



Review

Chemical Composition and Aromatherapy-Based Relaxation Potential of Selected Indonesian Herbal Essential Oils

Nurina Rizka Ramadhania *

Department of Chemistry, Faculty of Mathematics and Natural Sciences, Universitas Negeri Surabaya
Ketintang Gayungan, Surabaya 60231, East Java, Indonesia

*Corresponding author: nurinaramadhania@unesa.ac.id

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ABSTRACT. Aromatherapy, an alternative treatment approach, is gaining popularity in Indonesia due to its ability to provide psychological and physiological relaxation. The use of Indonesian herbal plants, especially *Syzygium polyanthum* (bay leaf), *Camellia sinensis* (green tea), *Cymbopogon citratus* (lemongrass), *Lavandula angustifolia* (lavender), and *Citrus limon* (lemon) in aromatherapy has long been recognized for its distinctive, refreshing aroma and diverse secondary metabolites. This scientific literature review is presented to reveal the relationships between the presence and diversity of chemical composition of selected Indonesian herbal plants and various influencing factors, such as plant origin and the extraction method used. The aroma-defining properties of eugenol, geraniol, linalool, citral, and limonene in essential oils, when combined, can synergistically trigger bioactivities, including antioxidant, antibacterial, anti-inflammatory, and relaxing effects. Scientifically, the relaxing effects of aromatherapy are produced through stimulation of the olfactory system, which connects to the limbic system in the brain, including the amygdala and hypothalamus, which are responsible for improving mood and enhancing emotional regulation. Based on this review, the metabolite profile of essential oils plays a role in determining their potential bioactivity, especially in selected herbal plants as sources of natural relaxation therapy.

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INTRODUCTION

Increased stress and anxiety disorders have become an increasingly pressing concern in the health sector because they can impact the quality of life of modern Indonesian society. Poor sleep quality, increased stress hormone levels, and physical tension are common effects of a fast-paced lifestyle. This is based on statistical data showing that Indonesian people experience several mental health problems, reaching 56%, with a very severe category of 0.85% and a mild category of 34.5% (Pinggian *et al.*, 2021). Aromatherapy is one of the alternative treatment methods that is increasingly popular in modern society due to its effectiveness in providing psychological and physiological benefits, such as relaxation, stress reduction, anxiety relief, and improved sleep quality (Chamine and Oken, 2015; Paula *et al.*, 2017). Aromatherapy has been scientifically proven to activate the

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limbic system in the brain (Horowitz, 2011; Yariibeygi *et al.*, 2017), which is directly related to mood and emotion regulation.

As the world's sixth-largest producer of essential oils, Indonesia could supply around 85% of the world's annual consumption by 2020. As many as 150 – 200 plant species in Indonesia can be extracted to produce high-quality essential oils (Warsito, 2021). Essential oils are volatile secondary metabolite compounds that are easily evaporated (volatile), easily soluble in organic solvents, and have a distinctive aroma, so they have potential as aromatherapy. Essential oils can generally be obtained from various plant families, including Pinaceae, Myrtaceae, Apiaceae, Asteraceae, Zingiberaceae, Lamiaceae, Poaceae, Rutaceae, and Rutaceae. Herbal plants used as essential oils, such as bay leaves (*Syzygium polyanthum*), green tea (*Camellia sinensis*), lemongrass (*Cymbopogon citratus*), lavender (*Lavandula angustifolia*), and lemon (*Citrus limon*), have long been used as traditional medicines, proven over centuries.

Abundance and traditional use of herbal plants in aromatherapy for relaxation were key factors in selecting the plants for this review. Potential local Indonesian plants such as bay leaves, green tea, and lemongrass were chosen because they are widely cultivated and frequently used in culinary and traditional medicine. Meanwhile, lavender and lemon are not native to Indonesia, but due to their high market demand, their use plays a crucial role in the aromatherapy and health industry in Indonesia (Avoseh *et al.*, 2015; Hasan *et al.*, 2024). These five essential oils are the most widely studied and utilized for relaxation, in terms of reducing anxiety and improving sleep quality, both in Indonesia and globally (Cavanagh and Wilkinson, 2002; Guo and Wang, 2020; Sharmeen *et al.*, 2021). The characteristics of this essential oil are determined by its secondary metabolite content, which produces a distinctive aroma, such as phenolics, phenylpropanoids, monoterpenes, sesquiterpenes, and other terpenoid compounds. As reported in previous studies, these compounds have demonstrated several biological activities, including antioxidant, antibacterial, antifungal, cytotoxic, analgesic, antiviral, and anti-inflammatory effects (Caputo *et al.*, 2020).

Research on the potential of essential oils from herbal plants has demonstrated that exploring the metabolites of essential oils is crucial and effective in aromatherapy and produces synergistic effects. Therefore, a literature review was conducted specifically in the context of developing locally based aromatherapy and its therapeutic uses. This approach aims to provide scientific information on the chemical composition of essential oils and their biological activities related to stress reduction and anxiety management in promoting health. A literature search was conducted using databases including Scopus, ScienceDirect, PubMed, and Google Scholar. Original research articles and relevant review papers discussing the essential oils of bay leaf, green tea, lemongrass, lavender, and lemon were published between 2000 and 2025. Keyword combinations included "essential oil", "herb", "secondary metabolite", "bioactivity", "aromatherapy", "relaxation", "stress", and "sleep quality".

