

Essential Oil Composition of Oleaster (*Elaeagnus Angustifolia L.*) Flowers and Comparative Assessment of Metabolic and Antioxidant Potential of Flower and Leaf Extracts

İğde (*Elaeagnus angustifolia L.*) Çiçeklerinin Uçucu Yağ Bileşimi ve Çiçek ve Yaprak Ekstraktlarının Metabolik ve Antioksidan Potansiyelinin Karşılaştırılması

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Abstract

The oleaster tree (*Elaeagnus angustifolia L.*) has different uses and is cultivated for fruit production, afforestation, landscape, as well as for food and medicinal purposes. The present study was conducted to identify volatile compounds of flowers and assess total phenolic, flavonoid, carotenoid and chlorophyll content of flowers and leaves and their antioxidant potentials. Oil yield of flowers was low (0.1%), 15 compounds were identified in flower oils, and the main volatile compounds were ethyl-cinnamate (93.87%) and ethyl phenylacetate (1.76%). The others were belong to six chemical class and accounted for less than 5% of oil. Total phenolic content of flowers was higher than that of leaves, but total flavonoid, carotenoid and chlorophyll content was higher in leaves. However, the antioxidant capacity measured by CUPRAC (67.49 vs 53.25 $\mu\text{mol TE}^{-1}$) and the radical scavenging activity measured by DPPH (22.30 vs 7.57 $\mu\text{mol TE}^{-1}$) were higher in flower extracts than the leaf extracts. These results suggest that oleaster flowers are a good source of ethyl-cinnamate and phenolic compounds.

Özet

İğde ağacı (*Elaeagnus angustifolia L.*) farklı kullanım alanlarına sahiptir ve meyve üretimi, ağaçlandırma, peyzaj ve bunlara ilave olarak gıda ve ilaç sanayisinde de kullanılmaktadır. Mevcut çalışma iğde çiçeklerinin uçucu bileşenlerini, çiçek ve yaprakların toplam fenolik, flavonoid, karotenoid ve klorofil içeriği ile antioksidan potansiyellerini belirlemek amacıyla yapılmıştır. İğde çiçeklerinin uçucu yağ verimi düşük (%0.1) bulunurken, yağda toplam 15 uçucu bileşik tespit edilmiş ve ana uçucu bileşenlerin etil-sinamat (%93.87) ve etil fenilasetat (%1.76) olduğu belirlenmiştir. Diğer bileşikler altı kimyasal sınıfa ait olup uçucu yağın %5'inden azını oluşturmaktadır. Çiçeklerdeki toplam fenolik madde içeriği yapraklara göre daha yüksek olurken; flavonoid, karotenoid ve klorofil içerikleri ise yapraklarda daha yüksek olmuştur. Bununla birlikte, CUPRAC yöntemi ile ölçülen antioksidan kapasite (67.49-53.25 $\mu\text{mol TE}^{-1}$) ve DPPH yöntemi ile ölçülen radikal temizleme aktivitesi (22.30 - 7.57 $\mu\text{mol TE}^{-1}$) çiçeklerde yapraklardakine göre daha yüksek çıkmıştır. Elde edilen bu sonuçlar iğde çiçeklerinin etil-sinamat ve toplam fenolik bileşen içeriği bakımından iyi bir kaynak olabileceğini göstermektedir.

INTRODUCTION

Oleaster (*E. angustifolia L.*) is a tree from the *Elaeagnaceae* family, naturally growing in Europe and Asia (Katz and Shafroth 2003). The oleaster tree is referred to as Russian olive, silver berry and wild olive as well (Sevindik et al. 2025). Thanks to its resilience to several abiotic stress conditions, including drought and salinity, it is a suitable tree for land rehabilitation and prevention of erosion (Khamzina et al. 2009). Moreover, the oleaster tree possesses the capability to enhance soil's mineral composition (DeCant 2008).

