Prospects for the creation of new phytochemical medicinal products based on Myrtus communis L. (a review)

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A – research concept and design; B – collection and/or assembly of data; C – data analysis and interpretation; D – writing the article; E – critical revision of the article; F – final approval of the article

The number of medicinal products based on biologically active substances (BAS) of plant origin is increasing every year. Scientists are exploring non-official plant raw materials used in non-traditional medicine to expand the raw material base for creating new phytopreparations. Among numerous plants, common myrtle (*Myrtus communis* L.), which is a fairly common indoor plant, is recognized as a valuable source of BAS.

The aim of the work is to analyze and summarize new literature data on the botanical characteristics, chemical composition, pharmacological and toxicological properties of *Myrtus communis* L.

Materials and methods. Data were collected from several legitimate databases and services such as PubMed, Medline, Scopus, Google Scholar, ResearchGate using the key terms "*Myrtus communis* L.", "botanical characteristics", "pharmacological studies", "phytochemical studies" in each database data Relevant and related data were filtered as appropriate if deemed relevant to the topic of interest. Time frames have also been adjusted to provide up-to-date information.

Results. *Myrtus communis* L., commonly known as common myrtle, is a widely recognized medicinal plant in the Mediterranean region. Various parts of this plant, including the leaves, fruits, and flowers, have been used in traditional medicine for treating a wide range of ailments. The pharmacological properties of common myrtle are attributed to the presence of essential oils and phenolic compounds, and these properties include antimicrobial, antiviral, antidiabetic, antispasmodic, vasodilator, antiulcer, antioxidant, antitumor, and anti-inflammatory effects. This article offers an overview of the botanical characteristics and chemical composition of different parts of common myrtle, and it presents a literature review of pharmacological studies that provide evidence for the plant's medicinal properties.

Conclusions. Common myrtle is a promising plant for further pharmacognostic research with the aim of expanding the raw material base, using the method of clonal micropropagation and creating new phytopreparations based on it.

Keywords: Myrtus communis L., botanical characteristics, pharmacological studies, phytochemical studies.

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Перспективи створення нових фітохімічних лікарських засобів на основі Myrtus communis L. (огляд)

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Щорічно зростає кількість лікарських засобів на основі біологічно активних речовин (БАР) рослинного походження. Увагу науковців привертає неофіцинальна рослинна сировина, яку використовують у нетрадиційній медицині для розширення сировинної бази для створення нових фітопрепаратів. Серед числених рослин цінним джерелом БАР визнано мирт звичайний (*Myrtus communis* L.), який є досить поширеною кімнатною рослиною.

Мета роботи – аналіз та узагальнення нових даних фахової літератури щодо ботанічної характеристики, хімічного складу, фармакологічних і токсикологічних властивостей *Myrtus communis* L.

Матеріали і методи. Дані були зібрані за кожною з офіційних баз даних і служб: PubMed, Medline, Scopus, Google Scholar, ResearchGate. Пошук здійснили за ключовими словами: «*Myrtus communis* L.», «ботанічна характеристика», «фармакологічні дослідження», «фітохімічні дослідження». Релевантні та пов'язані дані брали до аналізу, якщо вони відповідали тематиці дослідження. Часові рамки скориговані для отримання актуальної інформації.

Результати. *Myrtus communis* L. (мирт звичайний) – один із поширених лікарських видів середземноморського регіону. Різні частини цієї рослини використовують для лікування багатьох захворювань, що доведено численними фармакологічними дослідженнями. Вміст у листках, плодах і квітах ефірних олій і фенольних сполук зумовлює фармакологічні властивості мирту: антимікробні, противірусні, протидіабетичні, спазмолітичні, судинорозширювальні, противиразкові, антиоксидантні, протипухлинні та протизапальні.

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Keywords: Myrtus communis L., botanical characteristics, pharmacological studies, phytochemical studies.

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У статті проаналізовано й узагальнено інформацію щодо ботанічної характеристики, хімічного складу різних частин мирту звичайного, здійснили огляд фахової літератури, де наведено результати фармакологічних досліджень, які підтверджують лікувальні властивості цієї рослини.

Висновки. Мирт звичайний є перспективною рослиною для наступних фармакогностичних досліджень з метою розширення сировинної бази, використання методу клонального мікророзмноження та створення нових фітопрепаратів на його основі.

