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Indian Knowledge System and Respiratory Disease Management

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ABSTRACT

Traditional therapies and medicinal herbs have long been integral to the Indian Knowledge System (IKS) in managing respiratory diseases. Indigenous systems such as Ayurveda, Siddha, and Unani have historically utilized plant-based interventions to treat conditions including asthma, bronchitis, chronic cough, and chronic obstructive pulmonary disease (COPD). Many of these botanicals demonstrate pharmacological activities such as anti-inflammatory, antimicrobial, antioxidant, and bronchodilatory effects that contribute to improved respiratory pulmonary function. Therapeutic practices, including Nasya, Vamana, steam inhalation, *Pranayama*, and yoga, are often employed in conjunction with medicinal plants such as *Ocimum sanctum* (Tulsi), *Adhatoda vasica* (Vasaka), *Piper longum* (Pippali), *Curcuma longa* (Haridra), and *Glycyrrhiza glabra* (Yashtimadhu). These traditional remedies and phytocompounds exert their effects through diverse mechanisms, including modulation of signaling pathways, regulation of gene expression, and alteration of enzymatic activity, thereby influencing multiple physiological processes. Scientific exploration of these mechanisms is crucial not only to validate traditional knowledge but also to facilitate the discovery of novel therapeutics with broad-spectrum efficacy, to address drug resistance, and to develop safer and more effective treatments. Furthermore, understanding synergistic interactions among phytocompounds can help minimize side effects and contribute to sustainable, integrative healthcare practices.

Keywords: Indian Knowledge System (IKS), medicinal plants, Ayurveda, respiratory diseases, asthma, herbal remedies, traditional medicine, lung**.**

INTRODUCTION

Respiratory diseases are among the leading public health challenges globally, with conditions such as asthma, bronchitis, chronic cough, and chronic obstructive pulmonary disease (COPD) affecting millions of individuals annually. According to the Global Burden of Disease (GBD) report, chronic respiratory diseases account for approximately 10.9% of the total disease burden in India, which includes some of the highest global prevalence rates of COPD and asthma. Notably, India contributes to nearly 20% of the world's asthma-related deaths. The World Health Organization (WHO) estimates that respiratory disorders are responsible for 7–8% of global mortality each year.

Despite advancements in modern medicine, the management of respiratory diseases remains a major concern, particularly due to the side effects of conventional drugs, high treatment costs, and limited accessibility to healthcare facilities in rural and economically disadvantaged regions. These challenges highlight the relevance of traditional healthcare systems that emphasize natural and holistic approaches to disease management.

India possesses a rich heritage of traditional medical systems, including Ayurveda, Siddha, Unani, and various indigenous folk practices. These systems, practised for thousands of years, emphasize preventive care, detoxification, and the therapeutic use of medicinal plants. In the context of respiratory disorders, numerous herbs are recognized for their anti-inflammatory, bronchodilatory, immunomodulatory, and antimicrobial properties, providing symptomatic relief and improving pulmonary health without significant adverse effects.

The Indian Knowledge System (IKS) refers to an indigenous framework of knowledge that conceptualizes health as a dynamic equilibrium between the body, mind, and environment, forming the philosophical basis of Ayurveda, Siddha, and Unani, while also encompassing diverse folk healing traditions. Within this framework, respiratory diseases are primarily attributed to imbalances in *Vata* and *Kapha*, leading to obstruction of the airways, often triggered by environmental pollutants, smoking, poor dietary habits, seasonal changes, and reduced immunity. The Indian Knowledge System (IKS) approaches aim to restore physiological balance through the application of traditional therapies such as Nasya and Vamana, respiratory practices like Pranayama and yoga, along with the use of plant-based herbal formulations. This review explores the role of medicinal herbs within the Indian traditional systems for the prevention and management of respiratory diseases, while also examining their potential integration with modern therapeutic strategies.

Traditional Therapies for the Management of Respiratory Diseases

The Indian systems of medicine employ specialized therapies for the management of respiratory disorders. These include therapies such as Nasya (nasal administration of medicated oils), Vamana (therapeutic emesis), steam inhalation, and respiratory exercises like *Pranayama* and yoga.

These interventions are often combined with the use of herbal formulations to enhance lung function, reduce inflammation, expel mucus, and strengthen the immune system. By addressing both the symptoms and the root causes of respiratory imbalances, these therapies contribute to holistic and sustainable health outcomes.

Nasya (nasal administration of medicated oils/powder)

Nasya is a vital component of Panchakarma, the five-fold detoxification therapy in Ayurveda, and is specifically designed for the purification and treatment of the head and neck region. It involves the administration of medicated oils, powders, or herbal extracts through the nasal cavity considered the "gateway to the head" (Shiras) (Charaka Samhita, Sutrasthana 5/56). This ancient therapeutic practice has been employed for centuries to manage a variety of upper respiratory and neurological disorders.

The primary objective of Panchakarma is to eliminate accumulated doshas (bioenergetic imbalances) via the most appropriate and accessible routes. In the case of Nasya, the nasal cavity provides direct access to the cranial region, making it an ideal route for administering therapies aimed at detoxifying and revitalizing the upper body (Vagbhata, Ashtanga Hridaya, Sutrasthana 20).

Commonly used medicated oils in *Nasya* include Shadbindu Taila and Anu Taila, while herbal powders such as Katukaa (*Picrorhiza kurroa*), Katabhi, and Katphala (*Myrica esculenta*) are employed in specific procedures where the substances are gently insufflated into the nostrils. These interventions facilitate the expulsion of excess Kapha dosha and mucus from the sinuses and nasal passages, thereby relieving congestion and enhancing respiratory function (Chauhan et al., 2022).

