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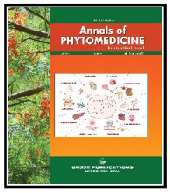

Review Article : Open Access

Fragrance and functionality: Therapeutic potential of essential oils in aromatherapy

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Abstract

Aromatherapy, which refers to the utilization of essential oils for therapeutic purposes, has garnered increasing interest due to its potential health benefits and holistic approach to well-being. This review critically examines the dual role of essential oils, focusing on their olfactory and functional properties, and their implications in clinical and therapeutic settings. Essential oils, complex mixtures of volatile compounds derived from plants, exhibit a broad spectrum of pharmacological activities, including anti-inflammatory, antimicrobial, anxiolytic, and antioxidant effects. This review focuses on current scientific research on the therapeutic efficacy of essential oils derived from commercially significant spices, ornamental and aromatic crops in aromatherapy, exploring their mechanisms of action, bioavailability, and clinical outcomes. Key areas of application such as stress reduction, pain management, sleep enhancement, and immune support, are discussed in detail. The review also addresses the methodological challenges in essential oil research, including variability in composition, dosage and delivery methods, and the need for standardized and rigorously controlled studies. By integrating traditional knowledge with contemporary scientific insights, this review highlights the therapeutic potential of essential oils in aromatherapy, advocating for their judicious and evidence-based use in improving health and quality of life.

1. Introduction

The application of concentrated essential oils extracted from flowers, herbs and other plant parts for therapeutic purposes is known as aromatherapy (Thangaleela *et al.,* 2022). Advocates of aromatherapy assert that they are part of a long-standing herbal medicine tradition that dates back thousands of years, have been practiced in nations like Egypt and India. Nonetheless, the French chemist Rene-Maurice Gattefosse coined the phrase in a book that was first released in 1936 (Agnihotry *et al*., 2024). The term aromatherapy typically implies massage with a variety of aromatic plant extracts known as essential oils. It is now commonly administered by massaging into the skin.

There has been a use of aromatic oils for nearly 5,000 years (Schmidt, 2020). Essential oils were used by the Egyptians for perfumes, cosmetics, embalming and love potions. Although, the majority of the development of modern aromatherapy has taken place in the last century, it began in Germany in the 16th century. The first Sanskrit medical treatises, the Charak Samhita and Sushrusha Samhita, were written around 2000 BC and list 700 plants, including aromatic ones like sandalwood, ginger, coriander, myrrh and cinnamon. The procedures for condensation and distillation of plant-based volatile oils are described in the Charak Samhita. Essential oils are pungent, highly volatile compounds found in plants (Buckle, 2014). Due to their erratic nature, these compounds can be identified by taste and smell and are extracted through steam distillation from an aromatic plant belonging to a single botanical species. Each essential oil is identified by the name of the plant from which it is derived and while the aroma is usually stronger (Rios *et al.,* 2016). It is comparable to the smell of the portion of the plant from which it is extracted. Recent advancements in analytical techniques and a growing interest in natural remedies have spurred a renaissance in aromatherapy research, prompting critical examination of its efficacy and mechanisms of action. Overall, this comprehensive review aims to:

- Elucidate the chemical composition of key essential oils and their bioactive components.
- Examine the physiological and psychological effects of aromatherapy on human health.
- Evaluate the current evidence supporting aromatherapy's role in managing various health conditions.

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- Address the challenges and limitations in aromatherapy research and clinical applications.

2. Advanced extraction methods of essential oil

2.1 CO_2 extraction

Advanced extraction method, *i.e.*, CO_2 extraction method is widely gaining popularity, which offers several advantages over traditional solvent-based methods. In this extraction method, carbon dioxide is pressurized to become a liquid, which is then used to extract the essential oils out of the plant material (Essien *et al.,* 2020). With this technique, temperature and pressure can be precisely controlled, producing high-quality oils with little degradation of sensitive aromatic components. CO_2 extraction is considered environmentally friendly, as it does not involve the use of harsh solvents and produces a pure and concentrated essential oil (Jyotimayee and Mahalik, 2021). It is often used for extracting oils from botanicals like herbs, spices and delicate flowers, ensuring superior aroma and therapeutic properties (Aziz *et al.,* 2018).

2.2 Microwave-assisted extraction (MAE)

It is a cutting-edge technique for extracting essential oils, taking advantage of microwave radiation to heat plant materials quickly and efficiently (Hamid *et al.,* 2024). The method works by releasing microwave radiation into the plant cells, where it interacts with polar molecules to produce ionic conduction and dipole rotation, both of which produce heat (Nour *et al.,* 2021; Destandau and Michel, 2022). The water inside the cells vaporizes due to the rapid internal heating, which builds pressure and eventually bursts the cell walls to release essential oils. MAE has a number of noteworthy benefits over conventional techniques such as steam distillation, such as much shorter extraction durations, less solvent usage, and higher essential oil yields with better thermolabile component stability (López-Salazar *et al.,* 2023). Chemat *et al.* (2017) has demonstrated that MAE not only accelerates the extraction process but also enhances the quality of the extracted oils by minimizing thermal degradation and oxidation. Vinatoru *et al.* (2017) noted that MAE is contributing to its growing popularity in the essential oil industry for producing high-quality pure extracts with minimal environmental impact.

2.3 Enzymatic extraction

This is a new and eco-friendly technique that releases essential oils by breaking down plant cell walls with the help of specific enzymes. This technique involves the use of enzymes such as cellulases, pectinases, and hemicelluloses (Rizwan *et al.,* 2024), which target the polysaccharides in the plant cell wall matrix, thereby enhancing the permeability of the cell walls and promoting the release of intracellular essential oils. Enzymatic extraction offers several advantages, including higher extraction yields, improved quality of essential oils, and lower energy consumption compared to conventional methods (Nadar *et al.,* 2018). Enzymatic treatment not only increases the efficiency of essential oil extraction but also preserves the integrity of delicate aromatic compounds that might be degraded by high temperatures in traditional extraction processes. In addition, this method is considered sustainable and eco-friendly as it reduces the need for harsh chemical solvents and high energy inputs, aligning with the growing demand for greener extraction technologies in the essential oil industry (Marathe *et al.,* 2017; de Souza and Kawaguti, 2021).

