Chemical Components and Bioactivities of Olive (*Olea europaea*)

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Abstract: The olive tree (*Olea europaea*), native to the coastal areas of eastern Mediterranean basin and parts of Asia, nowadays is cultivated all around the world. The products of olive trees, including olive leaves, fruit and oil, possess high nutritional and medicinal values. The characteristic bioactivities of olive products include antioxidant, anti-cancer, anti-hypertension and anti-atherosclerosis and so on. The studies suggest that these benefits mainly come from its balance of polyunsaturated fatty acids and saturate fatty acids, together with the considerable amount of phenolics, sterols, tocopherols, etc. The objective of this review is to summarize the chemical components and bioactivities of *Olea europaea*.

Keywords: *Olea europaea*; olive; fruit; oil; leaves; bioactive compound; bioactivities.

1. Introduction

The olive tree (*Olea europaea*), a species of small tree, belongs to the genus *Olea* of the olive family, the *Oleaceae*. It is an evergreen tree or shrub native to the coastal areas of the eastern Mediterranean Basin, Northern Iraq, and Northern Iran at the south of the Caspian Sea (Boskou, 2006). The traces of pollen verified the presence of *O. europaea* in the Mediterranean Basin about 3.2 million
years ago (Suc, 1984). The cultivation of olive tree in the eastern Mediterranean dates back to the Neolithic, about 6000 years BC (Quiles et al., 2006). In contemporary times, because of the increasing awareness of valuable nutrients contained in olive and its tolerance to tough environment and climate, the cultivation of olive got great expansion. The area used for cultivation of olive tree increased from 2.6 to 8.5 million of hectares (FAO, 2004). However, the Mediterranean region is still the largest production area, which produces 98% of the world’s olives (Ryan and Robards, 1998). People cultivate the olive trees for olive fruit, leaves and oil as well as fine woods.

It has been a long time since people started using the products of olive trees for their medicinal and nutritional values. Historically, the function of the products of olive trees includes emollients, laxatives, nutritive, sedatives and tonics (Waterman and Lockwood, 2007). People also used them to treat colic, alopecia, paralysis, rheumatic pain, sciatica, and hypertension (Hassan et al., 2005).

There are 250 cultivars of olive classified as commercial cultivars by the International Olive Oil Council, among the approximately 2500 varieties of olives (IOOC, 2011). The use of commercial cultivars is production of olive oil and table olives and 96%-98% of olive oil is concentrated in the pericarp of olive fruit (Ghanbari et al., 2012). Virgin olive oil are obtained from fruit of the olive tree solely by mechanical or other physical means under conditions that do not lead to alternations of the oil, especially thermal conditions, and can only undergo the treatment including washing, decantation, centrifugation and filtration (Quiles et al., 2006). Extra virgin olive oil is one special kind of olive oil, which has a maximum free acidity, expressed as oleic acid, of 1g per 100g oil. Olive leaves are silvery green and oval. People traditionally used olive leaves as a dietary component in the form of a whole herbal power (El and Karakaya, 2009).

Nowadays, because of the cognition of benefits of some certain nutrients and functional foods on human health, increasingly attention has been paid on the composition and bioactivities of different products of olive trees, consisting of olive fruit, leaves and oil. The main objective of this review is to summarize some recently researches concerning the chemical components and bioactivities of *Olea europaea*.

### 2. Chemical Components

#### 2.1. General Components

The olive fruit is an oval stone fruit. Mostly, the weight of olive fruits is 2-12g. An olive fruit is composed by a pericarp and an endocarp. The former includes the skin and pulp, which contributing almost 65%-83% of the fruit's total weight. The latter is a woody shell holding a seed (Boskou, 2006). The major chemical composition of fresh olive fruit is listed in Table 1. There are also some important minor components, such as pectins, organic acids, pigments, and phenolics (Boskou, 2006).
The qualitative and quantitative sugar profiling in olive fruit, leaves, and stems was measured by gas chromatography-tandem mass spectrometry (GC-MS/MS) after ultrasound-assisted leaching. Sugar was isolated through leaching into a 2:1 dichloromethane/methanol extraction solution under ultrasonic assistance. The results showed that mannitol, glucose, fructose and galactose are the major sugars in olive fruit and leaves (Table 2), which represent more than 60% total soluble carbohydrates of these olive tissues, while in the small stems, the major sugar is sucrose, D-glucuronic acid, mannitol and glucose. Besides these compounds, xylitol, 1,6-anhydro-β-D-glucose, arbutin, adonitol, N-acetyl-D-glucosamine and lactose are also detected in a very low concentration (Gómez-González et al., 2010).

