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The potential of *Lamiaceae* essential oils against respiratory tract diseases – a mini-review

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Abstract

Respiratory tract infections (RTIs) are common infections in the global population, particularly among children. Due to the rise of antibiotic resistance, multidrug-resistant bacteria, and the numerous adverse effects of synthetic drugs, there is a constant demand for new and safe alternative treatments. Natural plant-based alternatives have become more popular, while chemical drugs have been questioned for their safety and side effects. One of the most promising solutions to the global issue of respiratory tract infections is the exploration of the antiviral and antibacterial properties of essential oils (EOs). Because of their volatility, EOs can be inhaled, allowing them to reach both the upper and lower respiratory tracts. Additionally, their antimicrobial and anti-inflammatory properties along with their phytochemical composition make them more effective for treating respiratory tract infections. Humans are less likely to be affected by EOs because of their low toxicity and less risk of resistance to pathogenic organisms. *Lamiaceae* (also called *Labiatae*) is one of the most important herbal families, and it incorporates a wide range of plants like thyme, holy basil, rosemary, basil, etc. with potential therapeutic properties. The pharmacological properties of *Lamiaceae* are mainly due to its EOs, which have various activities like anti-tumor, anti-diabetic, insecticidal, neuroprotective, anti-asthmatic, and others. Overall, the main objective of this review is to provide an overview of the general characteristics of certain EOs from the *Lamiaceae* family about their ability to alleviate the signs and symptoms of respiratory diseases, including respiratory tract infections.

Keywords

Essential oil; *Lamiaceae*; Respiratory tract infections; respiratory diseases; terpene-based Nano-systems;

Introduction

Respiratory tract infections (RTIs) are amongst the most common infections in the general population and are associated with certain inevitable aspects of modern lifestyle, such as the crowding of cities, lengthy periods spent indoors with insufficient amount of fresh air, and second-hand smoking (1). These infections are the main reasons for work and school absenteeism. An infection of the respiratory tract (RTI) may occur due to a diversity of pathogens, including viruses, fungi, and bacteria. Pathogens and the immune system interact during the pathogenesis of RTIs. By inhaling droplets, organisms enter the respiratory tract and invade the mucosa. They can also cause epithelial destruction, redness, edema, hemorrhage, and sometimes exudate as well (2). When a pathogen multiplies in or on the epithelium, mucus secretion increases, mucociliary function is impaired, and other lung functions may be affected. In severe bronchiolitis, airways may

become blocked by mucus, cell debris, and edema fluid, whereas in pneumonia, the pathogen is usually inhaled through aerosolized particles. There are also other routes by which pathogens enter the body, such as aspiration of upper respiratory tract secretions, hematogenous spread, or direct extension from adjacent structures (3).

Predisposing factors are conditions that increase susceptibility toward developing an RTI. Some of these predisposing factors include age (young children under five years old and elderly people over 65 years old have weaker immune systems), smoking (damages lung tissue making it easier for pathogens to take hold), chronic lung diseases like COPD, emphysema or asthma (airways already have reduced function) and weakened immune system due to chemotherapy, transplant recipients, HIV positive patients, etc. (4-7). Respiratory Tract Infections (RTIs) are a significant global health concern, with a high disease burden and impact on quality of life. According to the World Health Organization (WHO), acute lower respiratory infections are a leading cause of over 3 million deaths annually worldwide, making it one of the leading causes of death globally (8). The Global Burden of Disease (GBD) Study estimates that in 2017, RTIs were responsible for approximately 4 percent of all deaths globally, with pneumonia being the most common cause. Additionally, RTIs also have a significant impact on disability-adjusted life years (DALYs), which is a measure of the overall disease burden. As per report of World Health Organization (WHO) reports that DALYs due to lower respiratory tract infections increased by nearly 20 percent from 1990 to 2017 (8-9).

Nevertheless, medical practitioners often prescribe synthetic antibiotics for RTIs, which is one of the leading causes of their irrational use of bacterial strains that become resistant to antibiotics (1). A variety of antibiotics are recommended for all children depending on their sensitivity spectrum, including amoxicillin, cephalexin, ciprofloxacin, levofloxacin, and cefixime (10). Modern drugs such as aspirin, atropine, morphine, ephedrine, quinine, reserpine, digoxin, and tubocurarine serve as illustrations of medications that were initially discovered through the observation of traditional healing practices employed by indigenous communities (11). Synthetic drugs can cause adverse side effects such as nausea, dizziness, headaches, and fatigue among others that may impact a patient's health significantly. Overuse of antibiotics or antimicrobial agents can lead to the development of drug-resistant bacteria and viruses which become difficult to treat using existing medications (12). Many synthetic drugs require large-scale manufacturing processes that generate toxic waste products harmful to the environment & public health. The cost of synthesizing new compounds is often high due to the advanced equipment required along with time-consuming regulatory approvals.

