

Review Article

PHARMACOGNOSY, PHYTOCHEMISTRY AND PHARMACOLOGICAL PROFILE OF *Mentha Piperita* (PEPPERMINT)

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ABSTRACT

Mint is a very popular household plant in Indian communities and is used daily as a condiment in every house. Mint has much more than just a condiment and holds medicinal value due to its volatile oil content. The present article is a review of the pharmacognosy, phytochemistry and pharmacology of Mint.

KEY WORDS

Mentha piperita, Mint, Peppermint, Menthol, Medicinal benefits,

INTRODUCTION:

Mentha piperita L. (Family: Lamiaceae; Synonym: *M. balsamea* Wild; commonly known as peppermint) is an important medicinal herb.¹ The hybrid mint species known as peppermint is produced by crossing spearmint with watermint.² Originally indigenous to Europe and the Middle East,³ peppermint is now grown and found all over the world. On rare occasions, it might be found growing with its parent plants.⁴ Even though the *Mentha* genus has more than 25 species, peppermint is still the most widely utilized type.⁵ While *Mentha piperita* is commonly referred to as peppermint in Western contexts, Chinese peppermint, also known as bohe, is made from

the fresh leaves of *Mentha haplocalyx* in China.⁶ Both species are prized for their high menthol and menthone content and are among the oldest herbs used in medicine and cooking.⁷ Peppermint oil is typically clear to pale yellow, with a watery texture and a sharp, refreshing menthol aroma. India is the leading global producer and exporter of mint oil. It is widely used across various industries, including food, pharmaceuticals, fragrances, and flavorings. One of its main active compounds, menthol, is a key ingredient in products such as Dabur Pudina Hara, lozenges, toothpaste, and balms for pain and cold relief. The oil is extracted primarily from the leaves of the *Mentha* plant.⁸



Figure 1: image of peppermint plant.

HISTORY:

Mentha piperita has been one of its species' most commonly used fragrant herbs for therapeutic purposes.⁹ *Mentha piperita*'s symbolic meaning in Greek mythology is also linked to its aromatic qualities. In the past, it was applied to floors as a natural room deodorizer to cover up the disagreeable smells of compacted soils.¹⁰ The famous Greek physician and herbalist Pedanius Dioscorides (c. 40–90 CE) made the first documented

attempt to categorize plants in the genus *Mentha*. In his groundbreaking work *Species Plantarum* (1753), centuries later, Carl Linnaeus (1707–1778) created a more organized classification.¹¹ Antoine Laurent de Jussieu also described and named the genus in 1789.¹²

CLASSIFICATION:

Mentha piperita is a popular plant and its taxonomical classification is given in table 1.¹³

Domain	Eukarya
Kingdom	Plantae
Subkingdom	Tracheobionta
Super division	Spermatophyta
Phylum	Angiospermophyta
Class	Magnoliopsida
Order	Lamiales
Family	Lamiaceae
Genus	<i>Mentha</i>
Species	<i>Mentha x Piperita</i>

Table 1: Taxonomical classification of *Mentha piperita*.

PHARMACOGNOSY:

Macroscopical Characteristics:^{14-15.}

PARAMETER	DESCRIPTION
Plant part	Dried aerial parts, including leaves and flowering tops.
Colour	Fresh leaves are dark
Odour	Characteristic aromatic scent due to menthol content.
Taste	Aromatic followed by a cooling sensation.
Size of leaves	1-9cm long and 0.5-5 cm wide.
Leaf shape	Ovate-lanceolate.
Leaf surface	Upper surface dark green and nearly glabrous; lower surface light green and hairy.
Leaf margin	Sharply serrate
Leaf Arrangement	Opposite and decussate (arranged in pairs at right angle to the pair above or below).
Stem	Quadrangular, erect, 1-3mm thick, green to dark purple, smooth or nearly glabrous with scattered hairs.
Inflorescence	Flowers are small, reddish-violet, present in the axils of the upper leaves, forming loose, interrupted spikes.
Fruit	Four ellipsoidal nutlets with a pale purplish or pink hue.