Ключові слова: Myrtus communis L., ботанічна характеристика, фармакологічні дослідження, фітохімічні дослідження.

Актуальні питання фармацевтичної і медичної науки та практики. 2024. Т. 17, № 1(44). С. 70-78

When creating new medicinal products, in addition to their effectiveness, more and more attention is paid to the safety of the products. Researching the properties of herbal medicines is an urgent task for scientists because they can successfully compete with synthetic drugs in terms of their effectiveness while being low-toxic, safe, mild in their action, and less allergenic.

Myrtus communis L. (common myrtle) is one of the popular medicinal species of the Mediterranean region, the raw materials of which are used to treat various diseases. Myrtle, in addition to its use in traditional medicine, is widely used in the perfume, food, cosmetic, spice, and pharmaceutical industries [1,2,3,4]. Different parts of common myrtle contain essential oils, phenolic acids, flavonoids (quercetin, catechin, myricetin), tannins, anthocyanins, pigments, and fatty acids, which determine its pharmacological properties. It has long been used against colds [5,6,7] and coughs [8,9], for the treatment of digestive problems [10,11], skin diseases [12,13,14], for the treatment of obesity [15,16], genitourinary system [17,18,19], hypercholesterolemia [16] and diabetes [20]. Myrtle is also used in dentistry for gingivitis and stomatitis [21,22,23,24]. This proves the perspective of the pharmacognostic study of common myrtle with the aim of standardizing plant raw materials as a source of biologically active compounds for obtaining phytosubstances based on them.

Aim

The purpose of the work is to analyze review and consolidate the latest literature concerning the botanical characteristics, chemical composition, and pharmacological properties of common myrtle. This comprehensive analysis aims to identify the potential applications of myrtle as medicinal plant material for the treatment of various diseases. The study will contribute to a deeper understanding of Myrtle's therapeutic potential and its role in developing new natural remedies.

Materials and methods

Data were collected from several legitimate databases and services such as PubMed, Medline, Scopus, Google Scholar, ResearchGate using the key terms "*Myrtus communis* L.", "botanical characteristics", "pharmacological studies", "phytochemical studies" in each database data Relevant and related data were filtered as appropriate if deemed relevant to the topic of interest. Time frames have also been adjusted to provide up-to-date information.

Botanical characteristics of Myrtus communis L. Myrtaceae (*Myrtaceae*) is a diverse family of woody flowering plants, encompassing approximately 5,500 species. Common myrtle, scientifically known as *Myrtus communis* L., is a particularly valuable species among essential oil medicinal plants within the Myrtaceae family. This plant is of great interest to scientists worldwide, with efforts focused on its potential cultivation as a source of raw materials for creating new herbal preparations. Myrtle is found growing in various regions across the globe and is both cultivated and wild [18]. Being widespread throughout the Mediterranean region, the species is one of the most important evergreen shrubs of the Mediterranean maquis. In Italy, it grows along the coast and on inland hills and is abundant on the islands, where it is one of the most characteristic species. In Portugal, myrtle grows wild mainly in the central and southern parts of the country. It occurs in coastal and forest areas, on the interior hills of northern Tunisia [25,26,27].

Myrtus communis L. is an evergreen perennial shrub or small tree that typically reaches heights of 1.8 to 3 meters with small leaves and deep fissures in the bark. The stem of the plant is erect, branched, has glossy dark green leaves, glabrous, opposite, paired or twisted, in shape from ovoid to lanceolate [28], with a rigid structure, entire, pointed, 2.5–3.8 cm long, they very fragrant due to the presence of numerous secretory receptacles. The flowers are white or pink [29], on thin peduncles, medium in size, 2 cm in diameter, hard with yellow anthers. The petals are white with glands and have a slightly forked edge, often covered with fine hairs.

The fruit of myrtle is a berry, typically measuring between 0.7 to 1.2 centimeters in diameter. It has a rounded or egg-elliptic shape with an inflated central part and retains remnants of a 4–5-parted cup on the outer part. Myrtle berries come in two primary colors: white and dark blue. White berries are rarer and are associated with unique leaves. From an ecological perspective, this species is characterized by low pollen production, limited seed dispersion, and relatively low adaptation to its environment, which may explain its scarcity in certain areas [30]. The unripe berries start as pale green, turn red as they mature, and eventually become dark indigo when fully ripe. While immature berries tend to be bitter, ripe ones are sweet [2,25,26,27].