### Table 1. Major chemical composition of fresh olive fruit

<table>
<thead>
<tr>
<th>Chemical composition</th>
<th>water</th>
<th>oil</th>
<th>carbohydrates</th>
<th>cellulose</th>
<th>protein</th>
<th>minerals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage</td>
<td>50%</td>
<td>22%</td>
<td>19%</td>
<td>5.8%</td>
<td>1.6%</td>
<td>1.5%</td>
</tr>
</tbody>
</table>

### Table 2. Major soluble carbohydrates of olive

<table>
<thead>
<tr>
<th></th>
<th>fruit and leaves</th>
<th>Small stems</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mannitol, glucose, fructose, galactose</td>
<td>sucrose, D-glucuronic acid, mannitol, glucose</td>
</tr>
</tbody>
</table>

#### 2.2. Fatty acids

Extra virgin olive oil, produced from fresh olive fruit, contains saponifiable and unsaponifiable components. The saponifiable component represents 98%-99% of the oil chemical composition, including triglycerides, partial glycerides, esters of fatty acids and phosphatides (Gavriilidou and Boskou, 1991). The major fatty acid of the triglycerides are monounsaturates (oleic acid), a low concentration of saturates and considerable amount of polyunsaturates (linoleic and α-linolenic). The unsaponifiable components are consisted of minor components, which include α-tocopherol, phenol compounds, carotenoids (β-carotene and lutein), squalene, phytosterols and chlorophyll (Aparicio and Aparicio-Ruiz, 2000).

The most abundant fatty acid of Tunisia Sayali olive cultivar was oleic acid, accounting for 77.4% of the total fatty acids (Table 3). There are also considerable amount of palmitic acid (C16:0) (11.0%) and linoleic (C18:2) (5.9%). Stearic acid (C18:0) (2.7%), linolenic acid (C18:3) (1.7%), gadoleic acid (C20:1) (0.6%), palmitoleic acid (C16:1) and arachidic acid (C20:0) (0.2%) were also detected (Sakouhi et al., 2010). In another study, the fatty acid composition of fruit from two olive cultivars (Chemlali and Neb Jmel) was compared by the method of GC-MS (Gas chromatography-
electron impact mass spectrometry) analysis. Total lipid was extracted by a chloroform/methanol mixture (1:1, v/v) and subsequently sodium methoxide solution was used to methylate total fatty acids. The results showed that fatty acid composition of olive oil varies with the cultivar (Brahmi et al., 2011).

Compared with some other edible oils, olive oil has a relatively high nutritional value, which comes from its balance of polyunsaturated fatty acids (MUFAs) and saturated fatty acids (SFAs). The SFAs, MUFAs, polyunsaturates ω-6, and polyunsaturates ω-3 represent 8%-14%, 65%-83%, 1.5%-2.5% and 0.5% of the total fatty acids in olive oil, respectively, while in peanut oil, SFAs, MUFAs, and polyunsaturates ω-6 represent 17%-21%, 40%-70%, and 13%-28% of the total fatty acids, respectively (Viola and Viola, 2009).

Table 3. Fatty acids in olive oil

<table>
<thead>
<tr>
<th>Major fatty acids of olive oil</th>
<th>Percentage of the total fatty acids</th>
</tr>
</thead>
<tbody>
<tr>
<td>oleic acid</td>
<td>77.4%</td>
</tr>
<tr>
<td>palmitic acid (C16:0)</td>
<td>11.0%</td>
</tr>
<tr>
<td>linoleic (C18:2)</td>
<td>5.9%</td>
</tr>
<tr>
<td>Stearic acid (C18:0)</td>
<td>2.7%</td>
</tr>
<tr>
<td>linolenic acid (C18:3)</td>
<td>1.7%</td>
</tr>
<tr>
<td>gadoleic acid (C20:1)</td>
<td>0.6%</td>
</tr>
</tbody>
</table>

Categories of fatty acids in olive oil

| SFAs                           | 8~14% |
| MUFAs                          | 65%~83% |
| Polyunsaturates ω-6            | 1.5%~2.5% |
| Polyunsaturates ω-3            | 0.5% |

2.3. Phenolic Compounds

Phenolic compounds are secondary metabolites in vegetables and fruits. Among them, olive fruit and olive oil can provide a considerable amount of phenols with important antioxidant potential (Bouaziz et al., 2005). The phenolic compounds in virgin olive oil can be divided into following categories: phenolic acids, phenolic alcohols, hydroxyisocromans, flavonoids, secoiridoids and lignans (Soler-Rivas et al., 2000). Secoiridoids has the highest amount among the phenols categories in virgin olive oil (Servili and Montedoro, 2002). There are 27.72 mg/kg of total secoiridoids in virgin olive oil (VOO) (Owen et al., 2000). The main secoiridoids in VOO are dialdehydic form of elenonic acid linked to 3,4-dihydroxyphenyl ethanol (3,4-DHPEA) or p-hydroxyphenyl ethanol (p-HPEA) (3,4-
DHPEA-EDA or p-HPEA-EDA) and an isomer of the oleuropein aglycon (3,4-DHPEA-EDA) (Montedoro et al., 1993).