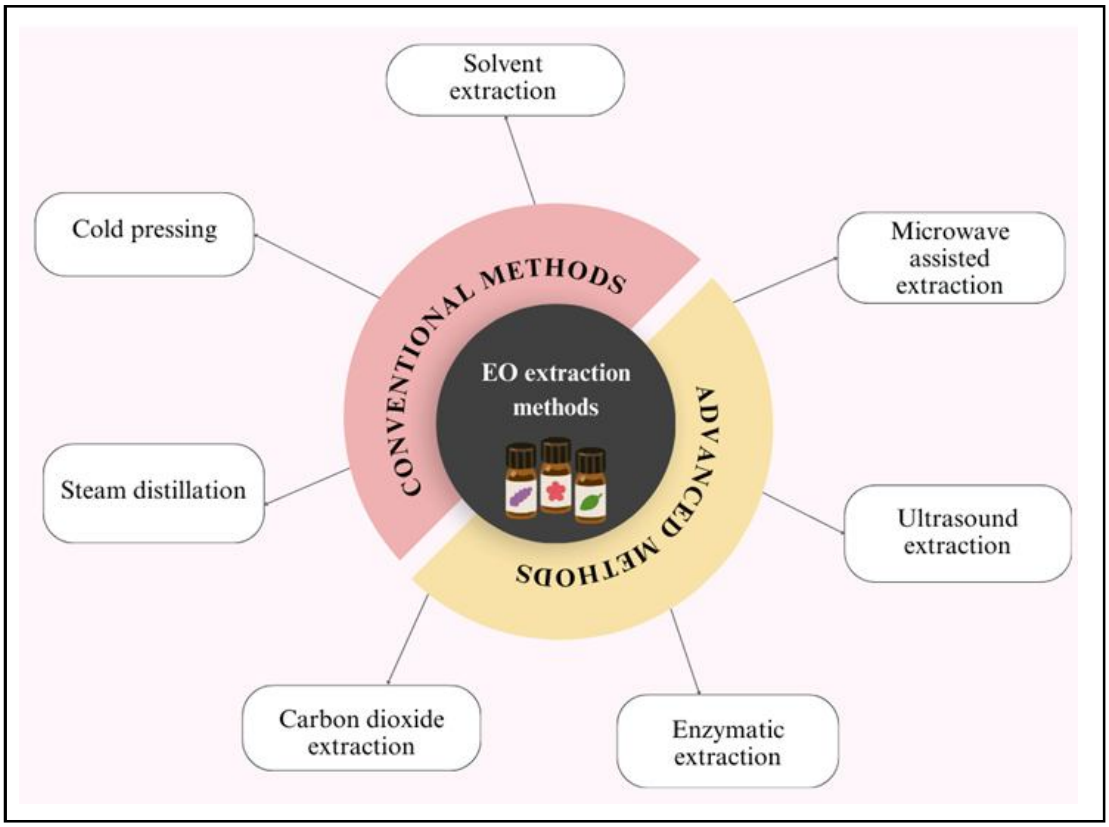

Figure 1: Conventional and advanced methods of essentialoil extraction.

2.4 Ultrasound-assisted extraction (UAE)

The UAE is a modern and efficient technique for extracting essential oils, utilizing high-frequency ultrasonic waves to enhance the extraction process (Shen *et al.,* 2023). The mechanism of UAE involves the propagation of ultrasonic waves through a liquid medium, creating cavitation bubbles that implode near the plant material. This implosion generates intense localized pressure and temperature, leading to the disruption of plant cell walls and facilitating the release of essential oils. According to Vinatoru *et al.* (2017), UAE has demonstrated superior efficiency in extracting essential oils, especially from plant materials with tough cell walls. The technique also minimizes the thermal degradation of heat-sensitive compounds, ensuring that the extracted essential oils retain their natural properties and potency. As noted by Chemat *et al.* (2012), UAE is considered an environmentally friendly extraction method due to its lower energy requirements and reduced use of organic solvents, making it a sustainable choice for the essential oil industry.