In contrast, herbal-based remedies used in traditional medicine grow naturally without any need for chemical fertilizers or pesticides, thus reducing the carbon footprint and environmental damage caused by pharmaceutical industries. Herbal-based treatments are relatively cheaper than their synthetic counterparts because they do not involve extensive processing or regulatory approval procedures (13). Therefore, one of the most encouraging solutions to this global issue is to explore the antibacterial and antiviral effects of EOs, which are commonly utilized in various fields such as cosmetics, healthcare, traditional medicine, pharmaceuticals, and the food industry (14). According to current conditions, studies on medicinal plants concerning their potential to treat respiratory diseases are often encouraged due to the availability of medicinal properties in certain plants and their safety unlike synthetic drugs (15).

According to the European Pharmacopeia 7th edition, essential oils are defined as aromatic products with a complex composition derived from plant raw materials (16). These oils are obtained through processes such as steam distillation, water distillation, dry distillation, or mechanical methods without heating. Various parts of the plants, including flowers, buds, peels, seeds, leaves, barks, and others, are used to extract these aromatic oily liquids. Different techniques of extraction are employed to obtain EOs. Essential oils are characterized by their lipophilic nature, which means they are soluble in organic solvents and have a lower density than water. The yield of essential oil extraction depends on the species of the plant and the specific plant parts used. In some cases, the yield can be as low as 1 percent, making these components highly valuable and rare. Overall, essential oils are complex mixtures of volatile compounds derived from plants, and their composition and properties can vary depending on the specific plant species, parts used, and extraction methods employed (17).

According to WHO, traditional and complementary medicines are vital components of the global healthcare system (18). The successful colonization of terrestrial habitats by plants is attributed to secondary metabolites, such as phenols, alkaloids, and terpenoids, which exhibit a variety of defensive roles in plant survival and propagation (19). Essential oils, also known as aetherolea, belong to a diverse group of secondary metabolites found in plants, mainly mono, and sesquiterpenoids, phenylpropanoids, etc., which contain thousands of individual chemical compounds and are used in aromatherapy, dermatology, cosmetology, food, and pharma industry (14, 20). Parenthetically, the defense mechanisms found in essential oils, including antimicrobial, antibacterial, and antioxidant properties, among others, hold great potential in meeting the global demand for novel antiviral and antibacterial drugs. Furthermore, these mechanisms can be harnessed to expand the development of safe, natural products derived from plants. By exploring the therapeutic applications of essential oils, we can unlock new avenues for combating viruses and bacteria while ensuring the safety and well-being of individuals. This approach offers a promising direction for innovation in the pharmaceutical and healthcare industries. A variety of aromatic spices belonging to the *Lamiaceae* family, such as thyme, mint, rosemary, basil, tulsi, sage, oregano, etc, are renowned for their biological and medicinal effects (21). Traditional Spanish remedies often use oregano, thyme, rosemary,

and sage to treat bronchitis, inflammation, infections, and dermatitis (22). Since ancient times, essential oils have been employed as traditional remedies in various ethnic medicinal practices for the treatment of respiratory tract infections. Essential oils used to treat colds are known for their antimicrobial and antioxidant properties and are also used in medicine to treat chronic and acute bronchitis, as well as acute sinusitis through inhalation therapy (23).

Lamiaceae family, also known as the mint family, is a cosmopolitan family with 236 genera consisting of 7136 species (19). The EOs belonging to the *Lamiaceae* family exhibit a complex mode of action, owing to their varied phytochemical composition. They appear to be most effective when inhaled, as their volatile nature enables them to reach the targeted areas of the respiratory tract (14). As such, this review aims to summarize the findings of various literature studies regarding the potential benefits of EOs derived from *Lamiaceae* plants in treating respiratory tract disorders.

Traditional uses of Lamiaceae members in treating cough and cold:

The Rig Veda is an important early document that emphasizes herbal medicinal knowledge. Indian herbalists like Maharshi, Charaka, and Sushruta later utilized the importance of medicinal plants for treating diseases. However, in the past century, allopathic medicine has rapidly gained popularity in India. Despite this, natural products, particularly plant-based remedies, continue to be widely used in the societies of rural tribal communities (24).

