The Healing Breath: Essential Oils and their Impact on Respiratory Infections

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Abstract

Respiratory infections, from relatively mild colds to severe illnesses such as pneumonia and chronic obstructive pulmonary disease (COPD), place a significant burden on global health, especially in low- and middle-income countries. Conventional treatments, often involving antibiotics and corticosteroids, also carry side effects and antimicrobial resistance, requiring alternative therapies. Essential oils (EOs) obtained from aromatic plants have appeared as promising natural remedies due to their antimicrobial, anti-inflammatory, and immunomodulatory activities. Key bioactive compounds in EOs include terpenes, phenols, and aldehydes, responsible for various medicinal properties, which range from controlling pathogens to decreasing inflammation and increasing responses of the immune system. Well-known examples of such bioactivity are thymol and carvacrol of thyme oil, 1,8-cineole from eucalyptus oil, and menthol from peppermint oil. Multiple routes of application for EOs exist, including inhalation, topical application, and oral administration, providing variability for treating infections on both the upper and lower respiratory tracts. Although EOs hold much promise, safety considerations relating to the right dosage, formulation, and intersubject variability still play a critical role in their effective use. Understanding and surveying how traditional knowledge merges with scientific evidence, this chapter further discusses therapeutic potential as followed from mechanisms of action and practical applications.

Keywords: Essential oils, Respiratory infections, Antibiotics, Corticosteroids, Antimicrobial resistance

Cite this Article as: Sultan R, Jabbar M, Anjum A, Ashfaq MM, Khan AY, Mehmood S, Arif A, Bahar E, and Ali S, 2025. Healing breath: essential oils and their impact on respiratory infections. In: Khan A, Hussain R, Tahir S and Ghafoor N (eds), Medicinal Plants and Aromatics: A Holistic Health Perspective. Unique Scientific Publishers, Faisalabad, Pakistan, pp: 135-141. https://doi.org/10.47278/book.HH/2025.20

A Publication of Unique Scientific Publishers

Chapter No: 25-021

Received: 12-Feb-2025
Revised: 25-Apr-2025
Accepted: 21-May-2025

Introduction

Traditionally, the most common diseases globally have been respiratory infections (Cock & Van Vuuren, 2022). Every year, millions of people fall victim to these infections that range from mild colds and seasonal flu to serious diseases including pneumonia, tuberculosis, and COPD (Martin, 2011). It therefore represents a whole range of diseases which affect the entire respiratory system ranging from the upper to the lower conducting airways which supply the entire body with oxygen (Michael Jaeger et al., 2019). Apart from causing immense distress to the patients, respiratory infections pose an enormous challenge to healthcare infrastructures all over the world due to their high prevalence, risk of complications, and economic burden (Kumar et al., 2024).

The upper respiratory tract infections, which include common cold, sinusitis, pharyngitis, and laryngitis, are a collection of illnesses (Levy et al., 1983). The conditions affect the nasal passages, sinuses, and throat. They are normally self-limited but contribute a lot to absenteeism from work and school and, therefore, have a high productivity loss (Dicpinigaitis et al., 2015). On the other hand, lower respiratory tract infections (LRTIs), which include bronchitis, bronchiolitis, and pneumonia, are more likely to be more severe and often require medical attention, especially in high-risk populations such as children, the elderly, and immunocompromised patients (Pattemore & Jennings, 2009).

Respiratory infections are an important cause of morbidity and mortality in all parts of the world (Saleri & Ryan, 2019). According to the World Health Organization (WHO), it is one of the leading causes of death worldwide, especially among the low- and middle-income countries with the most limited medical resources (Ezzati et al., 2018). Other than causing acute illnesses, respiratory infections can worsen chronic diseases, such as asthma and COPD, thereby leading to the degradation of quality of life for millions (Mathur & Singh, 2024).

The treatment of respiratory infections up to the present time has remained dependent upon a class of drugs such as antibiotics, antiviral agents, and corticosteroids (Chellappan et al., 2022). This treatment has been satisfactory on most counts, but it presents serious problems.