INDONESIAN HERBAL PLANTS

Characteristics and Morphology

Indonesia's natural products are incredibly diverse and widely used in the prevention and treatment of various diseases, including essential oils from plants, which play an important role in the global aromatherapy market. Each essential oil-producing plant has a specific part of the aromatic plant that is used, including leaves, roots, twigs, seeds, bark, buds, flowers, and fruits. The resulting essential oils are volatile, making them suitable for use in relaxing aromatherapy. Bay leaves (*Syzygium polyanthum*), which belong to the Myrtaceae family and the *Syzygium* genus, are known among Indonesians as "Salam". The *S. polyanthum* tree is native to Indonesia, Malaysia, and Indochina and grows well in tropical areas at low to medium altitudes. It is medium-sized and can reach 10 – 25 m in height. The leaves are single, oval, and have a distinctive spice aroma when crushed. It has small white flowers that turn purplish when ripe. The leaves of this plant are traditionally used for various medicinal purposes (Ismail and Ahmad, 2019). Bay leaves are edible and are generally used as a spice in traditional Indonesian cuisine.

Plants belonging to the genus *Camellia*, one of which is green tea (*Camellia sinensis*), are shrubs or small trees with a height of 1 – 3 m. It has a morphology of young, green leaves that are finely hairy, oval, and finely serrated. Green tea is primarily native to East and Southeast Asia, particularly in highland areas where young shoots are harvested (Li *et al.*, 2022). Green tea and lemongrass are now widely cultivated in various tropical and subtropical regions. The aromatic herb lemongrass (*Cymbopogon citratus*) belongs to the Poaceae family with a tree height of around 1 – 1.5 m. Lemongrass is long and slender, with a thick, rounded base, and fibrous roots and rhizomes (Ariani *et al.*, 2025). Lemongrass produces a distinctive aroma, making it useful in the perfume industry

and herbal medicine, for treating hypertension, fever, nervous disorders, and digestive disorders (Duru and Enyoh, 2020).

Lavender (*Lavandula angustifolia*) is a plant in the Lamiaceae family that grows as a small shrub about 30 – 90 cm tall. Lavender has narrow, grayish-green leaves with a hairy surface and purple flowers clustered at the ends of its stems. Lavender flowers and leaves produce a strong, distinctive aroma, making its essential oil used in aromatherapy and cosmetic products (Cavanagh and Wilkinson, 2002). Lemons (*Citrus limon*) are small trees that thrive in subtropical regions. With adequate sunlight, lemon trees can grow to 3 – 6 meters tall. Lemon leaves are single, oval, and fragrant when crushed. The flowers are fragrant and white-light purple. Lemon fruit is oval, bright yellow when ripe, with a thick skin and fresh, sour flesh. Lemon fruit is used as a flavoring, a drink, and a natural cleaning agent. Lemon peel waste is very abundant due to the consumption of lemons in very large quantities (Thapa *et al.*, 2022).

Essential Oil Metabolite Profile

Plants produce secondary metabolite compounds that function as self-defense from external attacks and interact with the surrounding environment. Various types of secondary metabolite compounds found include essential oils, alkaloids, flavonoids, and terpenoids. Essential oils are complex mixtures of volatile organic compounds, most of whose basic components are derived from isoprenoid biosynthesis. Their composition can include more than 300 compounds, dominated by terpenes, accompanied by other components such as phenols, aldehydes, ketones, esters, and various aromatic compounds (Vora *et al.*, 2024). Essential oils generally have a natural color depending on the plant species, have a relatively low refractive index, and exhibit optical activity, a characteristic used to assess oil quality (Dhifi *et al.*, 2016).

The metabolite profiles of the essential oils from each plant studied in this article have one or several main aroma compounds that can be considered as character-determining compounds with their high concentrations and distinctive aromatic characteristics (Abdelmohsen and Elmaidomy, 2025), as shown in Figure 1. Bay leaf essential oil generally contains a group of compounds called phenylpropanoids, oxygenated monoterpenes, and oxygenated sesquiterpenes. The main components identified include eucalyptol or 1,8-cineole (1), which imparts a fresh, camphorous aroma, and eugenol (2), which contributes a warm, spicy, clove-like aroma. Meanwhile, the presence of β -pinene (3) and α -pinene (4) compounds can enrich the aroma profile with fresh, sharp, woody, and balsamic notes.

The volatile compounds found in green tea are more complex, including terpenoid alcohols such as linalool, geraniol, benzyl alcohol, and α -terpineol. The combination of these compounds plays an important role in determining the characteristic fresh and floral aroma of green tea (Rubab *et al.*, 2020). Linalool (5) and geraniol (6) compounds impart fruity, floral, and woody aromas. However, benzyl alcohol and phenyl ethyl alcohol produce sweet and citrusy aromas. Furthermore, α -terpineol (7) and hexadecanoic acid-methyl ester (8) provide a fresh green leafy aroma, which may contribute to the floral, fresh, and chestnut aroma of green tea (Li *et al.*, 2022). Lemongrass is dominated by monoterpene aldehydes, particularly citronellal (9) and citral (10), which are responsible for its strong citrus aroma. Lemongrass oil contains citral (geraniol and neral), geraniol, myrcene, citronellol, dipentene, farnesol, nerol, sesquiterpenes, methyl heptenone, acids, esters, and others (Avoseh *et al.*, 2015).