In the Khatra Subdivision of Bankura district in West Bengal, a survey revealed that within the *Lamiaceae* family, 13 species belonging to 8 genera are commonly used in traditional healthcare practices. One such species, *Mentha piperita,* is traditionally utilized for treating asthma, cough, and cold. Another species, *Coleus aromaticus*, is known for its medicinal properties, with the juice of its leaves used to treat headache, fever, epilepsy, and dyspepsia. Additionally, a decoction of the leaves is administered for chronic cough and asthma (24).

Thymus species have been extensively utilized in traditional medicine throughout Europe, Asia, and North Africa for centuries, specifically for addressing conditions like colds, coughs, sore throats, and bronchitis. Another widely recognized medicinal plant is *Ocimum basilicum* L., commonly known as basil, which has been traditionally employed worldwide for its therapeutic properties against infectious diseases and coughs. Additionally, *O. kilimandscharicum* Guerke also referred to as "Basil African blue," is a shrub native to East Africa and is utilized in traditional medicine specifically for the treatment of coughs. In traditional Indian medicine, *O. canum* Sims. is highly valued for its ability to address conditions like colds, fever, inflammation, and headaches. Furthermore, *O. vulgare* L. finds application in traditional medicine as a remedy for colds (25).

Traditionally, thyme EO was used for treating pulmonary disorders as it had contamination-struggling and cough-suppressing properties (23). Again, the juice of the tulsi leaves, as well as tea or concoction, called 'jushanda', provides relief for colds and coughs. When the limbs are cold during fever, tulsi leaves paste is applied to the fingernails and toes, also the leaf juices are given to children suffering from catarrh and bronchitis. Tulsi tea (also called an instant pick-me-up energy drink) is also recommended for diseases that are associated with the "*Kapha*" dosha in the body (26-27). The herb component *O. basilicum* is regarded as a complex and multifunctional remedy for getting rid of both respiratory symptoms and causes. Coughs can be treated with a quarter cup of dry grass brewed in 250 ml of boiling water for half an hour, and taken 3-4 times a day (28).

Harnessing Nature's Power: Essential Oils as Potential Allies in the Fight Against COVID-19:

The COVID-19 pandemic has had a profound global impact, affecting individuals with a wide range of symptoms, from asymptomatic cases to severe respiratory illness. Common symptoms include cough, fever, fatigue, loss of appetite, and taste and smell dysfunction (29). In severe cases, the immune system's response is weakened, characterized by suppressed regulatory T cells, natural killer cells, and increased proinflammatory cytokines. While standard treatment options like antiviral drugs and monoclonal antibodies exist, considering alternative and complementary approaches is crucial due to the nature of the epidemic (30).

Essential oils, renowned for their wide array of biological activities, possess a rich heritage in traditional medicine. These oils showcase remarkable properties including anti-inflammatory, antioxidant, antimicrobial, and immunomodulatory effects. These oils, derived from various plant sources, contain compounds like terpenes, terpenoids, and phenylpropanoids (31). One essential oil of interest is eucalyptus oil, which contains eucalyptol (also known as 1,8-cineole) as its main active component. Eucalyptus oil and eucalyptol are recognized for their anti-inflammatory and antiviral properties. They have shown effectiveness against several viruses, including herpes simplex viruses, influenza A viruses, and poliovirus (32, 33, 34). In studies using molecular docking techniques and in vitro assays, eucalyptus oil, eucalyptol, and another component called jensenone have shown promising antiviral activity against SARS-CoV-2, particularly in inhibiting the Mpro enzyme of the virus (35). Garlic, scientifically known as *Allium sativum*, is a functional food that offers a multitude of beneficial properties and has garnered attention for its potential antiviral effects. This remarkable plant contains various bioactive components including organosulfur compounds, polysaccharides, phenolic compounds, and saponins. These compounds contribute to the diverse therapeutic properties associated with garlic. Organosulfur compounds, including allicin, play a crucial role in the antiviral, anti-inflammatory, antioxidant, and immunomodulatory properties of garlic (36). Clinical trials have demonstrated the protective effects of garlic against viral infections, including its potential to enhance the immune system's

response, reduce inflammation, and boost immune cells (35).