From a physiological perspective, *Nasya* therapy stimulates the olfactory nerve endings and receptors located in the nasal mucosa. These receptors interact with the pharmacologically active constituents of the administered oils or powders, transmitting signals to specific brain regions such as the limbic system and hypothalamus. This neural activation influences both physiological and psychological responses, contributing to the therapeutic effects of *Nasya*.

In modern pharmacological terms, nasal and intranasal drug delivery have emerged as reliable and non-invasive strategies to circumvent the blood–brain barrier (BBB), allowing direct transport of therapeutic agents to the central nervous system. This route offers several pharmacokinetic advantages, including a large absorptive surface area, rapid systemic and cerebral uptake, and the avoidance of hepatic first-pass metabolism. Extensive evidence from preclinical and clinical studies supports its efficacy, with various drugs and novel formulations demonstrating promising outcomes (Mittal et al., 2013; Kumar, 2017).

Thus, *Nasya* not only purifies the nasal and sinus passages but also enhances respiratory function, providing relief from conditions such as sinusitis, allergic rhinitis, and other respiratory ailments. As a targeted and holistic therapeutic intervention, *Nasya* exemplifies an integrative approach that bridges traditional Ayurvedic principles with modern concepts of nasal drug delivery and neuropharmacology.

Vamana Therapy in Ayurveda for Respiratory Disorders:

Vamana is one of the primary procedures in Panchakarma, the classical Ayurvedic detoxification regimen, employed under Shodhana Chikitsa (purificatory therapy) to eliminate excess or vitiated Kapha dosha through induced emesis. This therapy primarily targets disorders associated with Kapha accumulation in the upper gastrointestinal and respiratory tract, using the oral route as the expulsion pathway (Charaka Samhita, Sutrasthana 15).

The procedure involves preparatory steps (Purva Karma) such as internal oleation (*Snehapana*) and sudation (Swedana), followed by the main emesis-inducing procedure (Pradhana Karma), and concluded with post-care management (Paschat Karma). Vamana plays a pivotal role in alleviating symptoms of respiratory conditions like bronchial asthma (*Tamaka Shwasa*), chronic bronchitis (Kaphaja Kasa), and allergic rhinitis (Pratishaya) by cleansing the upper channels (Urdhwa Srotas) and restoring doshic balance (Ashtanga Hridaya, Sutrasthana 20).

Asthma can be compared to Tamaka Shwasa, which is described in Ayurveda as a disease caused by an imbalance of Vata and Kapha doshas. Vamana Karma (therapeutic vomiting) is considered the best treatment for removing excess Kapha and can be used to manage allergic asthma.

In the study, patients were assessed based on the symptoms of Tamaka Shwasa and allergic asthma, along with blood tests measuring serum IgE and absolute eosinophil count (AEC) before treatment, after treatment, and during the follow-up period.The findings showed that Vamana Karma significantly reduced symptoms such as shortness of breath (Shwasa Krichrata), cough (Kasa), and wheezing (Gurghuraka). There was also a marked decrease in IgE and AEC levels. Overall, Vamana Karma proved helpful in removing the vitiated dosha*s* from the body, reducing symptoms, and preventing the recurrence of asthma.(Yadahalli et al., 2024).

The emetic substances used during *Vamana* are selected based on the individual's *Prakriti* (constitution), disease condition, and severity. Common herbs include: Madanaphala (*Randia dumetorum*), emetic nut used in classical formulation,

Yashtimadhu Kwatha(*Glycyrrhiza glabra*), Kutaja (*Holarrhena antidysenterica*), Vacha (*Acorus calamus*) (Dp & H, 2025; Pandhare & Deshpande, 2021; Thawkar et al., 2024; Kulkarni et al., 2020).

These herbs help liquefy and mobilize Kapha and Ama (toxins), particularly from the stomach and lungs. The induced emesis aids in the expulsion of this accumulated mucus, which contributes to improved lung function and symptomatic relief in chronic respiratory diseases (Campbell, 2025). From a modern physiological perspective, it is proposed that Vamana-induced emesis may activate the sympathetic nervous system. This can lead to the release of catecholamines such as adrenaline (epinephrine) and noradrenaline (norepinephrine), which bind to β_2-adrenergic receptors (β_2ARs) in bronchial smooth muscle. The resultant bronchodilation facilitates easier breathing and may explain the rapid symptomatic improvement in patients with obstructive airway diseases (Saini et al., 2021).

Therefore, *Vamana* offers a holistic and mechanistically plausible approach for managing Kapha-predominant respiratory disorders, providing both detoxification and symptomatic relief through natural means.

Steam Inhalation in the Management of Respiratory Disorders:

Steam inhalation is a traditional, non-invasive, and widely practised home remedy used to relieve symptoms associated with various respiratory diseases. Although not a curative treatment, it plays a supportive role in symptom management and accelerates recovery by enhancing the body's natural defense mechanisms (Eccles, 2009).

The therapeutic effects of steam inhalation are achieved through a combination of physical**,** physiological**,** and mild pharmacological mechanisms**.** The inhalation of warm, moist air contributes to: Mucus thinning (mucolysis)**,** facilitating easier expectoration, Improved mucociliary clearance, enhancing the elimination of pathogens and irritants, Airway muscle relaxation through mild bronchodilation, Reduction of nasal and bronchial inflammation, and increased local blood circulation**,** which supports tissue healing (Desrosiers et al., 1997; Keck et al., 2000)

While steam inhalation does not eliminate infections directly, it contributes to the symptomatic relief of conditions such as the common cold, bronchitis, allergic rhinitis, and mild asthma. The inclusion of medicinal herbs and essential oils—such as *Ocimum sanctum* (Tulsi), *Eucalyptus globulus* (eucalyptus oil), and *Cinnamomum camphora* (camphor)-enhances the effectiveness of steam inhalation due to their antimicrobial, anti-inflammatory, and decongestant properties (Nanda, 2015).

