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RESEARCH ARTICLE

The Therapeutic Potential of Aromatic Plants: A New Frontier in Bioactive Compound Research

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ABSTRACT

Aromatic plants, historically used in folk medicine and as food preservatives, are gaining renewed attention for their therapeutic potential. Originating predominantly from the Mediterranean region, these plants, including oregano, rosemary, sage, anise, and basil, contain a variety of biologically active compounds such as polyphenolics. These compounds exhibit a range of beneficial properties, including antimicrobial, antioxidant, antiparasitic, antiprotozoal, antifungal, and anti-inflammatory activities. The growing demand for natural, eco-friendly, and generally recognized as safe products has highlighted the potential of aromatic plants and their derivatives for advancing human and animal nutrition and health. This review synthesizes the current literature on the in vivo and in vitro applications of aromatic plants, emphasizing their bioactive compounds and their therapeutic applications. It explores recent advancements in extraction technologies, the characterization of bioactive compounds, and emerging trends in integrating these plants into modern healthcare practices. Despite their promise, considerations related to safety and toxicity are crucial for their effective use. This review aims to provide a comprehensive overview of the therapeutic potential of aromatic plants and their future directions in research and application.

Key words: Aromatic plants, Bioactive compounds, Antimicrobial properties, Antioxidant activity, Therapeutic applications

INTRODUCTION

The exploration of aromatic plants and their bioactive compounds has garnered significant interest in recent years due to their potential therapeutic applications. Aromatic plants, such as lavender, rosemary, and peppermint, have been used for centuries in traditional medicine, and contemporary research continues to unveil their myriad health benefits. These plants produce a variety of bioactive compounds, including essential oils, phenolics, and flavonoids, which have demonstrated significant therapeutic potential across diverse domains (Schilcher, 2000; Perry et al., 2000).

The therapeutic properties of aromatic plants are largely attributed to their complex chemical compositions. Essential oils, for example, are volatile compounds extracted from various plant parts, such as leaves, flowers, and stems, and are known for their antimicrobial, anti-inflammatory, and antioxidant activities (Bakkali et al., 2008). These oils contain constituents like terpenes and phenylpropanoids, which have been extensively studied for their effects on human health. Lavender oil, with its prominent compound linalool, has been shown to possess anxiolytic and sedative effects, making it useful in treating anxiety and insomnia (Cavanagh & Wilkinson, 2002). Similarly, rosemary oil, rich in cineole, has demonstrated significant anti-inflammatory and cognitive-enhancing properties (Lopez et al., 2017).

The significance of bioactive compounds in aromatic plants extends beyond traditional uses. Recent advancements in analytical techniques have allowed for more precise identification and quantification of these compounds, revealing their potential in modern therapeutic contexts (Table 1). For instance, high-performance liquid chromatography (HPLC) and gas chromatography-mass spectrometry (GC-MS) are now standard methods for profiling the chemical constituents of essential oils (Santos et al., 2013).

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These methods have facilitated the discovery of novel compounds and the elucidation of their mechanisms of action, leading to a better understanding of their therapeutic efficacy.

Table 1: Applications of Aromatic Plants, Extracts, and Essential Oils

Main Activities	Uses	Specific Applications
Antioxidant activity	Feed additives	Antioxidants, growth promoters
Antimicrobial activity	Food industry	Flavors, fragrances, preservatives
Anticoccidial activity	Cosmetic industry	Perfumes, skin products
	Pharmaceutical industry	Medicines

The objective of this review is to provide a comprehensive overview of the therapeutic potential of aromatic plants, focusing on recent research advancements in bioactive compound studies. By examining the therapeutic applications of these plants, including their anti-inflammatory, antimicrobial, antioxidant, and anti-cancer properties, this review aims to highlight the progress made in this field and identify areas for future research. Additionally, it seeks to address the mechanisms of action underlying these therapeutic effects and the challenges associated with their use.

Aromatic plants represent a promising frontier in bioactive compound research, offering a wealth of therapeutic possibilities that extend far beyond their traditional uses. The continued exploration of these plants and their bioactive compounds is essential for unlocking new therapeutic strategies and advancing our understanding of their role in human health. As research progresses, it will be crucial to address the challenges associated with their use, including safety and efficacy considerations, to fully realize their potential in modern medicine (Cheng et al., 2024).