Laurus nobilis EO, which has been traditionally employed in folk medicine to address rheumatoid diseases, has exhibited the ability to impede the replication of SARS-CoV. Lemon, geranium, *Mentha* spp., *Citrus* spp., ginger, thyme, *ocimum* spp., oregano, and various other essential oils from medicinal aromatic plants have also been reported for their antiviral activity (37, 35). Essential oils exert their antiviral effects through various mechanisms, such as inhibiting viral attachment and entry, viral replication, and enhancing the host immune response. They have shown sensitivity against viral envelopes, making them effective against enveloped viruses like SARS-CoV-2. Specific components of EOs, such as α-pinene, α-terpinene, terpinen-4-ol, and thymol, have exhibited significant antiviral effects against certain viruses (35).

Inhalation of essential oils provides a direct route to the lungs and airways, which are the initial target organs for SARS-CoV-2 infection. Vaporized essential oils have shown better antibacterial effects and can effectively target the respiratory tract (38, 39). Inhalation allows for direct access to the affected area, avoiding first-pass metabolism and increasing bioavailability. The volatile nature of essential oils enables them to be readily cleared from the lungs, providing virucidal and local anti-inflammatory effects. Eucalyptol, for example, can be concentrated in the lungs, enhancing its potential virucidal effect (35). Therefore, essential oils offer potential therapeutic contributions to the treatment and prevention of COVID-19. Further research is needed to explore their full capabilities, and they may serve as valuable tools in combating coronaviruses when used alongside standard treatment options.

Phytochemistry of essential oils extracted from *Lamiaceae* members:

Essential oils (EOs) serve as the very essence of aromatherapy, encompassing volatile bioactive compounds derived from aromatic plants. Given the escalating demand for safe and natural food preservation methods, EOs have emerged as a compelling alternative to synthetic additives in the food industry. Notably, the *Lamiaceae* family plays a pivotal role in this domain, producing EOs with antioxidant properties, rendering them particularly significant in the industry (40).

Traditionally renowned as a treasure trove of species, the mint family is celebrated for its therapeutic, culinary, and soothing attributes. Its diverse range of plants offers soothing and relaxing effects, as well as the ability to strengthen, stimulate, and target specific organs. Furthermore, the active compounds found in *Lamiaceae* plants have been proven to possess natural antibacterial, antioxidant, antifungal, and antitumor properties, making them promising candidates for treating various diseases. These findings suggest that EOs from the *Lamiaceae* family can effectively replace synthetic products without causing side effects, making them suitable for long-term use (41). As the benefits of medicinal plants within the *Lamiaceae* family continue to be validated, their integration into various formulations is on the rise, showcasing therapeutic effects akin to those of synthetic chemical compounds. The absence of adverse reactions further bolsters their appeal and underscores their potential as valuable tools in promoting human health and well-being (42, 40).

The quantitative and qualitative yield, as well as the components, of EOs, can vary based on geographical regions and environmental factors such as climate, relief, and soil conditions (43). Essential oils, predominantly located in leaves, can also be found in flowers, buds, fruits, wood, seeds, roots, or rind. These oils consist of intricate blends of volatile compounds, which are secondary metabolites synthesized by plants as a defense mechanism. They play a vital role in safeguarding the plant from various threats (44). Essential oils are known to contain more than 300 different compounds, with the majority having a molecular weight below 300. In certain oils, such as those derived from *Lavandula*, *Geranium*, or *Rosmarinus*, the number of chemicals can reach 450 to 500. The main chemical components commonly found as phytoconstituents in the essential oils of *Lamiaceae* family members are presented in Table 1 (fig. 1). Essential oils

