Antioxidant Activities of *Mentha* spp. Essential Oils

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Plant essential oils (EOs) are produced predominantly using steam distillation, but can also be generated using fermentation, crushing, extraction, hydrolysis, and airing. EOs are used extensively in cosmetics in many different aspects as perfumes, in antiseptic applications, and in domestic cleaning products. The essential oils of *Mentha* (the Lamiaceae family) have been extensively studied for their biological actions.

Keywords: essential oil ; Mentha spp. ; antioxidant

1. Introduction

Plant essential oils (EOs) are produced predominantly using steam distillation, but can also be generated using fermentation, crushing, extraction, hydrolysis, and airing [1]. EOs are used extensively in cosmetics in many different aspects as perfumes, in antiseptic applications, and in domestic cleaning products [2][3]. They are volatile liquids or semi-liquids [4] that are limpid, but are rarely colored, and are soluble in organic solvents. All of the organs of the plants can synthesize EOs, which are stored in secretory compartments as cavities, canals, epidermic cells, or glandular trichomes. EOs are complex mixtures of terpenoides containing sesquiterpene and monoterpene, and their oxygenated derivatives. EOs may also incorporate a variety of other molecules such as fatty acids, oxides, and sulfur derivatives [5]. Both the terpenoid and phenylpropanoid families, which are sometimes identified as the principal constituents of several EOs, can constitute 85% of the total concentration of the oil. There are about 3000 well-recognized EOs, of which 300 are widely sold [6]. Various factors influence the chemical compositions of EOs, such as their geographic location, the seasonal period in which they are collected, the soil composition and cultivation method, their storage, and the oil extraction method [7][8]. The high level of interest in research regarding EOs is due to their many biological and medical properties [9]. They are generally recognized as safe, and they can act synergistically with other compounds, which are promising factors for their use as bioactive compounds [10].

Based on the number of search results in the PubMed database, the published studies on their antimicrobial, antioxidant, and anti-tumoral activities are 2671, 1186, and 108, respectively [11].

Mentha spp. Essential Oils

Many aromatic plants used in medicine, food, and pharmaceutical industries belong to the Lamiaceae family. In this family, *Mentha* is a well-known genus that includes 25–30 species that are generally grown in temperate areas around the world, particularly in Europe, North America, North Africa, Asia Minor, the northern parts of Iran, and near the east (Syria, Ethiopia). *Mentha* spp. includes plants that exhibit important biological activities and have high morphological variability and a great chemical diversity with respect to their EOs [10].

For this reason, *Mentha*-derived EOs have been used as a folk remedy for respiratory diseases such as bronchitis, sinusitis, tuberculosis, and the common cold [12]. *Mentha* acts as a good expectorant. The chemistry of *Mentha* EOs is complex and high variable. The main constituents of the most commonly used *Mentha* EOs revealed by gas chromatography–mass spectrometry (GC-MS) analysis show the presence of menthol, menthone, limonene, isomenthone, menthyl acetate, carvone, β-pinene, 1,8-cineole, pulegone, piperitone oxide, and micene. Each species has a characteristic prevalent compound (**Figure 1**). Studies that have already been carried out with *Mentha* spp. have shown antimicrobial activity related to some species of this genus. The most cited activities of the plant are its antiviral, antibacterial, antifungal [13], high antioxidant, and cytotoxic properties [14], and also other properties such as its antinociceptive, anti-inflammatory, and antiallergic qualities [15].