Aromatic Plants and Their Bioactive Compounds

Aromatic plants are distinguished by their ability to produce volatile compounds that contribute to their characteristic scents and flavors. These plants, which include species such as lavender (*Lavandula angustifolia*), rosemary (*Rosmarinus officinalis*), and peppermint (*Mentha piperita*), are not only valued for their sensory attributes but also for their rich array of bioactive compounds with therapeutic potential (Baser & Buchbauer, 2010).

Bioactive compounds in aromatic plants are primarily classified into essential oils, phenolics, and flavonoids. Essential oils are complex mixtures of volatile organic compounds, including terpenes (e.g., limonene, pinene) and phenylpropanoids (e.g., eugenol, cinnamaldehyde) (Cavalcante et al., 2016). These compounds are responsible for the therapeutic properties of the plants. For instance, the essential oil of peppermint contains menthol, which has demonstrated significant analgesic and antispasmodic effects, making it useful in treating gastrointestinal discomfort and respiratory issues (Rohde et al., 2002).

Phenolic compounds, another major class of bioactive molecules, are known for their antioxidant properties. They are widely distributed in aromatic plants and include compounds such as rosmarinic acid and caffeic acid (Pietta, 2000). These phenolics can neutralize free radicals and protect cells from oxidative stress, which is beneficial in preventing chronic diseases such as cardiovascular disorders and cancer (Rice-Evans et al., 1996). For example, rosmarinic acid, found in rosemary, has been linked to reduced inflammation and enhanced immune function.

Flavonoids, a diverse group of polyphenolic compounds, contribute to the color and health benefits of aromatic plants. These compounds possess various biological activities, including anti-inflammatory, anti-allergic, and antiviral effects (Heim et al., 2002). For instance, the flavonoid quercetin, present in many aromatic herbs, has shown potential in modulating immune responses and protecting against viral infections (D'Andrea, 2015).

The extraction and characterization of these bioactive compounds are critical for understanding their therapeutic potential. Traditional methods such as steam distillation and solvent extraction are commonly used to obtain essential oils from aromatic plants. More recent advancements have introduced techniques such as supercritical fluid extraction (SFE) and microwave-assisted extraction (MAE), which enhance yield and purity (Jaziri et al., 2014). Gas chromatography-mass spectrometry (GC-MS) and high-performance liquid chromatography (HPLC) are essential analytical techniques employed to identify and quantify these compounds, providing insights into their chemical composition and concentration (Santos et al., 2013).

These methods have enabled researchers to uncover novel compounds and assess their efficacy in various therapeutic contexts. For example, the use of GC-MS has facilitated the identification of new terpenoid compounds in essential oils, while HPLC has been instrumental in quantifying phenolic compounds in plant extracts (Cao et al., 2016). This enhanced ability to analyze and characterize bioactive compounds has paved the way for more targeted and effective therapeutic applications of aromatic plants.

Therapeutic Applications

Aromatic plants have garnered substantial attention for their diverse therapeutic applications, attributed to their complex array of bioactive compounds. Anti-inflammatory and analgesic effects are among the most well-documented therapeutic benefits of aromatic plants (Table 2 shows the history of documentation of aromatic plants). Essential oils such as those derived from lavender (*Lavandula angustifolia*) and rosemary (*Rosmarinus officinalis*) have been shown to exert significant anti-inflammatory effects through the modulation of inflammatory pathways. Lavender oil, rich in linalool and linalyl acetate, has demonstrated efficacy in reducing inflammation and pain, making it a valuable adjunct in managing conditions like arthritis and musculoskeletal pain (Cavanagh & Wilkinson, 2002). Similarly, rosemary oil, which contains cineole and rosmarinic acid, has been reported to inhibit pro-inflammatory cytokines and enzymes, offering relief in inflammatory disorders and chronic pain conditions (Lopez et al., 2017).

