic* | *Linolenic* | *Gadoleic* |
|---|---|---|---|---|---|---|
| Batem Pınarı | 1st | $0.33^{d}\pm0.000$ | $36.93^{a}\pm0.000$ | $28.67^{g}\pm0.000$ | $4.64^{d}\pm0.000$ | $0.25^{cd}\pm0.000$ |
| | 2nd | $0.52^{a}\pm0.000$ | $36.16^{b}\pm0.005$ | $28.86^{f}\pm0.030$ | $3.99^{g}\pm0.005$ | $0.23^{cd}\pm0.050$ |
| | 3rd | $0.52^{a}\pm0.025$ | $36.10^{b}\pm0.055$ | $28.88^{f}\pm0.045$ | $4.04^{g}\pm0.085$ | $0.19^{d}\pm0.020$ |
| Interdonato | 1st | $0.33^{d}\pm0.000$ | $36.82^{a}\pm0.095$ | $28.54^{h}\pm0.005$ | $4.63^{d}\pm0.020$ | $0.25^{cd}\pm0.000$ |
| | 2nd | $0.33^{d}\pm0.005$ | $35.09^{c}\pm0.025$ | $29.19^{e}\pm0.000$ | $4.96^{b}\pm0.005$ | $0.72^{a}\pm0.005$ |
| | 3rd | $0.33^{d}\pm0.005$ | $34.12^{d}\pm0.125$ | $31.26^{a}\pm0.085$ | $4.79^{c}\pm0.010$ | $0.38^{b}\pm0.000$ |
| Meyer | 1st | $0.44^{b}\pm0.000$ | $33.92^{e}\pm0.020$ | $29.34^{d}\pm0.015$ | $4.40^{e}\pm0.010$ | $0.23^{cd}\pm0.045$ |
| | 2nd | $0.41^{c}\pm0.005$ | $32.18^{g}\pm0.015$ | $30.97^{b}\pm0.020$ | $5.13^{a}\pm0.015$ | $0.20^{cd}\pm0.020$ |
| | 3rd | $0.43^{bc}\pm0.000$ | $32.86^{f}\pm0.050$ | $29.89^{c}\pm0.010$ | $4.24^{f}\pm0.005$ | $0.29^{c}\pm0.015$ |

*, mean in the same column with different letters are significantly different (P<0.05)

(28.12%), oleic (24.89%) and linoleic (38.26%) acids were major fatty acids in the seed oils. Anwar et al (2008) studied on the fatty acid composition of mandarin seed oil. Linoleic acid (39.55%) was determined as the highest fatty acid. Our results were in agreement with the results of these studies. There were some researches on harvesting time effects on fatty acid composition of some plants. Ozdemir & Topuz (2004) stated that oleic acid contents of two avocado cultivars' oil were increased from 47.2-59.3% to 59.5-73.0% at three different harvesting times. Fatty acid composition of almond cultivars was affected significantly from harvesting time (Piscopo et al 2010). Sakouhi et al (2011) and Dag et al (2011) found that fatty acid composition was affected significantly from harvesting time. Our results also showed similarities with these reports.

Another higher unsaturated fatty acid was oleic in mandarin seed oil. There were significant differences in oleic acid content of the samples depend on cultivars and their harvesting time. The average highest oleic acid content was determined in Yerli Apireno (28.71%), and followed by Klemantin Fina (26.69%), Batem Göral (26.12%) and Nova (23.87%) cultivars in descending order. Some changes were observed according to harvesting time of the samples. While oleic acid content of the Batem Göral sample increased from first harvesting to third harvesting time, this fatty acid ratio decreased from first harvesting to last harvesting time in Klemantin Fina seed oil. Another quantitatively high unsaturated fatty acid was linolenic acid, and it ranged from 2.97% (Yerli Apireno) to 4.55% (Nova). Palmitoleic and gadoleic acids also were detected in the seeds oils, but totally lower than 1% in these samples.

