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REVIEW ARTICLE

Elaeagnus angustifolia L.: A Comprehensive Review of Its Biological Activities, Phenolic and Chemical Constituents, and Applications

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Abstract

Elaeagnus angustifolia L. is an important plant species that has a wide geographical distribution and is used for both food and medicinal purposes in different cultures. In this review, the areas of use, medicinal properties, biological activities as well as the chemical and phenolic contents of *E. angustifolia* reported in the literature are examined. Studies show that this plant has been traditionally used in the treatment of different diseases. In particular, it is noteworthy that it can be a natural drug candidate thanks to its antioxidant and antimicrobial activities. It has been determined that many biologically active chemical and phenolic compounds are found in various parts of the plant such as root, leaf, flower and fruit. It has been determined that these compounds have effects such as neutralizing free radicals, providing anti-inflammatory effects and suppressing microbial infections. In addition, studies on the positive effects and pharmacological potential of phenolic substances found in the composition of *E. angustifolia* on human health further increase the medical importance of this plant. Natural components, especially polyphenols, flavonoids, alkaloids and essential oils, show that this plant can be a promising source in drug development processes. In conclusion, *E. angustifolia* is a biologically and chemically rich natural source that can be evaluated in a wide range from traditional medicine to modern pharmacological designs. Advanced studies on this plant can make significant contributions to the development of new treatment approaches.

Keywords Antimicrobial · Antioxidant · Phenolics · Silverberry · Herbal Treatment Potential

Introduction

Since ancient times, natural products have been widely used by people to combat many diseases (Doğan et al. 2023). Among natural products, plants are widely used due to their functional properties. Plants are used for many different purposes such as food, shelter, heating, equipment production, and medical purposes (El-Chaghaby et al. 2024). Plants, which are at the top of the diet lists with their nutritional properties, have become indispensable for people. In addition to these properties, they are also used in the fight against diseases (Mohammed et al. 2021a). Many studies have reported that plants have many biological activities such as anticancer, antimicrobial, antioxidant, anti-inflammatory, antiproliferative, hepatoprotective, antiallergic, antiaging, and DNA protection (Karcioglu et al. 2011; Özer et al. 2018; Korkmaz et al. 2021; Mohammed et al. 2020; Comlekcioglu et al. 2022; Kalkan et al. 2023). In this context, investigating the different properties of plants is very important in terms of their usage potential (Comlekcioglu 2019). In this study, the usage areas, chemical contents, phenolic contents, and biological activities of *Elaeagnus angustifolia* reported in the literature were compiled. *E. angustifolia* is in the Elaeagnaceae family. In the literature, it has been seen that there are names such as "Russian olive", "silver berry", "oleaster", and "wild olive". It is widespread in regions such as Asia, North America and Eastern Europe.

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Table 1 Usage areas of *Elaeagnus angustifolia*

Usage area	Parts used	References
Tonic, cataract, antipyretic, antidiarrheal, neoplastic, against kidney diseases, Alzheimer's and Parkinson's diseases, dysentery, asthma, rheumatoid arthritis, fever, tetanus, jaundice, rheumatoid arthritis, cardiovascular diseases, muscle relaxant effect, prenatal difficulties, gastro-intestinal ulcers	Fruit	Ahmadiani et al. (2000); Ayaz and Bertoft (2001); Lev and Amar (2002); Cansev et al. (2011); Torbati et al. (2016); Hamidpour et al. (2019)
Diarrhea, diuretic, antipyretic agent, wounds healing, asthma, cough, antipyretic, jaundice, rheumatoid arthritis, nausea, tonic	Flower	Saboonchian et al. (2014); Maghsoodlou et al. (2015); Tehranizadeh et al. (2016); Hamidpour et al. (2019)
Asthma, antipyretic, cough, nausea, diarrhea, fever, jaundice, rheumatoid arthritis, wounds healing, epilepsy	Leaves	Saboonchian et al. (2014); Tehranizadeh et al. (2016); Hamidpour et al. (2019)
Tonic, antipyretic, muscle relaxant	Seed	Hosseinzadeh et al. (2003); Torbati et al. (2016); Hamidpour et al. (2019)

E. angustifolia lives between 80 and 100 years. It grows up to 10 m in height and 30 cm in diameter. The leaves of *E. angustifolia* are lanceolate and have smooth edges. Its flowers are four-lobed, creamy yellow and calyxed, produced in clusters. It bears fruit after 5–6 years. In addition, its fruits have a sweet, dry and floury texture. Its fruits and seeds can be eaten raw or cooked. Dessert and sherbet are made from the fruits (Farzaei et al. 2015; Tehranizadeh et al. 2016; Hamidpour et al. 2017; Sabouri et al. 2021; Hällzon et al. 2022).