The oleaster tree naturally found in most regions of Türkiye, possesses potential applications in food, cosmetics, agriculture, and medicine (Ishaq et al. 2015). Different parts of the tree, including leaves, flowers, fruits, pits, bark, oil and gum, are utilized in traditional medicine owing to their therapeutic attributes, which encompass antibacterial, antioxidant, antimutagenic, anti-inflammatory, anticancer, antiarthritic and hepatoprotective characteristics (Zare et al. 2023). In alternative medicine, decoctions derived from the fruits, flowers, leaves, and bark of the oleaster tree have been documented to address numerous ailments and their

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symptoms, such as alleviating pain and inflammation, wound healing, asthma, flatulence, vomiting, and nausea (Asadiar et al. 2013, Hamidpour et al. 2017, Hamidpour et al. 2019). Phytochemical analyses of different extracts from fruits, leaves and flowers revealed the presence of secondary metabolites, including vitamins, flavonoids, polysaccharides, phenolcarboxylic acids, saponins, carotenoids and tannins (Abizov et al. 2008, Okmen and Turkcan 2013, Farzaei et al. 2015). In addition, oleaster leaves and flowers also contain essential oils that could serve as a natural source for chemical substances with different applications in agriculture, food, and medicine (Bucur et al. 2007, Özdemir 2023). Oleaster populations show high genetic and metabolite diversity even in the same regions (Incilay 2014, Karkar and Şahin 2022, Sevindik et al. 2023). To the best of our knowledge, essential oil composition of leaves and flowers of the oleaster tree naturally growing in Isparta region of Türkiye has not been investigated. Due to potential uses of oleaster, the present study was carried out to determine composition of essential oils obtained from flowers and to assess metabolic and antioxidant potential of flower and leaf extracts obtained by hydrodistillation.

MATERIAL AND METHOD

Plant Material

Oleaster (*E. angustifolia*) leaves and flowers were collected from the campus of Isparta University of Applied Sciences, Isparta, Türkiye, in June 15, 2023 and used for oil extraction (Figure 1).



Figure 1. Flowers and leaves of the oleaster tree

Methods

Essential Oil Extraction and Analysis

The essential oil of flowers was obtained using a Neo-Clevenger type hydro distillation system for 3 h. After the distillation process, the essential oil of flowers was collected in brown bottles and water from the oils were removed using anhydrous sodium sulfate. The gas chromatography/mass spectroscopy (GC/MS) (Shimadzu GC/MS-QP2010 SE, Japan) analysis was used to determine composition of essential oils. The instrument vaporizes the samples and separates their components using the SupportRx-5Sil MS capillary column (30 m x 0.25 mm, film thickness 0.25 µm). It is equipped with an FID (Flame Ionization Detector) for the identification of chemical compounds. The oven temperature was set first at 60 °C for 1 min and then increased to 250 °C at a rate of 4 °C min⁻¹ for 15 min and then remained at 250 °C for 15 min. The FID temperature was 280 °C and the same conditions applied for all analyses. One microliter of diluted sample was automatically injected from the closed vial, and helium was used as carrier gas with a 1 mL min⁻¹ flow rate. Simultaneous auto-injection was utilized to obtain equivalent retention times (RI). Peak areas in the chromatograms were used to identify the compounds (Erbaş et al. 2023). The compounds were identified by comparing the mass spectra obtained with NIST27 and NIST147 from the US National Institute of Standards and Technology (NIST) mass spectra libraries.

Preparation of Oleaster Flower and Leaf Samples for Extraction and Analysis

The flowers and leaves of Oleaster (*E. angustifolia*) were ground to powder in liquid nitrogen, and 1 g of sample was extracted with 20 mL of 80% methanol in an ultrasonic bath at 40 °C for 30 min (Önder et al. 2023). The antioxidant capacity (CUPRAC and DPPH), total phenolics and flavonoid content were measured from the supernatant after centrifugation at 10.000 rpm for 10 min.

Antioxidant capacities of the samples were determined by CUPRAC (Apak et al. 2004) and DPPH (Bener et al. 2022) methods. For the CUPRAC test, Cu (II) chloride and

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ammonium acetate were prepared with distilled water, and neocuproine was prepared in 96% ethanol. In the test tubes, 0.5 mL of the extract, 1 mL of Cu (II) chloride (10 mM), 1 mL of neocuproine (7.5 mM), 1 mL of ammonium acetate buffer (1 M), and 0.6 mL of distilled water were mixed. After 30 min, the absorbance of the samples was measured against the reagent blank at 450 nm with a UV-Vis spectrophotometer (Shimadzu UV-1280, Japan). Results were expressed as Trolox equivalent ($\mu\text{mol TE g}^{-1}$ FW).