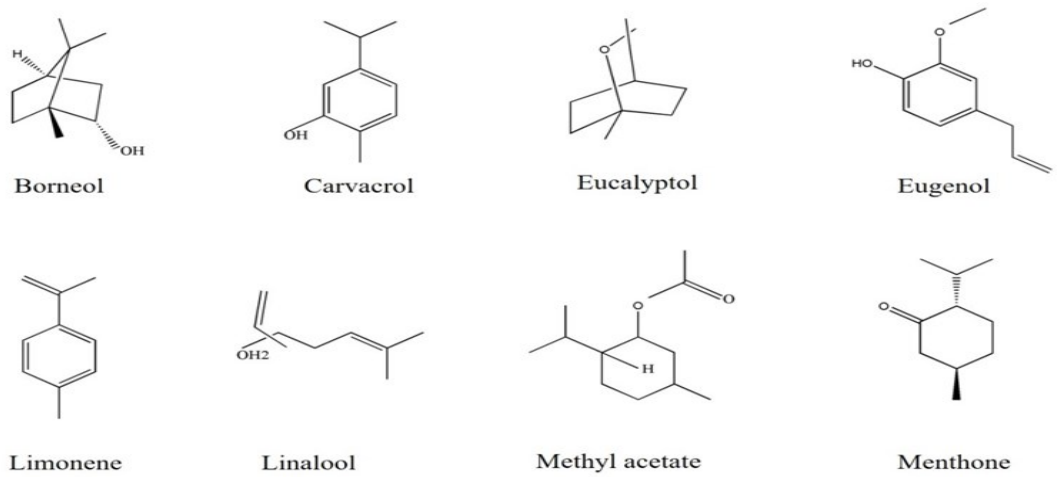

Fig.1: Major phytoconstituents of the Lamiaceae family.

Table 1: Major phytoconstituents found in selected members of the *Lamiaceae* family.

Plant	Common name	Phytoconstituents	Chemical classification	Method of extraction	Reference
Mentha piperita	Peppermint	Menthol,	Oxygenated Monoterpene	GC-MS; GC-FID	(45, 44)
		Menthone,	Oxygenated Monoterpene (Ketones)		
		Carvone,	Oxygenated Monoterpene (Ketones)		
		Menthyl acetate,	Ester		
		Eucalyptol,	Oxygenated Monoterpene		
		Pulegone	Ketones		
Mentha spicata	Spearmint	Pulegone,	Ketones	GC-MS; GC-FID	(45, 46, 44)
		Carvone,	Oxygenated Monoterpene		
		Menthol,	Oxygenated Monoterpene		
		Neomenthol,	Oxygenated Monoterpene		
		Limonene,	Oxygenated Monoterpene		
		Eucalyptol	Oxygenated Monoterpene		
Thymus vulgaris	Thyme	Carvacrol,	Oxygenated Monoterpene	GC-MS;	(47, 45, 44)
		Thymol,	Oxygenated Monoterpene		
		Borneol,	Oxygenated Monoterpene		
		Linalool,	Oxygenated Monoterpene		
		p-Cymene,	Monoterpene Hydrocarbon		
		Eucalyptol	Oxygenated Monoterpene		
Ocimum sanctum	Tulsi	Eugenol,	Phenylpropanoid	GC-MS	(47, 44)
		Methyl chavicol,	Phenylpropanoid		
		Linalool,	Oxygenated Monoterpene		
		α-Caryophyllene,	Sesquiterpene Hydrocarbon		
		Germacrene-D,	Sesquiterpene Hydrocarbon		
Ocimum basilicum	Basil	Carvone	Oxygenated Monoterpene	GC-MS; GC-FID	(48, 44)
		Linalool,	Oxygenated Monoterpene		
		Methyl chavicol,	Phenylpropanoid		
		Geraniol,	Oxygenated Monoterpene		
		Eucalyptol,	Oxygenated Monoterpene		
		p-Allylanisole,	Oxygenated Monoterpene		
		Eugenol	Phenylpropanoid		
Rosemarinus officinalis	Rosemary	α-Pinene,	Monoterpene Hydrocarbon	GC-MS; GC-FID	(49, 50, 44)
		Eucalyptol,	Oxygenated Monoterpene		
		Limonene,	Monoterpene Hydrocarbon		
		Camphor,	Oxygenated Monoterpene		
		Myrcene,	Monoterpene Hydrocarbon		
		Borneol	Oxygenated Monoterpene		
Salvia officinalis	Sage	Eucalyptol,	Oxygenated Monoterpene	GC-MS; GC-FID	(51, 44)
		Camphor,	Oxygenated Monoterpene		
		α-Thujone,	Oxygenated Monoterpene		
		Viridiflorol,	Oxygenated Sesquiterpene		
		β-Thujone,	Oxygenated Monoterpene		
		β-Pinene	Monoterpene Hydrocarbon		
Origanum vulgare	Oregano	Pulegone,	Ketones	GC-MS; GC-FID	(52, 44)
		Carvacrol,	Oxygenated Monoterpene		
		Cymenol,	Oxygenated Monoterpene		
		Thymol,	Oxygenated Monoterpene		
		o-Cymene,	Monoterpene Hydrocarbon		
		Terpinen-4-ol	Oxygenated Monoterpene		

contain active compounds that fall into diverse chemical classes, encompassing terpenes (such as monoterpenes and sesquiterpenes), aldehydes, esters, ketones, alcohols, coumarins ethers, and phenols (44).

