International Journal of Scientific Research in Biological Sciences
Vol.10, Issue.3, pp.58-64, June 2023
E-ISSN: 2347-7520
Available online at: www.isroset.org

Review Paper

Chemical Composition, Anti-bacterial and Anti-oxidant Activities of common Apiaceae Essential Oils

Ruba Joujeh[1*], Dima Joujeh[2]

[1]Faculty of Agriculture, University of Aleppo, Syria
[2]Faculty of Technical engineering, University of Aleppo, Syria

Corresponding Author: rubajoujeh3@gmail.com

Received: 10/Apr/2023; **Accepted**: 12/May/2023; **Published**: 30/Jun/2023

Abstract— Medicinal plants produce many compounds with biological or medicinal properties. Essential oils produced by plants have been used for health purposes for thousands of years. Apiaceae essential oils are chemically diverse and rich in effective compounds, so they can be used as an alternative to synthetic antibiotics and antioxidants, which will help to avoid the dangers of synthetic drugs. Therefore, this review provides useful information about essential oils of some Apiaceae species, including their chemical composition and some biological effects.

Keywords— Apiaceae, medicinal plants, chemical composition, essential oil, antibacterial, antioxidant.

1. Introduction

Medicinal plants constitute an essential part of the economy in the pharmaceutical, perfume, food and cosmetics fields. It is also an indispensable tool of folk medicine and the source of the most widely used medicine [1]. Recently, the use of these plants in herbal medicine has been greatly enhanced by the development of various herbs and fruits [2]. Many plants contain chemical compounds (phytochemical) which corroborate their biological or medicinal properties [3], such as essential oils (EOs) which are volatile and natural secondary metabolites [4]. They contain water-insoluble organic compounds consisting mainly of monoterpenes and sesquiterpenes [5].

The main feature of these oils, which has a special economic value, is its aromatic smell [6]. EOs are believed to represent smell and taste in the flower kingdom, hence their name. They have different fixed oil composition [7]. Plants produce EOs to protect them through their antibacterial, fungicides, antiviral, and pesticides activities. This oil also protects the plant from herbivores [8].

EOs are produced by means of special excretory structures in various parts of the plant, and the oil composition may vary may vary from region to region [4]. They are used for thousands of health purposes [9]. They were first created by the Arabs in the Middle Ages and known for their aroma and many other medicinal properties such as bactericidal, fungicidal, virucidal and antiseptic [10]. EOs can be obtained by effleurage, extraction, fermentation, or expression but of all these methods, hydrodistillation and steam distillation are widely used for commercial production [9].

EO extraction is expensive because large amounts of raw materials are required to produce a few milliliters of oil. This explains the high prices charged for EO [6].

This review covers the published literature and provides basic information on some common Apiaceae EOs, including the chemistry, the antibacterial and antioxidant activities of these oils, to open the doors for using them in medicine and industry.

2. Related work

Previous research focused on EOs and their applications as natural products in industries such as food preservation, pharmaceuticals, and cosmetics [9].
The chemistry of EOs and their significant biological effects such as anti-cancer, anti-microbial- anti-inflammatory, anti-oxidant, Proapoptotic activities have been summarized in previous work [10]. Previous work reported that the biological effects of EOs are due to the fact that they prevent lipid peroxidation and scavenge free radicals. The authors also noted that the EO components work synergistically [7].
Previous review has focused on the effect of EO in minimally processed food pathogens, including the more realistic applications. The authors suggested that EO can be considered as an "added value" for the food industry [4].

Scientific data has been introduced to support using of Apiaceae EOs and their components in insecticides against various mosquito species (Culex, Aedes, and Anopheles) [11].

3. Methodology

This study reviews the literature published over the past 20 years on the chemical and biological properties of Apiaceae EOs. The data was selected using the following keywords: Apiaceae, essential oil, chemical composition, antibacterial, and antioxidant.

4. Apiaceae Family

It is a family of flowering plants [11], representing one of the largest taxon in higher plants [12], including "3780" species in "434" genera. The family distribution ranges from the north to the tropics [11].
Apiaceae species are annual and perennial herbaceous plants. All parts of the plant contain well-developed secretory systems. This structure is important for the release of EOs that give each plant its aroma and flavor [13]. Generally, various parts of the Apiaceae plants, such as root (angelica and carrot), seeds (celery, coriander, anise, caraway, dill, angelica, cumin and fennel), leaves (parsley, coriander, fennel, celery, and dill), and leaf stalks (fennel) are consumed as spices or vegetables [14].

Coriandrum sativum (Coriander), *Foeniculum vulgare* (fennel), *Cuminum cyminum* (cumin), *Petroselinum crispum* (parsley), *Anethum graveolens* (dill), *Carum carvi* (caraway) and *Pimpinella anisum* (anise) are the most cultivated species of Apiaceae. These species are cultivated all over the world with an annual production of "25 million" tons [12].

Apiaceae species exhibit many biological activities. *Eryngium* is the largest genus in Apiaceae. Several species of this genus have been reported to have medicinal, culinary, ornamental and agricultural uses. In folk medicine, *Eryngium* species are used as hypoglycemic, diuretic, poison antidote, anti-inflammatory agent, stimulant, kidney stone suppressant, aphrodisiac and antitussive [15]. *Angelica* L. is rich in secondary metabolites. Angelica species have been used to improve the nervous, respiratory, immunity and circulatory system and to treat colds, bronchial diseases, tumors, indigestion, and in the food industry [16]. Cumin is the second most popular spice in the world. It has many medicinal properties. Cumin seeds are used as a carminative, astringent, eupeptic, antispasmodic, analgesic, and improve liver function, treat diarrhea, cough, dyspepsia, colic, dyspeptic headache, flatulence and digestive disorders [17]. Caraway has several medicinal uses particularly for digestion [18]. Coriander seeds are traditionally considered to be stomachic, anti-inflammatory, antidiabetic, carminative, stimulant, analgesic, aphrodisiac, diuretic and cholesterol lowering [19]. Aniseeds are used as mild expectorants, and to treat catarrh of the respiratory tract and indigestion complaints. It also has mild estrogenic effect, which explains its use in folk medicine to increase milk secretion [20].