The volatile compounds of medicinal herbs interact with receptors in the olfactory mucosa, transmitting nerve impulses to the olfactory bulb and then to higher brain centers such as the hippocampus, influencing neural and physiological responses (Maggio et al., 2016). An *in vitro* study using the broth microdilution volatilization method revealed that volatile constituents of *Thymus vulgaris* possess strong antibacterial activity against respiratory pathogens. These findings highlight the potential of *T. vulgaris* volatile compounds for use in inhalation-based therapies, offering a natural approach for managing respiratory infections (Antih et al., 2022).

***Pranayama* and Yoga in the Management of Respiratory Disorders**:

Pranayama (controlled breathing exercises) and yoga are integral components of traditional Indian health systems and have been increasingly recognized in modern medicine for their therapeutic benefits in respiratory disorders. These practices emphasize the regulation of breath, physical postures (Asanas), and mental focus, which together contribute to the enhancement of pulmonary function, autonomic balance, and overall well-being (Sengupta, 2012).

Pranayama techniques such as *Nadi Shodhana* (alternate nostril breathing), *Bhramari* (humming breath), *Ujjayi* and *Kapalabhati* are especially effective in improving respiratory efficiency. These practices: Increase vital capacity and lung compliance**,** improve oxygen saturation and alveolar ventilation**,** reduce bronchial reactivity**,** balance sympathetic and parasympathetic nervous system activity, contributing to bronchodilation and reduced respiratory rate (Joshi et al., 1992; Pal et al., 2014).

Yoga postures (Asanas) such as Bhujangasana (cobra pose), Dhanurasana (bow pose), and Ardha Matsyendrasana (spinal twist) promote thoracic mobility, enhance diaphragmatic efficiency, and improve chest wall compliance, thereby contributing to the mechanical optimization of pulmonary function (Bhagel & Saha, 2021).

These physical practices also help alleviate the sensation of breathlessness and significantly enhance exercise tolerance and functional capacity in individuals with chronic obstructive pulmonary disease (COPD) and bronchial asthma. Donesky-Cuenco et al., (2009) demonstrate that yoga and pranayama interventions contribute to significant improvements in respiratory function, symptom management, and overall quality of life in individuals with asthma and chronic obstructive pulmonary disease (COPD). These interventions have been shown to improve forced expiratory volume in one second (FEV_1) and peak expiratory flow rate (PEFR), reduce the need for rescue medications, and enhance overall quality of life and reduced anxiety associated with breathlessness (Khanam et al., 1996; Donesky-Cuenco et al., 2009).Furthermore, the anti-inflammatory and immunomodulatory properties of pranayama may help alleviate airway inflammation, contributing to sustained improvements in respiratory health.

Medicinal Herbs and Their Applications in Respiratory Disease Management

Medicinal herbs have long been integral to Indian traditional medicine systems, such as Ayurveda Siddha and Unani. Numerous plant species historically employed for respiratory ailments continue to be used in modern herbal formulations. These plants contain bioactive compounds with antimicrobial, anti-inflammatory, bronchodilatory, and mucolytic properties, which contribute to the management of respiratory tract infections and improvement of pulmonary function (Table 1).

Table 1: The most commonly used herbs in Indian systems for respiratory Diseases

Scientific Name	Common Name (Hindi)	Phyto-Compounds	Potential Benefits for Respiratory Health	Key Mechanisms
Acacia torta	Nikunjika	Saponins, tannins, steroids, and triterpenes (Batiha et al., 2022a)	Anti-inflammatory and Anti-oxidant Properties (Rao & Gurfinkel, 2000)	Inhibition of prostaglandin synthesis, suppressing T-Helper-1 pathway, (Girish et al., 2017a). Scavanging Free radical (Girish et al., 2017b).
Adhatoda vasica	Vasaka	Vascine, Vasicinone (Khandelwal et al., 2024)	Bronchodilatory effect, relaxes bronchial smooth and makes breathing easier (Singh, 2021)	Inhibition of 5-LOX Pathway (Nadkarni, 2002), Giménez-Bastida et al., 2021.Blocking of TRP1 Channel (Memon et al., 2023), Inhibition of Phosphodiesterase (Zohri& Zutshi, 2000)
Allium sativum	Garlic(Lahsun)	Allicin, and S-allyl cysteine (Ahmed et al., 2021)	Anti-inflammatory, and immunomodulatory properties, Anti-oxidant properties (Amagase, 2006; Bayan et al., 2014).	Inhibition of NF-κB Pathway(Arreola et al., 2015), (Sin et al., 2019), MAPK /PI3K-Akt Pathways (Batiha et al., 2020b). NrF2/HO-1 Pathway (Wang et al., 2021)
Curcuma longa	Turmaric (Haldi)	Curcumin (diferuloylmethane) (Patel et al., 2019)	Anti-inflammatory, and antioxidant properties (Gupta et al., 2012).	Inhibition of JAK -STAT P athway (Shaikh et al., 2020) , Inhibition of COX-1/ NF-κB Pathway (Budrmann et al., 2011), Inhibition of MAPK/ERK/JNK/p38 kinase Pathway (Yang et al., 2021)
Ephedra gerardiana	Somlata	Ephedrine (Kumar et al., 2023)	Bronchodilatory, Anti-inflammatory (Nazar et al., 2023)	Activation of beta-2 adrenergic receptors(Bosmann et al., 2012), PI3K/Akt/GSK3β signaling pathway (Zheng et al., 2013).
Glycyrrhiza glabra	Mulethi	Glycyrrhizin, Liquiritin, Isoliquiritigenin (Damle, 2014)	Anti-inflammatory, Immuno-modulatory, Anti-oxidant Properties (Bakr et al., 2022)	Lytic Pathway (Fujisawa et al., 2000),TLR4 Signaling Pathway (Fu et al., 2014), NF-κB/ERK/p38 Pathway (Kim et al., 2008),NrF2/HO-1 Signaling (Wang et al., 2015; Chen et al., 2023)
Ocimum sanctum	Holy Basil (Tulsi)	Eugenol, Orientin and Vicenin (Pradhan et al., 2022)	Anti-inflammatory and Antimicrobial properties, Anti-Oxidant Properties (Kumar et al., 2022)	Inhibition of NF-κB, COX-2 (Magalheas et al., 2010), Modulating Macro-phage activity (Barbosa-De-Oliveiera et al., 2023), Scavanging Free radical (Kelm et al., 2000)
Piper longum	Pippali	Piperine (Biswas et al., 2022).	Bronchodilator (Meghwal & Goswami, 2013)	Inhibition of NF-κB C/EBP, and AP-1 signaling (Lu et al., 2015),
Zingiber officinale	**Ginger**	Gingerols, shogaols, zingerone (Zhang et al., 2020)	Antioxidant, Anti-inflammatory, and Antimicrobial Properties(Mashhadi et al., 2013).	Inhibition of ERK and p38 MAPK – dependent pathways (Kim et al., 2009).Reduce inflammation through inhibition of cAMP and NF-κB pathway (Yocum et al., 2019)