The phenolic profiles of Turkish olives and olive oils were investigated by high performance liquid chromatography (HPLC) method. The concentrations of total phenolic compound in the olive fruit varied between 168.08 and 21326.12 mg/kg (Table 4). In all cultivars, the most abundant phenolic compounds were oleuropein and trans-cinnamic acid. Oleuropein concentrations varied between 27.43 and 17461.77 mg/kg. Trans-cinnamic acid varied between 33.07 and 12408.11 mg/kg (Yorulmaz et al., 2012). The hydroxytyrosol wasn't detected in the Turkish olive cultivars, while in some researches, it is one of the major phenolic compounds in olive fruit (Romero et al., 2002).

The method of ultrasound-assisted solid liquid extraction (USLE) was used to extract olive fruit phenols and HPLC-DAD-MS/MS was adopted to analyze the phenolics. According to the results, the most efficient parameters are a three-step extraction of 20 min with pure methanol (25 mL) at 45 °C. In such a condition, 94.1%-98.7% of the phenol in freeze-dried olive fruit can be recovered (Jerman et al., 2010).

Table 4. Phenolic profiles of Turkish olives

<table>
<thead>
<tr>
<th>Total phenolic compound</th>
<th>Concentration (mg/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fresh olive fruit</td>
</tr>
<tr>
<td>Total phenolic compound</td>
<td>168.08-21326.12</td>
</tr>
<tr>
<td>Categories</td>
<td>phenolic acids,</td>
</tr>
<tr>
<td></td>
<td>phenolic alcohols,</td>
</tr>
<tr>
<td></td>
<td>hydroxyisocromans,</td>
</tr>
<tr>
<td></td>
<td>flavonoids, secoiridoids, lignans</td>
</tr>
<tr>
<td>Most abundant phenolic compounds</td>
<td>Oleuropein (27.43-17461.77 mg/kg)</td>
</tr>
<tr>
<td></td>
<td>Trans-cinnamic acid (33.07-12408.11 mg/kg)</td>
</tr>
</tbody>
</table>

2.4. Volatile Compounds

The aroma of virgin olive oil can be ascribed to the various volatile compounds contained. Almost 80% of total volatile compounds in all the different oils were made up of six carbon aldehydes, alcohols, and their acetyl esters (Dabbou et al., 2009).

Headspace solid-phase microextraction (HS-SPME) was applied to analyze the volatile compounds of VOO, and twenty-seven compounds were characterized by GC-FID and GC-MS (Youssef et al., 2011). (E)-2-Hexenal was the most prevalent compounds, representing 20% of the total volatiles. Considerable amount of hexenal, (Z)-3-hexenyl acetate, 1-hexyl acetate, nonanal, α-copaene and (E,E)-α-farnesene were also detected. Most of the volatile compounds are produced during the climacteric stage of ripening and the period when oil is extracted from the olive fruit (Kalua et al., 2000). There are several pathways have been reported contributing to the produce of the aroma of the
olive oil, such as the LOX pathway and the fatty acids or amino acids metabolism (Brahmi et al., 2002).

2.5. Sterols (4-Desmethylsterols)

Sterol are tetracyclic compounds biosynthetically produced from squalene. The total amount of sterols in olive oil ranged from 1800 to 4939 mg/kg (Mulinacci et al., 2005). Sakouhi et al. (2010) analyzed the total lipid fraction from the Sayali variety of olive oil. The sterols were detected by GC-MS, and the quantification of sterols was achieved by GC-FID (Gas chromatography-flame ionization detection). The result showed that β-sitosterol was the most abundant component (147.5 mg/100 g oil), making up over 82% of total sterols. There are also other sterols quantified such as campesterol (3.7 mg/100 g oil), cholesterol (1.8 mg/100 g oil), stigmasterol (1.4 mg/100 g oil), 5,24-Stigmastadienol (0.3 mg/100 g oil), Δ7-avenasterol (0.2 mg/100 g oil) and Δ7-campesterol (0.3 mg/100 g oil).

