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Essential Oil Compositions and Biological Activities of the Genus *Chaerophyllum*: An Updated Review

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Abstract: The genus *Chaerophyllum* has economic value-added species. *Chaerophyllum* belongs to the family, Apiaceae, which comprises about 110 species, including annual and perennial herbal plants widely distributed in temperate and sub-temperate zones of Asia, Africa, and Europe. *Chaerophyllum* species are used for flavor and fragrance in the food industry. In some countries, a species of this genus is used in cheese production for its strong aroma. *Chaerophyllum* species were characterized by lignans, polyacetylenes, essential oils, phenolic acids, and flavone derivatives. This review summarizes the essential oil components and isolates of various extracts and their biological activities. In addition, since ancient times, essential oils have been used in many different traditional healing systems worldwide because of their biological activities. Moreover, this review will attract the attention of scientists from the aroma industry, nutritionists, and pharmaceutical industries to improve the use of essential oils for nutraceutical purposes with commercialization to aid and promote a healthy lifestyle, wellness, and well-being.

Keywords: Apiaceae; biological activities; essential oils; *Chaerophyllum villosum*.

1. Introduction

The genus *Chaerophyllum* L. belongs to the family Apiaceae, which includes annual and perennial herbal plants widely distributed in temperate and sub-temperate zones of Asia, Africa, and Europe [1, 2]. The Apiaceae family, including some of the widely used vegetables and aromatic herbs such as celery (*Apium graveolens* L.), carrot (*Daucus carota* L.), gotukola (*Centella asiatica* (L.) Urb), parsley (*Petroselinum crispum* L.), parsnip (*Pastinaca sativa* L.), wild celery (*Angelica archangelica* L.), coriander (*Coriandrum sativum* L.), cumin (*Cuminum cyminum* L.), fennel (*Foeniculum vulgare* Mill.), anise (*Pimpinella anisum* L.), dill (*Anethum graveolens* L.), and caraway (*Carum carvi* L.) are the economically important foods, herbs, and spice plants in the Apiaceae family [3-7]. In the flora of Türkiye, the genus *Chaerophyllum* L. is represented by 15 species, of which four are endemic [1]. From the genus *Chaerophyllum*, out of 72 species, one species from India was reported as *Chaerophyllum villosum* Wall. & DC., is widely distributed in the Himalayas at elevations of 2500 m to 3500 m, from India to Bhutan, Nepal, and China, and widely grows in moist, shady places, roadsides, or open grassy

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places [8]. *Chaerophyllum* species are used to add flavor and fragrance in the food industry. In the high-altitude tribes of Uttarakhand Himalaya (India), it was commonly known and sold in the name of 'Ganjari or Ganjiadi' and widely used by people in food, spice, and medicine [9]. *Chaerophyllum macropodum* Boss. (*C. macropodum*) is traditionally mixed into an herbal cheese, which is a famous dairy product known for its aroma and flavor in Türkiye [10-11]. *C. macropodum* (local name: mendi, mendo) is widely grown in Van and is used in the production of a very famous cheese known as "Van Otlu Peynir" [12, 13]. In the flora of Iran, the genus consists of 8 species of biennial or perennial herbs [14]. The seeds, leaves, and roots of the *Chaerophyllum* species have a carrot-parsley aroma and are sometimes used as flavoring agents in Iran, Türkiye, and Caucasian and Eastern Europe. *C. macrospermum* is the most widespread species of the genus in Iran, where it is known as Djafari-Farangi [15]. The main objective of this review is to focus on the components of essential oils, biological activities, and other nutraceutical potentials of essential oils and major isolates of the genus *Chaerophyllum*.

2. Taxonomy of the Genus *Chaerophyllum*

The scientific taxonomy of the Apiaceae started using morphological criteria, but afterwards, there were new diagnostic elements from several disciplines: anatomy, karyology, seedling morphology, palynology, and phytochemistry. The genus *Chaerophyllum* L. has economic value-added species. The Apiaceae, or plants of the 'Carrot Family', have been known by man since ancient times. Many local plants of this family were used in primitive cultures because people soon noticed their odor, flavor, esculence, or toxicity. Various Apiaceae are known in the early languages of China and in Sanskrit [16]. Cesalpino (1583) made the first overall grouping as 'Universum genus Ferulaceum' which comprised about 60 herbs [17]. The 'Umbelliferae' were born.