Table 2: summary of macroscopic characters

MICROSCOPIC CHARECTERS:¹⁴⁻¹⁵

Microscopic Feature	Description
Epidermis (upper and lower)	Covered with unicellular, warty, non-glandular trichomes and pellate-glandular trichomes.
Stomata type	Diacytic stomata present on both surfaces, more on the lower epidermis.
Glandular trichomes	Peltate glands with multicellular stalks and secretory heads; secrete volatile oils.
Non-Glandular trichomes	Long, pointed, unicellular, with thick walls and wide lumens.
Mesophyll	Dorsiventral leaf; palisade parenchyma below upper epidermis and spongy parenchyma beneath.
Vascular bundles	Collateral vascular bundles surrounded by parenchymatous bundle sheath.
Oil cavities	Large, round oil cavities in mesophyll containing volatile oil (mainly menthol and menthone).
Calcium oxalate crystals	Rare; when present, appear as small prismatic crystals in parenchyma.

Table 3: summary of microscopic characters

PHYTOCHEMISTRY:

Peppermint, primarily made up of menthol, is well-known for its anti-spasmodic properties. It contains several key chemical compounds, including:

Menthone (14.0–32.0%): Contributes to the minty scent and cooling effect.

Menthofuran (1.0–9.0%): Adds a slightly earthy and woody note.

Methyl acetate (2.8–10.0%): Known for its refreshing, cooling sensation.

Isomenthone (1.5–10.0%): Similar to menthone but with subtle differences in scent and effects.

Carvone (max. 1.0%): Provides a mild minty aroma, typically found in spearmint as well.

Pulegone (4.0%): Known for its minty fragrance and digestive benefits.

Cineole (3.5–14.0%): Also called eucalyptol, it contributes to a fresh, spicy aroma and supports respiratory health.

Limonene (1.0–5.0%): Adds a citrus-like note and offers mild antibacterial properties.

Together, these compounds give peppermint essential oil its distinct fragrance and therapeutic qualities, making it effective for muscle relaxation, digestive support, and respiratory relief.

Mint plants (*Mentha* species) contain many different natural chemicals, such as cinnamic acids, certain sugars, and plant-based compounds called flavonoids. However, the most important active ingredients in mint plants are their essential oils.¹⁶

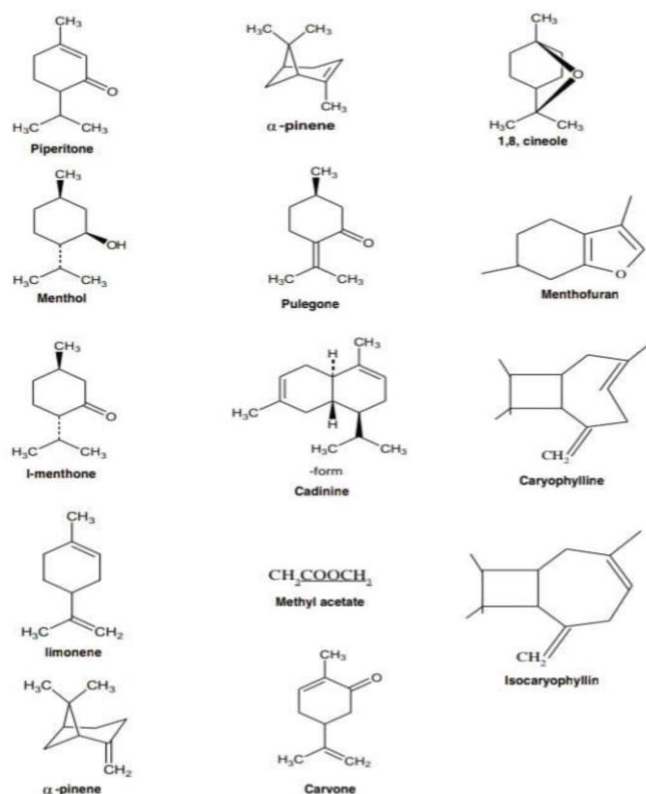


Figure 2: Phytochemical constituents of Peppermint.

Essential oils: These are natural substances with strong smells. They are made by plants and can be collected by using methods like boiling the plants with water (steam distillation).¹⁷ Mint plants are widely grown around the world to produce these essential oils. Some of the most commonly used essential oils come from different types of mint. For example: Corn mint oil comes from *Mentha canadensis* and is a major source of menthol. Peppermint oil comes from *Mentha piperita* and contains mostly menthol, menthone, and methyl acetate.¹⁸ Spearmint oils, which are high in carvone, come from *Mentha spicata*, *Mentha viridis*, and *Mentha gracilis*. *Mentha citrata* produces oils rich in linalool and linalyl acetate. *Mentha pulegium* produces pennyroyal oil, which is high in pulegone.¹⁹