Overuse and misuse of antibiotics have enabled the development and spread of drug-resistant strains of germs that pose a formidable challenge to public health (Ma & Poma, 2025). However, often, the side effects of the corticosteroids as well as other drugs prove to be a stumbling block in the long-term usage of these drugs (Harirforoosh et al., 2013). These problems led to the quest for other safer and effective therapies, and it is in this area that natural remedies have demonstrated promise.

Among the natural remedies considered, EOs have attracted considerable attention because of their potential therapeutic benefits (Baptista-Silva et al., 2020). These are liquids with concentrated volatile compounds derived from aromatic plants through steam distillation, cold pressing, and solvent extraction, contributing to their fragrance and biological activity (Capuzzo et al., 2013). These EOs have been used for ages in traditional medicine systems across cultures, including Ayurveda, Traditional Chinese Medicine (TCM), and European herbal practices like peppermint, rosemary, and Cinnamon Oil (Pan et al., 2014). Historical texts and ancient manuscripts often document their use in treating respiratory ailments, among other conditions.

There are many reasons for the growing interest in EOs. Of course, a naturalist approach toward health and wellness has fueled interest in plant-based treatments. General consumer interest has been rising lately in sustainable remedies that do not harm the environment, and people tend to consider EOs favorable to this. The history of scientific discovery has improved our knowledge of the bioactive constituents present in EOs and how these are responsible for various modes of action, thus validating much of traditional role (Angane et al., 2022). The versatility of EOs (e.g., peppermint, Eucalyptus, Lemon, and Rosemary EOs) which can be used in various forms, such as inhalations, topical applications, and even oral formulations, has made them more appealing as complementary therapy (Baptista-Silva et al., 2020).

The use of EOs for the treatment of respiratory infections is quite promising as it fights off the germs and reduces inflammation that may further support the immune system. These EOs possess a mix of plant chemicals including terpenes, phenols, aldehydes, ketones, and esters which collectively confer the health benefits (Siddiqui et al., 2024). For example, thyme oil has been found to consist of two main phenolic constituents: thymol and carvacrol. Besides the broad spectrum of activities towards microorganisms that include bacteria, viruses, and fungi, 1,8-cineole in eucalyptus oil, as well as menthol in peppermint oil, is responsible for decongestant and expectorant effects, respectively; therefore, useful in relieving the symptomatology of respiratory congestion (Jabbar et al., 2024).

EOs have powerful antimicrobial properties that can fight respiratory infections. In the lab, various microorganisms that cause breathing infections, among them, *Streptococcus pneumoniae*, *Haemophilus influenzae*, and several viruses that cause influenza are sensitive to essential oils (Leigh-de Rapper & van Vuuren, 2020). EOs break the membranes of germ cells, inhibit the enzymatic activities, and hinder the replication of the genetic material, leading to the death of the germs (Jugreet et al., 2020). Also, EOs can inhibit biofilms, which are protective layers formed by groups of microbes. This provides an added advantage in handling stubborn infections that do not respond to conventional treatments (Barman et al., 2024).

Besides their direct antimicrobial properties, EOs also regulate inflammatory events related to the pathogenesis of respiratory infections (Horváth & Ács, 2015). Inflammation is an essential part of immune responses to invading pathogens, although overproduction of inflammatory mediators may cause damage to tissues and worsen symptoms (Bennett et al., 2018). *Lavandula angustifolia* and *Matricaria chamomilla* are a few of the EOs, which have the capability to inhibit the release of pro-inflammatory cytokines like IL-6 and TNF-α. This prevents inflammation and reduces the pain but, at the same time, it helps in the healing process of the injury (Anyiam et al., 2023).

Important respiratory health effects linked to EOs include their implications on the immunity system (Fung et al., 2021). Researchers have identified essential oils in enhancing the level of activity between immune cells - macrophage and natural killer (NK) cells, significantly involved in recognizing and eliminating various pathogens (Grazul et al., 2023). To illustrate, boswellia (*Boswellia carterii*) and *Syzygium aromaticum* have illustrated immunomodulatory effects such that they produce a balance, ensuring effective cleaning of pathogens rather than causing further inflammation (Tanasă et al., 2024).