The main saturated fatty acid was palmitic acid in mandarin seed oils and ranged between 21.73% and 26.82%. This fatty acid ratio was significantly different between cultivars and their harvesting time. The highest palmitic acid ratio was determined in Nova and followed by Batem Göral, Klemantin Fina, Yerli Apireno cultivars, in descending order. And, palmitic acid ratios of these cultivars were decreased from first harvesting to third harvesting time except for Klemantin Fina. The other quantitatively higher saturated fatty acid was stearic acid, ranged from 5.59 (Nova) and 7.59% (Yerli Apireno). There were small differences in stearic acid content between harvesting time of each cultivar. This fatty acid ratio decreased from first harvesting to third harvesting time except for Batem Göral cultivar. Margaric, arachidic and behenic acids contents were lower than 1% in these samples. Margaric and behenic acids were not detected in citrus seeds oil in previous studies (El-Adawy et al 1999; Saidani et al 2004; Anwar et al 2008;

**Table 7- Saturated fatty acid composition of lemon seed oils depending on cultivars and harvesting time (%, mean±SE)**

*Çizelge 7- Limon çekirdek yağlarının hasat zamanlarına göre doymuş yağ asitleri bileşimi (%, ortalama±SH)*

| *Cultivar** | *Harvesting time* | *Palmitic* | *Margaric* | *Stearic* | *Arachidic* | *Behenic* |
|---|---|---|---|---|---|---|
| Batem Pınarı | 1st | $23.01^{e}$±0.000 | $0.53^{b}$±0.000 | $5.18^{e}$±0.000 | $0.46^{e}$±0.000 | trace |
| | 2nd | $24.36^{c}$±0.010 | $0.52^{b}$±0.005 | $4.94^{g}$±0.010 | $0.44^{e}$±0.005 | trace |
| | 3rd | $24.26^{c}$±0.075 | $0.54^{b}$±0.015 | $5.05^{f}$±0.070 | $0.45^{e}$±0.020 | trace |
| Interdonato | 1st | $22.95^{e}$±0.060 | $0.54^{b}$±0.005 | $5.50^{d}$±0.000 | $0.46^{e}$±0.005 | trace |
| | 2nd | $22.90^{e}$±0.050 | $0.49^{c}$±0.005 | $5.72^{c}$±0.010 | $0.63^{b}$±0.005 | trace |
| | 3rd | $22.91^{e}$±0.020 | $0.56^{a}$±0.000 | $5.18^{e}$±0.005 | $0.49^{d}$±0.000 | trace |
| Meyer | 1st | $24.65^{b}$±0.035 | $0.32^{d}$±0.005 | $5.99^{a}$±0.010 | $0.58^{c}$±0.005 | $0.16^{b}$±0.025 |
| | 2nd | $24.06^{d}$±0.020 | $0.32^{d}$±0.000 | $6.00^{a}$±0.000 | $0.59^{c}$±0.005 | $0.16^{b}$±0.000 |
| | 3rd | $25.08^{a}$±0.035 | $0.33^{d}$±0.000 | $5.85^{b}$±0.000 | $0.66^{a}$±0.000 | $0.39^{a}$±0.005 |

*, mean in the same column with different letters are significantly different (P<0.05)

Matthaus & Özcan 2012). These results could be sourced from cultivar differences.

The main fatty acids for lemon cultivar seed oils in the present study were determined oleic and linoleic acids as unsaturated and palmitic acid as saturated fatty acid. While linoleic acid was the highest fatty acid in mandarin cultivars, oleic acid was the main fatty acid in lemon seed oils and ranged from 32.18% to 36.93%. This fatty acid ratio was affected significantly from cultivars and their harvesting time. The average highest oleic acid ratio was determined as 36.39% in Batem Pınarı cultivars, followed by Interdonato (35.34%) and Meyer (32.99%), in descending order. Small decreasing was observed in oleic acid content of the samples from first harvesting to third harvesting time in lemon cultivars except for Meyer. Matthaus & Özcan (2012) reported oleic acid content of lemon seed oils to be 38.5-63.6%. The oleic acid ratio in the present study was lower than these results. On the other hand, the present results for lemon seed oils were quite comparable with those of reported (36.60%) by Saidani et al (2004).