Phytochemical studies. The chemical composition of the different parts of common myrtle studied contains essential oils, phenolic acids, flavonoids (quercetin, catechin, myricetin), tannins, anthocyanins, pigments, and fatty acids.

Myrtle essential oil consists mainly of monoterpene hydrocarbons, oxygenated mono- and sesquiterpenes, simple and complex esters, sesquiterpene and aliphatic hydrocarbons, alcohols, and phenols. These components are distributed in varying ratios depending on the geographical area (temperature, soil quality, day length), the time of collection, and the species' genotype [31]. Research conducted by Iranian scientists Donya Shahbazyan and others confirm that environmental conditions, genetic factors, and plant ontology are among the main factors determining the chemical composition of myrtle essential oil. Current studies have shown that the role of genetic factors was more prominent than the role of environmental conditions in causing the differences between the selected samples. Although 23 compounds were identified, cluster analysis using the median linkage method revealed four distinct groups in the dendrogram, including chemotype I: caryophyllene oxide / germacrene D / *α*-humulene / methyleugenol; II: *α*-pinene / *n*-cymol / *α*-humulene and (*E*)-*β*-caryophyllene; III: *α*-pinene / 1,8-cineole and linalool; IV: linalyl acetate / *γ*-terpinene / 1,8-cineole / limonene according to their main essential oil components [30]. The yield of oil in dry leaves in different phenological phases in March and October was different, but the main compounds were the same, even if they had different relative percentages. 1,8-cineole, linalool, α-pinene and α-terpineol [3,16,32,33].

A population consisting of 52 genotypes of *Myrtus communis* L., selected as part of a domestication program and grown in the same collection field in Oristano, was subjected to GC/MS analysis to assess the quantitative and qualitative composition of essential oils in the leaves. The chemical composition of the essential oils proved to be quite diverse, with the number of compounds ranging from 31 to 78 depending on the variety. In total, 118 compounds were identified in different genotypes. However, *α*-pinene, limonene, 1,8-cineole, *α*-terpineol, and linalool consistently appeared as the main components, with minor variations in their quantitative ratios among the samples [28].

Analysis of the essential oil from the aerial parts of *M. communis* by GC/MS revealed that the main compounds obtained were myrtenyl acetate (33.67 %), linalool (19.77 %), 1,8-cineole (10.65 %) and limonene (8.96 %) [34,35].

When it comes to fruits, samples collected in July (at the beginning of fruiting) and October (at the onset of ripening) were compared. Oil yields were similar, measuring 0.59 % and 0.48 %, respectively. The most prevalent compounds (with relative percentages above 5.0 %) included the following:

– In July: *α*-pinene (11.9 %), 3-carene (6.5 %), *o*-cymol (7.6 %), 1,8-cineole (6.4 %), *γ*-terpinene (5.1 %), *α*-terpinolene (5.2 %), linalool (8.8 %), and *α*-terpineol (6.1 %);

– In October: *α*-pinene (21.4 %), *o*-cymene (7.9 %), limonene (6.8 %), 1,8-cineole (12.2 %), and linalool (9.4 %) [32].

Another study examined 47 different candidate clones, including only five clones of *Leucocarpa varietas* and most of *Melanocarpa varietas*. The yield of essential oil from the berries varied greatly. GC-MS analysis of essential oils revealed the presence of 92 compounds. The main components were: geranyl acetate for 13 genotypes; 1,8-cineole for 7 genotypes; *α*-terpinyl acetate for 4 genotypes; linalool, *α*-humulene, trans-caryophyllene oxide, and *β*-caryophyllene for 3 genotypes; limonene for 2 genotypes; *α*-terpineol, bornyl acetate and humulene epoxide II respectively for 1 genotype each. *β*-caryophyllene was present in all genotypes, and methyleugenol – in 40 selections. Compounds present in only one genotype in small amounts were 2-methylbutanoic acid, 2-methylpropyl ether, *n*-mentha-1(7),8-diene, linalyl acetate, *β*-bisabolene, ledol, and isoleptospermone. Among the main components of myrtle essential oil, geranyl acetate was the compound with the highest relative abundance in the entire population of candidate clones (in 35 genotypes) [36].

A phytochemical study of the essential oil of *Myrtus communis* flowers showed that the main compounds were: *α*-pinene, 1,8-cineole, eugenol, linalool, geranyl acetate and *α*-terpineol [5].