The variety of applications of EOs in the management of respiratory infections ranges from applying aromatherapy to inhaling the dispersed compounds into the air using diffusers. Such a method increases the direct introduction of volatile substances into the affected segments of the respiratory tract, which directly increases their reduction by quickly relieving discomforts caused by nasal congestion and loss of breathing power (Al-Harrasi et al., 2022). Another method of topical application is popular where the diluted peppermint EOs are rubbed on the chest, back, or soles of the feet. It allows the combination of advantages for local action with systemic absorption through the skin. The other rather less commonly used technique that targets systemic infections involves oral administration, although the professionals can guide that (Sartelli et al., 2018).

Although the therapeutic ability of EOs is high, their use involves careful concern of safety and value (Baptista-Silva et al., 2020). EOs are highly concentrated substances, so improper use can lead to adverse effects, such as skin irritation, allergic reactions (Wojtunik-Kulesza, 2022). For instance, oils with a high concentration of menthol must be used carefully, especially on children, because in large amounts, they can cause respiratory distress if inhaled (Manoguerra et al., 2006). Furthermore, drug-drug interactions and inter-individual variability must be considered to have the drugs applied safely and effectively (Langmia et al., 2021).

In this chapter, deeper research is conducted on the potential of EOs in alleviating respiratory infections. To focus on their antimicrobial, anti-inflammatory, and immunomodulatory effects, key EOs that have proven efficacy are identified, mechanisms of action are discussed, and practical guidance given regarding application. This chapter integrates scientific evidence with traditional knowledge to provide a comprehensive understanding of how EOs can be used as a valuable tool in the management of respiratory infections. Continued research and education may place EOs increasingly alongside conventional medical approaches, offering a natural and holistic pathway to respiratory health.

Respiratory Infections: An Overview

Respiratory infections are a great concern in health worldwide and fall into two main categories: the URTIs and LRTIs (Hothan et al., 2022). Such categorization makes it easier to understand the kind of anatomical area affected by the infection. URTI involves the nasal passages, pharynx, and sinuses and includes such conditions as common cold, sinusitis, pharyngitis, and laryngitis (Guibas & Papadopoulos, 2017). The

former infections, usually mild and self-limiting though, can certainly cause a considerable amount of discomfiture and interfere with daily activities, whereas LRTIs affect lungs and airways, causing major illnesses like bronchitis and bronchiolitis and serious pneumonia (Douros & Everard, 2020). Those infections often endanger the health particularly of vulnerable patients, such as young children and the elderly as well as any patient with serious pre-existing or compromised immune deficiencies.

Several different types of causative pathogens for respiratory infections, most commonly including viruses and bacteria, have been identified (Charlton et al., 2018). Some of the main viral pathogens for URTIs include influenza viruses, rhinoviruses, , and coronaviruses, whereas some bacterial pathogens such as *Streptococcus pneumoniae*, *Haemophilus influenzae*, *Mycoplasma pneumoniae*, and *Bordetella pertussis*, may be involved with pneumonia and whooping cough, as the more dangerous types of infection. It is not rare for mixed infections with both viruses and bacteria to complicate diagnosis and treatment (Ginocchio, 2016).

The clinical manifestations of respiratory infections, depending on the specific pathogen, the site of infection, and the individual's immune response, can vary widely (Braciale et al., 2012). They commonly include cough, sore throat, nasal congestion, runny nose, fever, fatigue, and difficulty in breathing (Tristram, 2019). Some patients may experience more complicated presentations with chest pain, wheezing, and hypoxemia in LRTIs and may call for immediate medical attention (Liapikou & Torres, 2016). Secondary complications can also occur with respiratory infections such as sinus infections, ear infections, and exacerbations of chronic conditions like asthma and COPD (Leigh et al., 2021).