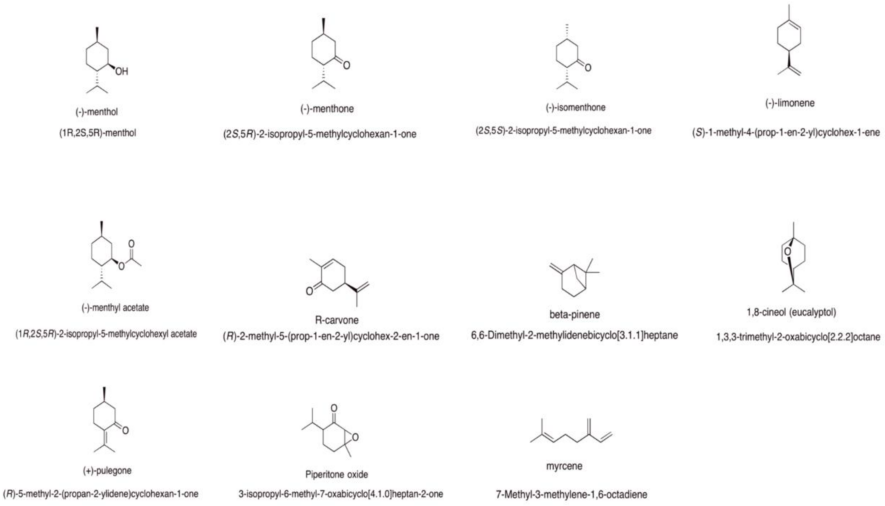

Figure 1. Chemical structures of the main components of *Mentha* spp. essential oils (EOs).

2. Antioxidant Properties

In recent years, there has been an increasing interest in the consumption of EOs as natural antioxidants [16]. It is well-known that reactive oxygen species (ROS) cause damage to cellular macromolecules, and they are implicated in the development of many human diseases. Under many pathological conditions the oxidation–reduction (redox) potential imbalance cannot remove excessive amounts of ROS [17]. Oxidant species such as hydrogen peroxide (H_2O_2) and superoxide (O_2^-) are produce following the phagocytosis of the pathogen by these cells as part of their machinery to respond to harmful insults [18]. Excessive nitric oxide (NO) production and increased levels of prooxidant species may lead to damage and poor perfusion of the vital organs of the host, contributing to multiple organ failure; thus, to counteract this response, antioxidant pathways are activated [19]. Free radicals generated by damaged membranes, when combined with EOs, produce radicals with scavenging activity.

Natural antioxidants such as phenolic compounds can be found in many plants. The antioxidant activity of essential oils does not always depend on its main component but can be modulated by other components [20].

Antioxidant activity can be evaluated using various methods, and analytical tools are utilized for measuring antioxidant content and total antioxidant capacity evaluation. The methods of antioxidant capacity evaluation include counting spectrometry, chromatography, and electrochemical techniques [21]. Generally, the most frequently used methods are 2,2-diphenyl-1-picrylhydrazyl, (DPPH), 2,2'-azino-bis (3-ethylbenzthiazoline-6-sulphonic acid), (ABTS), and others [22].

The main reaction occurring in spectrometric techniques is between a radical, radical cation, or a complex and an antioxidant molecule donor of a hydrogen atom. DPPH is a stable free radical, and the assay is based on electron transfer that produces a purple solution in ethanol, with an absorption band with a maximum of around 520 nm. When DPPH reacts with a hydrogen donor, it generates the reduced molecular form (DPPH), and the purple color disappears. The antioxidant concentration is linearly correlated with the absorbance diminution. The standard antioxidant used is Trolox. The standard curve was linear between 25–800 mM Trolox [23].

The biamperometric antioxidant capacity assay also uses the redox couple ABTS+/ABTS. The ABTS cation radical (ABTS+) [24], which absorbs at 743 nm (giving a green color), is formed by the loss of an electron by the nitrogen atom of ABTS. In the presence of Trolox (or another hydrogen-donating antioxidant), the nitrogen atom quenches the hydrogen atom, causing the solution's decolorization. ABTS can be oxidized by potassium persulfate [24][25] or manganese dioxide [26]. The standard curve was linear between 25–600 µM of Trolox. Unfortunately, the evaluation of the antioxidant activity of EOs remains a critical issue, because many "tests" are unsuitable and provide contradictory results [27].

Mentha piperita L. is a plant native to the Mediterranean region that is popularly known as peppermint; it is used medicinally for its antiproliferative and antioxidant actions. The plant is also used worldwide, especially in the perfume and food industries, for its taste and fragrance.