For the DPPH method, 0.2 mM DPPH reagent was dissolved in absolute ethanol. One mL of extract and 2 mL of 0.2 mM DPPH reagent were mixed, the final volume was brought to 4 mL with ethanol. The reaction was incubated at room temperature under dark for 30 min, and then the absorbance value was measured at 515 nm. The DPPH• radical-scavenging activity was expressed as Trolox equivalent ($\mu\text{mol TE g}^{-1}$ FW).

The total phenolics content of flowers and leaves was determined according to Folin-Ciocalteu method (1927). Sample extracts (100 μL) were mixed with 2.5 mL of deionized water and 100 μL of Folin-Ciocalteu reagent. The test tubes were mixed, and after 6 min, 0.5 mL of 20% sodium carbonate was added. The absorbance value of the reaction was measured at 760 nm using a spectrophotometer after a 30 min incubation period. Total phenolics content was given as gallic acid equivalents (GAE) in $\mu\text{g g}^{-1}$ FW.

Flavonoid content was assessed following Sanaka et al. (2005) using aluminum chloride. Sample extract (250 μL), 1.25 mL of deionized water, and 75 μL of 5% sodium nitrite were mixed in a tube and kept in the dark for 6 min. Then, 250 μL of 10% aluminum chloride was added and incubated for 5 min. Finally, 500 μL of 1 M sodium hydroxide and 0.275 mL of deionized water were added to the reaction to make a final volume of 2.5 mL. Absorbance values were measured at 510 nm using a spectrophotometer after incubation for 15 min under dark. Flavonoid content was expressed as (\pm)-catechin equivalents (CAE) in $\mu\text{g g}^{-1}$ FW.

To determine chlorophyll and carotenoid contents in flowers and leaves, samples (1 g) were extracted with dimethylformamide (10 mL). The obtained supernatant was measured at 480, 647 and 664 nm using a spectrophotometer. Chlorophyll and carotenoid content of the samples were calculated according to the following formula (Zhang and Huang 2013):

$$\text{Chlorophyll a } (\mu\text{g mL}^{-1}) = (12.7 \times A_{664}) - (2.79 \times A_{647})$$

$$\text{Chlorophyll b } (\mu\text{g mL}^{-1}) = (20.7 \times A_{647}) - (4.62 \times A_{664})$$

$$\text{Total chlorophyll} = (17.9 \times A_{647}) + (8.08 \times A_{664})$$

$$\text{Total carotenoid } (\mu\text{g mL}^{-1}) = [(1000 \times A_{480}) - (0.89 \times \text{chlorophyll a})] / 245$$

All analyses were carried out with three replications, and the average of replications along with standard deviations (SD) were presented.

RESULTS AND DISCUSSIONS

Essential Oil Composition of Flowers

Hydro-distillation of flowers resulted in a pale-yellow oil with a yield of 0.1% relative to the fresh mass. Table 1 displays the components in the sequence of elution from the DB-5 column, along with the percentage composition and retention indices of each compound identified in the oil samples. The GC/MS analysis identified 15 volatile compounds, varying from predominant to trace quantities. Oxygenated terpenoid compounds were the predominant portion of the oil, accounting for nearly all the volatile oil (94.66%) (Table 1). Among all the characterized components, ethyl cinnamate, an aromatic ester in the oxygenated monoterpene compound class, was found to be the major component (93.87%). The others (n=14) were found in minimal quantities, with most occurring at levels below 0.6%. Other oxygenated monoterpene compounds identified were 1.8-cineole (0.56 %) and 4-terpineol (0.12%). On the other hand, volatile chemical analysis of flowers revealed the presence of compounds with different functional groups, such as alkanes (1.53%), aldehydes (0.15%), esters (0.82%), phenylacetates (1.76%), and ketones (0.50%) as well. Several reports exist regarding the oil content and