The main approach to treating respiratory infections is pharmacotherapy. For example, oseltamivir against influenza will target a form of viral infection and antibiotics will deal with a case of bacterial infection (Świerczyńska et al., 2022). Some cases may also have corticosteroids and bronchodilators to help curb inflammation and function of the airway better (Cutrera et al., 2017). However, this widespread use of these drugs has brought about the challenges of the development of antimicrobial resistance (AMR), now a major public health threat (Ferri et al., 2017). The misuse and overuse of antibiotics have led to the emergence of resistant bacteria, thereby complicating the treatment of respiratory infections (Terreni et al., 2021). All these have encouraged attention in looking for alternative and complementary treatments to treat respiratory infections.

One of the promising alternatives is the use of EOs resulting from aromatic plants and used for times in traditional medicine (Giannenas et al., 2020). Science related to EOs has recently started to attention because of high performances of analytical techniques and the increasing results proving their therapeutic potential (Sadgrove & Jones, 2015). EOs are highly concentrated, volatile, and aromatic compounds obtained through various methods such as steam distillation, cold pressing, or solvent extraction (Stratakos & Koidis, 2016).

These compounds are primarily classified into five: terpenes, phenols, aldehydes, ketones, and esters. The overall combination of all these produces numerous biological activities synergistically (Dhifi et al., 2016). For instance, the limonene, pinene, and camphene terpenes possess the ability to function as antimicrobial, anti-inflammatory, and bronchodilators, thus contributing significantly to their applications in improving respiratory health (Siddiqui et al., 2024). The phenolic compounds thymol, eugenol, and carvacrol show strong antibacterial, antifungal, and antiviral activities to prevent a great many pathogens related to respiratory infections. Aldehydes-include cinnamaldehyde can have both antimicrobial effects and palliative action on mucous membranes.

Scientific research has proved the antimicrobial activity of EOs against respiratory pathogens (Fabio et al., 2007). For example, a combination of 1,8-cineole and eucalyptus oil displayed significant action against the bacterium *Streptococcus pneumoniae* and *Haemophilus influenzae* as well as the viruses of influenza (Hoch et al., 2023). Another such combination is the terpinen-4-ol-rich tea tree EOs. This oil is effective against many bacterial and viral pathogens, including drug-resistant types. The mechanisms that clarify the antimicrobial effects of EOs are microbial cell membrane disruption, inhibition of enzymatic activities, and interfering with nucleic acid synthesis, all of which constrain pathogen survival (Angane et al., 2022).

Furthermore, to antimicrobial activities, EOs have anti-inflammatory and immunomodulatory properties that play a serious part in the management of respiratory infections (Asif et al., 2020). The body responds to an infection with inflammation when chronic, leads to damage to respiratory tissues and enhances symptoms (Bennett et al., 2018). The EOs such as lavender, *Lavandula angustifolia*, and chamomile, *Matricaria chamomilla*, have compounds that prevent the synthesis of pro-inflammatory mediators, including cytokines and prostaglandins. This anti-inflammatory action supports decrease symptoms such as swelling, pain, and airway obstruction, promoting faster recovery and better respiratory function (Pandur et al., 2021).

EOs also control immune responses to increase the body's ability to fight infections (Peterfalvi et al., 2019). Some of these EOs improve the action of immune cells such as macrophages, neutrophils, and natural killer (NK) cells, which are very significant in the identification and destruction of pathogens (Alhazmi et al., 2021). For example, frankincense (*Boswellia carterii*) and clove (*Syzygium aromaticum*) oils have been described to increase phagocytic action and improve immune surveillance, thereby causing their overall therapeutic efficiency (Di Martile et al., 2020).

Mechanisms of Action of Essential Oils

Essential oil plants have shown high interest in therapeutics for respiratory infections and, in modern health care and practices, contribute highly to them due to unique chemical composition capable of producing extensive biological effects and impacts (Sadgrove & Jones, 2015; Boukhatem & Setzer, 2020). The remainder of this study investigates in detail the ways in which EOs work together with their various applications and the clinical relevance thereof to respiratory infection.

Antimicrobial Properties

The broad spectrum of antimicrobial activity that has been attributed to essential oils ranges from bacteria and viruses to fungi.

The most significant activity has been shown by tea tree oil (*Melaleuca alternifolia*) and eucalyptus oil (Eucalyptus globulus) against the respiratory pathogen (Iseppi et al., 2023). These EOs induce membranolytic activity, resulting in increased permeability, leakage of contents from the interior of cells, and eventual cell lysis and death (Liu et al., 2024).