Linalool (5), linalyl acetate (11), and lavandulyl acetate (12) are dominant monoterpene compounds in lavender essential oil, contributing to its characteristic floral-sweet odor profile and reported sedative activity (Mondal *et al.*, 2023). In addition, there are compounds such as perillyl alcohol, coumarin, tannin, caffeic acid, terpene, limonene, cis-amine, and camphor, whose relative concentrations vary among different species (Batiha *et al.*, 2023). Fresh lemon peel can be used to obtain volatile compounds that provide the distinctive citrus aroma and taste. Lemon essential oil yield averages 1.24 – 3.00%. This oil is colorless to yellowish and rich in monoterpene hydrocarbons, such as limonene and β -pinene, which give a fresh, uplifting citrus aroma (Ben Hsouna *et al.*, 2017). A large number of active phytochemicals are contained in it, such as naringin, nomilin, limonin, octanol, and cineole which are responsible for its bitter taste β -pinene (3), limonene (13), and γ -terpinene (14) are the main aroma compounds of lemon, with the most dominant citrus aroma contribution, with a slight mixture of balsamic and pine.

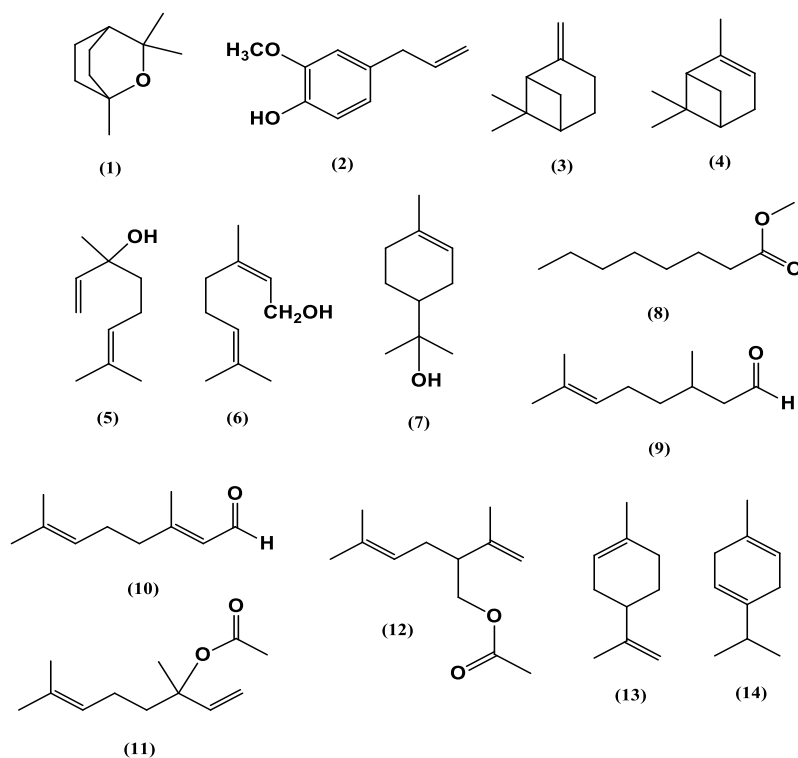


Figure 1. Aromatic compounds in herbal plants.

From a chemical perspective, the diversity of essential oil metabolites, the relative abundance of components, synergistic interactions between volatile compounds, and variations in extraction methods contribute to their aroma characteristics and biological activity. Monoterpene hydrocarbons, such as α -pinene, exhibit antimicrobial activity and produce a mild, fresh aroma (Hyldgaard *et al.*, 2012). Meanwhile, oxygenated monoterpenes such as linalool, eucalyptol, linalyl acetate, and citral, which produce a more lasting and distinctive aroma, also exhibit antimicrobial activity due to the presence of hydroxyl and aldehyde functional groups, which enhance interactions with microbial membranes and neurological targets (de Sousa *et al.*, 2023). The structure-activity relationships of essential oil constituents can be observed through synergistic interactions to produce distinct aroma characteristics. It was also influenced by a combination of molecular structure, component ratios, and the extraction method used.

Extraction Method and Environmental Conditions

Various extraction methods used on essential oils show selectivity towards the content of certain chemical compounds, as shown in Table 1. Identification of the chemical constituents of essential oils can be performed using Gas Chromatography-Mass Spectrometry (GC-MS). This analytical technique can separate components chromatographically and ionize them under specific conditions. The diversity of detected components depends on the habitat environment of the plant species, the extraction method, and the chromatography parameters used (Chouhan *et al.*, 2017). The percentage composition of various active compounds is influenced by the plant origin and extraction method. Furthermore, it can be influenced by the type of extraction, ratio of material to solvent or water, time, operating temperature, and pressure, which are known to affect the volatile compounds produced and the stability of thermolabile compounds.

Based on Table 1, the reported compounds are derived from various extraction techniques, where volatile compounds represent the core fraction of distillation-based essential oils. Meanwhile, non-volatile metabolites such as flavonoids, alkaloids, phenolics, and fatty acid derivatives are generated from solvent extraction and are presented only for comparative phytochemical context. The use of the bay leaf extraction method, namely hydrodistillation, can produce oxygenated monoterpenes and phenylpropanoids such as eucalyptol, eugenol, and α -terpineol (Lawal *et al.*, 2024), while steam distillation favors thermally stable volatile compounds, including aldehydes and sesquiterpenes (Hamad *et al.*, 2017). Meanwhile, ultrasonic-assisted extraction can increase the release of semi-volatile and non-volatile compounds, such as squalene and α -tocopherol, which are rarely detected using conventional distillation techniques (Rahim *et al.*, 2017).

Table 1. The profile of metabolites from herbal plant essential oils.