Usage Areas

Plants are functional natural products used for different purposes. In this study, the usage areas of *E. angustifolia* were compiled. The findings are shown in Table 1. The fruit, flower, leaves and seed parts of the plant have been used among the usage areas of *E. angustifolia*. It has been reported that the fruit part is used for tonic, cataract, antipyretic, antidiarrheal, neoplastic, against kidney diseases, Alzheimer's and Parkinson's diseases, dysentery, asthma, rheumatoid arthritis, fever, tetanus, jaundice, rheumatoid arthritis, cardiovascular diseases, muscle relaxant effect, prenatal difficulties and gastro-intestinal ulcers (Ahmadiani et al. 2000; Ayaz and Bertoft 2001; Lev and Amar 2002; Cansev et al. 2011; Torbati et al. 2016; Hamidpour et al. 2019). It has been reported that the flower part is used for diarrhea, diuretic, antipyretic agent, wounds healing, asthma, cough, antipyretic, jaundice, rheumatoid arthritis, nausea and tonic (Saboonchian et al. 2014; Maghsoodlou et al. 2015; Tehranizadeh et al. 2016; Hamidpour et al. 2019). It has been reported that the leaf part is used for asthma, antipyretic, cough, nausea, diarrhea, fever, jaundice, rheumatoid arthritis, wounds healing and epilepsy (Saboonchian et al. 2014; Tehranizadeh et al. 2016; Hamidpour et al. 2019). It has been reported that the seed part is used as tonic, antipyretic and muscle relaxant (Hosseinzadeh et al. 2003; Torbati et al. 2016; Hamidpour et al. 2019).

Biological Activities

Many natural products synthesize compounds with different biological activities. They exhibit different biological activities thanks to their bioactive compounds (Mohammed et al. 2021b). In our research, biological activity studies of *E. angustifolia* reported in the literature were compiled. According to the findings, it was observed that extracts such as methanol, water, ethanol, acetone, ethyl acetate, butanol, petroleum ether, hexane, soft extract, polysaccharides, chloroform and hydroalcoholic were used. Biological activity studies of *E. angustifolia* reported in the literature are shown in Table 2.

Table 2 Biological activities of *Elaeagnus angustifolia*

Biological activities	Extraction	Geographic regions	References
Antioxidant, antimicrobial, antimutagenic, antitumor, insecticidal, anticancer, anti-inflammatory, anti-angiogenic, antinociceptive, antidiabetic	Methanol, water, ethanol, acetone, ethyl acetate, butanol, petroleum ether, hexane, soft extract, polysaccharides, chloroform, hydroalcoholic	Iran, Türkiye, Romania, China, Pakistan, Afghanistan	Ramezani et al. (2001); Bucur et al. (2008); Caliskan et al. (2010); Si et al. (2011); Badrhadad et al. (2012); Chen et al. (2014); Incilay (2014); Okmen and Turkcan (2014); Ya et al. (2014); Abri and Maleki, (2016); Dehghan et al. (2016); Khan et al. (2016); Motevalian et al. (2017); Hassanzadeh and Hassanpour (2018); Sadat et al. (2020); Celebi et al. (2021); Karkar and Şahin (2022); Naseri et al. (2023); Syed et al. (2023); Monjazeb Marvdashti et al. (2024)