chemical composition of oleaster flowers from various countries. Oleaster flowers reported to have 0.05% (Bucur et al. 2007) and 0.01% (Torbati et al. 2016) oil content. Zhaolin et al. (1989) reported that the main component of the essential oil obtained from the flowers was *E*-ethyl cinnamate (78.88%). Other studies also revealed that the principal components detected in flowers of oleaster from Romania were limonene, *E*-ethyl cinnamate, 2-phenyl ethyl isovalerate, anethol, 2-phenyl ethyl benzoate, nerolidol, squalene and acetophenone (Bucur et al. 2007) and from China were *E*-ethyl cinnamate (77.36%), (*E*)-2-methoxy-4-(1-propenyl) phenol (3.03%), acetal (2.70%), *Z*-ethyl cinnamate (1.09%), and ethyl benzenacetate (1.06%) (Qiao et al. 2011). The comparison of our findings with prior literature reveals significant parallels and variances regarding the chemical composition and number of volatile constituents of the flower oil. The primary similarity between the previously analyzed oils and our studied flower oil is the presence of *E*-ethyl cinnamate as the principal component (93.87%), which has been shown to have insecticidal and nematocidal activities (Choi et al. 2006, Abdelgaleil et al. 2008, Özdemir 2023).

In contrast, different volatile compounds, such as anethole, squalene, limonene, β -myrcene and acetophenone, were identified in significant quantities in prior studies (Bucur et al. 2007, Incilay 2014); however, they were absent in our analyzed pure oils, indicating great variation exists for volatile constituents. Incilay (2014) and Karkar and Şahin (2022) reported that the amount of secondary metabolites differs between samples collected from various locations within the same district. These results suggest that various factors, such as climate, location, altitude, extraction procedures and collection time may contribute to the observed variances in the composition of flower oils (Mojarrab et al. 2013, Nikbakht et al. 2013). While the present study revealed total of 15 compounds, other researchers reported very different numbers for oleaster flower oil; 14, 17 and 22 (Elmi et al. 2017), 53 (Torbati et al. 2016), 44 (Incilay 2014) and 42 (Bucur et al. 2007) compounds were reported in oleaster flower oils. These results suggest that different chemotypes of oleaster could be found in this species, as was observed in basil (*Ocimum basilicum L.*) (Telci et al. 2006).

Antioxidant Capacity

The free radical scavenging ability and total antioxidant capacity of extracts from different parts of oleaster were evaluated using the DPPH and CUPRAC assays since these assays are different for selectivity, sensitivity and reaction mechanisms (Apak et al. 2007). The CUPRAC and DPPH assay results for the flower and leaf extracts of the plant are presented in Table 2. The CUPRAC method is a straightforward and broadly applicable technique for assessing the antioxidant potential of plasma antioxidants, flavonoids, phenolic compounds, vitamin C and E, utilizing the chromogenic oxidant Cu (II)-neocuproine (Nc) reagent (Apak et al. 2004). Furthermore, the reagent employed in this methodology is stable, cost-effective, readily obtainable, and reactive to both lipophilic and hydrophilic antioxidants (Apak et al. 2007). Results revealed that the antioxidant power of flowers exhibited stronger antioxidant ability compared to that of the leaves. The CUPRAC values of the tested flowers and leaves resulted in 67.49 ± 0.98 and 53.25 ± 1.50 $\mu\text{mol TE g}^{-1}$ FW, respectively.

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Table 1. Chemical composition of essential oils extracted from oleaster flowers

No	RI ^a	RI ^b	Components	Formula	Class	(%)
1	1032	1032	1,8-Cineole	C ₁₀ H ₁₈ O	OM	0.56
2	1066	1127	3,7-Dimethyldecane	C ₁₂ H ₂₆	Alk	0.39
3	1072	1221	3,7-Dimethylundecane	C ₁₃ H ₂₈	Alk	0.08
4	1107	1104	Nonanal	C ₉ H ₁₈ O	Ald	0.15
5	1170	1171.3	Ethyl benzoate	C ₉ H ₁₀ O ₂	Est	0.82
6	1180	1177.1	4-Terpineol	C ₁₀ H ₁₈ O	OM	0.12
7	1246	1244	Ethyl phenylacetate	C ₁₀ H ₁₂ O ₂	Phe	1.76
8	1287	1249	5-Butylnonane	C ₁₃ H ₂₈	Alk	0.36
9	1473	1460	Ethyl cinnamate	C ₁₁ H ₁₂ O ₂	OM	93.87
10	1480	1480.6	Germacrene D	C ₁₅ H ₂₄	SH	0.46
11	1500	1800	Octadecane	C ₁₈ H ₃₈	Alk	0.40
12	1576	1576.4	Spathulenol	C ₁₅ H ₂₄ O	OS	0.11
13	1841	1845	Phytone	C ₁₈ H ₃₆ O	Ket	0.50
14	2100	2100	Heneicosane	C ₂₁ H ₄₄	Alk	0.22
15	2300	2300	Tricosane	C ₂₃ H ₄₈	Alk	0.08
Class compositions						
Oxygenated monoterpene (OM)						94.55
Oxygenated sesquiterpenoid (OS)						0.11
Alkane (Alk)						1.53
Aldehyde (Ald)						0.15
Ester (Est)						0.82
Phenylacetate (Phe)						1.76
Sesquiterpene hydrocarbon (SH)						0.46
Ketone (Ket)						0.50
Total						99.88