5. Chemical Composition of Apiaceae EOs

EOs of Apiaceae species contain monoterpenes, sesquiterpenes, very few diterpenes, octyl esters, trimethylbenzaldehydes, phthalides, octanols and phenylpropanoids and aliphatic aldehydes [21].
This family is characterized by the high chemical diversity of its species, as well as different aromatic substances in different parts such as stem, flower, fruit, root, and leaf [16]. For example, the rhizomes oil of Laser trilobum was different from the fruit oil. α-pinene, γ-terpinene, p-cymene were the main compounds in the rhizomes oil, whereas the fruit oil contained limonene and perillaldehyde as main compounds.
Coriandrum sativum seeds oil was different from the leaves oil. 2-Decenoic acid and E-11-tetradecenoic acid were the main compounds of the leaves oil, where the seeds contained linalool, geranyl acetate, γ-terpinene, and α-cedrene. The main compounds of common Apiaceae EOs are displayed in Table 1.

Some components were detected in more than one species of the family Apiaceae, such as ɣ-terpinene was identified in the *Coriandrum sativum*, *Cuminum cyminum Crithmum maritimum*, *Laser trilobum*, *Ammi visnaga* EOs. α-pinene was also identified in the *Seseli globiferum*, *Laser trilobum*, *Angelica sylvestris*, *Foeniculum vulgare*, *Anethum graveolens* EOs. Whereas β-Pinene was identified in the *Seseli globiferum*, *Laser trilobum*, *Ferula cupularis* EOs, Limonene was also introduced as one of the main compounds of *Laser trilobum*, *Heracleum siamicum*, *Angelica sylvestris*, *Foeniculum vulgare*, *Carum carvi*, *Anethum graveolens* EOs. Anethole was also identified in the EOs of *Foeniculum vulgare*, *Pimpinella anisum* and *Carum carvi*. ρ-cymene was identified in the *Cuminum cyminum*, *Crithmum maritimum*, Laser trilobum EOs. 1,8-cineole was identified in the *Heracleum siamicum*, *Peucedanum ruthenicum* EOs. β-phellandrene was identified in the *Seseli globiferum* and *Ferula cupularis* EOs. Whereas α-phellandrene was identified in *Angelica sylvestris*, *Cuminum cyminum*, *Carum carvi*, *Anethum graveolens* EOs. Sabinene was identified in *Seseli globiferum*, *Anethum graveolens*, *Ferula cupularis* EOs.

In contrast, some compounds were found -as main compounds- in the unique species, such as dill ether in the *Anethum graveolens* EO, Apiole in the *Carum carvi* EO, n-octyl acetate in the *Heracleum siamicum* EO. fenchone in the *Foeniculum vulgare* EO, and 2-Decenoic acid in the *Coriandrum sativum* EO.
Figure 1. displays the chemical structures of some of the main compounds of Apiaceae EOs.

When evaluating an EO's composition, it is important to remember that oil production is influenced by many factors. These factors include genetic and physiological variables [21], such as the plant organ from which the EO is extracted, the plant age, the time of harvesting, the soil composition, and the extraction method used [4]. Therefore, even if the EO is extracted from the same region, the EO cannot be expected to be the same from year to year [22].

Table I. Main compounds of common Apiaceae EOs

Sp.	PP	Main compounds	Ref.
Coriandrum sativum	Leaves	(2-Decenoic acid); (E-11-tetradecenoic acid); (Capric acid); (Undecyl alcohol)	[23]
	seeds	(Linalool); (Geranyl acetate); (γ-Terpinene); (α-Cedrene); (Citronellal); (Geraniol)	
Pimpinella anisum	seeds	(trans-anethole); (estragol); (o-isoeugenol); (γ-himachalene); (cis-anethole)	[20]
Cuminum cyminum	Fruits	(trans-Dihydrocarvone); (γ-Terpinene); (p-Cymene); (α-Phellandrene)	[17]
Foeniculum vulgare	Fruits	(t-anethole); (fenchone); (estragole); (α-pinen); (limonene)	[24]
Carum carvi	seeds	(limonene); (carvone); (apiole); (anethole); (cis-Dihydrocarvone); (α-Phellandrene)	[25]
Anethum graveolens	Leaves	(α-phellandrene); (limonene); (dill ether); (α-pinene); (*n*-tetracosane); (sabinene); (neophytadiene)	[26]
Ammi visnaga	seeds	(Carvacrol); (Thymol); (Toluene); (Gamma-terpinene); (Gamma-Coniceine); (2-furanglycolic acid)	[27]
Eryngium pyramidale	aerial parts	(Sesquicineole); ((Z)-falcarinol); (spathulenol); (α-bisabolol); (14-hydroxy-(Z)-caryophyllene)	[15]
Angelica sylvestris	seeds	(limonene); (α-pinene); (camphene); (α-phellandrene); (bornyl acetate); (trans-caryophyllene)	[28]
Ferula cupularis	Flower	(DL-limonene); (δ -2-carene); (sabinene); (ß-phellandrene); (α-terpinolene); (δ -3-carene); (p-mentha-1-en-9-ol)	[29]
	Leaves	(ß-pinene); (ß-ocimene); (bornyl angelate); (allo-ocimene); (*trans*-isolimonene); (dihydro-linalool acetate)	
	Stems	(α-terpinyl isobutyrate); (δ -3-carene); (bornyl angelate); (trans-sabinol); (sothol); (*p*-cymen-9-ol); (terpinyl acetate); (linalool isobutyrate)	
Laser trilobum	Rhizomes	(α-pinene); (γ-terpinene); (*p*-cymene); (β-pinene); (1,4-dimethylazulene)	[30]
	Fruits	(Limonene); (Perillaldehyde); (α-Pinene); (cis-Limonene oxide); (trans-Limonene oxide)	
Heracleum siamicum	Fruits	(n-octyl acetate); (*o*-cymene); (limonene); (δ-2-carene); (*cis*-thujone); (isobornyl acetate); (*n*-octanol)	[31]
Crithmum maritimum	aerial parts	(ɣ-terpinene); (thymolmethyl ether); (ρ-cymene)	[32]
Peucedanum ruthenicum	Fruits	(1,8-cineole); (camphor); (*Z*-carveol); (lcarvone); (8,9-dehydroisolongifolene); (caryophyllene oxide); (caryophylla-4(12)	[33]
Seseli globiferum	aerial parts	(sabinene); (α-pinene); (β-phellandrene); (Myrcene); (Terpinen-4-ol); (β-Pinene); (camphene)	[34]