Peppermint leaves contain about 1.2% to 3.9% essential oil. These oils include over 300 different compounds. Most of these belong to the terpene group, especially monoterpenes (52%) and sesquiterpenes (9%). Other smaller groups include aldehydes (9%), alcohols (6%),

lactones (7%), aromatic hydrocarbons (9%), and some mixed types.²⁰

Phenolic compounds:

Phenolic compounds are natural substances found in almost all plants. They help protect the plant and can also be good for human health. There are over 8,000 different types of these compounds. Some are small and simple, while others are large and more complex. All phenolic compounds have at least one ring-shaped structure (called an aromatic ring) with one or more -OH (hydroxyl) groups. In plants, they are usually found in special forms called esters or glycosides. Mint plants (from the *Mentha* group) contain many of these phenolic compounds. Some common ones include:

- 1.Cinnamic acid
- 2.Glycine
- 3.Glycosides
- 4.Acylated flavonoids.

Mint is especially rich in flavonoids, which are natural chemicals that often act as antioxidants. The main types found in mint are

flavones and flavanones. One important flavone in mint is called luteolin, along with several of its similar forms.²⁰

PHARMACOLOGY:

Antimicrobial activity:

Essential oils from *Mentha piperita* (peppermint), widely used in pharmaceuticals, fragrances, and food, were tested for antibacterial activity against 21 pathogenic microorganisms affecting both humans and plants. In vitro methods—including agar diffusion, microdilution, and bioautography—showed that the oils were highly effective against plant pathogens, while their effect on human pathogens was less pronounced. Gas chromatography (GC) and GC-MS analyses were used to identify the oils' chemical components, with bioautography confirming menthol as the main contributor to their antibacterial effects.²¹

Spasmolytic properties:

Peppermint has been shown to have spasmolytic properties against a variety of convulsant medications, such as acetylcholine, histamine, serotonin, and anaphylatoxin. Isolated sections of guinea pig and rabbit gut, isolated guinea pig lungs, cat lungs “In situ,” and entire animals in anaphylactic shock are among the preparations utilized. Papaverine-like smooth muscle spasmolytic action is myotropic. It has been discovered that peppermint extract helps the lower esophageal sphincter relax and let more air escape.²²

Antiviral activity:

Many of the components of lemon balm, which has been demonstrated to have significant antiviral action, are also present in peppermint. Based on this, peppermint was studied and it was discovered that, in egg and cell-culture systems, peppermint inhibited various viruses, including West Nile, herpes simplex, Newcastle disease, vaccinia and Semliki forest viruses. The herb has a tannin that binds to the mumps and Newcastle viruses

and it also has a non-tannin fraction that has antiviral properties against the herpes simplex virus. It was determined whether peppermint oil has any virucidal effects on the herpes simplex virus. In viral suspension assays, peppermint oil showed strong virucidal action against HSV-1 and HSV-2. Plaque formation for HSV-1 and HSV-2 was dramatically decreased by 82 and 92%, respectively, at non-cytotoxic concentrations of the oil. Higher peppermint oil concentrations more than 90% lowered the viral titers of both herpesviruses. An investigation on the antiviral, anti-inflammatory, and antioxidant properties of *Mentha piperita* L. leaf ethanol extract (MPE) was conducted. MPE exhibited strong antiviral activity against RSV with a high selectivity index, high amounts of phenolic acid and flavonoids, and a marked reduction in NO, TNF- α , and IL-6 production.²³

Antibacterial Properties:

Agents that can stop the growth or kill the bacterial are called antibacterial agents.⁵⁷ Peppermint oil and other leaf extracts from *Mentha piperita* may help fight bacteria. They have been found to work against both types of bacteria—Gram-positive and Gram-negative. These natural substances can stop the growth of germs, similar to how some medicines work. In our study, we tested different types of bacteria and found that small amounts of peppermint oil could slow down or stop their growth. The results were similar to the effects of the antibiotic gentamycin. The smallest amount of oil needed to stop the bacteria ranged between 0.4% and 0.7% by volume.²³

Antioxidant Properties:

Antioxidants are the agents that reduce the oxidative stress.⁵⁸ Peppermint plant extracts (using methanol) showed strong antioxidant effects and helped protect brain-like cells (called PC12 cells) from damage caused by harmful chemicals like hydrogen peroxide. This means *Mentha piperita* can help reduce stress in cells. One study also found that peppermint

oil may help treat irritable bowel syndrome (IBS), likely because it has both antioxidant and anti-inflammatory effects. Both the oil and the peppermint extract had good antioxidant power, but the oil was only about half as strong as a common chemical antioxidant called BHT. Researchers also studied spearmint (*Mentha spicata*). Only its oil could kill bacteria, but the methanol extract had more helpful plant compounds and better antioxidant effects.²⁴

Anti-inflammatory effects:

The extracts of this plant have anti-inflammatory properties. In animal experiments, they lowered edema in rats and mice. In another study, menthol was administered to rats with intestinal irritation. It reduced the levels of certain toxic compounds in the colon, indicating that it could benefit those suffering from ulcerative colitis. In addition, scientists conducted laboratory tests on mint oil and L-menthol. L-menthol outperformed mint oil in terms of reducing inflammation-related chemicals in human cells. At certain concentrations, mint oil boosted and then lowered a molecule known as PGE2. These findings indicate that L-menthol may be more beneficial than mint oil in reducing inflammation, particularly when administered in special capsules that dissolve in the intestines.²⁵

Anti-diabetic Effects:

Agents that reduce the blood glucose levels are antidiabetic agents.⁵⁹ Studies show that peppermint juice can help lower blood sugar, cholesterol, fat in the blood (triglycerides), and bad cholesterol (LDL) in animals. Spearmint (*Mentha spicata*) was also tested to see if it helps with diabetes. In healthy rats, the extract didn't have much effect on blood sugar. But in diabetic rats, giving the extract regularly helped lower their blood sugar levels. At the amount used, the spearmint extract worked just as well as a common diabetes medicine called glibenclamide.²⁶

Anti-tumor Effects:

Mice treated with peppermint leaves had anti-tumor properties. Plants with therapeutic qualities and active compounds play a significant role in cancer treatment. A study examined extracts from ten different herbs, including peppermint, on L1210 cancer cells. All of the plants shown some potential to kill cancer cells, with lemon verbena being the most efficient. The results varied depending on how much was utilized and how long the cells were treated. These herbs seemed to kill cancer cells by creating more oxygen ions and enhancing the activity of antioxidant enzymes.²⁵

Cardiovascular activity:

Peppermint (*Mentha piperita*) has been shown to widen blood vessels, lower heart rate, and reduce high blood pressure in some animals. It also helps relax the muscles in the lungs, making it easier to breathe.²⁵

Hepatoprotective Effect:

Agents that protect the liver from hepatic damage are known as Hepatoprotective agents.⁶⁰ Researchers studied how peppermint and parsley leaf oils could protect the liver in rats from damage caused by a toxic chemical called carbon tetrachloride (CCl₄). This chemical usually increases bad fats in the blood (like cholesterol, LDL, VLDL, and triglycerides) and lowers the good fat (HDL). When the rats were given 0.5 ml of peppermint oil, parsley oil, or a mix of both, the damage caused by the chemical was reduced—especially with peppermint oil. These oils have strong antioxidant effects, which help fight harmful substances in the body. Peppermint oil, in particular, increased helpful enzymes (SOD and GSH) and lowered a harmful one (MDA). This shows that peppermint and parsley oils may help protect the liver by fighting off damage from toxins.²⁷

Larvicidal activity:

Mentha piperita oil was examined for its larvicidal activity against three mosquito

species: *Culex quinquefasciatus*, *Anopheles stephensi*, and *Aedes aegypti*. The study found that *Aedes aegypti*, *An. stephensi*, and *Cx. quinquefasciatus* were the most susceptible species. Applying 3 milliliters of oil per square meter of water surface area resulted in 100% mortality of *Cx. quinquefasciatus*, 90% for *Aedes aegypti*, and 85% for *An. stephensi* within 24 hours. *Aedes aegypti* fatality rate was 100% at 3 ml/m² in 48 h and 4 ml/m² in 24 h. Using 4 ml/m² for 72 hours resulted in 100% mortality for *An. Stephensi*.²¹

Antipyretic and antiulcer properties of Azulene:

Azulene is a compound found in the leftover material from making peppermint oil. It has strong fever-reducing and ulcer-preventing

properties. In one study, a small dose (0.1 g/kg) injected into rabbits helped heal burns on their ears caused by hot water. In another test, rats with stomach ulcers caused by a chemical (butadione) showed less damage after being given 0.05 g/kg of Azulene. However, high doses of Azulene can be harmful. It can be deadly at 1.5 g/kg in mice and 1.165 g/kg in rats when injected into the body.²⁸