^aRetention index were determined on a Restek Rxi®-5Sil MS column via standards consisting of C7-C30 n-alkanes

^bRetention index from literature (Babushok et al. 2011)

Table 2. Antioxidant potential, total phenolic, flavonoid, chlorophyll and carotenoid content of oleaster flowers

	Flowers	Leaves
CUPRAC (μmol TE ⁻¹)	67.49±0.98	53.25±1.50
DPPH (μmol TE ⁻¹)	22.30±0.25	7.57±0.30
Total Phenolic Content (μg g ⁻¹)	860.00±54.65	660.00±20.66
Total Flavonoid Content (μg g ⁻¹)	441.67±17.21	510.19±28.69
Chlorophyll a (μg mL ⁻¹)	11.80±0.37	24.26±0.10
Chlorophyll b (μg mL ⁻¹)	5.24±0.60	38.65±0.16
Total chlorophyll (μg mL ⁻¹)	17.04±0.97	62.89±0.26
Total carotenoid (μg mL ⁻¹)	8.27±0.17	13.11±0.05

In the DPPH assay, the lack of DPPH radical absorption at 515 nm due to receipt of an electron or hydrogen radical from an antioxidant compound to become a stable molecule and it is expressed as a measure of antioxidant capacity (Siddhuraju and Becker 2007). The DPPH results of antioxidant power (μmol TE g⁻¹ FW) of flowers and leaves also followed a similar order as in the CUPRAC test.

In the DPPH test, flowers produced a DPPH value of 22.30±0.30 μmol TE g⁻¹ FW, while leaves produced a DPPH value of 7.57±0.30 μmol TE g⁻¹ FW. Flowers of oleaster showed higher antioxidant properties than the leaves as measured by the DPPH method, and it was reported to range from 0.54 to 2.43 μg TEAC g⁻¹ DW (Incilay 2014). The same author also noted that oleaster

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populations exhibited different phenolic content and antioxidant capacity. However, extraction methods and solvents had significant effects on final concentration of phytochemicals and antioxidant capacity of the samples; therefore, optimal extraction parameters should be employed to obtain the highest yields for comparison of the results (Karkar and Şahin 2022, Darvishzadeh and Orsat 2022).

Total Phenolic and Flavonoid Content

Phenolic compounds and flavonoids play key roles in the diverse biological activities of plants. The total phenolic content in the flower and leaf extracts of oleaster was measured using the Folin-Ciocalteu method, with results expressed as $\mu\text{g GAE}$ per gram of fresh material. The total flavonoid content of oleaster flowers and leaves was quantified as mg CAE per gram of fresh sample. The current study assessed the floral ($860.00 \pm 54.65 \mu\text{g g}^{-1}$) and leaf total phenolic content ($660.00 \pm 20.66 \mu\text{g g}^{-1}$) of the oleaster. However, the total flavonoid content of the flowers ($441.67 \pm 17.21 \mu\text{g g}^{-1}$) of oleaster was lower than that of the leaves ($510.19 \pm 28.69 \mu\text{g g}^{-1}$). The total phenolic and flavonoid content of oleaster were assessed using fruits, leaves, flowers, and seeds. The total phenolic content of oleaster ranged from 0.01 to 1179.0 $\text{mg GAE } 100 \text{ g}^{-1}$ (Inciay 2014, Amini et al. 2019, Faki et al. 2022); however, it has been reported that the total flavonoid value varies between 0.40 and 489.50 $\text{mg CAE } 100 \text{ g}^{-1}$ (Amini et al. 2019, Simsek and Sufer 2021, Sevindik et al. 2025). Similarly, the total phenolic content of leaves was found to be lower than that of flowers, and the flower and leaf extracts yielded 16 and 20 phenolic compounds in oleaster (Saboonchian et al. 2014, Karkar and Şahin 2022); however, the total flavonoid content of flowers was reported to be higher in Niğde populations (Karkar and Şahin 2022). These results indicate that oleaster could serve as a source of natural compounds exhibiting various biological activities due to its abundant phenolic and flavonoid composition.