Antioxidant Activity

Antioxidants work to reduce the effects of free radicals (Ahmad et al. 2023). Free radicals do not have harmful effects at low levels, but can cause cellular damage as their levels increase (Bal et al. 2019). When free radicals reach high levels, the antioxidant defense system may be inadequate. In this case, oxidative stress occurs. As a result of oxidative stress, serious problems such as cancer, cardiological disorders, multiple sclerosis, and neurodegenerative diseases can be seen (Sevindik et al. 2017; Korkmaz et al. 2018; Krupodorova et al. 2022; Mohammed et al. 2023). Supplemental antioxidants can work to reduce the effects of oxidative stress. Plants are very important sources in terms of their potential as supplemental antioxidant sources (Mohammed et al. 2024). In this study, the antioxidant activity findings of *E. angustifolia* reported in the literature were compiled. In a study conducted in Iran, the antioxidant property of the methanol extract obtained from *E. angustifolia* was investigated using 2,2-diphenyl-1-picrylhydrazyl (DPPH), ferric reducing antioxidant power (FRAP) and Fe^{2+} chelating tests. As a result of the study, the best result was reported to be between 28.59 and 93.15% in the DPPH test (Hassanzadeh and Hassanpour 2018). In a study conducted in Türkiye, it was reported that water, methanol, ethanol, acetone, ethyl acetate, butanol, petroleum ether and hexane extract obtained from *E. angustifolia* had antioxidant properties using 2,2-azino-bis-3-ethylbenzothiazoline-6-sulfonic acid (ABTS), FRAP, DPPH and chromium reducing antioxidant capacity (CHROMAC) tests (Karkar and Şahin 2022). In another study conducted in Türkiye, the antioxidant property of the methanol extract obtained from *E. angustifolia* was investigated using ABTS and DPPH tests. As a result of the study, it was reported that the DPPH test value was 0.54–4.45 µg and the ABTS test value was 0.03–4.64 µg (Incilay 2014). In another study conducted in Türkiye, the determination of the total reduction ability of the ethanol extract obtained from *E. angustifolia* by ferric thiocyanate, Fe^{3+}-Fe^{2+} conversion method, DPPH, riboflavin/methionine/illumination system and superoxide anion radical scavenging tests were used to investigate the antioxidant status. As a result of the study, it was reported that linoleic acid emulsion inhibited lipid peroxidation and scavenged the free radical (DPPH) and superoxide anion radical, and the results obtained with ethanol extract of oleaster were also compared with standard antioxidant compounds such as butylated hydroxyanisole, butylated hydroxytoluene and α-tocopherol under the same conditions (Caliskan et al. 2010). In another study conducted in Iran, the DPPH test result of the methanol extract obtained from *E. angustifolia* reported that the lC50 (Inhibitor concentration) value was 0.33 g/L (Abri and Maleki 2016). In a different study conducted in Türkiye, the antioxidant status of the methanol extract obtained from *E. angustifolia* was analyzed using the DPPH test. As a result of the study, it was reported that the methanol extract exhibited a strong antioxidant activity (Okmen and Turkcan 2014). In a study conducted in Romania, the antioxidant activity value of the soft extract obtained from *E. angustifolia* was reported to be 25.7% (Bucur et al. 2008). In a study conducted in China, the DPPH test values of two polysaccharides fractions obtained from *E. angustifolia* were reported to be 0.27 and 0.38 mg/mL, and the hydroxyl radical scavenging activity test values were 52.3 and 39.8% (Chen et al. 2014). In another study conducted in China, the DPPH test value of ethyl acetate extract obtained from *E. angustifolia* was reported to be 94.9% (Ya et al. 2014). In another study conducted in China, the DPPH test LC50 values of ethyl acetate and butanol extracts obtained from *E. angustifolia* were reported to be 12.1 and 12.4 µg/mL, respectively (Si et al. 2011). In another study conducted in Iran, the DPPH test value of the methanol extract of *E. angustifolia* was reported to be 0.137 mg/mL (Naseri et al. 2023). In another study conducted in Pakistan, the best DPPH test IC50 value was reported to be 47.94% in the ethanol extract using water, methanol, and ethanol extracts of *E. angustifolia* (Syed et al. 2023). Findings in the literature show that extracts of *E. angustifolia* obtained with different extraction methods have a significant antioxidant potential. Studies with various test methods (DPPH, ABTS, FRAP, Fe^2 chelation etc.) revealed that the plant exhibits strong antioxidant properties such as free radical scavenging, inhibiting lipid peroxidation and neutralizing superoxide anion radical. Extracts obtained with solvents such as methanol, ethanol and ethyl acetate were found to have high activity especially in DPPH tests. These findings suggest that *E. angustifolia* can be evaluated as a promising natural antioxidant source in the prevention and treatment of diseases associated with oxidative stress.

Antimicrobial Activity

Nowadays, it is becoming increasingly difficult to combat microbial diseases (Baba et al. 2020). The reasons for this are seen as the increase in the number of resistant microorganisms due to unconscious antibiotic use (Eraslan et al. 2021). In this context, researchers have turned to the discovery of new antimicrobial drugs (Sevindik et al. 2021). Due to the possible side effects of synthetic drugs, people prefer the use of natural antimicrobial drugs (Sevindik et al. 2024). In this study, the antimicrobial activity findings of *E. angustifolia* reported in the literature were compiled. In a study conducted in Türkiye, the antimicrobial activities of methanol extract obtained from *E. angustifolia* against *Staphylococcus aureus, S. warneri, S. homini, S. epi-*