***Acacia torta*:**

Acacia torta (commonly known as Twisted Acacia) is a climbing shrub traditionally used in various indigenous medicinal systems, including Ayurveda. It has been employed to treat a range of ailments, particularly respiratory disorders such as asthma, bronchitis, and chronic cough.Phytochemical investigations have shown that *Acacia torta* contains several bioactive constituents, including saponins, tannins, steroids, and triterpenes (Batiha et al., 2022a).These compounds exhibit diverse pharmacological properties, such as anti-inflammatory, antioxidant, and bronchodilatory activities, which may offer therapeutic benefits in the management of respiratory diseases (Rao & Gurfinkel, 2000).

The hydroalcoholic extract of *Acacia torta* has demonstrated significant anti-inflammatory activity in *in vivo* models, such as carrageenan-induced paw edema in rats. This effect is likely mediated through the inhibition of prostaglandin synthesis, a key pathway involved in the inflammatory response (Gabr et al., 2018). Moreover, *A. torta* appears to modulate immune function *in vivo* by suppressing the T-helper 1 (Th1) pathway, thereby reducing the production of pro-inflammatory cytokines, including interleukin-12 (IL-12) and interferon-gamma (IFN-γ) (Girish et al., 2017).

The anti-inflammatory action of *A. torta*, combined with its antioxidant potential, contributes to the reduction of oxidative stress, as its antioxidant constituents directly scavenge reactive oxygen species (ROS) and free radicals (Arulselvan et al., 2016). A recent study (2023) reported that the hydroalcoholic stem extract of *A. torta* exhibited potent antioxidant activity, with an IC_{50} value of 135.9 µg/mL in a DPPH free radical scavenging assay. This activity is attributed to its rich phytochemical composition, including saponins, steroids, triterpenes, and tannins, which are well known for their radical-scavenging and cytoprotective properties (Girish et al., 2017).

Adhatoda vasica:

sho (L.) Nees, commonly known as Malabar nut, is a well-documented medicinal plant in traditional systems of medicine such as Ayurveda and Unani. It has been extensively used in the treatment of respiratory tract disorders, including bronchitis, asthma, and chronic cough (Dhuley, 1999; Fathima et al., 2020).The plant's major bioactive alkaloids vasicine**,** vasicinone**,** and deoxyvasicine have been shown to possess potent bronchodilatory**,** anti-allergic**,** expectorant**,** andanti-inflammatory properties (Khandelwal et al., 2024; Singh, 2021). These compounds act by relaxing bronchial smooth muscles, reducing airway inflammation, and facilitating mucus clearance, making them effective in managing obstructive respiratory diseases.

Adhatoda vasica also exhibits potent antioxidant and immunomodulatory activities. Its phytoconstituents effectively scavenge oxygen- and nitrogen-derived free radicals through hydrogen atom or electron donation, transition metal chelation, activation of antioxidant enzymes, and inhibition of pro-oxidant enzymes such as oxidases (Gheware et al., 2021). These mechanisms collectively protect respiratory tissues from oxidative stress and damage caused by environmental pollutants and pathogenic infections. Furthermore, the anti-inflammatory effects of the alkaloids vasicine and vasicinone are attributed to their inhibitory actions on the cyclooxygenase (COX) and lipoxygenase (LOX) pathways, leading to reduced synthesis of pro-inflammatory mediators such as leukotrienes and prostaglandins (Nadkarni, 2002). Recent studies have shown that these alkaloids also block transient receptor potential ankyrin 1 (TRPA1) channels in an in vitro model of wood and biomass smoke particulate matter (WSPM)-induced human airway epithelial cell (AEC) injury. This blockade inhibits the release of inflammatory mediators, thereby protecting airway epithelial cells from damage and mitigating inflammation (Memon et al., 2023).A novel bronchodilator 6,7,8,9,10,12-hexahydro-azepino-[2,1-b] quinazolin-12-one (RLX) derived from vasicine, inhibits phosphodiesterase (PDE) activity in in vivo shows inhibition of mast cell degranulation and histamine release, with decreased PDE and lipoxygenase activities (Zohri & Zutshi, 2000).By modulating these molecular pathways, vasicine and vasicinone not only suppress inflammation but also promote relaxation of bronchial smooth muscles, resulting in bronchodilation, improved airway patency, and enhanced respiratory function (Shoaib, 2022; Giménez-Bastida et al., 2021).