2.6. Tocopherols

There are four categories of tocopherol have been detected in olive oil, including α-, β-, γ- and δ-tocopherol. The total tocopherols in olive oil ranged from 100 to 270 mg/kg. α-Tocopherol is the major tocopherol in olive oils, ranging from 150 to 200 mg/kg oil and accounting for 95% of the total tocopherol. The optimum E/polyunsaturated fatty acid ratio (milligrams of vitamin E per gram of polyunsaturates) of olive oil contributes to its nutritional value. The ratio should never be less than 0.5, which in olive oil is 1.5 to 2.0 and is not common in other edible oils. In another study, the tocopherols and tocotrienols in olive oils was quantified by HPLC with three different detection systems, including fluorescence, ultraviolet, and evaporative light scattering. The results showed that HPLC with the fluorescence detector is the optimum way (Cunha et al., 2006).

3. Bioactivities

3.1. Antioxidant Activity

There are high proportion of monounsaturated fatty acids, considerable amount of polyunsaturated fatty acids, and other natural antioxidants in virgin olive oil, such as α-tocopherol, β-carotene, lutein, phenolic compounds, and squalene. Papadopoulos et al. (2003) used the chemiluminescence of N,N’-dimethyl-9,9’-biacridinium dinitrate (lucigenin) to measure the antioxidant activity (AA) of olive oil aqueous extracts. The result showed that compared with sunflower or corn oils, the olive oil had the highest AA (37-67%), which was 2-10 times higher than the seed oils. In another study, the oxygen radical absorbance capacity (ORAC) of olive oil was investigated by a spectrofluorometric method. Researchers measured the protection of the phenolic
compounds of the oil on the β-phycoerythrin fluorescence decay, and methanol was used to extract the phenolic compounds. The result showed that the maximal ORAC of extra-virgin olive oil was 5.89-6.51 μmol Trolox equivalent/g (Ninfali et al., 2001). In addition, Gorinstein et al. (2002) evaluated the antioxidant capacity of extra virgin olive oil using four radical scavenging activities: total radical-trapping antioxidative potential by ABAP (TRAPABAP), radical scavenging activity by DPPH (RSA-DPPH), antioxidant assay by β-carotene-linoleate model system (AA-β-carotene) and total antioxidant status by ABTS (TAA-ABTS). The results were 668 nmol/mL, 29.4%, 40.4% and 2.64 mmol TE/kg for TRAP-ABAP, RSA-DPPH, AA-β-carotene and TAA-ABTS, respectively. A high correlation between total phenols and antioxidant capacities was proved, while the highest for the β-carotene. The results showed the β-carotene test is the best method to determine the antioxidant capacity of olive oil.

Considerable antioxidant activities were also found in olive leaves. Lee et al. (2009) used different radical scavenging systems to measure the antioxidant activities of olive leaves that were extracted by several solvent methods. Following items were evaluated: electron-donating ability (EDA) by DPPH (2,2-diphenyl-1-picrylhydrazyl) radical, superoxide dismutase (SOD)-like activity, antioxidant activity in the linoleic acid system, and inhibition of auto-oxidation in linoleic acid emulsion (LAE) system of olive leaves. The results confirmed the antioxidant activity of olive leaves and showed total flavonoid and phenolic compounds in 80% ethanol extract, butanol, and ethyl acetate fractions was much higher than hexane, chloroform and water fractions. The significant amount of oleuropein and phenolics was proved to play an important role in the antioxidant capacity of olive leaves (Lee et al., 2009).

3.2. Anti-atherosclerosis

Epidemiological studies indicate that Mediterranean diet reduce the risk of coronary heart disease (CHD). Olive oil, as the main source of calories in the Mediterranean diet, has been proved by some studies to be protective against atherosclerosis (Patrick and Uzick, 2001; de Lorgeril and Salen, 2006 a & b). The precise mechanism of olive oil to help prevent atherosclerosis has not been fully understood, however several possible mechanisms have been proposed. According to Moreno and Mitjavila, (2003), some components in olive oil can modulate the cellular oxidative stress/antioxidant status, modify the lipoproteins, and lower the inflammatory mediators, thus prevent the development of atherosclerosis. These effects were ascribed to the polyunsaturated fatty acids in olive oil, while many recent researches concentrated on the role of the various minor components of olive oil in the prevention of atherosclerosis. First, hydroxytyrosol (HT) extracted from olives possessed an antioxidant activity on H2O2-induced intracellular reactive oxygen species in porcine pulmonary artery endothelial cells (VECs). The antioxidant activity was achieved by inducing the phosphorylation of
AMPK, which followed by activation of forkhead transcription factor 3a (FOXO3a) and catalase expression (Zrelli et al., 2011). Second, the phenolic extract from extra virgin olive oil was investigated and showed the capability of significantly reducing the cell surface expression of intercellular and vascular cell adhesion molecules (ICAM-1 and VCAM-1) in human umbilical vascular endothelial cell, subsequently reducing the mRNA expression. The ICAM-A and VCAM-1 and E-selectin are important for endothelial activation (Dell'Agli et al., 2006).