dermidis, Bacillus cereus, Enterococcus faecalis, Streptococcus mutant, Escherichia coli, Shigella flexneri, Enterobacter spp., *Salmonella* spp., *Klebsiella* spp., *Candida albicans* and *Saccharomyces cerevisiae* strains were investigated. As a result of the study, it was reported that the minimum inhibitory concentration (MIC) value varied between 62.5 and 500 µg/mL (Incilay 2014). In a different study in Türkiye, it was reported that methanol extract obtained from *E. angustifolia* showed a maximum inhibition zone of 16 mm against *Yersinia enterocolitica*, but did not show an inhibition zone against *E. coli* and *C. albicans* with methanol extract. In addition, it was reported that all bacterial strains except *Y. enterocolitica* showed the lowest sensitivity to methanol extract (3.5 mg/mL) of *E. angustifolia* in terms of MIC value (Okmen and Turkcan 2014). In a study conducted in Iran, MIC and minimum bactericidal concentration (MBC) values of aqueous extract obtained from *E. angustifolia* were reported to be 1.62–7.5 mg/mL and 1.62–7.5 mg/mL against *S. aureus, S. pneumoniae, E. coli, Klebsiella pneumoniae* and *C. krusii* (Dehghan et al. 2016). In a different study conducted in Türkiye, the MIC values of the ethanol extract of *E. angustifolia* obtained against *Proteus mirabilis, C. albicans, E. faecalis, S. aureus, S. epidermidis, E. coli, Pseudomonas aeruginosa* and *Acinetobacter baumannii* were reported to be ≥ 12,500, 1.562, 1.562, 3.125, 1.562, ≥ 12,500, ≥ 12,500 and ≥ 12,500 µg/mL, respectively (Celebi et al. 2021). In another study conducted in Iran, it was reported that the inhibition zone of methanolic, ethanolic and hydroalcoholic extracts of *E. angustifolia* against *B. subtilis, B. cereus, E. faecalis, S. typhi, S. thphi, S. aureus, Xantomonas compestris, Ralestonia solanacearum,* and *Clavibacter mishiganensis* was 14.66–35 mm (Naseri et al. 2023). In another study conducted in Iran, the effect of ethanol extract obtained from *E. angustifolia* against *S. aureus, E. coli, E. faecalis*, and *C. albicans* strains was investigated. As a result of the study, it was observed that the minimal inhibitory concentration (MIC) value varied between 1.87 and 3.75 mg/mL, while the maximum activity was exhibited against *S. aureus.* In addition, it has been reported that the MBC value varies between 3.75 and 7.5 mg/mL (Monjazeb Marvdashti et al. 2024). In another study conducted in Pakistan, the effects of water, methanol, and ethanol extracts obtained from *E. angustifolia* against *E. coli, K. pneumoniae, Listeria monocytogenes, P. aureginosa, Salmonella typhi*, and *S. aureus* were investigated. As a result of the study, it was reported that the best inhibition zone value belonged to *S. typhi* with 27 mm (Syed et al. 2023). Findings in the literature reveal that *E. angustifolia* exhibits significant antimicrobial activity against various microorganisms. It was determined that the extracts obtained with different extraction methods were effective especially against pathogens such as *S. aureus, S. typhi,* and *C. albicans*. In the studies conducted with MIC and MBC values, it was observed that the plant could be a potential natural antimicrobial agent against both bacterial and fungal species. These findings indicate that *E. angustifolia* is a promising source in antimicrobial drug development processes.

Other Activities

E. angustifolia has been observed to have different biological activities in addition to the antioxidant and antimicrobial activities reported in the literature. In a study conducted in Türkiye, the methanol extract obtained from *E. angustifolia* was evaluated for its antimutagenic activities against sodium azide with the Ames test in the absence of rat microsomal liver enzyme (-S9). As a result of the study, it was reported that sodium azide could inhibit mutagenic agents by 36%, and sodium azide inhibited plant leaf extracts showed moderate potential in reducing mutagenic agents in *S. typhimurium* (Okmen and Turkcan 2014). In a study conducted in China, it was observed that there was a concentration and polarity dependent relationship between the inhibitory effect of ethyl acetate extract obtained from *E. angustifolia* in the first 48 h. It has been reported that the higher the concentration and the stronger the polarity, the stronger the inhibitory effect and the inhibition rate is 74.34% (Ya et al. 2014). In a study conducted in Pakistan, it was reported that *n*-hexane, ethyl acetate, aqueous and chloroform extracts obtained from *E. angustifolia* caused the death of *Tribolium castaneum* and *Ephestia cautella* insects observed after 24 and 48 h (Khan *et al.* 2016). In a study conducted in Iran, it was reported that methanol and aqueous extracts of *E. angustifolia* had anticancer effects on human breast cancer cell line MCF-7 (Naseri et al. 2023). In another study conducted in Iran, the anti-inflammatory property of hydroalcoholic extract obtained from *E. angustifolia* was investigated. As a result of the study, it was reported that *E. angustifolia* extract at a concentration of 1000 mg/kg significantly reduced paw edema and inflammation in a dose-dependent manner (Motevalian et al. 2017). In another study conducted in Iran, hydroalcoholic extract of *E. angustifolia* and its sequential hexane, ethyl acetate, chloroform and aqueous fractions were used for the cytodex-collagen model. As a result of the study, it was reported that *E. angustifolia* at a concentration of 200 µg/mL potentially inhibited Human umbilical vein endothelial cells (HUVEC) angiogenesis activity. In addition, it was reported that 10 µg/mL of both ethyl acetate and chloroform fractions prevented this activity (Badrhadad et al. 2012). In another study conducted in Iran, the antinociceptive effect of extracts obtained from *E. angustifolia* was investigated in mice using hot plate and writhing tests. As a result of the study, it was reported that intraperitoneal injection followed