SP.: species, PP: plant part.

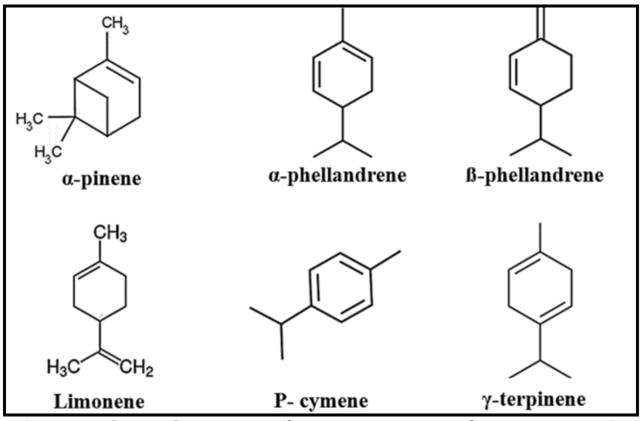

Figure 1. Chemical structures of some components of Apiaceae EOs (α-pinene, α-phellandrene, ß-phellandrene, limonene, p-cymene, γ-terpinene)

6. Antimicrobial Activity of Apiaceae EOs

Due to the increasing resistance of microorganisms to antibiotics and the negative effects of antibiotics, there is an interest in finding natural antimicrobials [19].

EOs are rich in active compounds, so, they can be used as antimicrobial food additives [35]. Antibacterial effect of EOs extracted from various Apiaceae genera, such as *Eryngium*, *Pimpinella*, *Ferula*, *Seseli*, *Ammi*, *Foeniculum*, *Coriandrum*, *Cuminum*, *Anethum*, *Angelica* and *Crithmum* have been documented.

Rezaei *et al*., (2016) indicated that the EO obtained from *Coriander* leaves has an antibacterial effect against various bacterial strains such as *Escherichia coli* (ATCC 8739), *Vibrio cholera* (PTCC 1611), *Yersinia enterocolitica* (PTCC 1477), *Salmonella enterica* (PTCC 1709), *Staphylococcus aureus (*ATCC 25913) with Minimum Inhibitory Concentration values ranged from 2.5 to 80 µg/ml [19].
The EO of *Ammi visnaga* aerial parts showed antibacterial effect against *Pseudomonas aeruginosa* (ATCC 27853), *S. aureus* (ATCC 43300), and *E. coli* (ATCC 25922) with MIC values of (16, 32, 16) µg/ml, respectively [36].

Janaćković *et al*., (2011) evaluated the antibacterial effect of the EO obtained from *Seseli globiferum* aerial parts against various bacterial species. The results showed MIC values of (0.5 µL/ml, 1.25 µl/ml, 1.25 µl/ml) for *P. aeruginosa* (ATCC 27853), *M. flavus* (ATCC 10240) and *E. coli* (ATCC 25922). No effect was noticed on *Enterobacter cloacae* (clinical isolates) and *Staphylococcus epidermidis* (ATCC 12228) [34]. The EO of *Foeniculum vulgare* was tested for antimicrobial effect against *S. aureus* (ATCC 25923), and *E. coli* (ATCC 25922) and *P. aeruginosa* (ATCC 27853). The results showed that MIC values ranged from 0.781 to 25 µl /ml [37]. The EO of *Crithmum maritimum* exhibited a strong antibacterial effect against *E. coli* (ATCC25922), *S. aureus* (ATCC25923), Methicillin-resistant *S. aureus* and *Listeria innucia*. All the EO sensitive strains showed the same level of sensitivity (MIC; 0.11 ± 0.01 µl/ml) [32].

However, the antimicrobial properties of EOs are highly variable, and are often related to their chemical composition and/or concentration [38]. The antibacterial properties of EOs are attributed to their main ingredients and to the synergistic or antagonist properties. Minor constituents also contribute to its biological effect [39].

Generally, EOs with a high content of phenolic compounds (thymol, eugenol, carvacrol, etc.) have significant antimicrobial properties [40]. Some EOs damage the lipid bilayer of the cell membrane, others inhibit protein synthesis and DNA replication, and others have negative effect on the cell cycle (S phase) of bacteria [38]. The antimicrobial properties of some Apiaceae EOs is represented in Table 2.