Anticarcinogenic Effect:

The leaf extract of *Mentha piperita* exhibited potent anticarcinogenic activity by preventing G1 phase cell cycle arrest and mitochondrial-mediated apoptosis. It also enhanced the oxidative balance in treated animals in a manner dependent on both dose and duration.²³

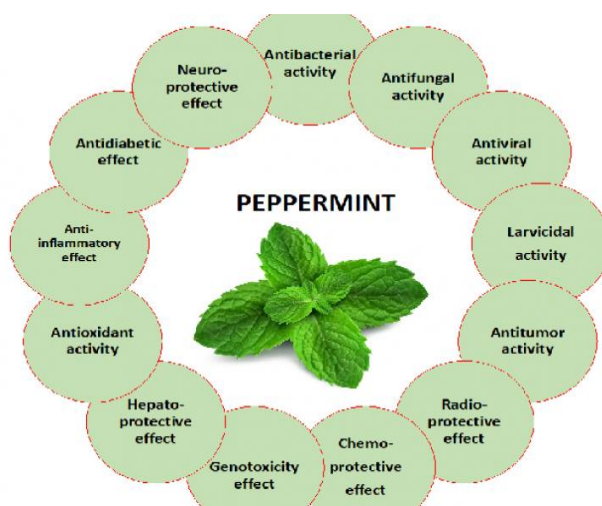


Figure 3: Pharmacology of Peppermint.²⁹

MEDICINAL VALUE:

Effect on Brain Health:

Inhaling the scent of peppermint oil before an exam or while driving may help improve mental alertness and reduce feelings of fatigue, stress, and irritability. By enhancing focus and supporting cognitive function, peppermint oil could also help ease certain symptoms associated with conditions like Alzheimer's disease.³⁰

Effect on treatment of Asthma:

Peppermint can help ease chest congestion, as its menthol content acts as a natural decongestant. It helps reduce inflammation in the nasal passages and clears mucus from the lungs. Mint also contains antibacterial, antioxidant, and antidiabetic properties, which help reduce oxidative stress and support the management of various health conditions.³¹

Effect on Digestive Relief:

Indigestion often occurs when food stays in the stomach for too long before moving through

the digestive tract. Mint, especially peppermint oil, can help relieve this discomfort. Acting as a carminative, peppermint oil relaxes the muscles of the digestive system and reduces spasms, making it effective in easing indigestion and promoting smoother digestion.³²

Irritable Bowel Syndrome (IBS) Treatment:

The menthol in peppermint oil helps relax the muscles in the digestive tract, providing relief from IBS symptoms. By soothing smooth muscle contractions, peppermint oil is commonly used to manage IBS. It is derived from the leaves, stems, and flowers of the peppermint plant.³³

Immune System Support:

Mint is packed with vitamins and powerful antioxidants that help enhance the immune system. Peppermint, when included in the diet, boosts antibody production and protects cells from oxidative damage. These natural compounds not only strengthen the body's defenses but may also help prevent the development of tumors, making mint a valuable addition to a healthy lifestyle.³⁴

Relieves Cold Symptoms:

Menthol, found in peppermint, is an effective nasal decongestant that helps clear congestion and improve breathing. Rich in phytonutrients, mint also offers antibacterial and anti-inflammatory benefits that promote overall well-being.³⁵

Healthy Hair:

Mint leaves extract and antioxidants that promote hair growth and prevent hair growth and prevent hair fall. Peppermint oil has anti-dandruff, pedicurist properties which accelerates hair growth, deepens the depth of hair follicle which helps to reduce stress and headache.³⁶

Enhances memory:

Mint, particularly peppermint, is known for its ability to enhance memory and support brain function. The refreshing scent of peppermint has been shown to improve alertness, which

can boost concentration and memory. By stimulating the brain, mint helps enhance attention and cognitive performance. Its menthol content may also aid in memory retention, making it easier to recall information. Regular use of mint, whether through its aroma or consumption, can promote mental clarity, focus, and overall cognitive health. Additionally, mint's mood-lifting properties may reduce stress, indirectly supporting better mental performance.³⁷

Allergy relief:

Mint contains rosmarinic acid, which plays a key role in reducing allergic reactions and inflammation. The anti-inflammatory effects of mint can help relieve symptoms like congestion, sneezing, and irritation, providing natural relief from allergies. Its ability to reduce inflammation makes mint an effective remedy for alleviating allergy discomfort.³⁸