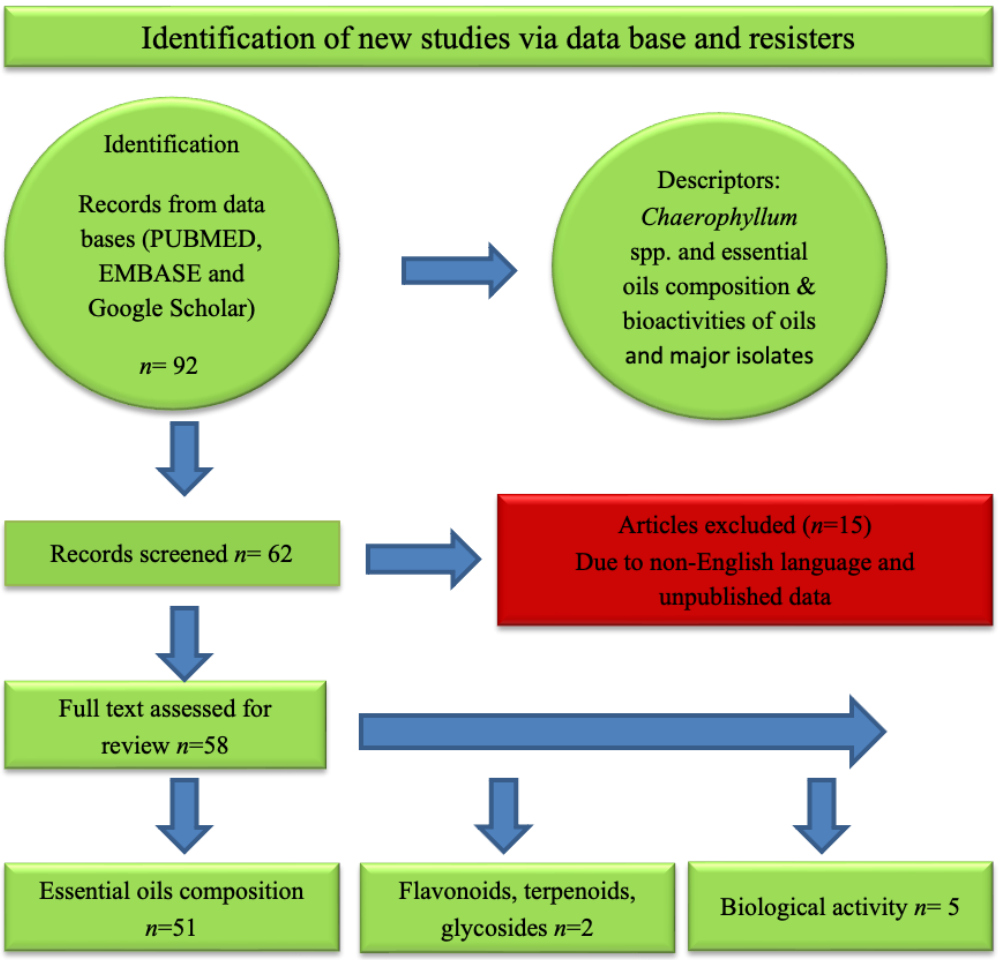

Figure 1. Flow chart showing the selection of the studies

The first monograph of a plant group independent of their uses was carried out by Morison (1672), who chose the Umbelliferae as a model, where he proposed a classification based mainly on fruit morphology [18].