Plants	Plant Origin	Methods	Yields	Metabolites	References
Bay leaves (<i>Syzygium polyanthum</i>)	Ilorin, Kwara State, Nigeria	Hydrodistillation	-	Eucalyptol (12.30%); 2-octyl-cyclopropanoic acid (9.16%); 7-tetradecyne (6.68%); eugenol (4.15%); β -pinene (0.93%); α -pinene (0.46%); etc	(Lawal <i>et al.</i> , 2024)
	Dubrava' forest, Lithuania	Hydrodistillation	2.65%	1,8-Cineole (39.40%); linalool (13.90%); α -terpinyl acetate (11.20%); sabinene (6.70%); and methyl eugenol (5.70%)	(Ilić <i>et al.</i> , 2024)
	Purwokerto, Central Java, Indonesia	Water vapor distillation	2.4 g (0.24 %)	<i>n</i> -Decanal (5.51%); <i>n</i> -octanal (2.24%); γ -cadinene (2.21%); α -muurolin (0.80%); <i>n</i> -dodecanal (0.34%); etc	(Choironi <i>et al.</i> , 2023)
	Ketereh district, Kelantan, Malaysia	Ultrasound-assisted extraction	-	Squalene (8.78%); phytol (8.41%); α -pinene (4.92%); α -tocopherol (4.90%); linalool (0.45%); etc	(Rahim <i>et al.</i> , 2017)
Green tea (<i>Camellia sinensis</i>)	Purwokerto, Central Java, Indonesia	Hydrodistillation	0.075 %	<i>cis</i> -4-Decanal (43.49%); 1-decyl aldehyde (19.75%); capryl aldehyde (14.09%); α -curcumene (2.27%); 1,2,3,3a,4,6a-hexahydropentalene (2.06%); etc	(Hamad <i>et al.</i> , 2017)
	Moulvibazar district, Bangladesh	Cold extraction	-	Hexadecanoic acid-methyl ester (14.02%); 9,12,15-octadecatrienoic acid-methyl ester (3.95%); oxirane, tetradecyl (2.04%); phenol-2,4-bis (1,1-dimethylethyl) (1.58%); heneicosanoic acid-methyl ester (1.48%); 9,12-octadecadienoic acid-methyl ester (1.40%); 2-pentadecanone; and 6,10,14-trimethyl (1.06%)	(Hasan <i>et al.</i> , 2024)
	Bulang Mountains, China	Simultaneous distillation– extraction	-	Linalool (28.00%); geraniol (13.00%); α -terpineol (10.00%); hotrienol (4.00%); and nerol (3%)	(Kowalsick <i>et al.</i> , 2014)
Lemongrass (<i>Cymbopogon citratus</i>)	Pakistan	Hydrodistillation	0.09 – 0.63%	β -Pinene (51.20%); α -pinene (30.20%); linalool (2.33%); limonene (1.85%); muurol-5-en-4-a-ol (1.25%); myrtenal (0.27%); estragol (0.21%); etc.	(Rehman <i>et al.</i> , 2008)
	Purwokerto, Central Java, Indonesia	Steam-water distillation method	1.69%	Citronellal (35.56%); citral (33.39%); geranyl acetate (21.84%); citronellyl acetate (5.46%); trans-citral (3.75%); etc.	(Ariani <i>et al.</i> , 2025)
	Mojokerto, East Java, Indonesia	Microwave-assisted hydrodistillation	-	Geraniol (30.06%); <i>Z</i> -citral (25.88%); eugenol (12.88%); betamyrcene (12.84%); etc.	(Variyana <i>et al.</i> , 2023)

Table 1. The profile of metabolites from herbal plant essential oils (continued).

Plants	Plant Origin	Methods	Yields	Metabolites	References
	Imo, Nigeria	Hydrodistillation	-	Sapogenin (60.13 µg/g); phenol (52.77 µg/g); naringenin (28.98 µg/g); tannin (21.35 µg/g); steroids (17.82 µg/g); flavanones (13.31 µg/g); etc.	(Duru and Enyoh, 2020)
Lavender (<i>Lavandula angustifolia</i>)	Pulwama, Jammu, and Kashmir, India	Negative pressure cavitation extraction	-	Linalool (27.12%); linalyl acetate (25.23%); etc.	(Gul <i>et al.</i> , 2023)
	Xinjiang, China	Microwave-assisted hydrodistillation	3.19 %	Linalool (32.90%); linalyl acetate (27.00%); lavandulyl acetate (10.90%); trans-β-ocimene (4.21%); α-terpineol (3.51%); etc.	(Liu <i>et al.</i> , 2018)
	Xinjiang, China	Hydrodistillation	3.23 %	Linalool (30.50%); linalyl acetate (22.80%); lavandulyl acetate (11.20%); α-terpineol (5.52%); trans-β-ocimene (3.82%); etc.	(Liu <i>et al.</i> , 2018)
Lemon (<i>Citrus limon</i>)	Southeast of Spain	Steam distillation	0.3 – 1.2%	Linalool (37-54%); linalyl acetate (21-36%); and (<i>E</i>)-β-caryophyllene (1-3%)	(Carrasco <i>et al.</i> , 2015)
	Kathmandu, Nepal	Steam distillation	-	Limonene (28.94 %); β-pinene (15.46 %); γ-terpinene (8.64%); α-terpineol (5.37%); geranial (5.28 %); terpinen-4-ol (3.29 %); α-pinene (3.18%); etc.	(Thapa <i>et al.</i> , 2022)
	Imo, Nigeria	Hydrodistillation	-	Quinine (50.63 µg/g); phenol (46.90 µg/g); sapogenin (34.44 µg/g); naringenin (27.11 µg/g); tannin (26.13 µg/g); steroids (19.81 µg/g); flavanones (17.74 µg/g); etc.	(Duru and Enyoh, 2020)
	Sfax slaughterhouse, Tunisia	Hydrodistillation	3%	Limonene (39.74%); β-pinene (25.44%); α-terpineol (7.30%); nerolidol (6.91%); farnesol (4.28%); acetate geranyl (3.03%); linalyl acetate (3.01%); linalool (2.16%); acetate neryl (1.74%); etc.	(Ben Hsouna <i>et al.</i> , 2017)
	Constantine, Algeria	Cold pression	0.81 ± 0.092 %	Limonene (66.75%); β-pinene (13.92%); γ-terpinene (3.10%); geranial (2.76%); α-pinene (2.15%); β-myrcene (1.41%); α-terpineol (0.36%); linalool (0.25); citronellal (0.19%); etc	(Louiza <i>et al.</i> , 2016)