Table 2: Historical Overview of Aromatic Plant Documentation (Giannenas et al., 2020)

Period	Dates	Key Events
Prehistory	60000 BC	Neanderthal period
Ancient History	5000 BC	Sumerian writings
	2700 BC	Chinese writings
	1800 BC	Egyptian writings
	1500 BC	Indian writings
	480-379 BC	Greek physician Hippocrates writings
Postclassical Era	1st Century AD	Jesus' birth: wisemen offered aromatic plants e.g. myrrh
	5th-12th century	Alchemists' documents
Mid Modern Period	13th century	Explorers' writings e.g. Marco Polo
	18th century	Herbalist Linnaeus' documents
Contemporary Period	19th century	Discovery and isolation of compounds of aromatic plants
	20th-21st century	Innovative uses of aromatic plants e.g. neutraceuticals

Antimicrobial and antiviral properties of aromatic plants have also been extensively studied, revealing their potential as natural alternatives to conventional antimicrobial agents. Essential oils such as tea tree oil (*Melaleuca alternifolia*) and thyme oil (*Thymus vulgaris*) are renowned for their broad-spectrum antimicrobial activity. Tea tree oil, which contains terpinen-4-ol and alpha-terpineol, has been widely recognized for its effectiveness against bacterial infections, including acne and fungal infections (Carson et al., 2006). Thyme oil, rich in thymol and carvacrol, exhibits potent antibacterial and antiviral activities, making it a promising candidate for addressing infections and supporting immune function (Hammer et al., 1999).

In addition to their anti-inflammatory and antimicrobial properties, aromatic plants possess notable antioxidant capabilities. Antioxidants are crucial in protecting cells from oxidative damage, which is implicated in the development of various chronic diseases. Aromatic plants such as rosemary and oregano (*Origanum vulgare*) are particularly rich in antioxidants. Rosmarinic acid, a major compound in rosemary, has been shown to scavenge free radicals and reduce oxidative stress, thereby providing protective effects against conditions like cardiovascular diseases and neurodegenerative disorders (Pietta, 2000). Oregano oil, containing high levels of phenolic compounds such as carvacrol, also exhibits significant antioxidant activity, contributing to its therapeutic benefits (Baser & Buchbauer, 2010).

The anti-cancer potential of aromatic plants is another area of growing interest. Research indicates that certain aromatic plant extracts and their bioactive compounds can inhibit cancer cell proliferation and induce apoptosis. For example, compounds such as curcumin from turmeric (*Curcuma longa*) and resveratrol from grapes (*Vitis vinifera*) have shown promise in preventing cancer by modulating various signaling pathways involved in tumorigenesis (Aggarwal et al., 2006). Lavender and rosemary essential oils, with their rich content of bioactive terpenes and phenolics, have also demonstrated cytotoxic effects against cancer cell lines, suggesting their potential as complementary agents in cancer therapy (Hosseinzadeh & Sadeghi, 2010).

Mechanisms of Action

The therapeutic effects of aromatic plants are primarily attributed to the intricate mechanisms of action of their bioactive compounds. These mechanisms involve interactions with various molecular targets and pathways that influence cellular processes, thereby contributing to their health benefits. One of the primary mechanisms through which bioactive compounds in aromatic plants exert their therapeutic effects is by interacting with cellular receptors. Essential oils and their constituents can modulate receptor activity, influencing various physiological responses. For example, linalool, a major component of lavender oil, has been shown to interact with GABA-A receptors, leading to anxiolytic and sedative effects (Cavanagh & Wilkinson, 2002). Similarly, menthol from peppermint oil interacts with transient receptor potential (TRP) channels, providing analgesic and antispasmodic effects (Takahashi et al., 2010). These interactions demonstrate how aromatic plant compounds can influence neural and sensory pathways, resulting in therapeutic outcomes.

In addition to receptor interactions, aromatic plant compounds can affect cellular signaling pathways, which play a crucial role in regulating inflammation, oxidative stress, and cell proliferation. For instance, rosmarinic acid, a prominent compound in rosemary, inhibits the nuclear factor kappa B (NF-kB) pathway, which is a key regulator of inflammatory responses (Mubashir et al., 2022). By suppressing NF-kB activation, rosmarinic acid reduces the production of pro-inflammatory cytokines and enzymes, thereby mitigating inflammation. Similarly, curcumin from turmeric affects various signaling pathways, including the mitogen-activated protein kinase (MAPK) and nuclear factor erythroid 2-related factor 2 (Nrf2) pathways, contributing to its anti-inflammatory and antioxidant effects (Aggarwal et al., 2006).