3. Material and Method

This current review focuses on an update on recent studies performed on the chemical composition and biological studies on the genus *Chaerophyllum*. The search engines Google Scholar, PubMed, ScienceDirect, and ResearchGate were used to access the literature. Relevant articles published in English were searched in different databases, specifically Google Scholar, Scopus, Wiley Online Library, Semantic Scholar, and Pub Med (Fig.1). The following terms were used in combination within search strings: "*Chaerophyllum*", "essential oils", "anti-inflammatory", "antioxidant", "antibacterial", "antifungal", "antimicrobial", and "antiviral". The search was restricted to English and experimental studies.

Table 1. Major component from different species of genus *Chaerophyllum.*

***Chaerophyllum* species**	**Collection Site**	**Parts of plant used**	**Major components present**	**Ref.**
C. aksekiense A. Duran & H. Duman	Türkiye	Crushed fruits	Heptacosane (10.1%), humulene epoxide II (7.8%), (*E*)-β-farnesene (6.2%), caryophyllene oxide (6.0%), α-humulene (5.5%), terpinolene (5.5%), nonacosane (5.3%), and terpinen-4-ol (4.6%)	[21]
C. aromaticum L.	Türkiye	Aerial parts	Sabinene (28.1%), terpinolene (16.7%) and γ-terpinene (16.1%)	[22]
C. aureum L.	Serbia	Fruits	Sabinene (18.5-31.6%), *p*-cymene (7.9-25.4%), and limonene (1.9-10.9%)	[23]
C. azoricum Trel.	Portugal	Leaves & stems	Terpinolene (44-62%) and γ-terpinene (9-31%) of the oil	[24]
C. byzantinum Boiss.	Türkiye	Aerial parts	Sabinene (30.0%) and *p*-cymen-8-ol (16.0%)	[25]
C. bulbosum L. ssp. *bulbosum*)	Greece	Whole plant	Apiol (37%), (*E*)-nerolidol (8.5%), linalool (7.7%), myristicin (6.9%), and eugenol (5.8%)	[26]
	Iran	Aerial parts	(*E*)-β-Farnesene (22.3%), (*Z*)-β-ocimene (18.8%), myristicin (17.1%), caryophyllene oxide (6.6%), *allo*-ocimene (5.1%), and (*E*)-β-ocimene (4.0%)	[27]
C. coloratum L.	Iran	Ripe fruits	(*E*)-β-Farnesene (79.2%), β-pinene (7.0%), and (*Z*)-β-ocimene (4.3%)	[28]
		Umbel	(*E*)-β-Farnesene (68.5%) and (*Z*)-β-ocimene (5.5%)	[29]
C. libanoticum Boiss. & Kotschy	Türkiye	Crushed fruits	β-Phellandrene (17.6%), limonene (15.9%), β-pinene (8.8%), and sabinene (8.5%)	[30]
C. macrospermum (Willd. ex Schult.) Fisch. & C.A. Mey	Iran	Inflorescences	1,8-Cineole (7.2%), linalool (6.7%), δ-3-carene (4.4%), α-terpineol (4.7%), and farnesol (4.0%)	[31]