Linoleic acid content was also high in the lemon seed oils. The average highest linoleic acid (30.07%) was determined in Meyer cultivar seed oil and followed by Interdonato and Batem Pınarı cultivars in descending order. Linoleic acid content of the samples showed significant differences between harvesting time of each cultivar. This fatty acid ratio increased from first harvesting to third harvesting time in Batem Pınarı and Interdonato cultivars. On the other hand, the highest linoleic acid ratio was determined in second harvest sample for Meyer. The linoleic acid content of the lemon cultivars analyzed in the present study agreed well with those reported (31.40%) by Saidani et al (2004). However, our results differed from the findings (26.8-44.5%) of Matthaus & Özcan (2012). Besides the cultivars, differences in linoleic acid content could be resulted from ecology, cultural practices, harvesting time etc. Another determined fatty acid in the lemon seeds oils was linolenic acid. This fatty acid ratio was significantly different between samples and ranged from 3.99% to 5.13%. The average highest linoleic acid ratio was determined as 4.79% for Interdonato and this one was followed by Meyer (4.59%) and Batem Pınarı (4.22%). Some differences were observed according to harvesting time of each cultivar. While the highest linolenic acid ratios were determined in second harvest samples for Interdonato and Meyer cultivars, the highest value was determined in first harvest sample for Batem Pınarı. Palmitoleic and gadoleic acids were lower than 1% in lemon seeds oils.

The main saturated fatty acid was also palmitic acid in lemon cultivars seed oil and ranged between 22.90% (Interdonato) and 25.08% (Meyer). Palmitic acid ratios showed significant differences between samples. The highest palmitic acid for cultivars was determined in Meyer (24.59%), followed by Batem Pınarı (23.88%) and Interdonato (22.92%), in descending order. This saturated fatty acid ratio was significantly different between their harvesting times except for Interdonato. The lemon seeds oil had important level stearic acid and ranged from 4.94% to 6.00% in lemon cultivars. This fatty acid ratio was significantly different between cultivars and their harvesting times. The highest stearic acid ratio was determined in first and second harvest samples of Meyer cultivar. And the lowest value was observed in second harvest sample of Batem Pınarı. Margaric, arachidic and behenic acids contents were lower than 1% in these samples. Qualitative differences among the studied lemon cultivars were only found for behenic acid that was not detected in two of the cultivars. Behenic acid was only detected in Meyer cultivars. This fatty acid content was significantly increased from second harvesting to third harvesting time in this cultivar.

## 4. Conclusions

Citrus seeds have considerable amounts of oil. As a result of general evaluation, the highest oil content could be obtained from Klemantin Fina cultivars. Oil content of the Klemantin Fina was calculated as 4.15 g for 1 kg fresh fruit. This cultivar was followed by Batem Göral, Yerli Apireno and Nova cultivars in descending order. Total oil contents of these cultivars showed differences between each harvesting time of these cultivars based on fresh fruit weight. And, the highest oil content was determined as 4.83 g for 1 kg fresh fruit on last harvesting time samples of Klemantin Fina. For lemon cultivars, the average highest oil content was calculated as 5.32 g for 1 kg fresh fruit. Fatty acid composition of the mandarin and lemon seeds showed significantly differences in terms of the cultivars and their harvesting time, and the main fatty acid were determined to be oleic, linoleic and palmitic acid for all samples. Fatty acids have importance in human nutrition and quality of edible oils. The seeds, remaining after processing the fruits into juice, could be subjected to oil extraction. This is important for making additional profit from these plants. Furthermore, the data could be useful for biochemical characterization of different mandarin and lemon cultivars.

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