So, as we can see, 1,8-cineole, linalool, *α*-pinene are the main components of the essential oil, which are present in different quantities in the raw materials of different parts of *Myrtus communis* L., regardless of the geographical area (temperature, soil quality, length of day), collection time and species genotype.

The leaves and berries of *Myrtus communis* L. are also rich in phenolic compounds such as phenolic acids, flavonoids, and flavanols. The extraction of phenolic compounds has several main points, such as the choice of the phenological stage of the plant, the choice of solvent, the method of extraction and purification, as well as the post-harvest technological processes, mainly the drying process. The total content of phenols, flavonoids, and proanthocyanidins in various extracts was significantly influenced by the drying methodology. For the analysis of the phenolic fractions of the extracts, the method of high-performance liquid chromatography was used in combination with high-resolution mass spectrometric detection. The total phenol content in the extracts increased from 39.6 GAE/g in air-dried leaves to 55.2 GAE/g after drying in a microwave oven and to 41.1 GAE/g in dryer-dried leaves at 70 °C. However, drying at temperatures of 100 and 120 °C reduced the total phenol content to 30.8 and 25.7 GAE/g, respectively [37]. The extraction of phenolic compounds from the pericap of Myrtus communis was carried out using ultrasound. The yield of total phenolic compounds was more affected by ethanol concentration, exposure time, liquid solvent/solid ratio, and amplitude, and the optimal parameter conditions established by the response surface methodology model were 70 % (v/v), 7.5 min, and 30 %, respectively [38].

Most of the phenolic compounds originate from the phenylpropanoid pathway, where phenylalanine ammonia lyase (PAL) enzyme activates the first step. This 2020 study aimed to understand how PAL activity in myrtle fruits and leaves influences certain phenolic compounds during the transition from flowering to full fruit ripening. The study found that PAL activity remained relatively constant in leaves but varied in berries. Specifically, PAL activity was higher in "Giovanni" berries compared to "Grazia" and increased from the time of berry color change to full ripening. This suggests that PAL plays a significant role in the phenolic compound biosynthesis of myrtle berries during the ripening process. PAL activity was fairly constant in leaves and varied in berries: greater in "Giovanni" berries than in "Grazia" and increased from berry color change to full ripening. In berries, a positive correlation was found between PAL and flavonoids, as well as between PAL and anthocyanins, and a negative correlation between PAL and total polyphenols. Regarding the quantitative content of phenolic compounds detected in the study, during ripening, the variety Gio"Giovanni" vanna showed a lower content of total phenolic compounds than the variety Grazia (37 and 46 mg gallic acid equivalent GAE/g DM (dry matter) for "Giovanni" and Grazia, respectively), as well as a lower content of total tannins (0.33 mg catechin equivalent CE/g DM for "Giovanni" and 2.73 mg CE/g DM for Grazia) [29]. The results of a study conducted in 2021 by the same researchers showed that the differences in color between the dark blue variety "Giovanni" and the white "Gracia" may be the result of over-regulation of some structural genes in dark blue fruits, in particular the LDOX and UFGT genes. Furthermore, this first molecular approach showed significant positive correlations between general and specific anthocyanin genes and total anthocyanin content, while no correlations were found with total phenolic content [39].

Quantitative analysis of the main phenolic compounds found in myrtle fruits showed that hydrolyzed tannins accounted for more than 90 % of the seed samples and dominated the phenolic profiles of both flesh and seed. Phenolic acids were detected in lower amounts, characterized only by the presence of gallic acid (52.21 mg/kg dry weight DW for pulp and 137.02 for seeds). Among the flavanols detected in fresh myrtle berries, quercetin-3-O-galactoside and, to a lesser extent, quercetin-3-O-rhamnoside were the only flavanols. As expected, anthocyanins were detected only in the pulp extract with malvidin 3-O-glucoside in the largest amount (41.98 mg/kg) [18,40]. In another study, no anthocyanins were found at all, probably because these compounds are completely extracted during the water-alcohol infusion of myrtle berries during liqueur production. In addition, the literature notes the low stability of these compounds, which easily decompose under the influence of light, high temperature, and air [41].

It was also found that myrtle berries, and in particular the seeds, contain a large number of valuable ellagitannins eugeniflorin D2 and enothein B [11].