In contrast, the cold extraction method for green tea can preserve compounds fresh with low to moderate volatility, including non-volatile compounds such as caffeine and fatty acid esters, due to minimal thermal stress (Hasan *et al.*, 2024). Some reported metabolites, such as flavonoids, alkaloids, fatty acid methyl esters, and phenolics, are classified as non-volatile compounds derived from non-distillation extraction methods or from plant matrices co-extracted from essential oils. Simultaneous distillation-extraction (SDE) is considered more effective for capturing characteristic aroma compounds such as linalool, geraniol, and α -terpineol because it combines heating with the use of an organic solvent (Kowalsick *et al.*, 2014). Hydrodistillation of green tea produced essential oils dominated by monoterpene hydrocarbons, such as β -pinene and α -pinene, indicating that this method tends to extract low-volatile compounds and is less selective toward more complex floral aroma components (Rehman *et al.*, 2008).

Lemongrass essential oil is generally extracted using steam-based distillation methods, such as steam-water distillation and microwave-assisted hydrodistillation. Steam-water distillation has been shown to be effective in producing high citral content, the primary determinant of citrus aroma (Ariani *et al.*, 2025). The microwave-assisted hydrodistillation method used in essential oil extraction has several advantages, including accelerating the extraction process and potentially reducing excess heat or thermal degradation, resulting in an essential oil profile containing monoterpene aldehydes and other aromatic compounds such as eugenol and betamyrsene with a higher composition (Variyana *et al.*, 2023). Similarly, conventional distillation methods used for lavender generally produce essential oils rich in linalool and linalyl acetate compounds, which contribute to the characteristic floral aroma of lavender essential oil. During conventional distillation, prolonged heating causes partial hydrolysis of the ester compounds described. Therefore, the supported technologies are microwave-assisted hydrodistillation and negative-pressure cavitation extraction, which are attractive approaches for reducing aroma interference under thermal conditions (Liu *et al.*, 2018; Gul *et al.*, 2023). Thus, the non-conventional method used has the advantage of maintaining the aroma quality of the essential oil.

Lemon essential oil can be extracted using steam distillation and hydrodistillation methods, which yield oil rich in β -pinene, γ -terpinene, and limonene as the main components, as well as oxygenated compounds such as α -terpineol and geraniol in small amounts (Thapa *et al.*, 2022). The cold-pressing method of lemon extraction has been shown to produce limonene-rich oil with a composition that is very similar to that of the oil glands in the fruit's skin (Louiza *et al.*, 2016). This suggests that heat-free methods can minimize thermal degradation and retain minor compounds that contribute to the characteristic fresh citrus aroma.

Steam distillation is generally a method for extracting essential oils from natural products, carried out at temperatures below the boiling point of the substance, thus maintaining the quality of the resulting oil product. The conventional, simple, and inexpensive hydrodistillation method requires a longer extraction time and can cause compound degradation, thus reducing oil quality. In comparison, microwave hydrodistillation, a newer method, offers shorter extraction times, higher efficiency, and lower environmental hazards. This makes it suitable for use in both the laboratory and industrial scale, as it maintains oil quality (Majewska *et al.*, 2019).

The use of different extraction methods generally results in variations in the chemical composition of essential oils and their relative proportions, even when derived from the same plant species. This phenomenon can also be influenced by geographic factors and environmental conditions that modulate the biosynthetic pathways that can produce the different characteristics of essential oils, in this case, the essential oils of bay leaves, green tea, lemongrass, lavender, and lemon from different locations of origin. For example, the use of steam distillation of essential oils on bay leaves from Indonesia, Malaysia, and Nigeria can produce different compositions of compounds, including *cis*-4-decene, eucalyptol, and squalene. Similarly, the essential oils of lemongrass, lavender, and lemon, which originate from different geographic regions, can produce varying relative concentrations of linalool, linalyl acetate, and limonene. Environmental conditions in a plant's native habitat, including temperature, rainfall, humidity, altitude, and maturity, can also influence secondary metabolite biosynthesis pathways in plants. Environmental temperature can control the biosynthesis of terpenoid compounds. Higher temperatures tend to increase the accumulation of monoterpenes, while lower temperatures favor the formation of sesquiterpenes (Rehman *et al.*, 2016). Rainfall and humidity levels also affect plant biosynthetic activity through water availability and physiological stress. These factors can reduce essential oil yields (Das and Prakash, 2024). Altitude in a plant's habitat also influences metabolite composition through changes in light intensity and temperature. This is often considered an adaptive response of plants to ultraviolet radiation (Sharma *et al.*, 2025). Plant growth and development go through several stages that influence the compound profile of essential oils. During the early growth phase, essential oils tend to be predominantly composed of monoterpene hydrocarbons, while mature plants

typically exhibit increased levels of more bioactive oxygenated compounds. Similarly, the flowering and harvest phases can also produce optimal active compound content, thus determining the plant's characteristics (Souadia, 2022; Abdelmohsen and Elmaidomy, 2025). Based on this analysis, it can be said that the diversity of the composition of active compounds in essential oils is caused by the adaptive response of plants to environmental influences and plant growth.