Table 2. Antimicrobial effect of some Apiaceae EOs

Sp.	Micro-organisms	MIC values	Ref.
Coriandrum sativum	*E. coli* ATCC 8739	40 µg/ml	[19]
	S. aureus ATCC 25913	5 µg/ml	
	Y. enterocolitica PTCC (1477)	2.5 µg/ml	
	S. enterica PTCC 1709	80 µg/ml	
	V. cholera PTCC 1611	5 µg/ml	
Pimpinella anisum	*S. aureus* (ATCC 25923)	6.25 ± 0.2 mg/ml	[2]
	P. aeruginosa (ATCC 25853)	25 ± 0.4 mg/ml	
	E. coli (ATCC 25922)	50 ± 0.1 mg/ml	
Cuminum cyminum	*S. typhi* (D1 Vi-positive)	3.4 ± 0.87 mg/ml	[41]
	S. typhi (G7 Vi-negative)	6.1 ± 2.3 mg/ml	
	S. paratyphi A	14 ± 1.7 mg/ml	
	E. coli (SS1)	3.4 ± 0.87 mg/ml	
	B. licheniformis (ATCC 14580)	4.3 ± 0.87 mg/ml	
Foeniculum vulgare	*S. aureus* (ATCC 25923)	0.781 µl/ml	[37]
	E. coli (ATCC 25922)	0.781 µl/ml	
	P. aeruginosa (ATCC 27853)	25 µl/ml	
Carum carvi	*B. subtilis* BTCC 17	200 ppm	[18]
	B. cereus BTCC 19	300 ppm	
	E. coli ATCC 25922	200 ppm	
	P. aeruginosa CRL(ICDDR, B)	300 ppm	
	S. dysenteriae AE 14396	100 ppm	
	S. typhi AE 14612	200 ppm	
	S. paratyphi AE 14613	200 ppm	
	S. aureus ATCC 6538	300 ppm	
	V. cholerae AE 14748	200 ppm	
Anethum graveolens	*E. coli* ATCC25922	1.25 mg/ml	[35]
	S. aureus ATCC25923	0.62 mg/ml	
	P. aeruginosa 8821M	1.5 mg/ml	
Ammi visnaga	*E. coli* ATCC 25922	16 µg/ml	[36]
	S. aureus ATCC 43300	32 µg/ml	
	P. aeruginosa ATCC 27853	16 µg/ml	
Eryngium pyramidale	*S. aureus* (ATCC 25923)	7.5 mg/ml	[15]
	S. epidermidis (ATCC 12228)	7.5 mg/ml	
	B. subtilis (ATCC 465)	>15 mg/ml	
	B. cereus (PTCC 1015)	15 mg/ml	
	B. pumilus (PTCC 1274)	7.5 mg/ml	
	E. faecalis (ATCC 29737)	15 mg/ml	
	K. pneumoniae (ATCC 10031)	15 mg/ml	
	E. coli (ATCC 25922)	7.5 mg/ml	
Angelica sylvestris	*S. aureus* (ATCC 25923)	28.40 µl/ml	[28]
	E. coli (ATCC 8739)	56.81 µl/ml	
Ferula cupularis	*B. subtilis* ATCC 6633	2.85 mg/ml	[29]
	S. aureus ATCC 6538	2.85 mg/ml	
	S. epidermidis ATCC 12228	2.85 mg/ml	
	E. coli ATCC 8739	2.85 mg/ml	
	K. pneumoniae ATCC 10031	1.42 mg/ml	
	P. aeruginosa ATCC 9027	22.75 mg/ml	
Laser trilobum	*S. aureus* ATCC 25923	100 µg/ml	[30]
	S. epidermidis ATCC 12228	50 µg/ml	
	M. flavus ATCC 10240	100 µg/ml	
	E. faecalis ATCC 29212	100 µg/ml	
	E. coli ATCC 25922	25 µg/ml	
	P. aeruginosa ATCC 27853	50 µg/ml	
	K. pneumoniae NCIMB 9111	25 µg/ml	
Heracleum siamicum	*B. subtilis* ATCC 6633	25 µg/ml	[31]
	Streptococcus aureus ATCC 29213	20 µg/ml	
Crithmum maritimum	*E. coli* ATCC25922	0.11 µl/ml	[32]
	S. aureus ATCC25923	0.11 µl/ml	
	Methicillin-resistant *S. aureus*	0.11 µl/ml	
	L. innocua CLIP 74915	0.11 µl/ml	
Peucedanum ruthenicum	*S. aureus* ATCC29737	0.03 mg/ml	[33]
	S. epidermidis ATCC14990	0.29 mg/ml	
	B. cereus ATCC 1247	0.10 mg/ml	
Seseli globiferum	*E. coli* (ATCC 25922)	1.25 µl/ml	[34]
	P. aeruginosa (ATCC 27853)	0.5 µl/ml	
	M. flavus (ATCC 10240)	1.25 µl/ml	
	B. cereus (clinical isolates)	2.5 µl/ml	

Sp.: species, *P. aeruginosa: Pseudomonas aeruginosa; E. coli: Escherichia coli; B. subtilis: Bacillus subtilis; B. licheniformis: Bacillus licheniformis; B. pumilus: Bacillus pumilus; B. cereus: Bacillus cereus; M. flavus: Micrococcus flavus; S. aureus: Staphylococcus aureus; S. epidermidis: Staphylococcus epidermidis; L. innocua: Lysteria innocua; Y. enterocolitica: Yersinia enterocolitica; S. enterica: Salmonella enterica; S. typhi: Salmonella typhi; S. paratyphi: Salmonella paratyphi; V. cholera: Vibrio cholera; K. pneumoniae: Klebsiella pneumoniae; E. faecalis: Enterococcus faecalis; S. dysenteriae: Shigella dysenteriae.*

7. Antioxidant Activity of Apiaceae EOs

Antioxidants play an important role against free radical toxicity by preventing damage caused by free radicals [42]. Many synthetic antioxidant products such as BHA and BHT have been shown to be toxic and/or mutagenic. Therefore, plant antioxidants are considered an interesting alternative [43].

Natural antioxidants from plants such as herbs, spices and the EOs extracted from them, have been popular for their cosmetic and medicinal uses recently [14].