The liquid chromatography analysis of *Myrtus communis* L. leaf extract revealed the presence of seventeen components, which are as follows: gallic acid, quercetin, p-coumaric acid, hesperidin, amentoflavone, luteolin, quercetin-3-O-glucoside, quercetin-3-O-glucuronic acid, isorhamnetin-7-O-pentose, luteolin-7-O-glucoside, kaempferol-3-O-glucuronic acid, kaempferol-3-O-pentose, kaempferol-3-O-hexose, deoxyhexose, catechin gallate, procyanidin, kaempferol and naringin. Quercetin-3-O-glucoside, isorhamnetin-7-O-pentose, and luteolin-7-O-glucoside were the most abundant components in the extract [42]. In another study, the main polyphenolic components in myrtle leaf extract were myricetin-3-O-rhamnose (36.68 %), myricetin-3-O-galactose (33.20 %), myricetin (14.48 %) and 5-O-haloylquinic acid (7.96 %) [15]. As already mentioned, the different compositions of components can be associated with different phenological stages of the plant, drying method, choice of solvent, extraction, and purification method.

Pharmacological research. Considering the rich chemical composition of myrtle raw materials, pharmacological studies were analyzed, which showed that *Myrtus communis* has a wide range of pharmacological activity, including antimicrobial, antifungal, antiulcer, gastroprotective, antidiabetic, anti-inflammatory, antihypertensive, antioxidant, antilipidemic, antithrombotic, antimutagenic.

Antimicrobial and antifungal activity. The antibacterial, antifungal and anti-inflammatory effects of myrtle have been proven by many studies. In their research, Italian scientists evaluated the antibacterial, cytotoxic and antiacetylcholinesterase properties of *Myrtus communis* leaf essential oil and its main components. All essential oil components were active against *P. carotovorum*, except myrtenyl acetate, which showed only 2.08 % biofilm inhibitory activity. In contrast, four major components (myrtenyl acetate (29.8 %), 1,8-cineole (21.9 %), *α*-pinene (14.7 %) and linalool (9.1 %)) resulted in blocking or limitation of *P. aeruginosa* and *S. aureus* biofilm formation [43].

Myrtle essential oil showed a powerful antibacterial effect against *L. monocytogenes in vitro* assays [3,4].

The results of a study conducted in Iran demonstrated the exceptional effect of the essential oil of *M. communis* leaves against Toxoplasma in mice infected with *Toxoplasma gondii* [44].

Nowadays, the combination of molecules affects their biological effects, and interesting results can be obtained from the interaction of different components. The effectiveness of combinations of essential oils against various bacteria was considered. A ternary mixture consisting of 17.1 %, 39.6 %, and 43.1 % of *M. communis*, *A. herba-alba*, and *T. serpyllum*, respectively, showed optimal inhibitory activity against *B. subtilis* [35].

Five different combinations (*Cupressus sempervirens* (cypress) combined with *Melaleuca alternifolia* (tea tree), *Hyssopus officinalis* (hyssop) combined with *Rosmarinus officinalis* (rosemary), *Origanum marjorana* (marjoram) combined with *M. alternifolia*, *Myrtus communis* (myrtle) in combination with *M. alternifolia* and *Origanum vulgare* (motherwort) in combination with *M. alternifolia*) were the most promising in the treatment of respiratory diseases, showing antimicrobial activity, reduced cytotoxicity and improved anti-inflammatory effects [8]. Another study evaluated the antibacterial, antibiofilm, and antiviral effects of combinations of different concentrations of *Rosmarinus officinalis* and *Myrtus communis* essential oils against the opportunistic pathogen *Staphylococcus aureus* [45].

The antimicrobial activity of essential oils obtained from Tunisian Myrtus communis flowers was assessed using agar diffusion and broth microdilution methods against a panel of pathogenic bacteria, which included six different gram-positive strains (such as *Bacillus cereus, B. subtilis, Enterococcus faecalis, Listeria monocytogenes, Staphylococcus aureus,* and *Staphylococcus epidermidis*), as well as three gram-negative bacteria (*Escherichia coli, Pseudomonas aeruginosa*, and *Salmonella enterica*). Myrtle essential oil effectively inhibited the growth of all tested bacterial strains at non-cytotoxic concentrations. It exhibited stronger antimicrobial activity against the Gram-positive bacteria, and it was bactericidal against *L. monocytogenes* [31].