The antioxidant properties of aromatic plant compounds are another critical aspect of their mechanisms of action. These compounds can neutralize free radicals and reduce oxidative stress, which is implicated in the pathogenesis of various chronic diseases. For example, carvacrol and thymol, found in thyme oil, exhibit strong free radical scavenging activities, thereby protecting cells from oxidative damage (Hernández et al., 2009). Rosmarinic acid also plays a significant role in antioxidant defense by chelating metal ions and modulating oxidative stress-related pathways (Pietta, 2000).

Synergistic effects of bioactive compounds from aromatic plants represent another important mechanism of action. Synergy occurs when the combined effect of multiple compounds is greater than the sum of their individual effects. For example, in essential oils containing multiple terpenes and phenolics, the combined action of these compounds can enhance their therapeutic efficacy. Studies have shown that blends of essential oils can exhibit greater antimicrobial and anti-inflammatory activities compared to individual components (Baser & Buchbauer, 2010). This synergy highlights the potential for developing more effective therapeutic formulations by combining various plant-derived compounds.

Safety and Toxicity

The safety and toxicity of aromatic plants and their bioactive compounds are crucial considerations for their therapeutic applications. While many aromatic plants are widely used and generally regarded as safe, it is essential to evaluate. Generally, aromatic plants and their essential oils are considered safe when used appropriately. However, toxicity can occur, particularly with excessive use or improper application. For instance, essential oils are highly concentrated and can cause irritation or allergic reactions if applied directly to the skin without dilution. Oils such as cinnamon (*Cinnamomum verum*) and oregano (*Origanum vulgare*), which contain strong bioactive compounds, are known to cause skin irritation or dermatitis in sensitive individuals (Lee et al., 2013). Therefore, it is recommended to use these oils in diluted forms and perform patch tests before widespread application.

Ingesting essential oils can also pose risks if not done under medical supervision. Some essential oils, like those from eucalyptus (*Eucalyptus globulus*) and camphor (*Cinnamomum camphora*), are toxic when consumed in large quantities. Eucalyptus oil, for instance, can cause gastrointestinal distress, nausea, and even neurotoxic effects in high doses (Benites et al., 2020). Similarly, camphor oil, if ingested in excessive amounts, can lead to seizures and central nervous system toxicity (Davidson & Dyer, 2010). Hence, proper dosage and administration are critical when using these oils internally.

The potential for drug interactions is another important aspect of safety. Aromatic plant compounds can interact with pharmaceuticals, potentially altering their efficacy or causing adverse effects. For example, essential oils containing bergamot (*Citrus bergamia*) can increase photosensitivity and interact with medications metabolized by the cytochrome P450 enzyme system, leading to altered drug metabolism (Mattioli et al., 2013). It is essential for individuals taking prescription medications to consult healthcare professionals before using essential oils to avoid potential interactions.

Additionally, the quality and purity of essential oils are vital for ensuring safety. The market is rife with adulterated or contaminated oils, which can pose health risks. Adulteration can dilute the therapeutic properties of essential oils and introduce harmful substances. It is advisable to use essential oils from reputable sources that provide information about their purity and quality through proper certification (Baser & Buchbauer, 2010).

Despite these considerations, many studies have shown that when used appropriately, aromatic plants and their essential oils offer a favorable safety profile. Research indicates that low to moderate doses of essential oils are generally well-tolerated and have minimal adverse effects (Brattström & Toft, 2017). Nonetheless, ongoing research and vigilance are necessary to monitor and mitigate any potential risks associated with their use.

Recent Advances and Emerging Trends

Recent advances in the field of aromatic plant research have unveiled new possibilities and emerging trends that enhance our understanding of their therapeutic potential and applications. Innovations in extraction technologies, advancements in phytochemistry, and evolving methodologies for evaluating bioactivity are driving the exploration of aromatic plants.

One notable advancement is the improvement of extraction and analytical techniques that enhance the yield and quality of bioactive compounds from aromatic plants. Traditional methods, such as steam distillation and solvent extraction, are being complemented by newer technologies like supercritical fluid extraction (SFE) and microwave-assisted extraction (MAE). SFE, utilizing supercritical CO_2 as a solvent, offers advantages in terms of high selectivity and purity of extracted compounds, minimizing thermal degradation (Miller & Goff, 2018). Similarly, MAE accelerates extraction processes and improves the efficiency of obtaining essential oils and other phytochemicals, which has implications for both research and commercial production (Chemat et al., 2017).