Total Chlorophyll and Carotenoid Content

Total carotenoid and chlorophyll content of oleaster flower and leaf extracts were expressed as $\mu\text{g mL}^{-1}$ sample. Leaves were found to have higher total carotenoid and chlorophyll content compared to flowers.

As expected, the total chlorophyll content of flowers was lower than that of leaves, which was determined to be 17.04 ± 0.99 and $62.89 \pm 0.26 \mu\text{g mL}^{-1}$, respectively. Similarly, total carotenoid content was higher in leaves ($13.11 \pm 0.05 \mu\text{g mL}^{-1}$) than in the flowers ($8.27 \pm 0.17 \mu\text{g mL}^{-1}$). Total carotenoid content was reported to be higher in leaf extracts than in flower extracts in oleaster populations from Niğde province (Karkar and Şahin 2022).

CONCLUSIONS

Oleaster is a tree species with significant potential and diverse applications in the food, cosmetic, and pharmaceutical industries. In summary, the composition of the essential oil obtained from its flowers was identified and reported. GC-MS analysis identified 15 components and the main component of the flower oil was ethyl cinnamate. Flower and leaf methanolic extracts were evaluated for their radical scavenging activity, total antioxidant capacity, total phenolic, flavonoid, chlorophyll, and carotene content. The total phenolic content, radical scavenging activity, and antioxidant capacity of extracts obtained from the flowers were higher than those of the leaf extracts. Conversely, total flavonoid, chlorophyll, and carotenoid content were higher in leaves. Diversity and number of chemical compounds show that there is a great variation exists within flower oils and differentiation of genotypes based on volatile constituents should be explored. The findings also suggest that oleaster flowers and leaves could be good sources of secondary compounds, and they may be used to obtain natural chemicals with diverse biological functions.

REFERENCES

- Abdelgaleil SA, Abbassy MA, Belal AS, Abdel Rasoul MA (2008) Bioactivity of two major constituents isolated from the essential oil of *Artemisia judaica* L. *Bioresource Technology*, 99:5947-5950.
- Abizov EA, Tolkachev ON, Mal'Tsev SD, Abizova EV (2008) Composition of biologically active substances isolated from the fruits of Russian olive (*Elaeagnus angustifolia*) introduced in the European part of Russia. *Pharmaceutical Chemistry Journal*, 42:696-698.
- Amini MH, Ahmady A, Zhakfar AM, Sediqi MN, Babak G (2019) Preliminary phytochemical profile, *in vitro* antioxidant and sun protective activities of *Alhagi pseudalhagi* and *Elaeagnus angustifolia* L. *Journal of Pharmaceutical Research International*, 31:1-13.