In the quest for new antimicrobial agents targeting Staphylococcus species, bioactive fractions of *Myrtus communis L.* were investigated. Phytochemical analysis led to the isolation and characterization of four alkyl phloroglucinol glycosides. Among these compounds, three were identified as halomyrtucummulones G–H and myrtucummulonoside, marking their first-time isolation and description. The results revealed that halomirtucummulone G (1) exhibited selective antimicrobial activity against both *S. aureus* strains at concentrations as low as 16 µg/mL. In contrast, halomirtucummulone D (3) demonstrated the most effective growth inhibition, with an IC50 of 64 µg/mL [46]. In another study, the antibacterial and anti-candidal activity of an aqueous extract of myrtle was examined against *Pseudomonas aeruginosa*, *Escherichia coli, Staphylococcus aureus*, and *Candida albicans*. The study found that the highest antimicrobial activity was observed against *E. coli* [47]. The impact of the ethanolic extract of common myrtle leaves on ten bacterial strains was also investigated. The results of the study confirm that gram-positive bacteria, including *Enterococcus faecalis, Staphylococcus epidermidis, Mycobacterium smegmatis mc,* and *S. aureus*, were sensitive to the extract. In contrast, the gram-negative strains showed resistance to the extract. It was observed that the inhibition of growth was associated with cell wall damage. Cells treated with the extract exhibited sensitivity to cell wall-targeting antibiotics and displayed morphological defects consistent with cell wall damage [2].

A study conducted in Iran aimed to determine the inhibitory effect of different fractions isolated from a standardized extract of *Myrtus communis* L. against both nystatin-susceptible and nystatin-resistant *Candida albicans*, which were isolated from HIV-infected patients. The total extract and fractions, including petroleum ether, chloroform, ethyl acetate, and methanol, were prepared using ultrasound treatment. The results of the study indicated that myrtle fractions exhibited a more potent anti-candidal effect compared to the total extract [48]. The berries and seeds of *M. communis* L. contain a component called enotein B, which can inhibit the growth of various *Candida* species (including *Candida albicans, Candida tropicalis*, and *Candida glabrata*) that are sensitive or resistant to fluconazole and are commonly found in the gastrointestinal tract. Additionally, enotein B displayed growth inhibitory properties against *H. pylori* [11]. A myrtle solution was found to be effective in treating dandruff [13].

Both aqueous and methanol extracts of *M. communis* leaves exhibited significant antibacterial activity against periodontal pathogens [21]. The combination of methanol extracts from *Myrtus communis* and *Eucalyptus galbie* demonstrated antibacterial effects against Enterococcus faecalis [23]. The water extract of *Myrtus communis* displayed antibacterial activity against *Actinobacillus actinomycetemcomitans, Porphyromonas gingivalis,* and *Prevotella intermedia*. Similarly, the methanolic extract exhibited antibacterial effects against *A. actinomycetemcomitans, P. gingivalis*, and *P. intermediate* [22]. A toothpaste was developed using extracts from the leaves of *Artemisia dracunculus*, *Satureja khuzestanica* (Jamzad), and *Myrtus communis* (Linn), mixed with sterile distilled water. This product was tested against five microorganisms, including *Streptococcus mutans, Lactobacillus casei, S. sanguis, S. salivarius*, and *Candida albicans*, using the agar diffusion method. The toothpaste demonstrated a strong inhibitory effect against Gram-positive bacteria and *C. albicans* [49].

Myrtle lotion is as effective as clindamycin in the treatment of mild to moderate acne caused by *P. acnes* [14].

Leishmania major is a parasite that causes skin lesions and wounds in humans. A study conducted on mice showed that the group receiving the ethanolic extract of common myrtle had the lowest parasite load. Notably, both aqueous and ethanol extracts were less toxic to normal macrophages compared to glucantime. Additionally, the option for oral administration, as opposed to injection, is another advantage of myrtle over glucantime. Therefore, this treatment can serve as an alternative approach for cutaneous leishmaniasis [12]. Furthermore, the ethanolic extract of *M. communis* exhibited high scolicidal activity against *Echinococcus granulosus* in an *in vitro* model [50].

Antihypertensive activity. *Myrtus communis* extract can improve cognitive dysfunctions in hypertension due to its antihypertensive, anti-inflammatory, and anticholinesterase activity [51].