In phytochemistry, the identification and characterization of novel bioactive compounds from aromatic plants have expanded our understanding of their therapeutic potential. Advances in chromatographic techniques, such as high-performance liquid chromatography (HPLC) and mass spectrometry (MS), have facilitated the discovery of new compounds and their mechanisms of action. For instance, recent studies have identified previously unrecognized compounds in plants like basil (*Ocimum basilicum*) and sage (*Salvia officinalis*) with potential anti-cancer and neuroprotective properties (Rattanachai, 2020). This expanding knowledge base supports the development of targeted therapeutic interventions and personalized medicine approaches.

Another emerging trend is the integration of aromatic plants in synergistic formulations and multi-target therapies. Researchers are exploring the potential of combining essential oils with other natural compounds or pharmaceuticals to enhance therapeutic efficacy and reduce side effects. For example, blends of essential oils with anti-inflammatory agents or antioxidants are being investigated for their enhanced ability to manage chronic diseases and inflammatory conditions (Mancini et al., 2020). This approach aligns with the concept of integrative medicine, where the combined effect of multiple agents offers a more comprehensive therapeutic strategy.

The use of nanotechnology in enhancing the delivery and bioavailability of aromatic plant compounds is also gaining traction. Nanoparticle-based delivery systems, such as nanocapsules and nanocarriers, are being developed to improve the stability, solubility, and targeted delivery of essential oils and their active ingredients. Research has demonstrated that nanotechnology can enhance the bioactivity of compounds, such as curcumin and resveratrol, by facilitating their absorption and distribution within the body (Patel et al., 2018). This trend holds promise for advancing the clinical application of aromatic plants and optimizing their therapeutic benefits.

Furthermore, the application of bioinformatics and computational tools in the study of aromatic plants is emerging as a significant trend. Systems biology approaches and molecular docking studies are being employed to predict the interactions of bioactive compounds with biological targets and identify potential therapeutic applications. These techniques enable researchers to simulate and analyze the effects of compounds at the molecular level, providing insights into their mechanisms of action and potential drug interactions (Morris et al., 2019).

Conclusion

Aromatic plants represent a rich and diverse source of bioactive compounds with significant therapeutic potential. The exploration of these plants has unveiled a range of health benefits, including anti-inflammatory, antimicrobial, antioxidant, and anti-cancer effects, underscoring their value in modern medicine. Advances in extraction technologies, phytochemistry, and formulation strategies have further enhanced our understanding and utilization of these natural products. The integration of novel methodologies, such as nanotechnology and bioinformatics, is poised to advance the application of aromatic plants in clinical settings, offering new avenues for therapeutic innovation.

Despite the promising therapeutic applications, it is essential to address safety and toxicity concerns associated with the use of aromatic plant compounds. Proper dosage, quality control, and awareness of potential interactions are crucial to ensure their safe application. As research progresses, ongoing evaluation and refinement of safety guidelines will be necessary to maximize the benefits while minimizing risks.

The recent advances and emerging trends in the field highlight a dynamic and evolving landscape, where traditional knowledge meets cutting-edge science. The continuous exploration of aromatic plants' bioactive compounds holds the potential to not only enhance our current therapeutic arsenal but also contribute to the development of novel treatments and integrative therapeutic approaches.

In summary, the therapeutic potential of aromatic plants offers a promising frontier in bioactive compound research. By bridging traditional practices with modern scientific advancements, we can unlock new possibilities for enhancing health and well-being. Continued research and innovation in this field will be vital in realizing the full potential of aromatic plants and translating their benefits into practical and effective therapeutic solutions.

REFERENCES

Aggarwal, B. B., Sundaram, C., Malani, N., & Ichikawa, H. (2006). Curcumin: The Indian solid gold. *Advances in Experimental Medicine and Biology, 595*, 1-75. https://doi.org/10.1007/0-387-46401-0_1

Bakkali, F., Averbeck, S., Averbeck, D., & Idaomar, M. (2008). Biological effects of essential oils—a review. *Food and Chemical Toxicology, 46*(2), 446-475. https://doi.org/10.1016/j.fct.2007.09.106

Baser, K. H. C., & Buchbauer, G. (2010). *Handbook of Essential Oils: Science, Technology, and Applications*. CRC Press.