Terpene-Based Nanosystems: Revolutionizing Essential Oil Delivery for Enhanced Therapeutic Applications:

Essential oils, particularly terpenes, enhance niosomes formulations by disrupting the stratum corneum structure, acting as penetration enhancers. They also improve niosome elasticity and vesicular fluidization, thereby increasing transdermal drug delivery (53). In a study by Eid et al. (54), it was found that the addition of essential oils, such as lemon oil, clove oil, and eucalyptus oil, significantly improved the permeation of felodipine-loaded niosomes. The extent of improvement depended on the type and quantity of essential oils used (55).

In studies focused on nanosystems designed for topical administration, essential oils (EOs) and terpenes fulfill distinct roles. The reviewed literature categorized EOs/terpenes into two main groups: bioactive ingredients and excipients. Among the eighty-two studies examined, fifty-six utilized terpenes/EOs as bioactive ingredients in their formulations, while twenty-nine studies incorporated them as excipients (55). For instance, a study by Zhang et al. (56) showcased the anti-inflammatory properties and enhanced skin penetration of the terpene Paeoniflorin when encapsulated in glycerosomes. Similarly, Castangia et al. (57) developed permeation-enhancing formulations containing *Santolina insularis* EO, which acted as both an antimicrobial agent and a permeation enhancer for percutaneous drug delivery.

The use of EOs and terpenes as bioactive ingredients in pharmaceutical formulations has gained attention due to their well-described biological and pharmacological activities. There is a growing interest in natural products as alternatives for drug development, and EOs and terpenes align with this trend. Terpenes, on the other hand, are commonly used as excipients to increase the permeation of active compounds through the layers of the skin (55). Overall, the review findings highlight the versatility of EOs and terpenes in nanosystems for topical administration, with their potential as bioactive ingredients and excipients being explored to enhance drug delivery through the skin.

Therapeutic potential of some selected *Lamiaceae* essential oils against respiratory diseases:

Mentha piperita (Peppermint):

The EO of *Mentha piperita* is a colorless, pale greenish-yellow liquid with a characteristic taste and odor, accompanied by the flu. The chief constituents are menthol, menthone, carvone, menthyl acetate, eucalyptol, and pulegone (58,45,44).

M. piperita has been found to have bronchodilatory effects, which can help alleviate symptoms of asthma and chronic obstructive pulmonary disease (COPD). This is because one of the constituents of peppermint oil is 1,8-cineole, which has been proven to be effective in treating respiratory diseases since it accelerates the beat frequency of cilia in the mucous membrane, which in turn causes mucolytic and primary anti-inflammatory effects. Since it acts both as a bronchodilator and anti-inflammatory agent, it is likely to be effective in treating acute bronchitis symptoms (59). Inhalation of 3–4 drops of peppermint oil added to hot water helps treat the symptoms of coughs and colds (14). Menthol in peppermint oil effectively helps in curing respiratory problems (23).

Mentha spicata (Spearmint):

Mentha spicata essential oil has been reported to possess antimicrobial properties against various pathogens, including bacteria, viruses, and fungi. The active compounds in the oil, such as menthol and carvone, have shown inhibitory effects on microbial growth, which may help in combating respiratory infections caused by pathogens (60).

Respiratory tract infections often involve inflammation of the airways. *Mentha spicata* essential oil contains components with potential anti-inflammatory properties, such as rosmarinic acid and luteolin. These compounds may help reduce inflammation in the respiratory system, alleviating symptoms associated with infections (60). *M. spicata* EO is believed to possess expectorant properties, which can help in clearing mucus and phlegm from the respiratory tract. This action may aid in relieving congestion and facilitating easier breathing. The essential oil may also have immunomodulatory effects, potentially enhancing the immune response against respiratory infections. This can help the body's defense mechanisms fight against pathogens more effectively (61).

Thymus vulgaris (Thyme):

Thyme EOs are commonly characterized by their transparent, yellow, or deep reddish-brown coloration, accompanied by an aroma that evokes the distinct scent of thymol. They are mainly made up of phenols, thymol, or carvacrol, borneol, linalool, p-cymene, and eucalyptol along with various other terpenoids (58,47,45,44).