Anti-ulcer and gastroprotective activity. A study was conducted to assess the gastroprotective effect of microencapsulated myrtle essential oil against acute gastric lesions induced by a mixture of ethanol and hydrogen chloride in rats. The results suggest that microencapsulated myrtle essential oil has the potential to be used in the treatment of acute stomach ulcers. Treatment of animals with microencapsulated essential oil of myrtle successfully inhibited oxidative damage and restored the integrity of the antioxidant system in the intestinal mucosa, demonstrating its protective properties [52].

Myrtle extract, administered at a dosage of 100 mg/kg, has shown a positive impact on rat health. It led to an increase in the number of lactobacilli and bifidobacteria colonies when compared to the control group. Additionally, it induced alterations in glycolytic enzymatic activity and brought about a minor change in tissue antioxidant activity [15].

Enothein B, found in the berries and seeds of *M. communis* L., demonstrates anti-inflammatory properties on human stomach epithelial cells, suggesting its potential therapeutic use in gastritis treatment [11].

Hepatoprotective activity. The study assessed the protective effect of *Myrtus communis* essential oil against CCl4-induced hepatotoxicity in rats. CCl4 administration led to hepatotoxicity, indicated by increased lipid peroxidation and protein carbonyl levels, as well as decreased antioxidant markers in liver tissue. The results suggest that *M. communis* essential oil may be effective in preventing hepatotoxicity complications [10].

Losing weight. Intragastric administration of laurel and myrtle essential oil to rats for two weeks results in weight loss [16]. Interestingly, the effects of myrtle extract on weight can vary with dosage: a dose of 100 mg/kg of myrtle leaf extract causes weight loss, while a dose of 50 mg/kg can lead to weight gain [15].

Anti-inflammatory and wound-healing activity. Extracts from the pulp and seeds of *M. communis* L., produced industrially for liquor production, contain polyphenols that inhibit the production of reactive oxygen species, protecting cells from oxidative stress-induced damage. These extracts also modulate the expression of cytochromes P450, potentially preventing chronic inflammation [40]. Notably, a polyphenol-enriched fraction displayed strong anti-inflammatory activity, prompting a study on mice to assess its wound-healing potential. Topical application of ointments (at 0.1 % and 0.05 % concentrations) containing this myrtle fraction demonstrated potent wound-healing effects [42].

Myrtucommuacetalon-1, an isolated compound from *Myrtus communis* L., displays robust anti-inflammatory activity by reducing the production of superoxide, hydrogen peroxide, and nitric oxide in macrophages [53].

Considering the anti-inflammatory, antibacterial, and antioxidant effects of *Myrtus communis* essential oil, it can be used to treat sepsis [54].

Antioxidant activity. Natural compounds found in myrtle exhibit a significant antioxidant effect. Pretreatment with myrtle extracts safeguards cells from premature aging by regulating the cell cycle and inducing telomerase expression. This suggests the potential utilization of these natural compounds in disease prevention and treatment, the delay of premature aging, and the preservation of tissue functions [1].

A study by Hamza Mechchate et al. demonstrated the antioxidant role of the polyphenol-enriched fraction from *Myrtus communis* using three different methods (TAC, FRAP, and *β*-carotene bleaching), confirming its action as a free radical scavenger or reducer [42]. The addition of various extracts from *M. communis* L. leaves enhanced the oxidative stability of soybean oil. Therefore, the use of *M. communis* L. extract may present a promising approach to prevent lipid oxidation in food [37].

Myrtus communis berry seed extracts, obtained during the production of myrtle liqueur, exhibited a higher antioxidant potential compared to pericarp extracts [41].

Studies conducted by Turkish scientists demonstrated the effect of *M. communis* extract on the antioxidant status of the eye lens. It can reduce oxidative stress in the lenses of obese rats induced by a high-fat diet by increasing boron levels [55].

It was established that hydrolyzed tannins contained in the extract of *M. communis* serve as both reducing agents and stabilizers [56].

Studies conducted to determine the ideal combination of six essential oils from different plants (motherwort compact, marjoram motherwort, common thyme, spearmint, common myrtle and white wormwood) in terms of antioxidant activity proved that none of the mixtures presented in the study has a better antioxidant effect , than one *M. communis* oil, where the activity reached 76.95 % [34].