Table 1: Commonly used essential oils in aromatherapy

S.No.	Essential oil name	Chemical composition	Type of application	Use	Reference
1	Lavender	Linalool, linalool acetate	Topical, inhalation	Reduce hypertension and anxiety	Setyawan and Kintoko, 2024
2	Eucalyptus	Cineole, limonene	Topical, inhalation	Antioxidant, anti-inflammatory, analgesic	Goger *et al.,* 2020
3	Peppermint	Menthol	Topical application	Anti-inflammatory, pain relief	Goudarzi *et al.,* 2024
4	Chamomile	α-bisabolol, chamazulene	Topical, inhalation	Calming, anti-inflammatory, antimicrobial	Paula *et al.,* 2017
5	Rosemary	Camphor, α-pinene, cineole, linalool, and α-terpene	Topical or diffused, inhalation	Calming anxiety, reduce depression	Enwright *et al.,* 2023; Mank *et al.,* 2024
6	Tea tree	Terpinen-4-ol, γ-terpinene, α-terpinene	Topical	Antimicrobial, anti-inflammatory, skin care	Badr *et al.,* 2023
7	Citrus	Linalool, citral, linalyl acetate	Topical and oral, inhalation	Reduce anxiety, reduce depression, antimicrobial, astringent, stimulant, antioxidant	Agarwal *et al.,* 2022
8	Rose	Citronellol, geraniol, nerol, nonadecane	Topical, inhalation	Skincare, stress relief, skin rejuvenation, hormone balancing	Godfrey, 2019
9	Jasmine	Linalool, indole, linalyl acetate, benzyl acetate	Inhalation, topical	Antianxiety, analgesics	Sultani *et al.,* 2023
10	Lemon	Citric acid, α-terpineol, β-pinene, citral, α-pinene, α-terpinolene, linalool	Inhalation, topical	Antibacterial, antioxidant, anti-coagulant, antiviral, antimicrobial, astringent	Farrar and Farrar, 2020; Denkova- Kostova *et al.,* 2021
11	Palmarosa	Geraniol, linalool, geranyl acetate	Inhalation, topical	Antimicrobial, antioxidant activity, antibacterial, antidepressant, antimicrobial	Mahant *et al.,* 2021; Onem, 2022
12	Geranium	Citronellol, geraniol, linalool, isomenthone	Inhalation, topical	Anti-inflammatory, analgesic, antioxidant, antimicrobial, anticancer	Gazerani *et al.,* 2021
13	Vetiver	Khusimol, vetivenes, β-vetivone, α-vetivone	Inhalation, topical	Stress relief, anxiety, antidepressant, antioxidant, antibacterial	Suyono and Susanti, 2020
14	Thyme	Thymol, carvacrol, linalool, cineole	Inhalation, topical	Antiseptic, antifungal, antibacterial, anthelmintic, antispasmodic	Kowalczyk *et al.,* 2020
15	Sandalwood	Santalol (α-santalol, β-Santalol)	Inhalation, topical	Antiseptic, antispasmodic, antipyretic, antiscabetic	Boruah *et al.,* 2023; Das and Khan, 2022
16	Clove	Eugenol, eugenyl acetate, β-caryophyllene	Topical, inhalation, oral	Antiseptic, anticarcinogenic, antinociceptive, antioxidant, antiallergic	Ansariniaki *et al.,* 2022

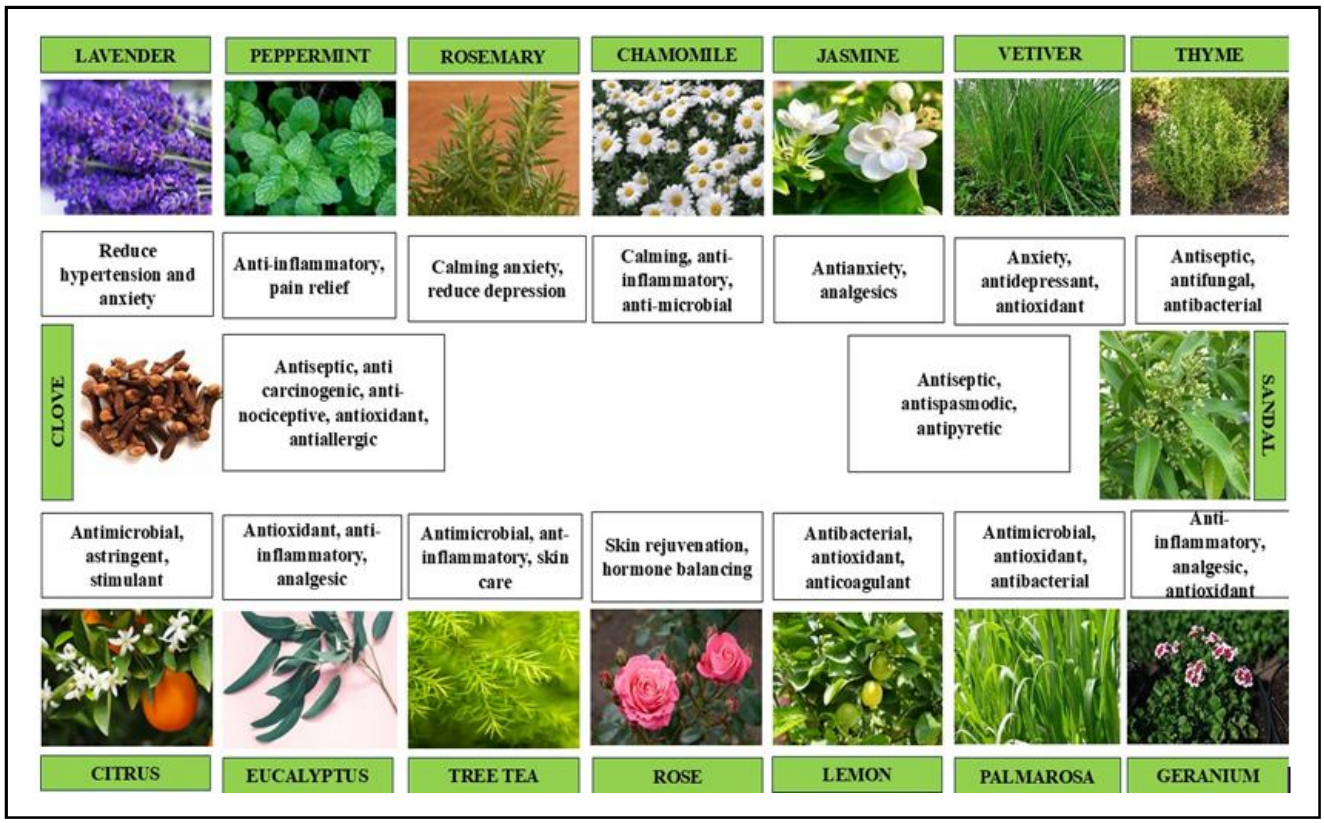

Figure 2: Uses of some commonly used essential oils.