Table 3 Chemical contents of *Elaeagnus angustifolia*

Parts used	Essential oil contents	References
Flowers	Nonanal (1.36%), methyl cinnamate (1.38–2.13%), E-ethyl cinnamate (47.6–85.5%), 4,6-dimethyl-dodecane (1.77%), *n*-elcosane (29.48%), 9-finland heptadecanoyl (29.48%), heneicos anoic (13.52%), cetane iodide (13.52%), *n*-hentriaconta (13.52%), alkyl benzoate (13.63%), ethyl 3 -phenyl propenoate (14.45–83.75%), *n*-decane (11.44%), nonadecane (7.10–22.19%), phytol (3.3%), hexahydrofanresyl acetone (2.8–11.6%), hexanoic acid (5.9–7.2%), dibutyl phthalate (2.3–7.0%), propanoic acid (5.4%), benzoic acid (1.8%), octanoic acid (1.7%), α-pinene, ethylhexanol, β-pinene, limonene, linalool, linalyl acetate, anisic aldehyde, cinnamic aldehyde, anethole, eugenol, *p*-xylene, acetophenone, 2-phenyl-ethyl isovalerate, nerolidore, 2-phenyl-ethyl benzote, squalene, α-thujene, sabinene, 3-carene, α-myrcene, β-phellandrene, β-ocimene, *p*-cymene, (E)-limonene oxide, 1-pentene-3-ol, (Z)-2-pentenol, 1-hexanol, Z-3-hexenol, 2-hexen-1-ol, (Z)-, α-methylbutanal, β-methylbutanal, benzaldehyde, 6-methyl-5-hepten-2-one, hexanal, heptanal,3,7-dimethyl-1,3,6-octatriene, ındole, ısoelemicin, trans-Isoeugenol, 3-phenyl-2-propen-1-ol, furfural	Bucur et al. (2007); Incilay (2014); Aynur et al. (2015); Jia-Wen et al. (2015); Torbati et al. (2016); Elmi et al. (2017); Mahboubi (2018); Liu et al. (2021); Panasenko et al. (2021)
Leaves	E-ethyl cinnamate (37.27%), phytol (3.57–12.08%), nonanal (10.74%), Z-3-hexenyl benzoate (7.65%), (-)-myrtenyl acetate (1.83%), β-caryophyllene (2.14%), β- Ionone (1.80%), caryophyllene oxide (1.70%), sitosterol (17.57%), 1-(2-hydroxy-5-methylphenyl)-ethanone (8.35%), pyrimidine, 2-methyl (7.2%), furfural (18.8%), 2-furanmethanol (5.8%), *p*-xylene (5.3%), pyrrolidine, 2-(cyanomethylene) (8.1%), 5-methylfurfural (9.6%), 1H-pyrrole-2-carboxaaldehyde (6.4%), 2-acetylpyrrole (4.3%), *p*-vinylguiacol (9.3%), *n*-propyl acetate (4.09%), 9-octadecenoic acid, 1,2,3-propanetriyl ester (10.72%), hexadecanoic acid (5.61%), bis (2-ethylhexyl) phthalate (3.48%), squalene (1.40%), linalool, α-thujene, sabinene, 3-carene, α-myrcene, β-phellandrene, β-ocimene, *p*-cymene, (E)-limonene oxide, 1-pentene-3-ol, (Z)-2-pentenol, 1-hexanol, Z-3-hexenol, 2-hexen-1-ol, (Z)-,α-methylbutanal, β-methylbutanal, benzaldehyde, 6-methyl-5-hepten-2-one	Incilay (2014); Torbati et al. (2016); Mahboubi (2018); Carradori et al. (2020); Panasenko et al. (2021); Syed et al. (2023)
Fruit	4H-pyran-4-one, 2,3-dihydro-3,5-di hydroxy-6-methyl (18.74%), 2,5-dimethyl-4-hydroxy-3(2H)-furan (1.0–2.68%), 2-furancarboxaldehyde, 5-(hydroxymethyl) (46.26%), 2-furanmethanol (2.98–7.0%), sitosterol (12.53%), propyl acetate (12.60%), chamazulene (11.97%), dihydro-2-methyl-furanon (5.8%), furfural (36.7%), 4-cyclopentene-1,3-dione (4.5%), acetyl furan (2.5%), 5-methylfurfural (2.7–25.3%), limonene,1-hexanol, Z-3-hexenol, 1-octen-3-ol, α-methylbutanal, benzaldehyde, β-methylbutanal, nonanal, hexanal, 2-pentanone,6-methyl-5-hepten-2-one	Incilay (2014); Carradori et al. (2020); Monjazeb Marvdashti et al. (2024)

by decoction (EaDE), ethanol extract (EaEE), aqueous and *n*-butanol fractions of a polyphenolic fraction (EaAF and EaBF, respectively), and two flavonoid-rich fractions of EaBF (EaBCF1 and EaBCF 2) showed significant antinociceptive activity, which significantly and dose-dependently increased the pain threshold in both tests (Ramezani et al. 2001). In a study conducted in Afghanistan, the effects of aqueous alcohol extracts obtained from *E. angustifolia* on blood sugar levels in diabetic rats divided into six groups at doses of 200, 400 and 800 mg/kg for 15 days were investigated. As a result of the study, it was reported that a significant decrease in blood sugar levels, improvement in glucose tolerance and increase in body weight were observed in all doses of the extract (Sadat et al. 2020). Findings in the literature show that *E. angustifolia* has a wide range of biological activities such as antimutagenic, anti-inflammatory, antinociceptive, anticancer and antidiabetic, in addition to its antioxidant and antimicrobial properties. Extracts of the plant obtained by different extraction methods have been found to have effects such as reducing mutagenic agents, suppressing cancer cells, increasing pain threshold, reducing inflammation and lowering blood sugar in diabetic conditions. These findings reveal that *E. angustifolia* is a natural resource with a wide potential in medical applications and can be evaluated in pharmacological research.