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- Apak R, Güçlü K, Özyürek M, Karademir SE (2004) Novel total antioxidant capacity index for dietary polyphenols and vitamins C and E, using their cupric ion reducing capability in the presence of neocuproine: CUPRAC method. *Journal of Agricultural and Food Chemistry*, 52:7970-7981.
- Apak R, Güçlü K, Demirata B, Özyürek M, Çelik SE, Bektaşoğlu B, Berker KI, Özyurt D (2007) Comparative evaluation of various total antioxidant capacity assays applied to phenolic compounds with the CUPRAC assay. *Molecules*, 12:1496-1547.
- Asadiar LS, Rahmani F, Siami A (2013) Assessment of genetic diversity in the Russian olive (*Elaeagnus angustifolia*) based on ISSR genetic markers. *Revista Ciencia Agronomica*, 44:310-316.
- Babushok VI, Linstrom PJ, Zenkevich IG (2011) Retention indices for frequently reported compounds of plant essential oils. *Journal of Physical and Chemical Reference Data*, 40: 043101.
- Bener M, Şen FB, Önem AN, Bekdeşer B, Çelik SE, Lalikoglu M, Aşçı YS, Capanoglu E, Apa R (2022) Microwave-assisted extraction of antioxidant compounds from by-products of Turkish hazelnut (*Corylus avellana* L.) using natural deep eutectic solvents: modeling, optimization and phenolic characterization. *Food Chemistry*, 385:132633.
- Bucur L, Stanciu G, Istudor V (2007) The GC-MS analysis of *Elaeagnus angustifolia* L. flowers essential oil. *Revista De Chimie-Bucharest-Original Edition*, 58:1027-1029.
- Choi IH, Park JY, Shin SC, Park IK (2006) Nematicidal activity of medicinal plant extracts and two cinnamates isolated from *Kaempferia galanga* L. (Proh Hom) against the pine wood nematode, *Bursaphelenchus xylophilus*. *Nematology*, 8:359-365.
- Darvishzadeh P, Orsat V (2022) Microwave-assisted extraction of antioxidant compounds from Russian olive leaves and flowers: optimization, HPLC characterization and comparison with other methods. *Journal of Applied Research on Medicinal and Aromatic Plants*, 27:100368.
- DeCant JP (2008) Russian olive, *Elaeagnus angustifolia*, alters patterns in soil nitrogen pools along the Rio Grande River, New Mexico, USA. *Wetlands*, 28:896-904.
- Elmi F, Dehghan G, Beigzadeh B (2017) Qualitative and quantitative changes of essential composition in the flowers of some populations of *Elaeagnus angustifolia*. *Future Natural Products*, 3:1-6.
- Erbaş S, Erdoğan Ü, Mutlucan M (2023) The scent compounds of immortelle ecotypes (*Helichrysum italicum* (Roth) G. Don.) grown in Türkiye and its new products (absolute and concrete). *South African Journal of Botany*, 158:301-311.
- Fakı R, Canbay HS, Gürsoy O, Yılmaz Y (2022) Antioxidant activity, physico-chemical and fatty acid composition of oleaster (*Elaeagnus angustifolia* L.) varieties naturally grown in Western Mediterranean Region of Turkey. *Akademik Gıda*, 20:329-335.
- Farzaei MH, Bahramsoltani R, Abbasabadi Z, Rahimi R (2015) A comprehensive review on phytochemical and pharmacological aspects of *Elaeagnus angustifolia* L. *Journal of Pharmacy and Pharmacology*, 67:1467-1480.
- Folin O, Ciocalteu V (1927) On tyrosine and tryptophane determinations in proteins. *Journal of Biological Chemistry*, 73:627-650.
- Hamidpour R, Hamidpour S, Hamidpour M, Shahlari M, Sohraby M, Shahlari N, Hamidpour R (2017) Russian olive (*Elaeagnus angustifolia* L.): from a variety of traditional medicinal applications to its novel roles as active antioxidant, anti-inflammatory, anti-mutagenic and analgesic agent. *Journal of Traditional and Complementary Medicine*, 7:24-29.
- Hamidpour R, Hamidpour S, Doostmohamadi P (2019) Chemistry, pharmacology and medicinal property of Russian olive (*Elaeagnus angustifolia* L.). *Cancer Science & Research*, 6:1-7.
- Incilay G (2014) Volatile composition, antimicrobial and antioxidant properties of different parts from *Elaeagnus angustifolia* L. *Journal of Essential Oil Bearing Plants*, 17:1187-1202.
- Ishaq S, Rathore HA, Sabir SM, Maroof MS (2015) Antioxidant properties of *Elaeagnus umbellata* berry solvent extracts against lipid peroxidation in mice brain and liver tissues. *Food Science and Biotechnology*, 24:673-679.