There are several methods to determine the antioxidant activity of EOs including DPPH, ABTS, FRAP, quantification of products produced during lipid peroxidation (β-carotene co-oxidation, TBARS and LDL oxidation), and etc. [44].

The antioxidant effect of Apiaceae EOs is well documented (Table III). Many studies have shown that Apiaceae plants are good natural antioxidants [14].

Singh *et al*., (2015) evaluated the antioxidant effect of coriander plant and seed EO. The results indicated that the percent inhibition of DPPH free radicals by seeds and plant oil was 54.58 and 73.59% at 50 μg/ml concentration [45].

Trifan *et al*., (2016) evaluated the antioxidant effect of EO extracted from *Carum carvi* fruits by three methods (reducing power, ABTS•+ scavenging effect and DPPH·). The results showed a positive effect with an IC50 value of 7.64 μg/ml, 5.34 and 46.51 μg/ml, respectively [46].

The EO of *Anethum graveolens* aerial parts showed antioxidant activity, in β-carotene bleaching test and reducing power, with (IC_{50}= 15.3 μg/ml) and (EC_{50}=11.24 μg/ml), respectively [47]. The antioxidant activity of *Eryngium foetidum* EO was determined by the DPPH free radical scavenging method. The IC50 values were 54.5 μg/ml, 46 μg/ml and 56 μg/ml, for the root, stem and leaf oils respectively [48].

The antioxidant effect of *Crithmum maritimum* EO was determined by FRAP, and DPPH method. EO extracted from various plant parts (flowers, stems and leaves) has been shown to have very low antioxidant activity [49].

With their ability to scavenge free radicals, EOs might play a significant role in preventing cancer and diseases such as brain damage, heart disease and immune problems [40].

EO consists of many organic compounds containing conjugated carbon double bonds and hydroxyl groups (OH), that donate hydrogen, to inhibit free radicals and reduce oxidative stress [50]. However, the composition and antioxidant properties of EOs are often affected by the environment and cultivation conditions, and the crop and post-crop processing [51].

Table 3. Antioxidant effect of common Apiaceae EOs

Sp.	pp	Technique	Con	Results	Ref.
Coriandrum sativum	seeds	DPPH	-	IC50=47.2 μg/ml	[45]
	Whole plant			IC50=35.4 μg/ml	
Pimpinella anisum	seeds	DPPH	50 μl/ml	scavenging activity%= 77.58%	[52]
Cuminum cyminum	seeds	DPPH	-	IC50= 3.32 mg/ml	[51]
		FRAP		IC50= 17.02 mg/ ml	
Foeniculum vulgare	Leaves	DPPH	-	IC50=900 μg/ml	[43]
Carum carvi	Fruits	DPPH	-	IC50=46.51 ± 1.61 μg/ml	[46]
		ABTS		IC50=5.34 μg/ml	
		FRAP		IC50=7.64 μg/ml	
Anethum graveolens	aerial parts	β-carotene	-	IC_{50}= 15.3 μg/ml	[47]
		reducing power		EC_{50}=11.24 μg/ml	
Ammi visnaga	seeds and umbels	DPPH	-	IC50=56.05 3μg/ml	[1]
Eryngium foetidum	stems	DPPH	-	IC50 =46 μg/ml	[48]
	roots			IC50 =54.5μg/ml	
	leaves			IC50 =56 μg/ml	
Angelica purpurascens	roots	DPPH	-	IC50 =2.95 mg/ml	[16]
Ferula tadshikorum	underground parts	DPPH	-	IC50 =17.8 mg/ml	[53]
		ABTS		IC50 =8.2 mg/ml	
Heracleum persicum	aerial parts	DPPH	-	IC50 = 1.25 mg/ml	[54]
Crithmum maritimum	Flowers	FRAP	33 μg/ml (final concentration in reaction system)	FRAP value=22.0 ± 2.3l mol Fe^{+2}/L	[49]
	Stems			FRAP value=42.0 ± 2.3 mol Fe^{+2}/L	
	Leaves			FRAP value=8.4 ± 2.4 mol Fe^{+2}/L	
	Flowers	DPPH		inhibition %=2.8 ± 0.0	
	Stems			inhibition %=2.8 ± 0.2	
	Leaves			inhibition %=2.6 ± 0.2	
Peucedanum dhana	Fruits	DPPH	-	IC50=9.13 mg/ml	[55]
		ABTS		IC50=9.36 mg/ml	
Seseli pallasii	Roots	DPPH	-	EC50=107. 10 mg/ml	[56]
	Stems			EC50=329. 11 mg/ml	
	Fruits			EC50=451. 23 mg/ml	

SP.: species, PP: plant part. Con: concentration. Ref: reference.
DPPH: (2,2-diphenyl-1-picrylhydrazyl); ABTS: (2,20-azino-bis (3-ethylbenzothiazoline-6-sulfonic acid)); FRAP: (ferric reducing antioxidant power).

8. Conclusion

According to the literature, we can conclude that the EOs of the Apiaceae species have antibacterial and antioxidant properties. These biological effects support these oils as natural alternatives in food and pharmaceutical industries, keeping in mind that their use can be hampered by the chemical variability of the oils. However, more specific studies are needed to determine the optimal procedures of application of these efficient EOs.

Statements & Declarations:
"The authors declare that no funds, grants, or other support were received during the preparation of this manuscript."

Author's Contribution:
The idea for the article was suggested by Dr. Ruba joujeh.
The literature search was performed by Dr. Dima joujeh.
Data analysis was performed by Dr. Ruba joujeh.
revising the work was performed by Dr. Dima joujeh.
Both authors read and approved the final manuscript.

Conflict of interest
The authors declare no conflict of interest.

References

[1] N Darkaoui, K Benbrahim, M Chaibi, S Boukhira, R Ez-Zriouli, Z Ouaritini. "Phytochemical and Antioxidant Activity of the Essential Oil of *Ammi visnaga* L. from Morocco". *Der Pharma Chem.* Vol. **9,** issue. **17,** pp. **68–72, 2017**.