Chemical Contents

Natural products synthesize different chemical compounds in their bodies. In this study, the chemical contents found in *E. angustifolia* in the literature were compiled. The findings are shown in Table 3. In studies conducted in different geographical regions, it was observed that the chemical content of parts such as flower, leaves and fruit of the *E. angustifolia* plant was examined according to literature data. In studies conducted in the flower section, it was observed that the chemical content obtained was given both as percentage results and only as content. It was reported that the flower section was nonanal (1.36%), methyl cinnamate (1.38–2.13%), E-ethyl cinnamate (47.6–85.5%), 4,6-dimethyl-dodecane (1.77%), *n*-elcosane (29.48%), 9-finland heptadecanoyl (29.48%), heneicos anoic (13.52%), cetane iodide (13.52%), *n*-hentriaconta (13.52%), alkyl benzoate (13.63%), ethyl 3-phenyl propenoate (14.45–83.75%), *n*-decane (11.44%), nonadecane (7.10–22.19%), phytol (3.3%), hexahydrofanresyl acetone (2.8–11.6%), hexanoic acid (5.9–7.2%), dibutyl phthalate (2.3–7.0%), propanoic acid (5.4%), benzoic acid (1.8%), octanoic acid (1.7%) α-pinene, ethylhexanol, β-pinene, limonene, linalool, linalyl acetate, anisic aldehyde, cinnamic aldehyde, anethole, eugenol, *p*-xy-

lene, acetophenone, 2-phenyl-ethyl isovalerate, nerolidore, 2-phenyl-ethyl benzote, squalene, α-thujene, sabinene, 3-carene, α-myrcene, β-phellandrene, β-ocimene, *p*-cymene, (E)-limonene oxide, 1-pentene-3-ol, (Z)-2-pentenol, 1-hexanol, Z-3-hexenol, 2-hexen-1-ol, (Z)-, α-methylbutanal, β-methylbutanal, benzaldehyde, 6-methyl-5-hepten-2-one, hexanal, heptanal,3,7-dimethyl-1,3,6-octatriene, ındole, ısoelemicin, trans-Isoeugenol, 3-phenyl-2-propen-1-ol and furfural both as percentage and content (Bucur et al. 2007; Incilay 2014; Aynur et al. 2015; Jia-Wen et al. 2015; Torbati et al. 2016; Elmi et al. 2017; Mahboubi 2018; Liu et al. 2021; Panasenko et al. 2021). In studies conducted in the leaves section, it was observed that the chemical content obtained was given both as percentage results and only as content. It has been reported that the leaf part contains E-ethyl cinnamate (37.27%), phytol (3.57–12.08%), nonanal (10.74%), Z-3-hexenyl benzoate (7.65%), (-)-myrtenyl acetate (1.83%), β-caryophyllene (2.14%), β- Ionone (1.80%), caryophyllene oxide (1.70%), sitosterol (17.57%), 1-(2-hydroxy-5-methylphenyl)-ethanone (8.35%), pyrimidine, 2-methyl (7.2%), furfural (18.8%), 2-furanmethanol (5.8%), *p*-xylene (5.3%), pyrrolidine, 2-(cyanomethylene) (8.1%), 5-methylfurfural (9.6%), 1H-pyrrole-2-carboxaaldehyde (6.4%), 2-acetylpyrrole (4.3%), *p*-vinylguiacol (9.3%), *n*-propyl acetate (4.09%), 9-octadecenoic acid, 1,2,3-propanetriyl ester (10.72%), hexadecanoic acid (5.61%), bis (2-ethylhexyl) phthalate (3.48%), squalene (1.40%), linalool, α-thujene, sabinene, 3-carene, α-myrcene, β-phellandrene, β-ocimene, *p*-cymene, (E)-limonene oxide, 1-pentene-3-ol, (Z)-2-pentenol, 1-hexanol, Z-3-hexenol, 2-hexen-1-ol, (Z)-, α-methylbutanal, β-methylbutanal, benzaldehyde and 6-methyl-5-hepten-2-one both in percentage and content (Incilay 2014; Torbati et al. 2016; Mahboubi 2018; Carradori et al. 2020; Panasenko et al. 2021; Syed et al. 2023). It has been observed that the chemical content obtained in the studies conducted on the fruit part is given both as percentage results and only as content. It has been reported that the fruit part is 4H-pyran-4-one, 2,3-dihydro-3,5-di hydroxy-6-methyl (18.74%), 2,5-dimethyl-4-hydroxy-3(2H)-furan (1.0–2.68%), 2-furancarboxaldehyde, 5-(hydroxymethyl) (46.26%), 2-furanmethanol (2.98–7.0%), sitosterol (12.53%), propyl acetate (12.60%), chamazulene (11.97%), dihydro-2-methyl-furanon (5.8%), furfural (36.7%), 4-cyclopentene-1,3-dione (4.5%), acetyl furan (2.5%), 5-methylfurfural (2.7–25.3%), limonene,1-hexanol, Z-3-hexenol, 1-octen-3-ol, α-methylbutanal, benzaldehyde, β-methylbutanal, nonanal, hexanal, 2-pentanone and 6-methyl-5-hepten-2-one both as percentage and content (Incilay 2014; Carradori et al. 2020; Monjazeb Marvdashti et al. 2024). In addition, the major components obtained from the flower, leaves and fruit parts were determined. The major components for the flower part were found to be E-ethyl cinnamate, ethyl 3-phenyl propenoate, *n*-elcosane, 9-finland heptadecanoyl and nonadecane. The major components for the leaves part were reported to be E-ethyl cinnamate, nonanal, sitosterol, furfural and 1,2,3-propanetriyl ester. The major components of the fruit part were found to be 4H-pyran-4-one, 2,3-dihydro-3,5-di hydroxy-6-methyl, 2-furancarboxaldehyde, 5-(hydroxymethyl), furfural and 5-methylfurfural. Findings in the literature show that the flower, leaf and fruit parts of *E. angustifolia* have a rich chemical content. In the studies, it was determined that compounds such as E-ethyl cinnamate, ethyl 3-phenyl propenoate and nonadecane were prominent in the flower part; compounds such as E-ethyl cinnamate, sitosterol and furfural were prominent in the leaf part; and compounds such as 4H-pyran-4-one, 2-furancarboxaldehyde and furfural were prominent in the fruit part. These results reveal that *E. angustifolia* has great importance as a natural biological resource with its chemical diversity and potential biological activities.