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	Iran	Aerial parts	(*E*)-β-Ocimene (40.0%), tricyclene (19.4%), δ-3-carene (18.3%), and myrcene (10.1%)	[31]
	Iran	Aerial parts	(*E*)-β-Ocimene (55.9%), terpinolene (9.8%), α-pinene (7.5%), β-phellandrene (4.3%), and β-pinene (4.2%)	[32]
	Iran	Seeds	(*E*)-β-Farnesene (27.1%), (*Z*)-β-ocimene (18.8%), *p*-cymene (14.3 %), α-fenchyl acetate (12.7%), and spathulenol (8.8%)	[33]
	Iran	Aerial parts	Terpinolene (21.4%), myristicin (18.9%), *p*-cymen-8-ol (11.9%)	[34]
	Iran	Aerial parts	α-Pinene (23.0%), β-pinene (17.3%), and fenchyl acetate (13.8%)	[34]
C. macropodum Boiss.	Iran	Flowering aerial parts	(*E*)-ß-Ocimene (34.5 %), (*E*)-β-Farnesene (11.8 %), (*Z*)-β-ocimene (10.4 %), *p*-cymene (7.3 %) and spathulenol (6.5 %)	[35]
	Türkiye	Fruits	*p*-Cymene (39.3%), spathulenol (7.3%), *p*-cymen-8-ol (5.9%), octanal (5.2%), and (*E*)-β-ocimene (4.5%)	[36]
	Iran	Flowers,	Myristicin (42.5%) and (*E*)-β-ocimene (41.0%)	[37]
		Leaf	(*E*)-β-Ocimene (24.9%), myristicin (15.7%), terpinolene (14.5%), fenchyl acetate (13.9%), (*Z*)-β-ocimene (6.3%), and sabinene (6.1%)	
		Stem	(*E*)-β-Ocimene (54.2%), myristicin (22.4%), and sabinene (8.9%)	[38-39]
C. prescotti DC.	Iran	Root	Myristicin (39.2 %), terpinolene (23.1 %), (*E*)-β-ocimene (21.9 %) and γ-terpinene (5.4 %).	[40]
	Iran	Aerial parts	(*E*)-β-Ocimene (29.3 and 29.3%), myrcene (14.5 and 14.6%), and terpinolene (14.4 and 14.3%)	[40]
	Siberia	Flowering tops	(*E*)-β-Ocimene (35.6%), (*Z*)-β-ocimene (19.4%), γ-terpinene (18.8%), myrcene (10.6%), and terpinolene (4.6%)	[40]
.*C. villosum* Wall. & DC	India	Root	Carvacryl methyl ether (31.1%), myristicin (19.1%), thymyl methyl ether (18.6 %), and γ-terpinene (11.7%)	[41, 42]
	India	Leaf	γ-Terpinene (74.9%), *p*-cymene (10.0%), terpinolene (2.9%) and β-pinene (2.5%)	[43]

4. Essential Oil Compositions of the Genus *Chaerophyllum*

Essential oils and natural volatiles are one of the industry's most successful commodities since they are used as flavors in lotions and shampoos, as fragrances and for skin and hair rejuvenation as perfumes, in candles, soaps, liquids that sterilize, and in conventional or medical aromatherapy. The oils are in different plant parts such as roots, stems, leaves, flowers, fruits, and even seeds, depending on the plant species. In these plant parts, the essential oil accumulates in cells, secretory cavities, or glandular hairs [19, 20]. There are several publications on *Chaerophyllum* essential oil compositions from various geographical locations, which are summarized in Table 1 and structures of major compounds, are shown in Fig. 2.