BIOACTIVITIES

The bioactivity of essential oils generally stems from the interaction of various secondary metabolites contained within them, rather than from a single compound. This reflects the phytochemical diversity responsible for their therapeutic properties, making them potentially effective in treating various diseases. This review will clearly and systematically discuss biological activities in the context of aromatherapy. Activities such as antioxidant, antibacterial, anti-inflammatory, and relaxing effects are related to neurophysiological responses triggered through the olfactory pathway and modulation of the central nervous system.

Antioxidant Activity

The most widely reported biological activity of essential oils is antioxidant, especially associated with potential metabolite compounds such as phenolic groups and oxygenated monoterpenes, namely eugenol, linalool, citral, and α -terpineol. Essential oils derived from bay leaves and lemongrass are reported to have high free radical scavenging capacity, which may be attributed to the presence of eugenol and citral as their dominant compounds. In contrast, lavender essential oil generally exhibits moderate antioxidant activity, primarily due to the presence of linalyl acetate and linalool, naturally occurring monoterpenes, and is relatively lower than that of essential oils rich in phenolic compounds. This difference confirms that the chemical profile plays a role in determining the antioxidant strength of each essential oil.

Bay leaf essential oil was reported to exhibit antioxidant activity with an EC_{50} of 1.43 mg/mL (Ilić *et al.*, 2024). Green tea extract with an inhibitory concentration 50 (IC_{50}) value of 69.51 μ g/mL shows strong DPPH radical scavenging activity, although it is still lower than that of ascorbic acid (IC_{50} of 10.70 μ g/mL) as a positive control (Hasan *et al.*, 2024). The main terpenoid compounds in essential oils, including monoterpene hydrocarbons such as limonene and β -pinene, confer lemon essential oil with a DPPH radical scavenging capacity of 0.120 ± 0.049 μ g/mL (Louiza *et al.*, 2016). Likewise, the citral compound, which belongs to the monoterpene aldehyde group in lemongrass essential oil, can stabilize free radicals through co-oxidation with target substrates and enhance oxidative chain reactions (Baschieri *et al.*, 2017). Furthermore, *in vivo* studies on lavender essential oil have reported protective effects against conditions associated with oxidative stress. This is evidenced by the study's results, which effectively protected body tissues from oxidative damage in conditions associated with diabetes by reducing lipid peroxidation and increasing the body's internal antioxidant defenses (Sebai *et al.*, 2013). These findings suggest that the stability and availability of antioxidant compounds may influence the antioxidant effectiveness of essential oils.

Antibacterial Activity

Bioactive compounds in essential oils have broad-spectrum antibacterial activity against both gram-positive and gram-negative bacteria. The antibacterial activity of compounds such as eugenol, limonene, linalool, 1,8-cineole, and citral involves disrupting the structure of bacterial cell membranes and inhibiting intracellular enzyme function, leading to cell damage and death (Ramadhania *et al.*, 2018). Bay leaf essential oil contains phenylpropanoid and aldehyde compounds, such as eugenol, octanal, decanal, and dodecanal, which are associated with antibacterial activity. This is evidenced by the minimum inhibitory concentration (MIC) values of 31.25 μ g/mL against *Bacillus subtilis* and 250 μ g/mL against *Bacillus cereus* (Hamad *et al.*, 2017; Choironi *et al.*, 2023). In contrast, green tea extracts rich in non-volatile polyphenolic compounds such as catechins have been reported to exhibit antibacterial potential with MIC values ranging from 10 – 35 mg/mL against several pathogens, including *Escherichia coli*, *Staphylococcus aureus*, *Enterococcus faecalis*, and *Salmonella typhimurium* (Liu *et al.*, 2022). However, these findings represent the activity of extracts obtained from solvents, not the volatile essential oil fraction. The antibacterial mechanisms of these polyphenolic compounds are generally associated with protein binding, enzyme inhibition, and induction of oxidative stress.

Lemongrass essential oil exhibited potent antibacterial activity, evidenced by inhibition zone diameters of 30.56 ± 0.02 mm and 31.94 ± 0.02 mm against *S. aureus* and *E. coli*, respectively (Ariani *et al.*, 2025). The

antibacterial activity of lemon peel essential oil was carried out against *B. subtilis* by producing an inhibition zone of 21 mm (Thapa *et al.*, 2022). The citral compound in lemongrass oil exhibits effective natural antibacterial activity through a mechanism that disrupts cell membrane permeability, causing leakage of cell contents and reducing energy (ATP) production, which ultimately kills bacterial cells or prevents their proliferation (Majewska *et al.*, 2019). Furthermore, encapsulated lavender essential oils exhibited inhibitory activity against resistant pathogenic bacteria, *E. coli* and *S. aureus*, with MIC and MBC values of 0.50 – 1.66 mg/mL (Soulaïmani *et al.*, 2025). These findings confirm the important roles of monoterpene and oxygenated compounds in determining the antibacterial potential and stability of various essential oils, particularly lemongrass, lemon, and lavender oils.