Phenolic Acid Contents

Secondary metabolites are compounds that do not have nutritional properties but are medically important (Uysal

Table 4 Phenolic contents of *Elaeagnus angustifolia*

Parts used	Phenolic contents (mg/g)	References
Branch	P-cumaric acid (1.44–2.37 mg/g), ferulic acid (0.21–0.66 mg/g), kaempferol (0.04–038 mg/g), sinapic acid (0.10 mg/g), quercetol (0.10 mg/g)	(Bucur et al. 2009)
Fruit	Cafeic acid (0.0026–0.32 mg/g), ferulic acid (0.1022–0.023 mg/g), protocatechuic acid (0.28 mg/g), 4-hydroxycinnamic acid (0.18 mg/g), vanillic acid (0.0837–0.14 mg/g), 4-hydroxybenzoic acid (0.0738–0.45 mg/g), (-)-epicatechin (0.001 mg/g), (+)-catechin (0.0046 mg/g), 2-hydroxycinnamic acid (0.0007 mg/g), chlorogenic acid (0.0008 mg/g), gallic acid (0.0315 mg/g), kaempferol (0.0011 mg/g), *p*-coumaric acid (0.0235 mg/g), protocatechuic acid (0.068 mg/g), syringic acid (0.017 mg/g), sinapic acid (0.0296 mg/g), quercetin (0.0024 mg/g)	(Ayaz and Bertoft 2001; Dilek Tepe and Doyuk 2020)
Seed	(-)-Epicatechin (0.00098 mg/g), (+)-catechin (0.01786 mg/g), 2-hydroxybenzoic acid (0.00008 mg/g), 3-hydroxybenzoic acid (0.0014 mg/g), 4-hydroxybenzoic acid (0.0331 mg/g), cafeic acid (0.0014 mg/g), chlorogenic acid (0.0004 mg/g), ferulic acid (0.0557 mg/g), gallic acid (0.0177 mg/g), kaempferol (0.0027 mg/g), luteolin (0.0002 mg/g), *p*-coumaric acid (0.0132 mg/g), protocatechuic acid (0.0186 mg/g), quercetin (0.0024 mg/g), vanillic acid (0.0424 mg/g), syringic acid (0.0113 mg/g), sinapic acid (0.0137 mg/g)	(Dilek Tepe and Doyuk 2020)

Table 5 Total phenolic and flavonoid contents of *Elaeagnus angustifolia*

Parts used	Total phenolic values	Total flavonoid values	References
Fruit, leaves, flower, seed	0.01–1179.0 mg GAE/100 g	–	Incilay (2014); Saboonchian et al. (2014); Sardarodiyan et al. (2016); Hassanzadeh and Hassanpour (2018); Amini et al. (2019); Carradori et al. (2020); Simsek and Sufer (2021); Fakı et al. (2022); Karkar and Şahin (2022); Gecer (2023); Pirbodaghi et al. (2023); Zare et al. (2023); Say et al. (2024)
	–	0.40–489.50 mg CAE/100 g	Saboonchian et al. (2014); Sardarodiyan et al. (2016); Hassanzadeh and Hassanpour (2018); Amini et al. (2019); Simsek and Sufer (2021); Fakı et al. (2022); Karkar and Şahin (2022); Pirbodaghi et al. (2023); Zare et al. (2023); Say et al. (2024)