Oral care:

Chewing pudina (mint) leaves can significantly improve dental health and oral hygiene. The essential oil in mint helps freshen breath, while its rich content of vitamins D and E, iron, phosphorus, and calcium support overall oral health. Mint leaves help combat bad breath by eliminating bacteria and fungi growth. Their natural antibacterial properties prevent plaque buildup, reducing the risk of cavities and gum disease. Additionally, the antifungal compounds in mint help prevent infections like oral thrush, and its anti-inflammatory effects can soothe gum irritation.³⁵

MESELLANEOUS:

Toxicology:³⁹

Menthol Toxicity:

Menthol, the primary active component in peppermint oil, has a strong cooling effect and is commonly utilized in topical applications. However, if consumed in large quantities or applied aggressively to the skin, it might cause: Gastrointestinal Distress: Too much menthol can cause nausea, vomiting, and stomach

discomfort. Central Nervous System (CNS) Effects: High doses can cause dizziness, confusion, and, in severe cases, seizures. Excessive inhalation of peppermint oil or menthol vapor can induce respiratory distress, especially in people who have asthma or other prior lung diseases.

Toxicity in children:

Because of its high menthol concentration, the usage of peppermint oil in youngsters raises concerns. Children are especially susceptible to menthol poisoning, and the improper usage of peppermint oil can result in: Respiratory Depression: Ingesting peppermint oil or inhaling menthol fumes might induce respiratory issues in youngsters. Large doses might cause nausea, vomiting, and stomach cramps.

Severe Toxicity: Consuming too much peppermint oil can cause systemic toxicity, particularly harming the liver and kidneys.

Allergy:^{40,41}

Allergies to *Mentha piperita* are relatively rare but can result in a range of symptoms, from mild irritation to more serious systemic responses.

1. Contact Dermatitis: Symptoms include redness, itching, burning, blistering, or dry skin. Usually happens after skin contact with peppermint oil in cosmetics, toothpaste, or topical balms. Peppermint is regarded as a sensitizer in vulnerable persons.
2. Respiratory Reactions: Inhalation of peppermint oil vapors can cause: Sneezing, Runny nose, Wheezing, exacerbation of asthma.
3. Oral allergy syndrome: In sensitive people (particularly those allergic to pollen), eating peppermint may cause: Tingling or itching in the lips, mouth, throat, Swelling of oral tissues. Frequently related with cross-reactivity with ragweed or birch pollen.

INTERACTIONS:

Drug Metabolism Interactions:⁴²

Modulation of Cytochrome P450 Enzymes Peppermint oil and its constituents, particularly menthol, have been demonstrated to influence hepatic drug-metabolizing enzymes: Inhibition of CYP3A4 and CYP1A2: These enzymes metabolize a variety of medications, including statins, calcium channel blockers, benzodiazepines, and certain chemotherapeutics. In vitro and animal studies suggest that peppermint oil may impair the metabolism of medications metabolized by these enzymes, potentially leading to increased drug levels and toxicity.

Interactions with gastrointestinal drugs:⁴³

Peppermint alters gastric motility, which may impair medication absorption: Antacids with Enteric-Coated Capsules: Peppermint oil is commonly used in enteric-coated capsules to treat irritable bowel syndrome (IBS). However, co-administration with antacids can promote premature capsule dissolution, lowering efficacy and resulting in adverse effects such as heartburn. Peppermint can slow stomach emptying, potentially altering the pharmacokinetics of medicines taken orally.

Neurological Drug Interactions:⁴⁴

Peppermint can enhance the effects of central nervous system depressants like benzodiazepines and barbiturates due to its modest sedative properties. Co-administration may cause greater sleepiness or CNS depression.

Interaction with Anticoagulants:⁴⁵

Peppermint contains menthol, which may have minor antiplatelet effects. Peppermint may raise the risk of bleeding when taken with anticoagulant or antiplatelet medications such as clopidogrel, warfarin, or aspirin.

