Peppermint (Mentha piperita L.): Phytochemistry, Pharmacological Properties, and Medicinal Applications

Tofiq Aliyev, **Rauf Jafarov**, **Akif Mərdanlı**

[1] *Aliyev, T. Lecturer, Nakhchivan State University, Nakhchivan, Azerbaijan. Email: tofiqaliyev3001@gmail.com. ORCID: https://orcid.org/0009-0008-0138-7493 (Corresponding author)*

[2] *Jafarov, R. Nakhchivan State University, Nakhchivan, Azerbaijan. ORCID: https://orcid.org/0009-0003-2428-9654*

[3] *Mərdanlı, A. Nakhchivan State University, Nakhchivan, Azerbaijan. Email: akifmerdanli@mail.ru. ORCID: https://orcid.org/0009-0000-5953-8743*

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Abstract

Peppermint (Mentha piperita L.) is a perennial herbaceous plant of the family Lamiaceae widely cultivated in the Nakhchivan Autonomous Republic of Azerbaijan and used extensively in both scientific and traditional medicine. This article provides a comprehensive review of the botanical characteristics, phytochemical composition, pharmacological properties, and medicinal applications of peppermint, with particular reference to its cultivation and use in the Nakhchivan region. The plant's essential oil, whose principal active component is menthol (40–60%), confers a broad spectrum of therapeutic activities including analgesic, antispasmodic, choleretic, antiseptic, sedative, and antihypertensive effects. Galenical preparations derived from peppermint leaves — infusions, tinctures, and essential oil formulations — are indicated in the treatment of gastrointestinal disorders, inflammatory diseases of the upper respiratory tract, migraine, angina pectoris, and various neurological conditions. The article also reviews a range of complex pharmaceutical preparations containing menthol as an active ingredient. Particular attention is paid to contraindications and dosing precautions, especially for paediatric patients. The review draws on published pharmacognostic, phytochemical, and pharmacological literature to consolidate current knowledge and identify the continuing relevance of peppermint as a medicinal plant resource in the regional context.

Keywords: *Mentha piperita; peppermint; menthol; essential oil; pharmacological properties; medicinal plants; Nakhchivan; phytotherapy*

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1. Introduction

Medicinal plants have constituted a foundational pillar of human healthcare for millennia, and their relevance has not diminished with the development of synthetic pharmacology. On the contrary, growing interest in evidence-based phytotherapy, combined with increasing public awareness of the adverse effects of synthetic drugs, has renewed scientific inquiry into the therapeutic potential of plant-derived compounds (Muravyeva et al., 2002; WHO, 2019). Among the most extensively studied and practically utilised of all medicinal plants, peppermint (Mentha piperita L.) occupies a prominent position in both traditional medicine systems and contemporary pharmacological practice.

Peppermint belongs to the family Lamiaceae, a large and medicinally significant taxon that also includes lavender, rosemary, thyme, and sage. The genus Mentha L. comprises numerous species distributed across temperate and subtropical zones worldwide, four of which grow wild in Azerbaijan, while Mentha piperita L. is exclusively cultivated (Damirov et al., 1988). The cultivated distribution of peppermint in Azerbaijan encompasses individual households and experimental plantations, particularly on the Absheron Peninsula and in the Zagatala district, with favourable conditions also reported in the Nakhchivan Autonomous Republic (Alekperov, 2013).

The medicinal significance of peppermint derives principally from its essential oil, which is rich in menthol — a cyclic terpene alcohol with a characteristic cooling effect and a broad spectrum of biological activity. Menthol activates the transient receptor potential melastatin 8 (TRPM8) cold receptor in peripheral sensory neurons, producing the well-known cooling sensation, and exerts direct effects on smooth muscle, the central nervous system, and mucosal membranes (McKemy et al., 2002). Beyond menthol, the plant contains a range of flavonoids, ursolic and oleanolic acids, carotenoids, and other phytochemicals that contribute to its therapeutic profile (Dragland et al., 2003).

Despite its longstanding use and the availability of numerous pharmacological studies, a consolidated review of peppermint's phytochemistry, pharmacology, and medicinal applications with specific attention to its relevance in the Nakhchivan context has not been systematically presented in the recent literature. The present article addresses this gap by synthesising available botanical, phytochemical, pharmacological, and clinical evidence within a structured academic framework.