[2] N Ouis, A Hariri. "Chemical Analysis, Antioxidant and Antibacterial Activities of Aniseeds Essential Oil". *Agric. conspec. sci.* Vol. **86,** issue. **4,** pp. **337–348**, **2021.**

[3] T. Olaleye, O. Ogunbiyi. "Characterization, Phytochemical Screening and Antimicrobial Properties of stem bark extract of Theobroma cacao (Cocoa)". *Int. J. Sci. Res. in Biological Sciences.* Vol.**9**, Issue.**6**, pp.**20-25, 2022.**

[4] M Santos, C Marques, J Mota, L Pedroso, A Lima. "Applications of Essential Oils as Antibacterial Agents in Minimally Processed Fruits and Vegetables-A Review". *Microorganisms*. Vol. **10,** issue. **760,** pp. **1–24, 2022**.

[5] C Popa, A Lupitu, M Mot, L Copolovici, C Moisa, D Copolovici. "Chemical and Biochemical Characterization of Essential Oils and Their Corresponding Hydrolats from Six Species of the Lamiaceae Family". *Plants*. Vol. **10,** issue**. 2489,** pp. **1–18, 2021.**

[6] M Butnariu, I Sarac. "Essential Oils from Plants". J. *Biotechnol. Biomed. Sci*. Vol. **1,** issue**. 4,** pp. **35–43, 2018.**

[7] H Rassem, A Nour, R Yunus. "Biological activities of Essential Oils –A review". *Pacific Int. J.* Vol. **1,** issue**. 2,** pp. **1–14, 2018.**

[8] S Chouhan, K Sharma, S Guleria. "Antimicrobial Activity of Some Essential Oils- Present Status and Future Perspectives". *Medicines*. Vol. **4,** issue**. 58,** pp. **1–21, 2017**.

[9] R Herman, E Ayepa, S Shittu, S Fometu, J Wang. "Essential Oils and Their Applications-A Mini Review". *Adv Nutr Food Sci,* Vol. **4,** issue**. 4,** pp. **1–13, 2019**.

[10] S Kar, P Gupta, J Gupta. "Essential Oils: Biological Activity Beyond Aromatherapy". *Nat. Prod. Sci*. Vol. **24,** issue**. 3,** pp. **139–147, 2018.**

[11] E Spinozzi, F Maggi, G Bonacucina, R Pavela, M Boukouvala, N Kavallieratos, et al. "Apiaceae Essential Oils and their constituents as insecticides against mosquitoes-A review", *Ind. Crops Prod*. pp.**171, 2021**.

[12] B Sayed-Ahmad, T Talou, Z Saad, A Hijazi, O Merah. "The Apiaceae: Ethnomedicinal family as source for industrial uses". *Ind. Crop. Prod*. Vol. **109,** pp. **661–671, 2017**.

[13] M Aćimović, N Milić. "Perspectives of the Apiaceae Hepatoprotective Effects– A Review". *Nat. Prod. Commun*. Vol. **12,** issue. **2,** pp. **309–317, 2017.**

[14] Thiviya P, Gamage A, Piumali D, Merah O, Madhujith T. "Apiaceae as an Important Source of Antioxidants and Their Applications". *Cosmetics*. Vol. **8,** issue. **111,** pp. **1–19, 2021**.

[15] M Nejati, S Masoudi, D Dastan, N Masnabadi. "Phytochemical Analysis and Antibacterial Activity of *Eryngium pyramidale* Boiss. & Hausskn". *J. Chil. Chem. Soc.* Vol. **66,** issue. **2,** pp. **5230–5236, 2021**.

[16] S Türkuçar, A Karaçelik, M Karaköse. "Phenolic compounds, Essential Oil composition, and antioxidant activity of *Angelica pur- purascens* (Avé-Lall.) Gill", *Turk J Chem,* Vol. **45,** pp. **956-966, 2021**.

[17] N Chaudhary, S Husain, M Ali. "Chemical Composition and Antimicrobial Activity of Volatile Oil of the Seeds of *Cuminum cyminum* L.", *World J. Pharm. Pharm. Sci*. Vol. **3,** issue. **7,** pp. **1428–1441, 2014**.

[18] J Begum, M Bhuiyan, J Chowdhury, M Hoque, M Anwar. "Antimicrobial Activity of Essential Oil from Seeds of *Carum carvi* and Its Composition". *Bangladesh J Microbiol,* Vol. **25** issue. **2,** pp. **85–89, 2008.**

[19] M Rezaei, F Karimi, N Shariatifar, E Shiri. "Antimicrobial Activity of the Essential Oil from the Leaves and Seeds of *Coriandrum sativum* towards the Food-borne Pathogens". *West Indian Med J.* Vol. **65,** issue**. 1,** pp. **8–12, 2016.**

[20] S Saibi, M Belhadj, E Benyoussef. "Essential Oil Composition of *Pimpinella anisum* from Algeria". *Anal. Chem. Lett.* Vol. **2,** issue**. 6,** pp. **401–404, 2012.**

[21] R Chizzola. "Essential Oil Composition of Wild Growing Apiaceae from Europe and the Mediterranean". *Nat. Prod. Commun*. Vol**. 5,** issue**. 9,** pp. **1477–1492, 2010**.

[22] H Elshafie, I Camele. "An Overview of the Biological Effects of Some Mediterranean Essential Oils on Human Health". *Biomed Res. Int.* pp. **1–14, 2017.**

[23] M Bhuiyan, J Begum, M Sultana. "Chemical composition of leaf and seed Essential Oil of *Coriandrum sativum* L. from Bangladesh". *Bangladesh J Pharmacol*. Vol**. 4,** pp. **150-153, 2009**.