MARKET VALUE:^{46,47}

The global market for *Mentha piperita* (peppermint) and its derivatives, particularly peppermint oil, has been experiencing

significant growth due to its extensive applications in various industries such as food and beverages, pharmaceuticals, cosmetics, and aromatherapy. Below is an overview of the market value and trends:

Global Market Overview:⁴⁶

The global peppermint oil market was valued at approximately USD 331.7 million in 2021 and is projected to reach USD 658.2 million by 2031, growing at a CAGR of 6.6% during the forecast period. Peppermint oil is widely used as a flavoring agent in food and beverages, as a fragrance in cosmetics and personal care products, and for its therapeutic properties in pharmaceuticals and aromatherapy. North America held the largest market share of around 38.7% in 2021, attributed to high consumption in the United States.

Indian Market Insights:⁴⁷ India is one of the leading producers and exporters of peppermint oil, accounting for more than 60% of global exports. In 2023, Indian exports of peppermint oil increased by 8%, reaching a value of USD 35 million. The Indian government, through the National Medicinal Plants Board (NMPB), has invested USD 15 million over two years to enhance mint cultivation and processing, aiming to boost India's global market share.

Market Trends.⁴⁷ There is an increasing consumer preference for natural and organic products, driving the demand for peppermint oil in various sectors. Peppermint oil is recognized for its therapeutic properties, including relief from headaches, indigestion, and muscle pain, contributing to its popularity in aromatherapy and pharmaceuticals.

SUMMARY TABLE:⁴⁸⁻⁵⁶

Summary table of Peppermint plant as described below in Table 4:

S. No	Plant Part	Activity	Extract	Model	Standard Drug	Dose	Parameters	Mechanism	Stats P Value	Author Year
1	Leaves	Analgesic	Aqueous	Acetic acid-induced writhing in mice	Acetylsalicylic acid	200-400 mg/kg (i.p.)	% inhibition writhing	Peripheral and central analgesic effects	<0.01	Taher, 2012.48
2	Leaves	Analgesic	Aqueous	Hot plate test in mice	Morphine	200-400 mg/kg (i.p.)	Response latency time	Central analgesic effect via opioid pathways	<0.001	Taher, 2012.48
3	Leaves	Anti-inflammatory	Aqueous	Carrageenan induced paw edema in mice	Indomethacin	200-400 mg/kg (i.p.)	Paw thickness measurement	Inhibition of inflammatory mediators	Not significant	Taher, 2012.48
4	Leaves	Anti-inflammatory	Essential oil	Carrageenan induced paw edema in mice	Sodium diclofenac	2, 20, 200 µL/kg (oral)	% edema inhibition	Reduction of pro-inflammatory mediators	Not specified	Al-Snafi, 2023.49
5	Leaves	Antioxidant	Ethanollic	DPPH assay & oxidative stress in rats	Not specified	5, 10, 20 mg/200g BW (oral)	IC50 value, MDA levels	Free radical scavenging, lipid peroxidation inhibition	Significant	Rosmalena, Putri NA, 2022.50
6	Leaves	Antibacterial	Ethanollic	Agar well diffusion against uropathogens	Not specified	1000 µg (in vitro)	Zone of inhibition, MIC values	Disruption of bacterial cell membranes	Not specified	Sowjanya Pulapati, 2016.51

7	Leaves	Antihyperglycemic	Ethanollic	Streptozotocin-induced diabetic rats	Glibenclamide	300 mg/kg (oral)	Blood glucose, insulin, glycogen levels	Enhancement of insulin secretion and glycogen storage	Significant	Chandrasegaran G, 2014.52
8	Leaves	Neuroprotective	Freeze-dried extract	Scopolamine-induced amnesia in mice	Not specified	Not specified	Neurotransmitter levels, behavioural assessments	Cholinesterase inhibition, antioxidant activity	Significant	Hanumanthachar Joshi, 2014.53
9	Leaves	Anticholinesterase	Essential oil & extracts	Enzymatic assays & molecular docking studies	Galantamine	IC ₅₀ : 10.66 µg/mL (AChE)	Enzyme inhibition percentages	Inhibition of AChE and BChE enzymes	Not specified	Manel Srief, Moustafa Bani, 2023.54
10	Stems & Leaves	Menthol production	Steam distillation	In vitro tissue culture	Not applicable	0.3 g in 25 mL distilled water	Menthol concentration via GC analysis	Secondary metabolite biosynthesis	Not specified	Wijaya BK, 2019.55
11	Roots	Antibacterial	Ethanol & ethyl acetate	Agar well diffusion against various bacteria	Tetracycline	Not specified	Zone of inhibition	Disruption of bacterial cell membranes	Not specified	Para Sujanal, 2013.56

Table 4: summary table of Peppermint plant.

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