Allium sativum:

Allium sativum L., commonly known as garlic (*lahsun*), is one of the most widely used culinary and medicinal plants across the world. It has a long history of use in traditional medicine for the prevention and treatment of various diseases, owing to its broad spectrum of biological activities. Garlic exhibits antioxidant, hypoglycemic, anti-inflammatory, antihyperlipidemic, anticancer, antimicrobial, and hepatoprotective properties (Amagase, 2006; Bayan et al., 2014).

The principal bioactive constituents responsible for the therapeutic potential of garlic are allicin, diallyl disulfide (DADS), diallyl trisulfide (DATS), ajoenes (E- and Z-isomers), and vinyldithiins (Ahmed et al., 2021). These organosulfur compounds are predominantly generated upon mechanical disruption of garlic tissue, wherein the stable precursor alliin (S-allylcysteine sulfoxide) undergoes enzymatic conversion by alliinase (Borlinghaus et al., 2014).

In the context of respiratory diseases such as asthma and bronchitis, garlic phytocompounds exert therapeutic effects by modulating key cellular signaling pathways, including NF-κB, MAPK, PI3K/AKT, and Nrf2 pathways (Batiha et al., 2020b). Allicin, the principal component, can covalently interact with thiol (-SH) groups in cysteine residues of regulatory proteins, thereby affecting transcriptional

regulation and inflammatory mediator production by modifying 332 proteins and stimulating IL-2 production.(Gruhlke et al., 2018). S-allyl cysteine suppresses the activation of the Nuclear Factor-kappa B (NF-κB) signaling pathway, a key regulator of inflammatory responses. Inhibition of this pathway leads to reduced expression of pro-inflammatory cytokines such as IL-1β, IL-6, IL-8, and TNF-α, which play crucial roles in airway inflammation and are significantly elevated in ovalbumin-induced allergic asthma models (Arreola et al., 2015; Shin et al., 2019).

In addition, S-allyl cysteine modulates the Mitogen-Activated Protein Kinase (MAPK) and Phosphoinositide 3-Kinase/Akt (PI3K-Akt) signaling pathways. The inhibition of these cascades contributes to decreased eosinophil infiltration and suppression of mucin overproduction in lipopolysaccharide (LPS)-induced Acute Respiratory Distress Syndrome (ARDS) models. By downregulating the expression of pro-inflammatory mediators (IL-6, TNF-α, CD86, and IL-12) and upregulating anti-inflammatory markers (IL-10, CD206, and TGF-β), S-allyl cysteine effectively attenuates bronchial inflammation and mucus hypersecretion (An et al., 2020).

Moreover, the antioxidant activity of S-allyl cysteine enhances the expression of detoxifying and cytoprotective genes through activation of the Nrf2/Heme Oxygenase-1 (HO-1) signaling pathway in bovine mammary epithelial cells (BMECs). This activation confers protection to respiratory epithelial cells against oxidative stress induced by environmental pollutants and infections (Wang et al., 2021).

Curcuma longa: *Curcuma longa* L., commonly known as turmeric (*Haldi*), is a perennial herb extensively used in traditional medicine systems such as Ayurveda, Siddha, Unani, and Traditional Chinese Medicine. Its therapeutic use dates back thousands of years, particularly across India and Southeast Asia (Chattopadhyay et al., 2004). Turmeric has long been valued for treating a wide array of conditions, including gastrointestinal ailments**,** skin disorders**,** wound healing**,** and particularly inflammatory diseases. The primary bioactive component of turmeric is curcumin, a polyphenolic compound that belongs to the class of curcuminoids. Curcumin is well-documented for its anti-inflammatory**,** antioxidant**,** antimicrobial, and anticancer properties (Patel et al., 2019: Gupta et al., 2012). Its antioxidant capacity stems from its ability to scavenge reactive oxygen and nitrogen species (ROS and RNS), which are often implicated in oxidative stress and inflammation-related tissue damage (Menon & Sudheer, 2007).

In respiratory diseases such as asthma, bronchitis, and chronic obstructive pulmonary disease (COPD), curcumin exerts significant protective effects by modulating key molecular signaling pathways. These include peroxisome proliferator-activated receptor gamma (PPAR-γ), nuclear factor-kappa B (NF-κB), Toll-like receptor 4 (TLR4), cyclooxygenase-2 (COX-2), and the cannabinoid receptor CB2 (Hewlings & Kalman, 2017; Shahid et al., 2019). NF-κB and COX-2 are central mediators of inflammation that are frequently upregulated in chronic respiratory disorders. Curcumin primarily suppresses the NF-κB signaling pathway by preventing the degradation of its inhibitory protein IκBα and blocking the nuclear translocation of the p65 subunit. This results in the downregulation of pro-inflammatory mediators, including COX-2, which plays a crucial role in prostaglandin synthesis and inflammatory responses. Furthermore, curcumin directly inhibits COX-2 enzymatic activity, thereby further reducing the production of inflammatory mediators, as demonstrated in in vitro models using human tenocytes (Budrmann et al., 2011).