3.3. Anti-hypertension

In traditional medicine, olive fruits and leaves are used to treat hypertension. The epidemiological evidence also suggests olive oil consumption is related to a reduced risk of hypertension. In addition, in vivo laboratory studies and human clinical trials have been conducted to find out the possible mechanisms to explain these effects (Keys et al., 1986; Ferrara et al., 2000; Alonso et al., 2006; Susalit et al., 2011).

In normotensive anaesthetized rats, the aqueous-methanolic crude extract of O. europea fruit was proved to have a dose-dependent (30-100 mg/kg) effect on the reduction of arterial blood pressure. This study suggested that the possible mechanism was through calcium channel blockade (CCB) effect (Hassan et al., 2005).

Olive leaves also possesses a protective ability against hypertension. The clinical effect was proved by comparison with Captopril, at its effective dose of 12.5-25 mg twice daily, olive (Olea europaea) leaf extract, at the dosage regimen of 500 mg twice daily, had a similar effect in reducing systolic and diastolic blood pressures of patients with stage-1 hypertension (Susalit et al., 2011).

Several hypotheses have been proposed to explain the olive oil’s mechanism of anti-hypertension action. (1) working as a calcium channel antagonist (Hassan Gilani et al., 2005); (2) via improve endothelial function (Perona et al., 2006); (3) decreasing vascular tone; (4) change fatty acid and phospholipid composition of the aorta (Waterman and Lockwood, 2007).

3.4. Anti-cancer

Epidemiological data show that olive oil has protective effects against cancer, especially breast, colon, stomach and endometrium cancer (Martin-Moreno et al., 1994; La Vecchia et al. 1995; Tzonou et al., 1996; Braga et al., 1998; Riboli et al. 2002; Bingham and Riboli, 2004; Zamora et al., 2004; Garcia-Segovia et al., 2006). Many studies have been done to explain this phenomenon, and the results suggest that such effect could be from oleic acid, a MUFA in olive oil, and some minor compounds such as squalene and phenolics. However, the components responsible for these anticancer effects have not been fully defined and the mechanisms of the effects are not completely understood.
Recently, Menendez et al. (2006) hypothesized that the anticancer effect of olive oil may be related to oleic acid of olive oil to specifically regulate oncogenes. To prove it, they conducted transient transfection experiments with human Her-2/neupromoter-driven luciferase gene, and the results showed that olive oil can specifically repress the transcriptional activity of Her-2/neu gene. Tightly modulation of Her-2/neu oncogene was proved by previous studies to be important for normal cellular function, and in several human cancers overexpression of Her-2/neu oncogene is frequently happened. Besides oleic acid, certain minor components have been proved to have anticancer effects by various mechanisms. Phenols extracted from virgin olive oil have been found to inhibit several stages in colon carcinogenesis in vitro including initiation, promotion and metastasis (Gill et al., 2005).

Researchers also found that maslinic acid (MA), a triterpenoid of olives, has anti-cancer capacity. The study proved that in salivary gland adenoid cystic carcinoma (ACC) cells, MA induced the apoptosis through following mechanism: MA induced a dose-dependent increase of Ca\(^{2+}\) and evoked p38 MAPK phosphorylation, which lead to the activation of caspase-3 (Wu et al., 2011).

The study found that olive leaves have the ability of anti-cancer as well. Dry olive leaf extract (DOLE) was proved to have significant anti-melanoma potential. DOLE was found to have an effect of disrupting the melanoma cell membrane integrity and fragmenting the genetic material in a caspase-independent manner (Mijatovic et al., 2011).

4. Conclusions and Prospects

As an important part of Mediterranean diet and traditional medicines, olive fruit, oil and leaves contain various chemical components with considerable bioactivities, while the mechanism of these effects still needs for further study. And considering the potential medical use of these valuable compounds, efforts should be made to better isolating, purifying and recovering them. Meanwhile, the development of methods to control the loss of nutrients in the process of manufacturing olive products is of great importance.

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