Anti-inflammatory Activity

Lavender and lemongrass essential oils exhibit potent anti-inflammatory effects, supporting their traditional use in aromatherapy and topical applications. The anti-inflammatory efficacy of lemongrass essential oil has been demonstrated through the reduction in edema after oral administration, with an inhibition rate reaching 82.75% at a dose of 10 mg/kg and increasing to 86.2% at a dose of 100 mg/kg, comparable to the effect of the standard anti-inflammatory drug diclofenac (50 mg/kg). This activity is due to the presence of monoterpene aldehyde compounds, such as geranial and neral, which help suppress the release of inflammatory mediators and reduce the acute inflammatory response (Pérez *et al.*, 2011). Meanwhile, lavender essential oil also exhibits anti-inflammatory activity by inhibiting the lipoxygenase pathway, due to the presence of linalool, limonene, p-cymene, and camphor compounds (Carrasco *et al.*, 2015). Lavender oil has been reported to modulate the innate immune response by enhancing the activity of human macrophages against *S. aureus* in nosocomial infections, thus positioning it as a multifunctional agent with anti-inflammatory and immunomodulatory potential (Giovannini *et al.*, 2016; Cavanagh and Wilkinson, 2002). This essential oil, which contains oxygenated monoterpene compounds, including linalool, α -terpineol, and citral, generally modulates key inflammatory mediators, including cytokines, prostaglandins, and nitric oxide. Furthermore, it can inhibit inflammatory pathways, specifically by suppressing the activity of the enzymes cyclooxygenase and inducible nitric oxide synthase (De Cássia da Silveira e Sá *et al.*, 2013).

Synergistic Bioactivities Underlying Relaxation Effects

The relaxing effects of aromatherapy are the result of the synergistic interaction of a variety of secondary metabolites with diverse biological activities, not the action of a single compound. In addition to their antioxidant and anti-inflammatory properties, essential oils are also reported to exhibit antiviral, analgesic, anxiolytic, and insecticidal activity. These bioactivities play a crucial role in supporting the relaxing effect by suppressing oxidative stress and neuroinflammation, which are known to be closely linked to anxiety and stress disorders (Caballero-Gallardo *et al.*, 2025). The compounds citral, linalool, eugenol, and limonene from aromatherapy are reported to be able to ward off free radicals through the mechanism of inhibiting inflammatory pathways, thereby increasing the anxiolytic and stress-relieving effects and helping to maintain the stability of the central nervous system (Miguel, 2010).

Essential oil derived from bay leaves is reported to contain various bioactive compounds, including eugenol, eucalyptol, methyl chavicol, and pinene, which contribute to its aromatic character and enhance its relaxing effect (Salehi *et al.*, 2019). Green tea-based aromatherapy provides a relaxing effect through the combined synergistic interaction of caffeine, L-theanine, and other volatile aromatic compounds in influencing anxiety levels and sleep quality (Kim *et al.*, 2019). Lemongrass essential oil content dominated by citral compounds is generally known to have various biological activities, including antioxidant, antibacterial, antifungal, insecticidal, and insect repellent activities, which indirectly contribute to health and physiological balance (Majewska *et al.*, 2019). Additionally, lavender and lemon essential oils are widely used in aromatherapy for their calming, mood-boosting effects. This is due to the ability of the compounds linalool, α -terpinene, linalyl acetate, limonene, and β -pinene to modulate the central nervous system (Guo and Wang, 2020; Sharmeen *et al.*, 2021). These findings confirm that the synergistic interaction of various bioactive compounds has the potential to produce the relaxing effects of aromatherapy. Therefore, the use of essential oils is being explored for further development in the pharmaceutical, cosmetic, and functional food sectors.

ESSENTIAL OILS AS AROMATHERAPY RELAXATION

A holistic therapeutic approach in aromatherapy utilizes the volatile aromatic properties of essential oils to promote relaxation. Essential oils consist of a complex mixture of various secondary metabolites, primarily terpenoid-derived compounds such as monoterpenes and oxygenated monoterpenes, produced in the secretory tissues of plants, particularly the glandular trichomes of leaves and flowers (Sharifi-Rad *et al.*, 2017). Compounds such as citral, linalyl acetate, linalool, limonene, and eugenol, commonly found in bay leaves, lavender, lemon, and lemongrass, have been widely reported to possess anxiolytic, sedative, and mood-regulating activities, thus supporting their use in aromatherapy-based relaxation applications.

The pharmaceutical and healthcare industries are developing essential oils in various product forms, including aromatherapy diffusers, perfumes, roll-ons, and sprays. Aromatherapy applications include not only inhalation but also topical applications such as medical treatments, massage, and cosmetic products. The mechanism of relaxation through inhalation involves stimulation of the olfactory system and the psycho-aromatherapy process. After aromatherapy is inhaled, volatile molecules interact with olfactory receptors in the nasal epithelium and send signals to the limbic system, especially to the parts of the brain of the amygdala (an emotional center) and the hypothalamus (which regulates stress, hormones, and sleep) (Ali *et al.*, 2015). Activation of this system is achieved by stimulating the release of neurotransmitters such as serotonin (a mood stabilizer) and endorphins (a natural pain reliever), which contribute to stress reduction, reduce muscle tension, and promote relaxation. Essential oils with a high content of oxygenated monoterpenes, particularly lavender oil, which is predominantly composed of, are known to be highly effective in modulating the central nervous system and producing a calming effect. The relationship between chemical composition and psychological responses is shown in Figure 2.