In addition to its effects on NF-κB, curcumin acts as a potent scavenger of reactive oxygen species (ROS), which are known to initiate and amplify inflammatory signaling. By neutralizing ROS, curcumin prevents oxidative damage and disrupts redox-sensitive inflammatory cascades. Moreover, curcumin modulates other critical signaling pathways such as the Janus Kinase/Signal Transducer and Activator of Transcription (JAK/STAT) pathway in vivo (Shaikh et al., 2020). Its protective effects against inflammation and oxidative stress have also been linked to the regulation of the MAPK and NF-κB pathways in BEAS-2B human bronchial epithelial cells exposed to PM2.5-induced COPD. The MAPK pathway, which includes ERK, JNK, and p38 kinases, is a key regulator of cellular inflammation. Studies have shown that curcumin inhibits ERK phosphorylation, leading to decreased inflammatory responses in bronchial epithelial cells (Yang et al., 2021).

Furthermore, curcumin downregulates the expression of pro-inflammatory cytokines such as TNF-α, IL-1β, and IL-6. Through activation of PPAR-γ and suppression of TLR4, it alleviates airway inflammation and reduces airway hyperresponsiveness in asthma models. The CB2 receptor, which plays an important role in immune regulation, represents another novel target through which curcumin mitigates inflammatory cell infiltration and tissue injury in the lungs. Overall, these molecular interactions contribute to the anti-inflammatory**,** bronchodilatory**,** and immunomodulatory effects of curcumin in the management of respiratory conditions.

***Ephedra gerardiana*:**

Ephedra gerardiana Wall. ex Stapf, commonly known as Gerard's jointfir or Somlata, is a small, shrubby plant native to the Himalayan regions of India. It has been traditionally used in ethnomedicine and is an integral part of the Ayurvedic system for the treatment of a variety of ailments, particularly respiratory disorders such as asthma, bronchitis, cough, and common cold (González-Juárez et al., 2020).

The principal bioactive compound in *Ephedra gerardiana* is ephedrine (EPH), a phenylethylamine alkaloid known for its bronchodilatory, stimulant, and decongestant properties

(Kumar et al., 2023; Nazar et al., 2023). Ephedrine primarily exerts its therapeutic effects by activating adrenergic receptors, particularly the β_2- and α-subtypes. Stimulation of β_2-adrenergic receptors increases cyclic adenosine monophosphate (cAMP) via Gαs-mediated activation of adenylyl cyclase, leading to relaxation of airway smooth muscle and bronchodilation. Additionally, β_2-agonists demonstrate anti-inflammatory effects in *in vivo* LPS-induced acute lung injury models by suppressing pro-inflammatory mediators and inhibiting JNK activation, thereby reducing airway inflammation and obstruction in asthma and chronic obstructive pulmonary disease (COPD) (Bosmann et al., 2012). Complementarily, ephedrine hydrochloride enhances anti-inflammatory activity by upregulating IL-10 and downregulating proinflammatory cytokines (IL-6, TNF-α, IL-12, IL-1β) through the PI3K/Akt/GSK3β signaling pathway (Zheng et al., 2013). Furthermore, α-adrenergic stimulation causes subepithelial vasoconstriction in the respiratory tract, indirectly modulating airway smooth muscle tone and promoting clearance of bronchoconstrictor mediators such as histamine and leukotrienes, thereby improving airway function (Mazzone et al., 2010). Due to these combined bronchodilatory, anti-inflammatory, and decongestant actions, *Ephedra gerardiana* has long been used to alleviate symptoms of asthma, colds, chills, and fever. However, due to its potential cardiovascular and central nervous system side effects, its use is now regulated or restricted in several countries (Bent et al., 2004).

Glycyrrhiza glabra:

Glycyrrhiza glabra L., commonly known as licorice and referred to as Yashtimadhuor Mulethi in Ayurveda, is a native herb of Central and South-Western Asia. It has been widely used in ethnomedicine, particularly within the Ayurvedic**,** Unani, and Traditional Chinese Medicine systems for over two millennia (Hasan et al., 2021). Traditionally, it has been employed to treat respiratory diseases**,** gastric ulcers**,** hepatitis, and skin conditions due to its broad-spectrum anti-inflammatory**,** antiviral**,** antibacterial, and antioxidant properties (Pastorino et al., 2018).

The therapeutic potential of *Glycyrrhiza glabra* is primarily attributed to its major bioactive constituents glycyrrhizin (glycyrrhizic acid), glycyrrhetinic acid, liquiritin, and isoliquiritigenin (Damle, 2014). Among these, glycyrrhizin, a triterpenoid saponin glycoside, is the most extensively studied compound known for its potent anti-inflammatory and immunomodulatory effects (Bakr et al., 2022). It exerts protective activity by blocking the complement lytic pathway, thereby preventing membrane attack complex formation and tissue damage during inflammation (Fujisawa et al., 2000).

Glycyrrhizin modulates cytokine production and selectively inhibits glycyrrhizin-binding protein phosphorylation, contributing to its broad anti-inflammatory profile (Shamsa et al.,2010). Furthermore, in vivo models glycyrrhizin has shown significant efficacy against lipopolysaccharide (LPS)-induced mastitis, where it reduces the expression of pro-inflammatory cytokines TNF-α, IL-1β, and IL-6and limits neutrophil infiltration. These effects are mediated through activation of the ATP-binding cassette transporter A1 (ABCA1) and inhibition of lipid raft–dependent Toll-like receptor 4 (TLR4) signalling, leading to a marked attenuation of inflammatory responses (Fu et al., 2014). Collectively, these findings underscore glycyrrhizin's ability to regulate multiple inflammatory pathways, supporting its therapeutic value in inflammatory and immune-mediated disorders, including respiratory diseases.