3. Chemical composition of essential oil

Essential oils are extraordinary mixtures with a complex chemical makeup that capture the essence and medicinal potential of plants. These are mostly made up of volatile organic compounds, but they can also include terpenes, phenols, alcohols, esters, aldehydes, ketones and oxides, among other chemical classes (Moghaddam and Mehdizadeh, 2017; Zuzarte and Salgueiro, 2015) (Figure. 3). A basic hydrocarbon found in essential oils is isoprene. Mono-, sesqui-, and diterpenes are the result of combination of two, three and four isoprene joined together, respectively (Murti *et al.,* 2023). Monoterpenes and sesquiterpenes, which make up a large portion of terpenes, are responsible for the unique scent and medicinal qualities of essential oils. Sesquiterpenes like beta-caryophyllene have antioxidant, analgesic and anti-inflammatory qualities (Machado *et al.,* 2018; Sharma *et al.,* 2016), while monoterpenes like limonene and pinene are uplifting and clarifying. Strong antibacterial, antimicrobial and antifungal activity makes phenols like eugenol and thymol useful in the fighting against infections (Marchese *et al.,* 2017; Rua *et al.,* 2019; Kachur and Suntres, 2020). Alcohols that contribute to the oils' calming and balancing properties, like linalool and geraniol, add floral notes. Linalool- sedative effect (Ali *et al.,* 2015). Esters, which are present in oils such as chamomile and lavender, have a fruity scent and are well known for their sedative and calming properties. Citral is one of the aldehydes (Shi *et al.,* 2016) that contributes to citrusy scents and may have antibacterial qualities (Kang *et al.,* 2022). Ketones have cooling and decongestant properties, such as camphor and menthone (Debra and Jones, 2017), while oxides, like 1,8-cineole, support the respiratory system (Hoch *et al.,* 2023). The multifaceted chemical composition of essential oils highlights their extensive therapeutic applications, rendering them indispensable instruments in the fields of aromatherapy, skincare and holistic wellness.

4. Mechanism of action in aromatherapy

In aromatherapy, essential oils exert their effects through multiple mechanisms of action, primarily involving the olfactory system, skin absorption and systemic effects. Whether through inhalation or topical application, essential oils facilitate holistic well-being by harmonizing mind, body and spirit, making aromatherapy a versatile and potent healing modality.

4.1 Olfactory system

When the essential oils are inhaled through nose, the volatile molecules interact with specialized olfactory receptors in the nasal cavity. These receptors are known as olfactory sensory neurons (OSN) which are designed to detect and bind with specific chemical compounds found in various aromas. Each type of essential oil contains a unique composition of volatile compounds, which determines the specific receptors it activates (Zhang *et al.,* 2024). For example, lavender contains linalool and linalyl acetate, while peppermint contains menthol. Once the olfactory receptors are activated, they convert the chemical interactions into electrical signals that travel along the olfactory nerve. These signals first reach the olfactory bulb, a structure located just above the nasal cavity, which processes the sensory input. From the olfactory bulb, signals are relayed to higher brain regions, including the limbic system (Heinbockel *et al.,* 2016). The limbic system is a group of interconnected structures in the brain that helps in regulating

emotions, memory, and certain physiological functions, including the autonomic nervous system. The primary components of the limbic system involved in the olfactory pathway include the amygdala, hippocampus, and hypothalamus (Shipley *et al.,* 2008).Amygdalais primarily involved in the processing of emotions, especially those related to fear, stress, and pleasure (\imic*et al.,* 2021). When signals from the olfactory receptors reach the amygdala, they can directly influence emotional states, which is why certain aromas can elicit immediate emotional responses. Hippocampus involved in memory formation (Tang *et al.,* 2020). The connection between olfaction and memory is well established, and olfactory stimuli often trigger the recollection of past experiences. This is why certain essential oils can evoke nostalgic or calming memories. Hypothalamusacts as the control center for many autonomic functions, including heart rate, digestion, and hormone regulation. The hypothalamus influences the release of neurotransmitters such as serotonin and dopamine, which can affect mood and stress levels. Through this connection, essential oils can have physiological effects beyond emotional responses, such as reducing stress or enhancing alertness.

Due to the direct connection between the olfactory system and the limbic system, essential oils can evoke both emotional and physiological responses. Some well-researched examples include:

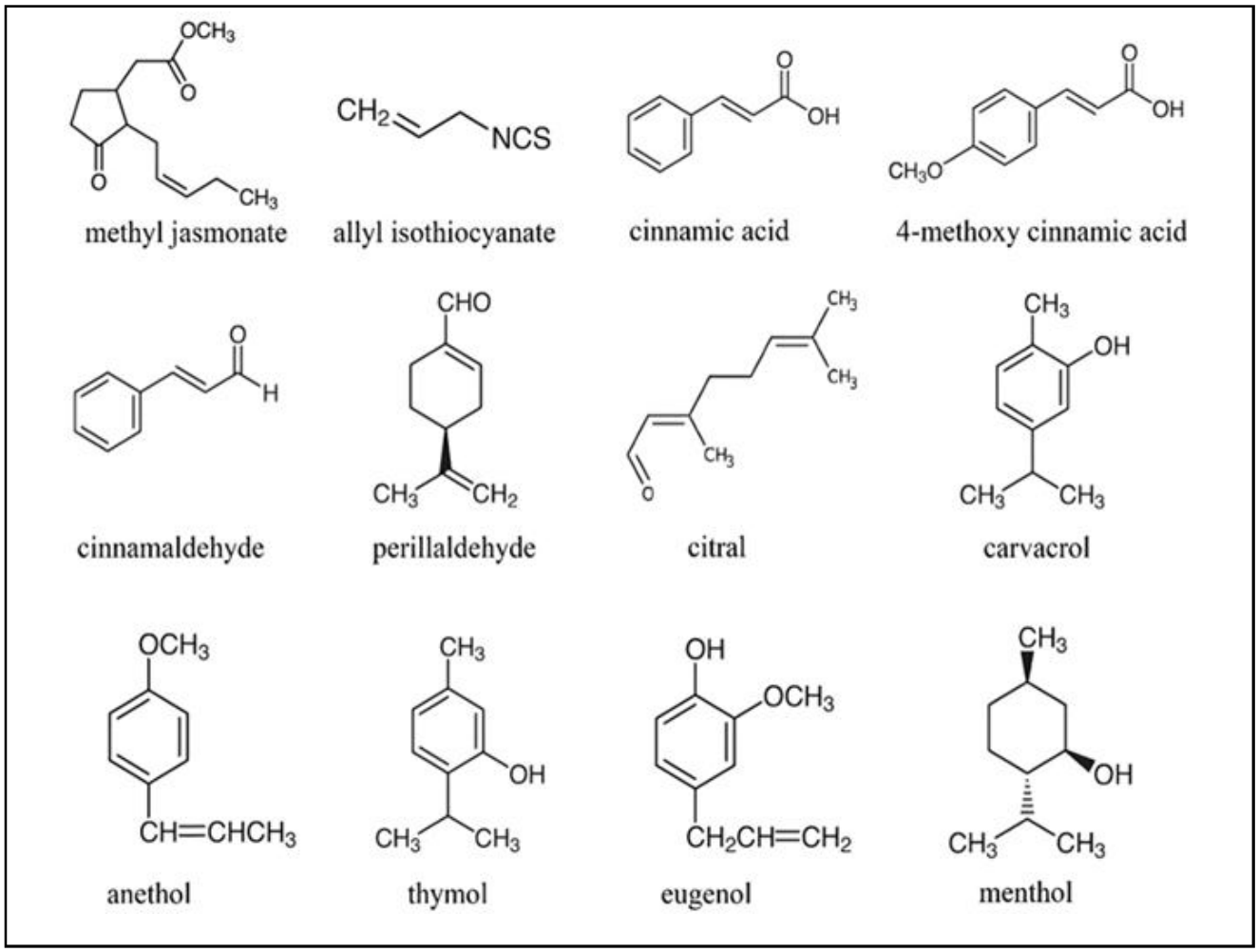

Figure 3: Chemical structures of constituents of some essential oils (Source:Namiotaand Bonikowski, 2021).

4.1.1 Lavender oil

It contains essential compounds like linalool and linalyl acetate, which have been found to activate specific olfactory receptors associated with relaxation and anxiety reduction (Arslan *et al.,* 2020). When these molecules reach the limbic system, particularly the amygdala and hypothalamus, they promote the release of calming neurotransmitters, such as GABA (gamma-aminobutyric acid) (Agarwal *et al.,* 2022), which helps reduce the activation of the stress response. This can lead to decreased anxiety and improved relaxation.

4.1.2 Peppermint oil

It contains menthol, which stimulates receptors linked to alertness and cognitive function (Moss *et al.,* 2016).When the peppermint oil is inhaled, the interaction of menthol with olfactory receptors sends signals to the brain that enhance alertness and mental clarity. Peppermint oil is often used in environments requiring focus and concentration, as its stimulating effect on the central nervous system can improve cognitive performance.

4.2 Skin absorption

In the topical application of essential oil, it penetrates the skin through pore spaces and hair follicles (Allah *et al.,* 2022). The outermost layer of the skin, stratum corneum serves as the primary barrier, but certain essential oil molecules are small enough to pass through this barrier. The degree of absorption depends on factors such as the molecular size of the oil, the lipophilic nature of its compounds, and the condition of the skin (Agatonovic *et al.,* 2020). Once essential oils pass through the skin's outer layer, they can enter the bloodstream *via* capillaries present in the deeper layers of the skin. This allows for systemic distribution of the essential oil compounds throughout the body, where they can exert therapeutic effects in different organs and systems. The absorbed molecules are then metabolized by the liver and excreted through the kidneys, lungs, or skin. After being absorbed into the bloodstream, essential oils can affect internal organs and systems, and produces therapeutic actions similar to when they are being inhaled. These effects depend on the bioactive compounds in the oils and their pharmacokinetic properties. As suppose, lavender essential oil if applied topically shows to promote relaxation and reduce anxiety by being absorbed into the bloodstream and affecting the central nervous system, much like when it is inhaled (Arslan *et al.*, 2020). Once the essential oil reach in bloodstream, the essential oil molecules are metabolites primarily in the liver, where they undergo enzymatic processes to break down into less active or inactive metabolites. These metabolites are then excreted through the kidneys, lungs, or sweat glands, which ensures that the compounds are eliminated from the body after they have produced their therapeutic effects.