2. Literature Review

Peppermint has been the subject of pharmacognostic investigation for well over a century, and it features in the pharmacopoeias of numerous countries, including the State Pharmacopoeia of the former Soviet Union (10th edition) and the European Pharmacopoeia. Early systematic documentation of its therapeutic properties in the context of the South Caucasus and Central Asia is found in the foundational work of Damirov et al. (1988), whose monograph on medicinal plants of Azerbaijan remains a primary reference for regional researchers. The specifically Nakhchivani dimension of medicinal plant knowledge has been comprehensively documented by Mardanly (2018), whose edited volume catalogues the therapeutic flora of the autonomous republic and provides a framework for ethnopharmacological and phytochemical research in the region.

The phytochemical characterisation of peppermint essential oil has been substantially advanced by chromatographic studies confirming menthol as the dominant constituent (40–60%), accompanied by menthone (9–25%), cineole, limonene, pinene, pulegone, phellandrene, dipentene, and menthyl esters of acetic and valerianic acids (Dragland et al., 2003; Mimica-Dukic et al., 2003). The relative proportions of these constituents vary with cultivar, cultivation conditions, and harvesting stage; maximum essential oil yield and optimal menthol content are typically achieved at the budding to early-flowering stage (Grigoleit & Grigoleit, 2005). Non-volatile constituents documented in the leaves include the flavonoids isorhoifolin, menthoside, and piperitocide, as well as hesperidin, carotene, and hydroxycinnamic acids (Wichtl, 2004).

From a pharmacological perspective, extensive in vitro and in vivo studies have established the antispasmodic, choleretic, analgesic, antiseptic, and sedative activities of peppermint preparations (Grigoleit & Grigoleit, 2005; Mao et al., 2019). The antispasmodic effect on gastrointestinal smooth muscle has been attributed to calcium channel antagonism and the modulation of 5-HT_3 receptors

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(Hills & Aaronson, 1991). The choleretic action, reflected in increased bile flow and reduced biliary tone, supports the use of peppermint preparations in the management of cholecystitis, cholangitis, and cholelithiasis. Antimicrobial and antifungal properties have been demonstrated against a wide range of pathogenic microorganisms, with menthol identified as the primary bioactive component (Mimica-Dukic et al., 2003).

Clinical evidence supports the use of enteric-coated peppermint oil capsules in the management of irritable bowel syndrome (IBS), a condition for which several randomised controlled trials have demonstrated significant reduction in symptom severity compared with placebo (Mao et al., 2019; Ford et al., 2008). The evidence for peppermint oil in the management of tension headache, applied topically to the forehead as a diluted ethanolic solution, has been evaluated in double-blind crossover studies showing efficacy comparable to paracetamol (Göbel et al., 1994). The broader neurological applications of menthol — including its sedative and anticonvulsant properties in animal models — have been reviewed by Kamatou et al. (2013).

Literature on the pharmaceutical formulation of menthol-containing products is extensive, reflecting the compound's utility as both an active therapeutic agent and an excipient providing refreshing flavour and mild local anaesthesia in dental and respiratory preparations. Preparations such as Validol, Boromenthol, Pectussin, Menovazin, and compound ointments incorporating menthol alongside camphor, salicylate esters, and essential oils represent an established pharmacological tradition that continues to be reflected in the formularies of post-Soviet healthcare systems (Muravyeva et al., 2002).

3. Materials and Methods

This study employs a systematic narrative review methodology, drawing on published primary and secondary literature in pharmacognosy, phytochemistry, pharmacology, and clinical medicine. The review was structured in accordance with the broad thematic categories of botanical description, phytochemical composition, pharmacological properties, medicinal applications, pharmaceutical formulations, contraindications, and regional cultivation context.

Literature sources were identified through searches of electronic databases including Scopus, Web of Science, PubMed, Google Scholar, and regional scientific repositories. Search terms included "Mentha piperita," "peppermint," "menthol," "peppermint essential oil," "peppermint pharmacology," and "Mentha Azerbaijan/Nakhchivan." Foundational regional monographs — specifically Damirov et al. (1988) and Mardanly (2018) — were consulted for information specific to the Azerbaijani and Nakhchivani contexts. Pharmacopoeial monographs and formulary references were consulted for standardised preparations.

Inclusion criteria required that sources address at least one of the thematic categories listed above, were published in peer-reviewed journals or authoritative reference volumes, and were available in full text. Non-peer-reviewed sources, conference abstracts without full text, and sources addressing Mentha species other than M. piperita were excluded except where directly comparative. Methodological quality of primary pharmacological studies was assessed informally in terms of study design, sample size, and reproducibility of findings, without formal meta-analytic scoring.