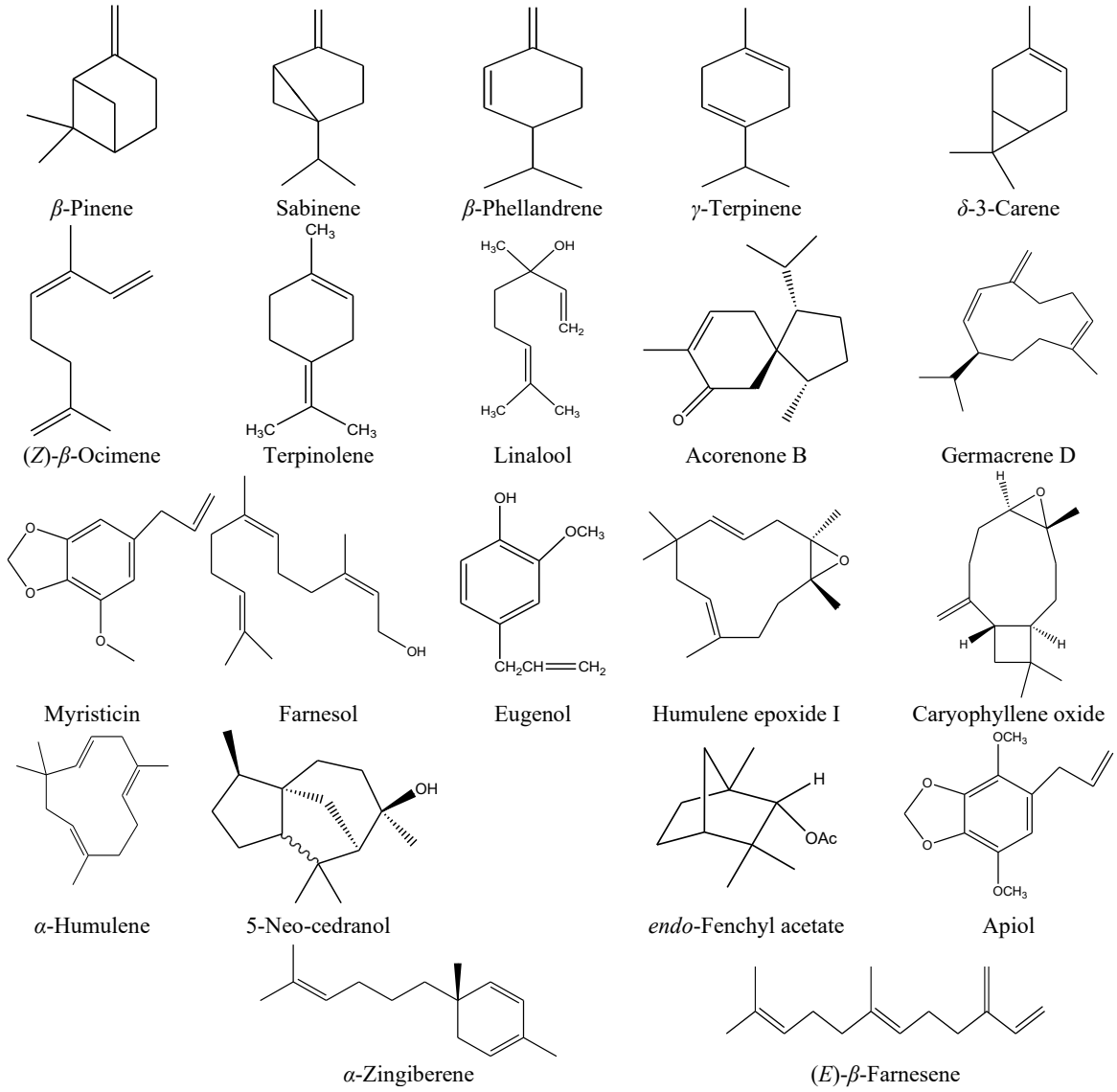

Figure 2. Structures of some major common compounds of *Chareophyllum* species

5. Phytochemical Constituents Isolated from Different Extracts

Plants contain a large number of bioactive constituents such as alkaloids, tannins, flavonoids, terpenoids, glycosides, etc [44-46]. *C. villosum* were collected from Miranjani top Pakistan and subjected to methanolic, chloroform, and aqueous extract and investigated for bioactive constituents and reported adequate presence of alkaloids, amino acids, saponins, tannins, and glycosides and also showed moderate presence of reducing sugar, fats, oils, and phytosterols. Fresh leaves of *C. byzantinum* were collected from Samsun, Türkiye. The samples were extracted with 80% methyl alcohol and the total phenolic content (TPC) was determined by measuring the phenolic compounds with a Folin-Ciocalteu solution in an alkaline medium. The results of analysis on leaves of the plants were found as; dry matter 16.43 ± 0.41%, ash 2.03 ± 0.20%, crude cellulose 1.95 ± 0.23%, crude protein 4.36 ± 0.31%, crude fat 0.57 ± 0.16%, total phenolics 2890.15 ± 945.33 mg/kg. From the roots of *C. bulbosum*, which were collected from Türkiye, three known compounds were isolated from hexane extracts as *n*-heptadecanyl eicosanoate, stigmasterol, and *β*-sitosterol-3-*O*-*β*-D-glucopyranoside [47-48].