Mentha piperita EO possesses antiradical activity with respect to DPPH and hydroxyl (OH^-) radicals; indeed, Schmidt et al. [28] have reported the antiradical activity of this EO for DPPH as (IC_{50}), while some authors have reported its radical scavenger activity against the ABTS radical [29].

Recently, similar results were confirmed by Sun et al. [30], specifically the action of peppermint EO as a scavenger of hydroxyl radicals, and the potential for it to be an antioxidant at concentrations ≥200 µg/mL. da Silva Ramos et al. [31] reported an antioxidant activity of 79.9 ± 1.6% and IC_{50} = 414.6 µg/mL. On the contrary, other researchers [32] have described low antioxidant activity. More probably, the antioxidant actions of *M. piperita* may be due to the presence of phenolic constituents in its leaves, including rosmarinic acid and different flavonoids such as rutin, naringin, eriocitrin, luteolin, and hesperidin, which are present in aqueous extracts [33][34], but not in the essential oil. Furthermore, *M. piperita* EO is associated with increased levels of intracellular ROS, which is indicative of an apoptotic process [35] without the loss of the plasma membrane integrity.

M. pulegium, another species of *Mentha*, has been used in traditional medicine to treat numerous illnesses, such as microbial infections and oxidative stress. Kamkar et al. and Cherrat et al. [36][37] have described the lower antioxidative activity of the *M. pulegium* EO with respect to aqueous or methanol extracts. This difference could be due to a lack of diverse antioxidants in the EO. On the contrary, some authors [38][39] have observed a good radical scavenging ability of *M. pulegium* EO compared with ascorbic acid and Trolox.

Regarding other species of the genus *Mentha* used as antioxidants, *Mentha spicata* EO has been used. In this case, different results were reported; some authors described the antioxidant activity of *M. spicata* EO [40], while others [41] described a weak antioxidant activity.

Mentha longifolia L. (*M. longifolia*) is known as a wild mint named Puneh, and is a fast-growing and perennial herb that creeps along an underground rootstock, which can grow to 1–2 m tall. Eissa et al. [42] revealed that *M. longifolia* EOs possesses the highest scavenging activity against peroxyl radicals.

Mentha suaveolens Ehrh is a communal wild plant that is found near streams, bogs, and humid places. There are different subspecies, each including several varieties. El-Askary et al. [43] reported a potent antioxidant activity in vivo, which was about 96% relative to vitamin E, while Ferreira et al. [44] described the AChE inhibitory capacity as higher than 50% in the essential oil fraction of *M. suaveolens*. The antioxidant capacity in this case is due to piperitone oxide being present at 88% [45]. Other authors have reported no relevant antioxidant activity for this species [46]. Some *Mentha* spp. have not been assessed for antioxidant activity as yet. **Table 1** reports antioxidant information about *Mentha* spp. EOs.

Table 1. Radical scavenging activity of *Mentha* essential oils (EOs). ABTS: 2,2'-azino-bis 3-ethylbenzthiazoline-6-sulphonic acid, DPPH: 2,2-diphenyl-1-picrylhydrazyl.

EOs	DPPH Activity	ABTS Activity	References
M. piperita	860 µg/mL	-	[28]
	57.9 ± 1.34%	80.6 ± 1.45%	[29]
	600 µg/mL	-	[30]
	540 µg/mL	-	[31]
	11.289 ± 0.514 µg/g	0.154 ± 0.006 mmol/g	[32]
	14736 ± 156 µg/mL	-	[36]
	30.38 ± 0.8%	-	[37]
M. pulegium	69.60 µg/mL	-	[38]
	321.41 ± 2.53 µg/mL	-	[39]
M. spicata	3 µg/mL	-	[40]

EOs	DPPH Activity	ABTS Activity	References
	3450 ± 172.5 µg/mL	40.2 ± 0.2 µg/mL	[41]
M. longifolia	57.4 µg/mL	-	[42]
M. suaveolens	31 µg/mL	-	[43]
	52.4 ± 2.5%	-	[44]

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