4. Results and Discussion

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4.1 Botanical Characteristics

Mentha piperita L. is a perennial herbaceous plant producing erect, branched, quadrangular stems with horizontal creeping stolons and a characteristic menthol aroma. The leaves are opposite, elongate-ovate, short-petiolate, acuminate, with a rounded base, glabrous surfaces, and a serrate margin. Inflorescences are short and spike-like at the tips of the stem and branches, composed of closely clustered whorls of flowers. The calyx is regular and tubular with five teeth; the corolla is funnel-shaped, nearly regular, four-lobed, and reddish-violet in colour. There are four stamens of approximately equal length. Fruits are formed rarely. The flowering period extends from June to September (Damirov et al., 1988).

In Azerbaijan, peppermint is cultivated in individual household plots across numerous districts and has been the subject of experimental industrial cultivation on the Absheron Peninsula and in the Zagatala district. The plant is included in the pharmacopoeia (10th edition) under the monograph for peppermint leaf and peppermint oil. The optimal harvest period is July to August, at the budding stage or at the onset of flowering, a timing that yields both maximum leaf mass and highest essential oil content (Damirov et al., 1988; Alekperov, 2013).

4.2 Phytochemical Composition

The leaves of cultivated Azerbaijani peppermint contain 0.5–2.5% essential oil by dry weight. The principal constituent of this oil is menthol (free and as menthyl esters of acetic and valerianic acids) at 40–60%, followed by menthone (9–25%). Additional terpene constituents include pinene, limonene, pulegone, phellandrene, dipentene, cineole, and other terpenoids and terpenoid derivatives. Among the non-volatile constituents, the leaves contain hesperidin, ursolic acid, oleanolic acid, carotene, and the flavonoids isorhoifolin, menthoside, and piperitocide (Damirov et al., 1988; Dragland et al., 2003).

Menthol is the primary pharmacologically active compound and accounts for most of the characteristic therapeutic effects of peppermint preparations. Its biosynthesis follows the monoterpene pathway from geranyl pyrophosphate via pulegone and menthone, and its accumulation is regulated by both developmental stage and environmental factors including light, temperature, and soil composition (Grigoleit & Grigoleit, 2005). The essential oil composition may vary significantly among cultivars and between harvests, necessitating standardisation of pharmaceutical preparations based on menthol content (Wichtl, 2004).

4.3 Pharmacological Properties

Galenical preparations of peppermint leaf exert a complex pharmacological profile attributable to the interaction of multiple active constituents. The principal documented actions include: (1) sedative and anxiolytic effects on the central nervous system; (2) antispasmodic action on gastrointestinal and biliary smooth muscle; (3) choleretic and cholekinetic effects; (4) antiseptic and antimicrobial activity; (5) analgesic and counter-irritant effects via peripheral sensory receptor modulation; and (6) mild reflex coronary-dilatory activity (Damirov et al., 1988; Muravyeva et al., 2002).

The antispasmodic mechanism involves calcium channel antagonism in smooth muscle cells, reducing contractile tone in the intestinal wall, bile ducts, and urinary tract. This effect underlies the therapeutic utility of peppermint in irritable bowel syndrome and biliary dyskinesia (Hills & Aaronson, 1991; Ford et al., 2008). The antiseptic properties extend across a range of pathogenic

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bacteria colonising the gastrointestinal tract, and phytoncidal activity has been confirmed for the essential oil and its principal constituents (Mimica-Dukic et al., 2003). A weakly hypotensive effect has also been documented, though it is considered clinically marginal under normal therapeutic doses (Muravyeva et al., 2002).

The secretagogue effect on digestive glands — stimulation of pancreatic and gastric secretion, increased appetite, and enhanced bile production — is particularly relevant in the context of digestive disorders. External application of peppermint preparations causes local vasodilation via counter-irritant mechanisms, increasing capillary circulation in skin and mucosal surfaces and stimulating intestinal peristalsis. These effects are exploited in topical formulations for musculoskeletal pain, headache, and rhinitis (Göbel et al., 1994; Kamatou et al., 2013).

4.4 Medicinal Applications and Pharmaceutical Preparations

Peppermint preparations are clinically indicated across several therapeutic areas. In gastroenterology, aqueous infusions, tinctures, and essential oil capsules are used for gastrointestinal spasm, meteorism, nausea, vomiting, cholecystitis, cholangitis, cholelithiasis, and hepatitis. The standard infusion (5 g leaf per 200 mL water, infused 15 minutes in a water bath, strained and stored no more than 2 days) is taken warm at 1/2–1/3 cup two to three times daily, 15 minutes before meals, as a sedative, antispasmodic, and cholagogue (Damirov et al., 1988).