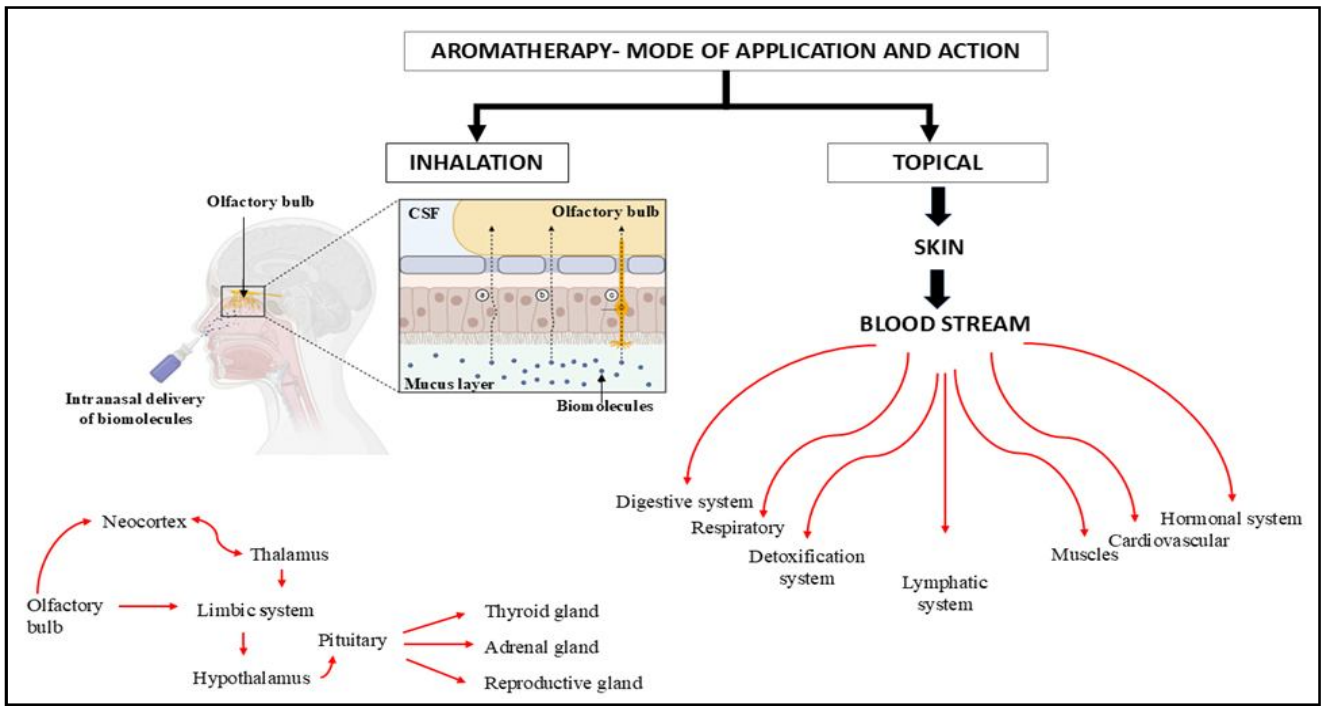

Figure 4:Mode of action and application in aromatherapy.

5. Therapeutic applications of essential oil

The uses of essential oils encompass mental, emotional, and physical well-being. Aromatherapy frequently involves diffusing essential oils to create a soothing environment, alleviate stress, and promote relaxation (Marisa *et al.,* 2024). Lavender oil is well-known for its calming properties that improve sleep quality (Ayik and Ozden, 2018) and reduce anxiety levels (Donelli *et al.,* 2019). Peppermint oil, on the other hand, is prized for its invigorating properties, offering improved digestion, relief from headaches, nausea (Heshelow, 2023) and fatigue when applied topically or inhaled (Zhao *et al.,* 2022). Many essential oils possess antibacterial, antiviral and anti-inflammatory qualities, making them valuable additions to natural remedies for conditions like colds, muscle aches and skin irritations (Winska *et al.,* 2019). Tea tree oil's potent antibacterial effects make it a common remedy for minor wounds and acne (Nascimento *et al.,* 2023). Eucalyptus oil is revered for its decongestant effects (Ahmad *et al.,* 2023), offering relief from respiratory issues such as sinusitis and bronchitis (Ahmad *et al.,* 2023) when inhaled or applied topically. Even though essential oils offer numerous therapeutic benefits, it is essential to use them safely, considering factors like proper dilution, individual sensitivities and guidance from qualified practitioners, ensuring optimal efficacy and minimizing potential adverse reactions.

5.1 Stress and anxiety relief

Essential oils used in aromatherapy, have shown promising therapeutic applications in the management of stress and anxiety (Cui *et al.,* 2022). The anxiolytic properties of certain essential oils, such as lavender (*Lavandula angustifolia*), chamomile (*Chamaemelum nobile*), and bergamot (*Citrus bergamia*), are well-documented in scientific literature. The primary mode of action is through inhalation, where the volatile compounds interact with the olfactory system, leading to the activation of the limbic system, which regulates emotions and stress responses (Heinbockel *et al.,* 2016). For instance, linalool and linalyl acetate, key constituents of lavender oil, have been shown to exert a calming effect by modulating

the release of neurotransmitters like serotonin and gamma-aminobutyric acid (GABA) (Bavarsad *et al.,* 2023). Clinical studies have reported significant reductions in anxiety levels among individuals exposed to these essential oils, both in situational contexts and in chronic conditions (Malcolm and Tallian, 2017; Metu, 2021). Research has demonstrated that the application of essential oils in massage therapy has a synergistic effect, enhancing relaxation and reducing cortisol levels, a biomarker of stress (Seifert *et al.,* 2018).

5.2 Pain management

Essential oils have emerged as valuable adjuncts in the management of pain, leveraging their anti-inflammatory, analgesic, and antispasmodic properties. Essential oils such as eucalyptus (*Eucalyptus globulus*), peppermint (*Mentha piperita*), and rosemary (*Rosmarinus officinalis*) contain bioactive compounds like eucalyptol, menthol, and camphor, which are known to modulate pain pathways (Kazak, 2022; Zhao *et al.,* 2022; Teja *et al.,* 2024). These compounds interact with receptors in the skin and mucous membranes, leading to the inhibition of pain signals and the reduction of inflammation. Clinical studies have demonstrated that inhalation of lavender oil can significantly reduce pain perception (Arslan *et al.,* 2020), while topical application of peppermint oil has been effective in alleviating tension headaches and relieve pain (Petluru *et al.,* 2024). Also, essential oils can enhance blood circulation and promote muscle relaxation, contributing to their analgesic effects.

5.3 Sleep disorder

Essential oils have demonstrated significant potential in the management of sleep disorders, primarily due to their sedative and calming properties. Lavender oil (*Lavandula angustifolia*) is particularly notable for its efficacy in improving sleep quality (Samadi *et al.,* 2021). The active components of lavender, including linalool and linalyl acetate, interact with the central nervous system to promote relaxation and enhance sleep onset (Soares *et al.,* 2021). Clinical trials have shown that inhalation of lavender oil significantly increases sleep duration and quality in individuals with insomnia and other sleep disturbances (Luo and Jiang, 2022). Furthermore, essential oils such as chamomile (*Matricaria recutita*) and valerian (*Valeriana officinalis*) have also been reported to have sleep-inducing properties (Gohil *et al.,* 2023; Alvarado-García *et al.,* 2024), likely due to their ability to reduce anxiety and improve overall mental well-being. The use of essential oils in aromatherapy for sleep disorders offers a non-pharmacological alternative that can be integrated into a complete treatment plan, providing a natural and effective approach to enhancing sleep health.