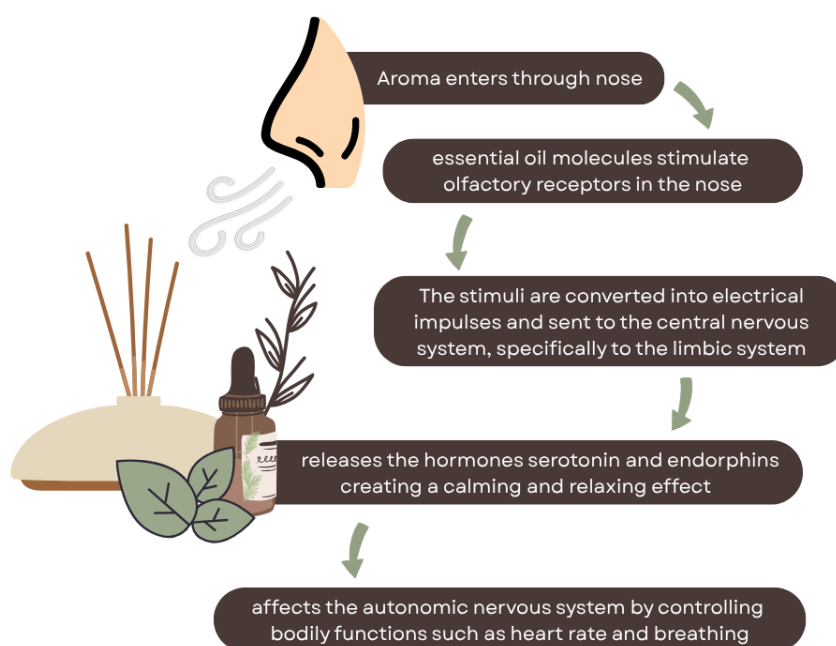


Figure 2. The mechanism of essential oils as body relaxation agents.

In addition, volatile compounds in aromatherapy also play a role in regulating the central nervous system, either when inhaled directly through the olfactory bulb or when absorbed directly through the lungs into the systemic circulation. This allows for rapid neuromodulatory effects and promotes physiological relaxation by modulating heart rate and respiratory rhythm, reducing muscle tension, and thus reducing stress (Cui *et al.*, 2022; Vora *et al.*, 2024). Previous studies have also reported. Previous studies also reported that essential oils strengthen their role in emotional balance and stress management by regulating hormone levels, stimulating neurogenesis, and suppressing neurogenic inflammation (Fung *et al.*, 2021; Yuan *et al.*, 2021).

Overall, the effectiveness of essential oils in relaxation therapy has been shown not only to demonstrate changes in psychological parameters, such as reduced anxiety levels and improved mood, but also to provide physiological benefits, including increased blood circulation, vasorelaxation, pain relief, and immune support

(Kennedy, 2018; Cheong *et al.*, 2021). This is evident in the oxygenated monoterpene compounds, particularly linalool, which are abundant in lavender and other essential oils. Several studies have reported anxiolytic and sedative effects through modulation of the GABAergic system. In vivo studies have shown that linalool enhances GABA receptor-mediated neurotransmission, thereby reducing neuronal excitability and eliciting behavioral responses that mimic anxiolytic effects (Milanos *et al.*, 2017). Meanwhile, limonene contributes to its relaxing effects through the serotonergic pathway by influencing serotonin (5-HT) signaling and monoaminergic neurotransmission, both of which play roles in mood regulation and stress responses. Inhalation of limonene increases serotonergic activity and suppresses stress-induced behavioral responses in animal models (Eddin *et al.*, 2021). Aromatherapy's relaxation potential results from the synergistic interaction between the chemical composition and bioactivity of essential oils, supporting their rational, evidence-based use as therapeutic agents to promote holistic physical and emotional health.

CONCLUSION

Selected herbal essential oils extracted from bay leaves, green tea, lemongrass, lavender, and lemon are rich in secondary metabolites that exhibit relaxing effects and antioxidant, antibacterial, and anti-inflammatory activities. Eugenol and citral compounds are known to have antibacterial and anti-inflammatory potential in inhibiting microbial growth and suppressing inflammatory responses. Meanwhile, linalool, linalyl acetate, limonene, and geraniol are highly effective in influencing the central nervous system through activating the olfactory pathway connected to the limbic system. The synergistic interaction between these components helps create a calming effect, elevating mood, and relieving stress. The chemical composition and biological activities of the related compounds strengthen the scientific basis for the use of Indonesian herbal essential oils as natural aromatherapy-based relaxants. However, further research is still needed, particularly human clinical trials using standardized extraction methods and the development of effective and safe formulations, to support widespread application in the pharmaceutical and healthcare sectors.

CONFLICT OF INTEREST

There is no conflict of interest concerning this work.

AUTHOR CONTRIBUTION

NRR: Conceptualization, Manuscript Review, Drafting Supervision, and Finalization of Manuscript.

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DECLARATION OF GENERATIVE AI

The author used artificial intelligence (AI) tools to improve grammar and clarity. All scientific content, analysis, and conclusions were developed, verified, and are the sole responsibility of the author.

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