6. Biological Activities

Essential oils play a major role in plants and act as antibacterials, antivirals, antifungals, and insecticides and protect the plants from herbivores. Essential oils are a complex mixture of molecules, which generally contain more than twenty different components of low molecular weight with very

variable concentrations. In general, monoterpenes and sesquiterpenes are the main components of essential oils, though diterpenes and phenylpropanoids can be present to a different extent. Many of these molecules are found in low concentrations, while few of them are the main components that can represent up to 70% of total oil and will be the main ones responsible for the biological effects of the oil [49-50]. Great efforts are performed to investigate the potential therapeutic effects of oils against several diseases, especially those characterized by excessive cell growth and proliferation such as cancer or bacterial infections [51-53]. Some biological activities shown by different *Chaerophyllum* species are summarized in Table 2.

Table 2. Different types of bioactivities shown by different species of *Chaerophyllum.*

***Chaerophyllum* species**	**Different biological activities**	**Ref.**
C. aureum L.	Antibacterial activity was evaluated against two Gram-positive and three Gram-negative bacteria. The Gram-positive bacteria used were: *Bacillus subtilis* and *Staphylococcus aureus.* The Gram-negative bacteria utilized in the assay were *Escherichia coli, Pseudomonas aeruginosa,* and *Salmonella abony.* The results of antibacterial assay showed that the oil was not active at concentration of 3 and 5 mg per disk.	[54]
C. bulbosum L.	The essential oil was evaluated for its in vitro antibacterial activity against two Gram-positive and three Gram-negative bacteria by disk diffusion assay. The obtained results showed that essential oil isolated from dry inflorescences of *C. bulbosum* had significant antibacterial activity against Gram-positive bacteria, *Staphylococcus aureus* and *Bacillus subtilis* subsp. *spizizenii* (diameter of inhibition zone 24 mm and 21 mm, respectively) and moderate antibacterial activity against *Escherichia coli*, *Salmonella abony* and *Pseudomonas aeruginosa* with inhibition zones of 17 mm, 15 mm, and 14 mm, respectively.	[55]
C. macropodum Boiss.	The essential oil of *Chaerophyllum macropodum* was tested for inhibition of ACE which is regarded as fundamental of hypertension treatment. *Chaerophyllum macropodum* have shown inhibitory effects on human plasma ACE with an IC_{50} value of 1.14 mg/mL.	[56]

7. Conclusions

Species of *Chaerophyllum* have been used as traditional herbal medicines. This review demonstrated the high chemical and biological potential of essential oils from their species. *C.bulbosum* from Greece, Iran, Türkiye and Serbia is dominated by apiol, (*E*)-*β*-farnesene, (*Z*)-*β*-ocimene and myristicin. *C. macrospermum* reported from Iran was dominated by (*E*)-*β*-ocimene, tricyclene, *δ*-3-carene, (*E*)-β-farnesene, and (*Z*)-β-ocimene. *C. macropodum* essential oils from Iran and Türkiye were dominated by α-pinene, β-pinene, *p*-cymene myristicin, (*E*)-β-ocimene, and (*Z*)-β-ocimene. *C. crinitum* from Türkiye and Iran was dominated by (*E*)-β-ocimene, and α-terpinolene, and some other species including *C. aureum, C. prescotti, C. byzantinum, C. libanoticum, C. villosum, C. temulum, C. hirsutum,* and *C. aromaticum* from different regions were dominated by some common components like sabinene, (*E*)-β-ocimene, β-phellandrene, carvacryl methyl ether, γ-terpinene, (*Z*)-falcarinol, and acorenone B. *Chaerophyllum* species are also used as flavor and fragrance additives in the food industry and also used as spices. This review shows that the genus *Chaerophyllum* is very rich in beneficial chemical components in essential oils and in different extracts. Essential oils and extracts exhibit significant biological and pharmacological activities. Several species are very useful in the present scenario for daily life in fragrance and perfumery. As well as in aromatherapy and many other purposes, nowadays, aromatic plants and essential oils are used in the cosmetic industries. We can conclude that the genus

Chaerophyllum is very useful in many ways in daily life, so more studies and commercial production of essential oils will be useful to society, perfume, cosmetics, and pharma industries.

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