5.4 Immune support

The antimicrobial, anti-inflammatory, and immunomodulatory properties of essential oils make them promising for immune support. Bioactive compounds like terpinen-4-ol, eucalyptol, and thymol found in essential oils such as tea tree (*Melaleuca alternifolia*), eucalyptus (*Eucalyptus globulus*), and thyme (*Thymus vulgaris*) have been shown to enhance immune function. The growth of pathogens can be inhibited by these compounds, as demonstrated in a study by Man *et al.*(2019). According to research by Gandhi *et al.* (2020), these compounds have the ability to regulate the release of pro-inflammatory cytokines. These compounds can also enhance the activity of immune cells like macrophages and lymphocytes. Clinical trials have shown that essential oils can boost the body's natural defense mechanisms, thus reducing both the severity and duration of infections. Ben-Arye *et al.* (2011) reported that eucalyptus oil contributes to improved respiratory function and alleviated symptoms in people with upper respiratory tract infections. Integrating essential oils into aromatherapy as a means to strengthen the immune system presents a holistic approach to enhancing overall well-being and fortifying the body's defenses against infections. This supports their use alongside traditional medical treatments.

6. Safety considerations in aromatherapy

In order to ensure the safe and successful use of essential oils in aromatherapy, safety considerations are critical. Knowing how strong essential oils can be and the potential negative effects they may havecrucial, particularly when used improperly or undiluted (Heshelow, 2023). It is imperative to dilute the oil with a carrier oil because this helps to disperse the oil over a greater surface area and lowers the possibility of skin irritation (Worwood, 2016). When exposed to sunshine or UV radiation, some essential oils have the potential to induce burns or skin irritation this is known as phototoxicity (Kuttan and Liju, 2017). To preserve their efficacy and avoid deterioration, essential oils must be stored properly, out of direct sunlight and heat. Essential oils can be hazardous when used orally, thus you should never take them without seeing a licenced aromatherapist or other healthcare provider. Before using essential oils, anyone with specific medical issues, the elderly, children, and pregnant women should use caution and consult a healthcare provider. Finally, as everyone reacts to essential oils differently, it is critical to honour individual sensitivities and preferences.

7. Formulation and delivery methods

Essential oils are formulated and delivered in various ways in aromatherapy to optimize their therapeutic effects and ensure safe application. One common formulation method is dilution with a carrier oil, such as almond oil, coconut oil, or jojoba oil (Marshal *et al.,* 2023). This dilution not only helps to reduce the concentration of the essential oil but also facilitates even distribution and absorption into the skin during topical application (Herman and Herman, 2015). Another formulation technique involves blending multiple essential oils together to create synergistic blends tailored to specific therapeutic goals, such as relaxation, energy enhancement, or immune support.

In terms of delivery methods, inhalation is one of the most popular and effective ways to use essential oils in aromatherapy (Acimovic, 2021). This can be achieved through methods like diffusers (Lee, 2016), which disperse the oils into the air as fine mist or vapor, allowing for easy inhalation and absorption through the respiratory system (Al-Harrasi *et al.,* 2022). Direct inhalation from a bottle or inhaler stick is another option, providing quick access to the aromatic benefits of essential oils.

Applying diluted essential oils directly to the skin, often through massage or targeted application to specific areas of concern, is known as topical application (Allard and Katseres, 2016). Through this method, the oils can be absorbed through the skin to exert their therapeutic effects locally (Abelan *et al.,* 2022) or enter the bloodstream for systemic benefits. To prevent skin irritation or sensitization, it's crucial to conduct a patch test and follow proper dilution guidelines. Other delivery techniques include baths, in which

diluted essential oils are placed to a cloth and applied to the skin as a warm or cold compress, allowing the oils to be inhaled and absorbed via the skin. Some people may choose to take essential oils internally, with the supervision of a licenced aromatherapist or medical practitioner. However, this method necessitates rigorous safety and dosage calculations.

Table 2: Safety considerations for some commonly used essential oil

Essential oil	Common precautions	Dilution guidelines	Specific constrain	Safe for indications	Safe for pregnant children /breast feeding
Peppermint	Avoid on sensitive skin, keep away from eyes	2-3% for adults	Can cause respiratory issues in young children	No (under age 6)	Use with caution; consult healthcare provider
Tea tree	Do not ingest; can cause skin irritation if undiluted	2-3% for topical use	May cause allergic reaction; patch test recommended	Yes (diluted)	Use with caution; avoid on sensitive areas
Eucalyptus	Not recommended for young children; avoid use near face of infants and toddlers	1-2% for children, 3% for adults	Can cause breathing issues in young children	No (under age 6)	Consult healthcare provider before use
Lemon	Photosensitive; avoid sun exposure for up to 12 h after application	1-2% for skin	Can cause skin irritation in sensitive individuals	Yes (diluted)	Generally safe when diluted
Lavender	Generally safe, but may cause irritation in some; avoid over-use in sedative meds	Up to 5% for topical applications	Possible skin sensitivity; check for allergic reactions	Yes	Yes
Rosemary	Avoid in people with epilepsy or high blood pressure	1-3% for topical use	May trigger seizures in sensitive individuals	No (under age 10)	Consult healthcare provider before use
Bergamot	Photosensitive; avoid direct sunlight after topical use	1-2% for skin	Skin irritation possible if exposed to UV light	Yes (diluted)	Use with caution; consult healthcare provider
Chamomile	Generally safe but may cause reactions in people allergic to ragweed	Up to 5% for topical applications	Allergic reactions possible with ragweed allergy	Yes	Yes
Clove	Strong; can irritate skin and mucous membranes; avoid undiluted use	0.5-1% for skin	May irritate sensitive skin; patch test recommended	No (under age 2)	Consult healthcare provider before use
Cinnamon	Can be irritating to skin; avoid mucous membranes	0.5-1% for skin	High potential for skin irritation; avoid undiluted	No (under age 6)	Avoid during pregnancy and breastfeeding
Jasmine	Generally safe, though strong scent can trigger headaches in some	1-3% for topical use	Not ideal for those with scent sensitivity	Yes	Yes
Ginger	May cause skin sensitivity in some people	1-2% for skin	Mild irritation possible; patch test recommended	Yes	Consult healthcare provider before use