In addition to glycyrrhizin, the flavonoids liquiritin and isoliquiritigenin also exhibit potent anti-inflammatory activities. Both compounds significantly suppress LPS-induced expression of pro-inflammatory mediators such as iNOS, COX-2, TNF-α, IL-1β, and IL-6 in BV2 microglial cells (Yu et al., 2015). Comparative studies indicate that isoliquiritigenin exerts a stronger inhibitory effect on nitric oxide (NO) and prostaglandin E_2 (PGE_2) production in RAW 264.7 macrophages than liquiritin, primarily through suppression of the NF-κB signaling pathway via inhibition of IKK, ERK1/2, and p38 phosphorylation (Kim et al., 2008).Moreover, both flavonoids attenuate macrophage activation by upregulating heme oxygenase-1 (HO-1) and activating the Nrf2 signaling pathway through inhibition of its negative regulator Keap1 (Wang et al., 2015). Recent evidence further indicates that isoliquiritigenin exerts multifaceted anti-inflammatory effects by coordinated inhibition of NF-κB, activation of Nrf2, suppression of NLRP3 inflammasome activation, and restraint of MAPK signaling (Chen et al., 2023).

Overall, these studies collectively highlight that the phytoconstituents of *Glycyrrhiza glabra* particularly glycyrrhizin, liquiritin, and isoliquiritigenin-modulate diverse molecular targets and signaling pathways, making this plant a promising therapeutic candidate for inflammation-associated and respiratory diseases. Isoliquiritigenin has been reported to suppress the Toll-like receptor 4 (TLR4)/Myeloid differentiation primary response 88 (MyD88) signaling pathway, a key regulator of the innate immune response and inflammation. MyD88 serves as a critical adaptor protein in both the TLR and interleukin-1 receptor (IL-1R) signaling cascades, and its inhibition represents a potential therapeutic strategy for chronic obstructive pulmonary disease (COPD) (Padova et al., 2018). Evidence from both in vitro and in vivo models indicates that isoliquiritigenin exerts potent anti-inflammatory effects in acute lung injury by covalently binding to the myeloid differentiation protein-2 (MD2) domain, a component of the TLR4 complex, thereby disrupting downstream inflammatory signaling (Yang et al., 2024).Glycyrrhizin has been shown to inhibit SARS-CoV-2 entry by targeting the angiotensin-converting enzyme 2 (ACE2) receptor, the primary cellular entry site for the virus. It

prevents viral attachment by inhibiting the interaction between the spike (S) protein and ACE2, while also down regulating ACE2 expression in Vero E6 cells in vitro (He et al., 2022).

Ocimum sanctum:

Ocimum sanctum L., commonly known as Holy Basil or Tulsi, is a sacred medicinal herb native to the Indian subcontinent and holds a revered position in traditional medical systems such as Ayurveda, Siddha, and Unani. Beyond its cultural and spiritual significance, *O. sanctum* is recognized for its broad-spectrum therapeutic potential against various diseases, including respiratory disorders, owing to its rich phytochemical composition (Pattanayak et al., 2010; Cohen, 2014).

The plant contains a diverse range of bioactive constituents such as eugenol, cirsilineol, circimaritin, isothymusin, apigenin, and rosmarinic acid, which collectively contribute to its antioxidant, anti-inflammatory, antimicrobial, antidiabetic, and anticancer properties ((Pradhan et al., 2022; Kumar et al., 2022). Among these, eugenol is the principal active compound responsible for modulating immune and inflammatory pathways. *In vivo* studies have shown that eugenol suppresses cyclooxygenase-2 (COX-2) expression, inhibits NF-κB activation, and downregulates pro-inflammatory cytokines such as TNF-α and IL-1β (Magalhães et al., 2010). In murine models of respiratory allergy, eugenol effectively reduces airway inflammation and Th2 cytokine production, indicating its potential as a bronchodilator and immunomodulatory agent in the management of asthma (Campos et al., 2014).

Furthermore, eugenol has been reported to modulate macrophage activity, attenuating the release of pro-inflammatory mediators while enhancing anti-inflammatory cytokines such as IL-10 in *in vivo* and *in vitro* models of acute lung injury (ALI) induced by cigarette smoke (Barbosa-De-Oliveira et al., 2023).

In addition, rosmarinic acid, another major phenolic compound of *O. sanctum*, exhibits strong antioxidant and cyclooxygenase (COX) inhibitory activities. *In vitro* assays demonstrate its ability to scavenge free radicals and suppress COX-mediated inflammatory responses, further supporting its pharmacological relevance in managing inflammation-associated respiratory diseases (Kelm et al., 2000).

Piper longum:

Piper longum L., commonly known as Indian long pepper or *Pippali*, is a perennial climber native to the Indo-Malaya region, and it grows widely in the tropical rainforests of India and Southeast Asia. It has been extensively used in traditional medicine systems such as Ayurveda**,** Siddha, and Unani, where it is considered a key ingredient for treating respiratory disorders**,** digestive issues**,** and metabolic imbalances(Biswas et al., 2022).

The pharmacological properties of *Piper longum* are primarily attributed to its diverse bioactive alkaloids, including piperine, piperlongumine, piperettine, piperonaline, and asarinine. These compounds exhibit a broad spectrum of biological activities such as anti-inflammatory, antioxidant, antimicrobial, immunomodulatory, and bronchodilatory effects (Meghwal & Goswami, 2013).