- Karkar B, Şahin S (2022) Determination of phenolic compounds profiles and antioxidant properties of oleaster (*Elaeagnus angustifolia* L.) grown in Turkey. *European Food Research and Technology*, 248:219-241.
- Katz GL, Shafroth PB (2003) Biology, ecology and management of *Elaeagnus angustifolia* L. (Russian olive) in western North America. *Wetlands*, 23:763-777.
- Khamzina A, Lamers JP, Vlek PL (2009) Nitrogen fixation by *Elaeagnus angustifolia* in the reclamation of degraded croplands of Central Asia. *Tree Physiology*, 29:799-808.
- Mojarrab M, Delazar A, Esnaashari S, Afshar FH (2013) Chemical composition and general toxicity of essential oils extracted from the aerial parts of *Artemisia armeniaca* Lam. and *A. incana* (L.) druce growing in Iran. *Research in Pharmaceutical Sciences*, 8:65-69.
- Nikbakht MR, Esnaashari S, Afshar FH (2013) Chemical composition and general toxicity of essential oil extracted from the stalks and flowers of *Rheum ribes* L. growing in Iran. *Journal of Reports in Pharmaceutical Sciences*, 2:165-170.
- Okmen G, Turkan O (2013) The antibacterial activity of *Elaeagnus angustifolia* L. against mastitis pathogens and antioxidant capacity of the leaf methanolic extracts. *Journal of Animal and Veterinary Advances*, 12:491-496.
- Önder D, Erdoğan Ü, Önder S (2023) Comparison of biochemical and antioxidant activities of ultrasonic-assisted extraction with different solvents in olive leaf. *Biotech Studies*, 32:31-40.
- Özdemir FGG (2023) İğde (*Elaeagnus angustifolia* L.) yaprak ekstraktının kök ur nematoduna karşı kullanımı. *ÇOMU Ziraat Fakültesi Dergisi*, 11:300-305.
- Qiao HJ, Yang JT, Yang X, Zhao LB, Li TH (2011) GC-MS analysis of chemical composition of volatile oil from flowers of *Elaeagnus angustifolia* L. *Food Science*, 32:233-235.
- Saboonchian F, Jamei R, Sarghein SH (2014) Phenolic and flavonoid content of *Elaeagnus angustifolia* L. (leaf and flower). *Avicenna Journal of Phytomedicine*, 4:231-238.
- Sakanaka S, Tachibana Y, Okada Y (2005) Preparation and antioxidant properties of extracts of Japanese persimmon leaf tea (kakinoha-cha). *Food Chemistry*, 89:569-575.
- Sevindik E, Özbent S, Sofyaloğlu E (2023) Genetic relationship analysis of some *Elaeagnus angustifolia* L. populations grown in Izmir, Türkiye, using SCoT markers. *Erwerbs-Obstbau*, 65:1185-1190.
- Sevindik M, Krupodorova T, Sevindik E, Koçer O, Uysal I, Ünal O (2025) *Elaeagnus angustifolia* L.: a comprehensive review of its biological activities, phenolic and chemical constituents, and applications. *Applied Fruit Science*, 67:70.
- Siddhuraju P, Becker K (2007) The antioxidant and free radical scavenging activities of processed cowpea (*Vigna unguiculata* (L.) Walp.) seed extracts. *Food Chemistry*, 101:10-19.
- Simsek M, Sufer Ö (2021) Physical, bioactive and textural properties of oleaster (*Elaeagnus angustifolia* L.) fruit from different locations in Turkey. *Turkish Journal of Agriculture-Food Science and Technology*, 9:723-727.

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- Telci I, Bayram E, Yılmaz G, Avcı B (2006) Variability in essential oil composition of Turkish basils (*Ocimum basilicum L.*). *Biochemical Systematics and Ecology*, 34:489-497.
- Torbati M, AsnaashSevindikari S, Afshar FH (2016) Essential oil from flowers and leaves of *Elaeagnus angustifolia* (Elaeagnaceae): composition, radical scavenging and general toxicity activities. *Advanced Pharmaceutical Bulletin*, 6:163-169.
- Zare A, Khorshidi J, Vafae Y (2023) Natural biochemical and morphological diversity of oleaster (*Elaeagnus angustifolia L.*) genotypes from the west of Iran: applicable for conservation, domestication, and breeding. *Genetic Resources and Crop Evolution*, 70:2575-2592.
- Zhang Z, Huang R (2013) Analysis of malondialdehyde, chlorophyll proline, soluble sugar, and glutathione content in *Arabidopsis* seedling. *Bio-Protocol*, 3:e817.
- Zhaolin L, Ning C, Dunyuan X, Haiquan L, Yaozu C (1989) Study on chemical constituents of volatile oil of fresh flowers of *Elaeagnus angustifolia L.* *Chemical Journal of Chinese Universities*, 10:804-808.