2023). Plants produce bioactive compounds with different effects in their bodies. In this study, the phenolic content of *E. angustifolia* reported in the literature is shown in Table 4 as mg/g. Branch fruit and seed parts of *E. angustifolia* were used for literature data. The presence of *p*-cumaric acid (1.44–2.37 mg/g), ferulic acid (0.21–0.66 mg/g), kaempferol (0.04–038 mg/g), sinapic acid (0.10 mg/g) and quercetol (0.10 mg/g) has been reported (Bucur et al. 2009). In the fruit section cafeic acid (0.0026–0.32 mg/g), ferulic acid (0.1022–0.023 mg/g), protocatechuic acid (0.28 mg/g), 4-hydroxycinnamic acid (0.18 mg/g), vanillic acid (0.0837–0.14 mg/g), 4-hydroxybenzoic acid (0.0738–0.45 mg/g), (-)-epicatechin (0.001 mg/g), (+)-catechin (0.0046 mg/g), 2-hydroxycinnamic acid (0.0007 mg/g), chlorogenic acid (0.0008 mg/g), gallic acid (0.0315 mg/g), kaempferol (0.0011 mg/g), *p*-coumaric acid (0.0235 mg/g), protocatechuic acid (0.068 mg/g), syringic acid (0.017 mg/g), sinapic acid (0.0296 mg/g) and quercetin (0.0024 mg/g) was reported in the branch part (Ayaz and Bertoft 2001; Dilek Tepe and Doyuk 2020). The presence of (-)-epicatechin (0.00098 mg/g), (+)-catechin (0.01786 mg/g), 2-hydroxybenzoic acid (0.00008 mg/g), 3-hydroxybenzoic acid (0.0014 mg/g), 4-hydroxybenzoic acid (0.0331 mg/g), cafeic acid (0.0014 mg/g), chlorogenic acid (0.0004 mg/g), ferulic acid (0.0557 mg/g), gallic acid (0.0177 mg/g), kaempferol (0.0027 mg/g), luteolin (0.0002 mg/g), *p*-coumaric acid (0.0132 mg/g), protocatechuic acid (0.0186 mg/g), quercetin (0.0024 mg/g), vanillic acid (0.0424 mg/g), syringic acid (0.0113 mg/g) and sinapic acid (0.0137 mg/g) in the seed part has been reported (Dilek Tepe and Doyuk 2020). The findings in the literature show that various phenolic compounds are found in the branches, fruits and seeds of *E. angustifolia*. Compounds such as *p*-coumaric acid, ferulic acid and kaempferol were detected in the branches; caffeic acid, protocatechuic acid and vanillic acid were detected in the fruits; and (-)-epicatechin, (+)-catechin and gallic acid were detected in the seeds. These phenolic compounds provide significant contributions to the biological and pharmacological potential of the plant, making *E. angustifolia* a valuable source of natural metabolites.

Total Phenolic and Flavonoid Contents

Phenolic and flavonoids found in plants highlight their different properties. In this study, the total phenolic and flavonoid contents of *E. angustifolia* reported in the literature were compiled and shown in Table 5. According to literature data, total phenolic and flavonoid contents of *E. angustifolia* were determined in fruit, leaves, flower and seed parts. It was reported that total phenolic values varied between 0.01–1179.0 mg GAE/100 g (Incilay 2014;

Saboonchian et al. 2014; Sardarodiyan et al. 2016; Hassanzadeh and Hassanpour 2018; Amini et al. 2019; Carradori et al. 2020; Simsek and Sufer 2021; Fakı et al. 2022; Karkar and Şahin 2022; Gecer 2023; Pirbodaghi et al. 2023; Zare et al. 2023; Say et al. 2024). It has been reported that total flavonoid value varies between 0.40 and 489.50 mg CAE/100 g (Saboonchian et al. 2014; Sardarodiyan et al. 2016; Hassanzadeh and Hassanpour 2018; Amini et al. 2019; Simsek and Sufer 2021; Fakı et al. 2022; Karkar and Şahin 2022; Pirbodaghi et al. 2023; Zare et al. 2023; Say et al. 2024). These results reveal that *E. angustifolia* is a potential source of natural compounds with different biological activities with its rich phenolic and flavonoid profile.

Conclusion

Elaeagnus angustifolia is a plant species with high potential and has a wide range of uses in the food and pharmaceutical industries. In this study, the areas of use, chemical and phenolic contents, total phenolic and flavonoid levels and biological activities of *E. angustifolia* were compiled. The findings showed that the plant has a wide range of potential in the field of health and stands out as a traditional material in the production of desserts and sherbets. The rich bioactive compounds it contains increase the importance of the plant as a natural compound source. Especially its antioxidant and antimicrobial properties show that it can be evaluated as a sustainable natural resource in the health and food sectors. In terms of future perspectives, more detailed examination of the biological activities of *E. angustifolia* may contribute to new product development processes in pharmaceutical applications. Advanced studies, especially on its anticancer, anti-inflammatory and antinociceptive effects, will allow us to better understand the potential of the plant in the field of health. In addition, research on its use as a natural additive or functional food ingredient in food technology may increase its industrial value. In addition, expanding the agricultural production of the plant and developing appropriate cultivation methods in terms of environmental sustainability can provide economic and ecological benefits. In this context, *E. angustifolia* offers great potential as a natural and versatile resource for future generations.

Conflict of interest M. Sevindik, T. Krupodorova, E. Sevindik, O. Koçer, I. Uysal and O. Ünal declare that they have no competing interests.

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