Piperine, the principal alkaloid of *Piper longum* and *Piper nigrum*, plays a crucial role in modulating inflammatory and immune responses. It inhibits the NF-κB signaling pathway in models of acute lung injury, thereby reducing the expression of pro-inflammatory cytokines, including IL-1β, TNF-α, and IL-6, which are central mediators in asthma and bronchitis (Lu et al., 2015). Piperine also down regulates the activation of key transcription factors—NF-κB, C/EBP, and AP-1—thus suppressing the release of inflammatory mediators. *In vitro* studies on murine macrophages confirmed its ability to inhibit these pathways (Kim et al., 2012), while research in A549 and BEAS-2B epithelial cells and BALB/c mice further demonstrated its efficacy in reducing cytokine production and oxidative stress (Saha et al., 2022).

Moreover, molecular docking and dynamics simulations suggest that piperine may exhibit antiviral potential by binding to the angiotensin-converting enzyme 2 (ACE2) receptor, thereby disrupting the spike–ACE2 complex and restricting SARS-CoV-2 entry into host cells. Additionally, it has been proposed to inhibit viral replication by binding to the RNA-binding pocket of the nucleocapsid protein (Choudhary et al., 2020; Nag et al., 2021).

Another significant constituent, piperlongumine, possesses potent antioxidant and anti-inflammatory properties. It modulates reactive oxygen species (ROS) levels, reducing oxidative stress commonly implicated in respiratory diseases (Prasad & Tyagi, 2016). Traditionally, *P. longum* has been employed in the treatment of respiratory infections and related ailments. Experimental studies demonstrate that piperlongumine attenuates inflammation and lung injury in cigarette smoke–induced models by regulating inflammatory mediators, mitigating oxidative damage, and maintaining pulmonary function (Sant'Ana et al., 2020).All these findings highlight the multifaceted therapeutic potential of *Piper longum* and its alkaloids in managing bronchitis, asthma, viral respiratory infections, and other inflammatory airway disorders.

Zingiber officinale*:*

Zingiber officinale Roscoe, commonly known as ginger**,** is a flowering plant of the family Zingiberaceae, native to Southeast Asia, including India. It has been widely used for centuries in Ayurvedic**,** Unani**,** and Traditional Chinese Medicine for the treatment of digestive, inflammatory, and respiratory ailments (Ali et al., 2007; Grzanna et al., 2005).

The primary bioactive phytoconstituents of ginger include gingerols**,** shogaols**,** zingerone**,** and paradols (Zhang et al., 2020)**.** Among these, 6-gingeroland 6-shogaolare recognized for their antioxidant**,** anti-inflammatory**,** analgesic**,** anticancer**,**

and antimicrobial properties (Mashhadi et al., 2013).The primary bioactive constituents of ginger (*Zingiber officinale*)[6]-gingerol, [8]-gingerol, and [6]-shogaol-exhibit notable bronchodilatory and anti-inflammatory properties relevant to respiratory diseases. These compounds induce bronchodilation by modulating intracellular calcium levels in airway smooth muscle (ASM), as demonstrated in isolated human ASM, guinea pig trachea**,** and A/J mouse models**,** indicating potential therapeutic applications in asthma and airway hyper responsiveness (Townsend et al., 2013).Among them,[6]-gingerolsignificantly suppresses IL-1β–induced Mucin 5AC(MUC5AC) gene expression in in-vitro human airway epithelial cells viaERKandp38 MAPK–dependent pathways**,** suggesting its role as an anti hyper secretory agent against mucus overproduction (Kim etal., 2009). Furthermore**,** gingerolsattenuate airway inflammation by suppressingTh2-mediated immune responses in murine models of allergic asthma**,** demonstrating reduced eosinophilic infiltration and cytokine release (Ahui et al., 2008). Similarly**,** 6-shogaol reduce airway inflammation in a murine asthma model through mechanisms involving cAMP augmentation and inhibition of NF-κB signalling and decreases airway hyper responsiveness in mice (Yocum et al., 2019).

Recent molecular docking and in vitrostudies suggest that ginger compounds may interact with the angiotensin converting enzyme 2 (ACE2)receptor and RdRP proteins the primary entry point for SARS-CoV-2**-** there by potentially inhibiting viral binding and entry into respiratory epithelial cells (Afrida et al., 2021). Collectively, these findings highlight the multifaceted therapeutic potential of ginger-derived compounds in managing inflammatory and infectious respiratory diseases**.**

CONCLUSION

Traditional therapies and medicinal herbs from the Indian Knowledge System (IKS) offer a holistic and time-tested approach to managing respiratory diseases. These natural remedies contain bioactive compounds that aid in the prevention and treatment of conditions such as asthma, bronchitis, and other pulmonary disorders. Owing to their affordability and generally lower incidence of side effects compared to modern pharmaceuticals, these herbal treatments are gaining increasing recognition in respiratory healthcare.

To fully understand and effectively integrate these traditional practices, it is essential to preserve and systematically investigate them through modern scientific methodologies. However, current research is constrained by several challenges, including the lack of large-scale clinical trials, inadequate standardization protocols, and limited availability of well-characterized phytocompounds. Addressing these limitations will pave the way for future research directions, such as pharmacokinetic analyses, randomized controlled trials, and exploration of the synergistic effects of polyherbal formulations.

Comprehensive scientific validationof these medicinal plants will help determine their efficacy, ensure safety, and facilitate the development of standardized therapeutic regimens. Ultimately, integrating traditional wisdom with modern medical science will not only protect India's rich medicinal heritage but also contribute to the creation of a more effective, inclusive, and sustainable healthcare system.

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