[24] Aprotosoaie A, Șpac A, Hăncianu M, Miron A, Tănăsescu V, Dorneanu V, et al. "The chemical profile of Essential Oils obtained from fennel fruits (*Foeniculum vulgare* Mill.)". *Farmacia*. Vol. **58,** issue**. 1,** pp. **46–53, 2010.**

[25] M Nehiri, E Aouane, K Tarfaoui, S Choukri, Y Chaib, S Inekach, L Zeghari, N Berrid, Ouhssine M. "Evaluation of the Antibacterial Activity of *Carum carvi* L. Essential Oil". *Am. J. Innov. Res. Appl. Sci.* Vol**. 5,** issue**. 6,** pp. **67–70, 2017.**

[26] Kazemi M, Abdossi V. "Chemical composition of the Essential Oils of *Anethum graveolens* L.". *Bangladesh J. Bot.* Vol**. 44,** issue**. 1,** pp. **159–161, 2015.**

[27] Nayebi Sh, Kakeshpour T, Hasanvand A, Nadri M, Monfared S. "Composition of volatile compounds of extract of *Ammi majus* from Iran by GC-MS". *J. Sci. Islam. Repub. Iran.* Vol**. 24,** issue**. 4,** pp. **335–338, 2013.**

[28] M Aćimović, A Varga, M Cvetković, J Stanković. "Chemical characterisation and antibacterial activity of the Essential Oil of wild *Angelica* seeds". *Bot. serbica*. Vol**. 42,** issue**. 2,** pp. **217–221, 2018**.

[29] Z Alipour, P Taheri, N Samadi, Z Alipour, P Taheri, N Samadi. "Chemical composition and antibacterial activity of the Essential Oils from flower, leaf and stem of *Ferula cupularis* growing wild in Iran". *Pharm Biol*. Vol**. 53,** issue**. 4,** pp. **483–487, 2015**.

[30] M Drobaca, S Petrović, M Milenković, M Couladis, J Kukić-Markovića, M Niketić. "Composition and Antimicrobial Properties of Essential Oils of *Laser Trilobum* Rhizomes and Fruits". *Nat. Prod. Commun.* Vol**. 12,** issue**. 3,** pp. **445–448, 2017**.

[31] Kuljanabhagavad T, Sriubolmas N, Ruangrungsi N. "Chemical Composition and Antimicrobial Activity of the Essential Oil from *Heracleum siamicum*". *J Heal. Res.* Vol**. 24,** issue**. 2,** pp. **55–60, 2010.**

[32] N Nabet, H Boudries, N Chougui, S Loupassaki, S Souaguid, F Burló, et al. "Biological activities and secondary compound composition from *Crithmum maritimum* aerial parts". *Int. J. Food Prop.* Vol**. 20,** issue**. 8,** pp. **1843–1855, 2017**.

[33] S Alavi, N Yassa, M Fazeli. "Chemical constituents and antibacterial activity of Essential Oil of *Peucedanum ruthenicum* M. Bieb. Fruits". *Iran. J. Pharm. Sci.* Vol**. 1,** issue**. 4,** pp. **217–222, 2005.**

[34] P Janaćković, M Sokovićb, L Vujisićc, V Vajsd, I Vučkovićc, Z Krivošeje, et al. "Composition and Antimicrobial Activity of *Seseli globiferum* Essential Oil". *Nat. Prod. Commun.* Vol**. 6,** issue**. 8**, pp.**1163–1166, 2011.**

[35] S Derakhshan, M Navidinia, A Ahmadi. "Antibacterial Activity of Dill (*Anethum graveolens*) Essential Oil and Antibiofilm Activity of Cumin (*Cuminum cyminum*) Alcoholic Extract". *Infect Epidemiol Microbiol.* Vol**. 3,** issue**. 4,** pp. **122–126, 2017**.

[36] A Khalfallah, A Labed, Z Semra, B Kaki, A Kabouche, R Touzani, et al. "Antibacterial activity and chemical composition of the Essential Oil of *Ammi visnaga* L. (Apiaceae) from Constantine,

Algeria". *Int. J. Med. Arom. Plants*. Vol. **1,** issue. **3,** pp. **302–305, 2011.**

[37] S Abdurahim, B Elamin, A Bashir, A Almagboul. "In Vitro Test of Antimicrobial Activity of *Foeniculum Vulgare* Mill. (Fennel) Essential Oil". J. Multidiscip. *Eng. Sci. Stud.* Vol. **3,** issue. **4,** pp. **1609–1614, 2017.**

[38] M Galgano, P Capozza, F Pellegrini, M Cordisco, A Sposato, S Sblano, et al. "Antimicrobial Activity of Essential Oils Evaluated in Vitro against *Escherichia coli* and *Staphylococcus aureus*". *Antibiotics*. Vol. **11,** issue. **979,** pp. **1–13, 2022**.

[39] J Vieira, C Gonçalvesa, J Villarreala, V Gonçalvesb, R Lund, R Freitag, et al. "Chemical composition of Essential Oils from the Apiaceae family, cytotoxicity, and their antifungal activity in vitro against candida species from oral cavity". *Brazilian J. Biol.* Vol. **79,** issue. **3,** pp. **432–437, 2019.**

[40] W Dhifi, S Bellili, S Jazi, N Bahloul, W Mnif. Essential Oils' Chemical Characterization and Investigation of Some Biological Activities: A Critical Review". *Medicines*. Vol. **3,** issue. **25,** pp. **1–16, 2016**.

[41] R Naveed, I Hussain, A Tawab, M Tariq, M Rahman, S Hameed, et al. "Antimicrobial activity of the bioactive components of Essential Oils from Pakistani spices against *Salmonella* and other multi-drug resistant bacteria". *BMC Complement. Altern. Med.* Vol. **13,** issue. **265,** pp. **1–10, 2013.**

[42] Y Elshiekh1, M Abdelmageed. "Antioxidant, Cytotoxicity and Antitumor of Bergia suffruticosa (whole plant)". *Int. J. Sci. Res. in Biological Sciences*. Vol.**6**, Issue.**6**, pp.**52-55**, **2019**.