8. Clinical and research studies

Recent investigation carried out by Doner *et al.* (2024), detailed the effect of aromatherapy massage with peppermint and lemon essential oil on menopausal symptoms. The study found that aromatherapy massage with peppermint and lemon essential oil effectively reduced menopausal symptoms. Peppermint essential oil was more effective than lemon essential oil in reducing the menopausal symptoms. Pourshaikhian *et al.*(2024) studied the effects of aromatherapy with essential oil of *Matricaria chamomile* on anxiety and hemodynamic indices in patients with acute coronary syndrome and in the result, they advocated aromatherapy with *M. chamomile* essential oil could reduce anxiety and improve hemodynamic indices in ACS patients. Yin *et al.*(2024) conducted a study to access the effects of inhalation aromatherapy with lavender essential oil on depression and sleep quality in patients with post-stroke depression, and they concluded that lavender essential oil inhalation aromatherapy may help reduce depression and improve sleep quality in patients with PSD. Rezaei *et al.* (2024) conducted the clinical trial of the effect of aromatherapy and music therapy upon anxiety and non-stress test results during pregnancy with 195 primiparous participants in their trial they found the application of lavender oil as aromatherapy with or without music therapy is effective in reducing state anxiety during pregnancy and enhancing NST results. Basak *et al.* (2024) studied the effect of rose oil aromatherapy and hand holding on pain due to peripheral intravenous catheter insertion on 126 patients and they observed rose oil aromatherapy was more effective on pain than the hand-holding intervention. Mank-Halati*et al.*(2024) conducted a clinical trial on effect of rosemary aromatherapy and music therapy on anxiety levels in 236 patients undergoing general surgery, in the observations they found that inhalation aromatherapy, music therapy, and combined aromatherapy and music therapy are all effective approaches for anxiety reduction in surgical patients. Erdal *et al.* (2024) studied the effect of orange oil aromatherapy on pain and anxiety during invasive interventions in 80 patients with Hematopoietic stem cells transplants in result they found that orange

oil inhalation has been determined to reduce pain during invasive interventions. Monfared *et al.* (2020) conducted a clinical trial for the assessment of effect of aromatherapy with Lavender essential oil on the preoperative anxiety of endoscopy candidates in Iran, in results they found; aromatherapy with lavender essential oil was effective in the reduction of pre-endoscopic anxiety in the patients. Soleimani *et al.* (2022) conducted a clinical trial with 64 patients to evaluate the peppermint aromatherapy on patients with acute coronary syndrome in the emergency department in results they found the inhalation of peppermint essential oil can reduce the level of anxiety in patients. Sitorus *et al.* (2023) conducted a study with 30 women in labor during first stage. The results showed that the administration of sandalwood essential oil aromatherapy proved effective in reducing the intensity of labor pain during the first stage of labor.Sultani *et al.* (2023) assessed the effect of jasmine essential oil aromatherapy on sleep quality of 54 hemodialysis patients with age group 18-70 in result they observed aromatherapy with jasmine essential oil can increase the sleep quality and duration of the patients. Pourshaikhian *et al.* (2024) conducted a randomized clinical trial on 154 acute coronary syndrome patients for the evaluation of efficacy of aromatherapy anxiety and hemodynamic indices and in the results; they found Aromatherapy with *Matricaria chamomile* essential oil could reduce anxiety and hemodynamic indices.Veiskaramian *et al.* (2021) conducted a clinical trial on 72 patients affected by acute coronary syndrome to study the effect of *Melissa officinalis* essential oil aromatherapy on stress level and hemodynamic parameters in result they observed inhalation of *Melissa* essential oil could relieve stress and regulate hemodynamic changes in patients. Mohammadi *et al.* (2022) conducted a clinical trial on the impact of Aurantium essential oil aromatherapy on sleep quality of 68 pregnant women with sleep disorders and investigated *Citrus aurantium* essential oil enhances the sleep quality of pregnant women with sleep disorders. Scandura *et al.* (2022) conducted a controlled trialto study the effectiveness of neroli essential oil in relieving anxiety and perceived pain on 88 women during different stages of labor in result the concluded that neroli oil aromatherapy can be used to relieve anxiety and perceived pain during all labor stages.

9. Challenges and limitations

Essential oils, as natural products, exhibit considerable variation in composition, influenced by factors such as plant origin, cultivation conditions, and extraction methods (Sharmeen *et al.,* 2021; Chrysargyris *et al.,* 2020). This variability can lead to inconsistent therapeutic effects and poses challenges for reproducibility in research. Moreover, standardization of essential oil quality and precise dosing remains difficult, further complicating clinical trials and the evaluation of efficacy (Li *et al.,* 2023). Also, the optimal delivery methods for essential oils are not yet fully established, with inhalation, topical application, and oral administration each presenting distinct pharmacokinetic profiles and bioavailability concerns. These factors collectively underscore the need for rigorously designed, controlled studies with standardized methodologies to better understand the therapeutic mechanisms and safety of essential oils. Therefore, in depth studies need to be done to address these limitations to substantiate the clinical use of aromatherapy and integrate essential oils into evidence-based healthcare practices.

10. Conclusion

Essential oils represent a promising frontier in aromatherapy, offering diverse pharmacological activities supported by empirical evidence. Their multifaceted effects on stress reduction, pain management, sleep enhancement, and immune support underscore their therapeutic potential. However, challenges such as standardization, bioavailability, and safety profiles remain significant hurdles. Moving forward, integrating rigorous scientific validation with traditional knowledge can enhance their clinical efficacy and ensure safe usage. Further research should focus on elucidating the mechanisms of action, optimizing delivery systems, and conducting large-scale clinical trials to substantiate their therapeutic benefits conclusively. By addressing these gaps, essential oils can realize their full potential as effective, evidence-based therapeutic agents in holistic health practices.

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Conflict of interest

The authors declare no conflicts of interest relevant to this article.

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