Compounds identified in thymol and oregano, isolated from the respective oils from thyme and oregano, for example, exhibit potent bactericidal activity specifically against multidrug-resistant pathogens including MRSA (Fimbres-García et al., 2022). The compounds disrupt the lipid bilayer structure of the bacterial membrane and functionally interact with critical protein components that support microbial survival mechanisms (Hurdle et al., 2011).

Anti-inflammatory Effects

The symptoms become worse, and the recovery time is extended; therefore, inflammation plays a major role in the pathology of respiratory infections (Chalmers et al., 2019). Pro-inflammatory cytokines like interleukin-6 (IL-6) and tumor necrosis alpha (TNF-α) are suppressed through the bioactive compounds present in essential oils, such as lavender (*Lavandula angustifolia*) and chamomile (*Matricaria chamomilla*) (Tyagi et al., 2020). This suppressive action reduces tissue damage and lessens swelling and pain. Most essential oils contain antioxidant compounds that have a neutralizing effect on oxidative stress, one of the primary mediators of inflammation. For instance, linalool and eugenol reduce oxidative damage through their scavenging effects on ROS (Zhao et al., 2023).

Mucolytic and Expectorant Properties

Respiratory infections often cause mucus to accumulate in the airways, leading to congestion and breathing problems. Eucalyptus and peppermint (*Mentha piperita*) are among the most recognized essential oils with mucolytic properties (Misra et al., 2024). The major component of eucalyptus oil, eucalyptol, or 1,8-cineole, reduces the viscosity of mucus, thereby making it easier to clear from the respiratory tract (Chandorkar et al., 2021). The cooling effect of menthol in peppermint oil calms irritated airways and enhances airflow, thus alleviating nasal congestion and shortness of breath (Keifer et al., 2008).

Immunomodulatory Effects

Another important mechanism of essential oils is the boosting of the immune system's ability to fight infections (Tariq et al., 2019). Frankincense (*Boswellia carterii*) and clove (*Syzygium aromaticum*) oils are known to enhance immune function (Peterfalvi et al., 2019). These oils stimulate phagocytosis, the process by which immune cells engulf and destroy pathogens. These key oils increase NK cell activity as a part of the innate immunity system. They speed up pathogen removal, making infections that are not that severe (Sharifi-Rad et al., 2017).

Application of Essential Oils in Respiratory Infections

Essential oils can be administered through various methods, each tailored to maximize therapeutic efficacy.

1. Inhalation Therapy

Inhalation is one of the most used and efficient delivery methods to allow essential oils into the respiratory system (Cimino et al., 2021). When a few drops of an EO are added to boiling water, a person inhales its steam and brings volatile compounds right into the airways (Dunning, 2006). It especially works well with the use of eucalyptus and peppermint for treating congestion. Using a diffuser disperses the molecules of EOs into the air, thereby providing continuous exposure to therapeutic compounds (Bunse et al., 2022). Lavender and frankincense oils are often used in this manner for their calming and anti-inflammatory effects (Ali et al., 2015).

2. Topical Application

The skin can be directly applied with essential oils diluted with carrier oils such as coconut or almond oil (Kreidel & Jhaveri, 2021). Oils like eucalyptus and peppermint are commonly found in vapor rubs, which are used to help relieve congestion and improve breathing (Beerling et al., 2002). Topical applications with massage can enhance blood circulation and allow for the absorption of EOs into the bloodstream.

3. Oral Administration

Oral administration of essential oils is rare but can be useful for LRTIs (Wenzler et al., 2016). Oregano and thyme are examples of EOs ingested in regulated amounts by the healthcare provider as a treatment for serious infections (Osaili et al., 2023). Because of the danger of toxicity, oral administration is always done cautiously and under the guidance of healthcare professionals.

In conclusion, EOs are promising multifaceted tools for managing respiratory infections that offer antimicrobial, anti-inflammatory, and immune-boosting properties. Incorporation into conventional medicine can revolutionize respiratory care.

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