Inhaling 4-5 drops of thyme oil helps to treat respiratory disorders (supportive treatment of pertussis, and bronchial catarrh). Thyme has been found to have bronchodilatory effects, making it potentially useful for treating coughs and bronchitis (14, 62). These days, it is generally used as an expectorant in cough-associated conditions, and the extract of thyme is antiviral against influenza viruses, while the cytopathic effect of influenza can be reduced with non-cytotoxic thyme extracts at concentrations of 0.03-0.33 % (v/v) (14,62).

Ocimum sanctum (Holy basil/Tulsi):

The EO from *Ocimum sanctum* leaves is a bright yellow volatile oil with a pungent taste and aromatic odor. Tulsi is considered sacred in India and is ubiquitous in Hindu tradition. Eugenol, nerol, methyl chavicol, germacrene-D, carvone, eugenol methyl ether, terpinene-4-ol-decylaldehyde, α-caryophyllene, eucalyptol, camphor, α-pinene, linalool, and carvacrol are the principal components in the leaf EO (47, 26, 44, 27). In a study by Sarkar., 2022, steam inhalation of holy basil oil can reduce the symptoms of upper respiratory tract infections and

helps in improving the respiratory status among 3-6-year-old children (63).

The leaves of holy basil are effective against bronchitis, asthma, influenza, coughs, and colds when taken with honey and ginger. To alleviate influenza symptoms promptly, a mixture of leaves, cloves, and common salt can be prepared by boiling them with half a liter of water until the water volume is reduced by half. Subsequently, the resulting concoction can be consumed for immediate relief (64).

Ocimum basilicum (Basil):

The EO of basil is a volatile oil with a light yellowish color and is characterized by a peculiar smell. The biologically active components present in basil are eugenol, ursolic acid, ocimene, germacrene, methyl chavicol, geraniol, p-allyl anisole, linalool, eucalyptol, β- caryophyllene, etc which synergistically show therapeutic characteristics (48, 28, 44). Basil essential oil contains various bioactive compounds, such as linalool, eugenol, and methyl chavicol, which contribute to its therapeutic properties. These compounds have shown antimicrobial, anti-inflammatory, and antioxidant activities, which are relevant in the context of respiratory tract infections (65).

The EO of basil reduces bronchospasm and has a moderate sedative effect, reducing the excitability of the nervous system's cough center, in addition, basil oil also has anti-inflammatory, secretolytic (expectorant) effects, demonstrates antiviral activity against adenoviruses that cause acute respiratory diseases (66). Basil EO (16 µg/ml solvent) inhibits arachidonic acid metabolism including the cyclooxygenase and lipoxygenase pathways, preventing lung infections and asthma (66).

Rosmarinus officinalis (Rosemary):

The EO of *Rosmarinus officinalis*, commonly known as rosemary, possesses a unique flavor with a camphoraceous taste. It can vary in color from colorless to pale yellow and contains numerous phytoconstituents, predominantly eucalyptol, camphor, α-pinene, borneol, camphene, limonene, verbenone, myrcene, and caryophyllene (49, 50, 67, 44).

An antibacterial effect of rosemary oil has been demonstrated against a variety of respiratory pathogens isolated from clinical specimens, including *Streptococcus pyogenes*, *Streptococcus agalactiae*, *Klebsiella pneumoniae*, *Streptococcus aureus*, and *Stenotrophomonas maltophilia* (68). Inhalation and oral administration of rosemary oil stimulate the respiratory system in mice, indicating that one or more of its constituents may play a direct role. In particular, eucalyptol and rosmarinic acid have shown promising potential in terms of evaluating respiratory responses in humans (69). Furthermore, a growing body of evidence indicates that rosemary EOs, rosemary extracts, and individual constituents can provide relief from diverse respiratory diseases due to their anti-inflammatory properties, particularly following oral exposure in animals (69, 70).