Antilipidemic and antithrombotic activity. Intragastric administration of laurel and myrtle essential oil to rats for two weeks reduces glycolytic activity, lipid parameters (cholesterol, triglycerides, low-density lipoprotein cholesterol, and very low-density lipoprotein cholesterol), and indicators of atherogenicity, which leads to protection of the cardiovascular system [16].

Anticancer activity. The fraction from *Myrtus communis*, enriched with polyphenols, can inhibit the proliferation of cancer cell lines without affecting non-cancerous ones [42]. Another study also found that the essential oil of the leaves of *Myrtus communis* subsp. *tarentina* (L.) can reduce the viability of castration-resistant prostate cancer cells, activate the process of apoptosis, and reduce the migration ability of these cancer cells [33].

The compound myrtucommuacetalone-1, isolated from *Myrthus communis* L., showed moderate anticancer activity against lung cancer cells *in vitro* [53].

Results

Myrtus communis L. (myrtle) is one of the common medicinal species of the Mediterranean region of the *Myrtaceae* family. This evergreen perennial shrub contains essential oils, phenolic acids, flavonoids, alkaloids, as well as simple phenols, lignans, carotenoids, vitamins, and terpenoids. The leaves are rich in tannins, coumarins, haloyl glucosides, caffeic, gallic, and ellagic acids, and various terpenoid compounds [15].

In the essential oil of the different parts studied, α-pinene, limonene, 1,8-cineole, α-terpineol, and linalool were consistently the main components, with slight variations among samples. Myrtle essential oil, as demonstrated in numerous studies, exhibits potent antibacterial activity against both gram-positive and gram-negative bacteria, with a particularly strong antimicrobial effect against gram-positive bacteria. Thanks to its anti-inflammatory and antioxidant properties, myrtle essential oil has the potential for use in treating acute stomach ulcers, countering liver intoxication, protecting the cardiovascular system, and aiding in weight loss. The main polyphenols in *Myrtus communis*, varying based on the plant parts studied, phenological stage, drying method, choice of solvent, extraction, and purification methods, include quercetin-3-*O*-glucoside, isorhamnetin-7-*O*-pentose, luteolin 7-*O*-glucoside, myricetin-3-*O*-rhamnoside, myricetin-3-*O*-gallac, myricetin, and 5-*O*-haloylquinic acid. Both aqueous and methanol extracts of *M. communis* demonstrate strong antibacterial activity against numerous gram-positive microorganisms, as well as sensitive and fluconazole-resistant *Candida* species, including *Candida albicans, Candida tropicalis*, and *Candida glabrata*.

This versatility makes myrtle extracts suitable for treating colds, flu, ENT diseases, periodontal issues, gastrointestinal disorders, skin conditions, and genitourinary problems. Furthermore, myrtle extract polyphenols display anti-inflammatory and antioxidant properties, and they exhibit potential for inhibiting the proliferation of cancer cell lines, suggesting promise in anticancer therapy. However, additional research is required to address this potential fully.

Over the past three decades, scientists from various countries have been engaged in myrtle culture research, investigating the influence of macronutrients, growth regulators, and light on the multiplication and rhizogenesis of regenerating plants [57]. Their work has revealed that plants propagated through *in vitro* microclonal propagation are genetically identical to the donor plant, healthier, and possess an optimal chemical composition. Consequently, they offer significant advantages compared to those grown in natural conditions [57].

Conclusions

1. An extensive review of recent literature data has revealed that *Myrtus communis* L. contains essential oils, phenolic acids, flavonoids (such as quercetin, catechin, and myricetin), tannins, anthocyanins, pigments, and fatty acids in its chemical composition. These components grant this plant a diverse range of pharmacological properties, including antibacterial, antifungal, antiulcer, gastroprotective, antidiabetic, anti-inflammatory, antihypertensive, antioxidant, antilipidemic, antithrombotic, and antimutagenic effects. The quality of the plant raw materials can be influenced by external conditions, leading to the potential use of *in vitro* plant cultures for the production of medicinal products.
2. The *in vitro* cultivation of myrtle for obtaining planting material holds promise as it allows for controlled plant growth conditions, resulting in healthy seedlings and greater precision and reliability in research outcomes.
3. Additionally, it is intriguing to determine the quantitative and qualitative composition of biologically active substances in the plant raw material obtained from common myrtle under regenerative plant growing conditions in open ground, as this composition may differ from that of raw material obtained from traditionally vegetatively reproduced plants.

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