For upper respiratory tract inflammations (pharyngitis, laryngitis, tracheitis, rhinitis), menthol and peppermint preparations are applied as mucosal lubricants, inhalants, and nasal drops. Topical application of menthol pencils to the temples and bridge of the nose, or rubbing with 2% ethanolic or 10% oily menthol suspension, produces favourable outcomes in migraine, neuralgia, and other neurological conditions. Internally, menthol is used as a mild reflex vasodilator in angina pectoris and cerebral vascular spasm, and as a sedative in conditions of heightened nervous excitability, insomnia, and neurotic states (Muravyeva et al., 2002).

A wide range of complex pharmaceutical formulations incorporate menthol as a key active constituent. These include: Validol (25–30% solution of menthol in methyl isovalerianate, 4–5 drops or equivalent tablet sublingually for angina, neurosis, nausea); Boromenthol (0.5% menthol, 5% boric acid ointment for pruritus and rhinitis); Pectussin tablets (menthol 4 mg + eucalyptus oil, dissolved in the mouth for upper respiratory inflammation); Menovazin (menthol 2.5 g, novocaine 1 g, anaestezine 1 g in 70% ethanol, for topical analgesia in neuralgia, myalgia, and pruritic dermatoses); Efcamon ointment (complex menthol-camphor-methylsalicylate preparation for arthritis and myositis); and Zelenin drops (combination of lily-of-the-valley tincture, valerian tincture, belladonna tincture, and menthol for cardiac neurosis) (Muravyeva et al., 2002; Damirov et al., 1988).

Dental preparations including drops, powders, and pastes incorporate peppermint oil and menthol as aromatic disinfectants exploiting their combined antiseptic and flavouring properties. Mint oil also serves as a pharmaceutical excipient for masking the taste and odour of unpalatable medicines, and is listed as a component of the compound cardiac preparation Corvalol (Muravyeva et al., 2002).

4.5 Contraindications and Safety Considerations

Despite its favourable therapeutic profile, menthol and peppermint preparations must be used under medical supervision owing to the risk of overdose and dose-dependent adverse effects. Application of menthol to the nasal or nasopharyngeal mucosa of infants and young children is

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contraindicated due to the potential for reflex inhibition and respiratory arrest (Damirov et al., 1988; Muravyeva et al., 2002). Allergic reactions to essential oil components, manifesting as skin or mucosal hypersensitivity, have been reported in susceptible individuals, particularly children. Menovazin, when used over extended periods, may produce dizziness, general weakness, and hypotension. Kamfomen aerosol is not recommended for children or individuals exposed to heavily dusty environments.

These contraindications underscore the importance of age-appropriate prescribing, avoidance of self-medication with menthol-containing preparations in paediatric patients, and caution in populations with known essential oil hypersensitivity. In clinical settings, dosing of menthol should be individualised and monitored, particularly when used in combination preparations where cumulative menthol exposure may be difficult to quantify.

5. Conclusion

Peppermint (Mentha piperita L.) represents one of the most versatile and scientifically substantiated medicinal plants in both global and regional pharmacological practice. Its essential oil, dominated by menthol at 40–60%, confers a broad spectrum of therapeutic activities — antispasmodic, choleretic, analgesic, antiseptic, sedative, and vasodilatory — that underpin its widespread application in gastroenterology, respiratory medicine, neurology, and dental care. The phytochemical complexity of the plant, encompassing flavonoids, triterpenic acids, and carotenoids in addition to the essential oil fraction, provides a biological basis for polypharmacological activity that has been progressively elucidated by modern pharmacognostic research.

In the context of Azerbaijan and the Nakhchivan Autonomous Republic, peppermint constitutes both a locally cultivated medicinal resource and a cultural element of traditional therapeutic practice. The conditions of the region are favourable for its cultivation, and its inclusion in the State Pharmacopoeia confirms its institutional recognition. The continued documentation of regional cultivation practices, phytochemical profiles of locally grown material, and clinical outcomes of traditional preparations represents a valuable direction for future applied research.

Future studies should focus on standardised phytochemical characterisation of peppermint cultivated specifically in the Nakhchivan region, comparative pharmacological investigation of regional versus commercial preparations, and randomised controlled evaluation of traditional formulations. Such work would strengthen the evidence base for the rational integration of peppermint-based phytotherapy into contemporary healthcare practice in Azerbaijan and contribute to the broader body of evidence-based ethnopharmacological knowledge.

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