[43] E El Ouariachi, N Lahhit, A Bouyanzer, B Hammouti, J Paolini, L Majidi, et al. "Chemical composition and antioxidant activity of Essential Oils and solvent extracts of *Foeniculum vulgare* Mill. from Morocco". *J. Chem. Pharm. Res*. Vol. **6,** issue. **4,** pp. **743–748, 2014**.

[44] L Da Silva, O Ferreira, J Cruz, C Franco, T dos Anjos, M Cascaes, et al. "Lamiaceae Essential Oils, Phytochemical Profile, Antioxidant, and Biological Activities, Evidence-Based Complement". *Altern. Med,***1-18, 2021**.

[45] K Singh, R Rani, P Bansal, S Medhe, M Srivastava. "Antioxidant Activity of Essential Oil of *Coriandrum sativum* and Standardization of HPTLC Method for the Estimation of Major Phytomarkers". *J. Anal. Chem.* Vol. **70,** issue. **2,** pp. **220–224, 2015**.

[46] A Trifan, A Aprotosoaie, O Cioancă, M Hăncianu, A Jităreanu, E Gille, et al. "Antioxidant Activity of Essential Oil from *Carum carvi* L. Cultivated in North- Eastern Romania". *Rev. Med. Chir. Soc. Med. Nat., Iaşi*. Vol. **120,** issue. **3,** pp. **732–736, 2016.**

[47] M Kazemi. "Phenolic profile, antioxidant capacity and anti-inflammatory activity of *Anethum graveolens* L. Essential Oil, Former". *Nat. Prod. Lett*. Vol. **29,** issue. **6,** pp. **551-553, 2015**.

[48] P Thomas, E Essien, S Ntuk, M Choudhary. "*Eryngium foetidum* L. Essential Oils: Chemical Composition and Antioxidant Capacity". *Medicines*. Vol. **4,** issue. **24,** pp. **1–7, 2017.**

[49] I Mekinic, I Blazˇevic, I Mudnic, F Burcˇul, M Grga, D Skroza, et al. "Sea fennel (*Crithmum maritimum* L.): phytochemical profile, antioxidative, cholinesterase inhibitory and vasodilatory activity". *J Food Sci Technol*. Vol. **53,** issue. **7,** pp. **3104–3112, 2016.**

[50] L do Nascimento, A de Moraes, K da Costa, J Galúcio, P Taube, C Costa, et al. "Bioactive Natural Compounds and Antioxidant Activity of Essential Oils from Spice Plants: New Findings and Potential Applications". *Biomolecules*. Vol. **10,** issue. **988,** pp. **1–37, 2020**.

[51] M Abbdellaoui, E Bouhlali, L El Rhaffari. "Chemical Composition and Antioxidant Activities of the Essential Oils of Cumin (*Cuminum cyminum*) Conducted Under Organic Production Conditions". *J. Essent. Oil Bear. Plants*, pp. **1–8, 2019**.

[52] S El-sayed, N Ahmed, S Selim, A Al-khalaf, N El Nahhas, S Abdel-hafez, et al. "Acaricidal and Antioxidant Activities of Anise Oil (*Pimpinella anisum*) and the Oil's Effect on Protease and Acetylcholinesterase in the Two-Spotted Spider Mite (*Tetranychus urticae* Koch)". *Agriculture*. Vol. **12,** issue. **224,** pp.**1–14, 2022**.

[53] F Sharopov, P Khalifaev, P Satyal, Y Sun, A Safomuddin, S Musozoda, et al. "The Chemical Composition and Biological Activity of the Essential Oil from the Underground Parts of *Ferula tadshikorum* (Apiaceae)". *Rec. Nat. Prod*. pp. **1–6, 2018**.

[54] M Gharachorloo, M Honarvar, S Mardani. "Chemical compositions and antioxidant activity of *Heracleum persicum* Essential Oil". *Brazilian J. Pharm. Sci*. Vol. **53,** issue. **3,** pp. **1–6, 2017**.

[55] S Khruengsai, T Sripahco, N Rujanapun, R Charoensup, P Pripdeevech. "Chemical composition and biological activity of *Peucedanum dhana* A. Ham Essential Oil". *Sci. Rep.* Vol. **11,** issue. **19079,** pp. **1–11, 2021.**

[56] V Jovanović, S Simonović, M Ilić, M Marković, V Mitić, A Djordjević, et al. "Chemical Composition, Antimicrobial and Antioxidant Activities of *Seseli pallasii* Besser. (syn *Seseli varium* Trev.) Essential Oils". *Rec. Nat. Prod.* Vol. **10,** issue. **3,** pp. **277–286, 2016.**

AUTHOR'S PROFILE

Ruba joujeh PhD in Plant Sciences, University of Damascus, Syria. She is currently lecturing in the Department of basic science, Faculty of Agriculture, University of Aleppo, Syria. Her interests are in phyto-chemistry, phyto-medicine, anatomical and taxonomical researches. She has published over 12 research manuscripts both in reputable local and international journals, most of which is available online. She has over 10 years teaching and research experience.

Dima joujeh PhD in Biotechnology engineering (Animal tissue culture), Faculty of Technical engineering, University of Aleppo, Syria. She is currently lecturing in the Department of Biotechnology engineering, Faculty of Technical engineering, University of Aleppo, Syria. Her interests are in phyto-medicinal, cell culture, stem cells and Cytogenetics researches. She has published over 8 research manuscripts both in reputable local and international journals most of which is available online. She has over 9 years teaching and research experience.