Salvia officinalis (Sage):

Salvia officinalis, commonly known as sage, is an herb that has been traditionally used for various medicinal purposes, including respiratory tract infections. The essential oil derived from *Salvia officinalis* has been studied for its potential therapeutic effects in treating respiratory tract infections. The antimicrobial properties of *S. officinalis* essential oil have been investigated, and it has demonstrated activity against various bacteria, including those associated with respiratory tract infections (51, 71, 44). The oil contains several active compounds, such as thujone, viridiflorol, pinene, β-camphor, and eucalyptol, which have been shown to possess antimicrobial activity [71]. A preparation containing *S. officinalis* (Echinacea or sage) is equally effective and well tolerated compared to a chlorhexidine/lidocaine spray in the treatment of acute sore throats (72). Additionally, *S. officinalis* is commonly used to treat various respiratory conditions such as sore throat, common cold, flu, tonsillitis, cough, asthma, and bronchitis. It is also utilized for its mucolytic properties. Additionally, *S. officinalis* is employed in the management of tonsillitis, oral aphthous ulcers, and laryngitis (73). A study conducted by Hubbert et al. (74) investigated the effectiveness and tolerability of a spray containing *S. officinalis* (which includes camphor) for the treatment of acute pharyngitis. The researchers observed that the spray provided pain relief within two hours after the initial administration.

Origanum vulgare (Oregano):

Origanum vulgare essential oil, commonly known as oregano oil, has been studied for its potential therapeutic effects in respiratory tract infections. It contains several active compounds, including pulegone, carvacrol, cymenol, o-cymene, terpinen-4-ol, and thymol which are believed to contribute to its antimicrobial and anti-inflammatory properties (52, 44). Studies have indicated that *O. vulgare* essential oil exhibits antimicrobial activity against various respiratory pathogens. For instance, a study published by Sienkiewicz (2011) demonstrated the antibacterial effects of oregano oil against respiratory pathogens such as *Streptococcus pneumoniae* and *Haemophilus influenzae* (71).

The combination of thymol and carvacrol, both present in significant amounts in *O. vulgare* essential oil, has been reported to exhibit synergistic antimicrobial activity against certain bacteria associated with upper respiratory tract infections (75). Subsequently, the potent antifungal activity of *O. vulgare* oil can be attributed to its high content of thymol and carvacrol (76).

Breathing Relief: Unraveling the possible mechanisms of Essential Oils in Treating Respiratory Diseases:

Indeed, respiratory diseases often involve dysregulated immune responses, and there is evidence suggesting that essential oils (EOs) have the potential to modulate these responses (77). Juergens and colleagues explored the use of EOs as long-term therapy for asthma control and prevention of COPD exacerbations. The anti-inflammatory and anti-oxidative properties of EOs may contribute to reducing airway inflammation and oxidative stress, which are the key factors in these conditions. By addressing inflammation and oxidative damage, EOs may help improve symptoms and prevent exacerbations in asthma

and COPD (33).

Wittmann and colleagues investigated the effects of EOs on mucous membrane ciliary movement, bronchospasmolytic (bronchodilation), and secretolytic (mucus-thinning) properties. The findings suggest that EOs may have positive effects on the respiratory system by improving ciliary movement, which aids in clearing mucus from the airways. Additionally, the bronchospasmolytic and secretolytic properties of EOs may help relax and open the airways, facilitating easier breathing and reducing mucus congestion. These studies provide evidence of the potential therapeutic effects of essential oils in respiratory conditions. Nevertheless, it is crucial to acknowledge that additional research is necessary to comprehensively grasp the mechanisms of action, optimal formulations, and dosages, as well as the long-term safety and efficacy of essential oils in these specific contexts (78).

Conclusion

The literature survey highlights the versatility of *Lamiaceae* species and their EOs in the treatment of respiratory tract infections. These plants are rich in terpenoids, flavonoids, and other phytochemicals that exhibit anti-inflammatory, antimicrobial, and antioxidant properties. Studies have shown the potential of EOs and terpenes in managing respiratory conditions like asthma and COPD by improving control, preventing exacerbations, enhancing ciliary movement, and alleviating bronchospasm and mucus congestion. The use of natural products like EOs and terpenes aligns with the growing interest in alternative and sustainable approaches to drug development. Their diverse properties and potential therapeutic benefits make them promising candidates for further research and development in the field of respiratory health. While more research, especially human trials, is needed to fully understand the potential benefits of *Lamiaceae* plants for respiratory diseases, there is evidence suggesting their therapeutic potential. However, it is important to note that these plants should not be used as a substitute for conventional medical treatment and should be used under the guidance of a healthcare professional.

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Authors' contributions

Jyotirmayee Lenka: Writing - original draft, review & editing. Snehalata Khuntia: Writing - review & editing. Nikita Panda: review & editing. Basudeba Kar: Conceptualization, Supervision, Suprava Sahoo: Conceptualization, Supervision, Writing - review & editing.

Compliance with ethical standards

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