Benites, J. R., Silva, T. M., & Pereira, J. C. (2020). Eucalyptus essential oil: A review of its chemical composition and therapeutic potential. *Phytotherapy Research, 34*(2), 156-178. https://doi.org/10.1002/ptr.6635

Brattström, L., & Toft, B. (2017). Safety and efficacy of essential oils: A review. *Journal of Alternative and Complementary Medicine, 23*(12), 925-934. https://doi.org/10.1089/acm.2017.0297

Cao, G., Sofic, E., & Prior, R. L. (2016). Antioxidant and prooxidant behavior of flavonoids: Structure-activity relationships. *Free Radical Biology and Medicine, 22*(5), 679-688. https://doi.org/10.1016/S0891-5849(96)00303-1

Carson, C. F., Hammer, K. A., & Riley, T. V. (2006). Melaleuca alternifolia (tea tree) oil: A review of antimicrobial and other medicinal properties. *Clinical Microbiology Reviews, 19*(1), 50-62. https://doi.org/10.1128/CMR.19.1.50-62.2006

Cavalcante, L. S., Silva, A. A., & Lima, S. G. (2016). Essential oil composition of aromatic plants. *Journal of Essential Oil Research, 28*(2), 162-174. https://doi.org/10.1080/10412905.2015.1119642

Cavanagh, H. M. S., & Wilkinson, J. M. (2002). Lavender essential oil: A review. *Australian Journal of Herbal*

Medicine, 14(4), 2-8.

Chemat, F., Vian, M. A., & Julien, D. (2017). *Green Extraction of Natural Products: Principles and Applications*. Elsevier.

Cheng, H., Yang, C., Ge, P., Liu, Y., Zafar, M. M., Hu, B., ... & Ren, M. (2024). Genetic diversity, clinical uses, and phytochemical and pharmacological properties of safflower (Carthamus tinctorius L.): an important medicinal plant. *Frontiers in Pharmacology*, *15*, 1374680.

D'Andrea, G. (2015). Quercetin: A flavonoid with multifaceted therapeutic applications? *Fitoterapia, 106*, 256-271. https://doi.org/10.1016/j.fitote.2015.03.018

Davidson, S., & Dyer, W. (2010). Camphor toxicity: A case report and review. *Journal of Clinical Toxicology, 48*(7), 987-993. https://doi.org/10.3109/15563650.2010.501210

Hammer, K. A., Carson, C. F., & Riley, T. V. (1999). Antimicrobial activity of essential oils and other plant extracts. *Journal of Applied Microbiology, 86*(6), 985-990. https://doi.org/10.1046/j.1365-2672.1999.00780.x

Heim, K. E., Tagliaferro, A. R., & Bobilya, D. J. (2002). Flavonoid antioxidants: Chemistry, metabolism and structure-activity relationships. *Journal of Nutritional Biochemistry, 13*(7), 572-584. https://doi.org/10.1016/S0955-2863(02)00208-5

Hernández, T., Gómez, J. A., & Jaramillo, G. (2009). Antioxidant and antimicrobial activities of essential oils: An overview. *Journal of Essential Oil Research, 21*(4), 325-332. https://doi.org/10.1080/10412905.2009.9700064

Hosseinzadeh, H., & Sadeghi, N. (2010). Lavender (Lavandula angustifolia) essential oil: A review of its potential therapeutic applications. *Journal of Essential Oil Research, 22*(2), 101-109. https://doi.org/10.1080/10412905.2010.9700444

Jaziri, M., Scher, J., & Hnina, M. (2014). Comparison of traditional and modern extraction techniques for obtaining essential oils. *Journal of Essential Oil Research, 26*(4), 279-288. https://doi.org/10.1080/10412905.2014.958982

Lee, S. J., Kwon, S. K., & Kim, S. H. (2013). Skin irritation and allergenic potential of essential oils: A review. *Contact Dermatitis, 68*(2), 101-112. https://doi.org/10.1111/cod.12023

Lopez, V., Sanchez, M., Gaya, P., & Ramos, A. (2017). Rosemary (Rosmarinus officinalis L.) essential oil: A potential source of natural antimicrobial agents. *Journal of Essential Oil Research, 29*(3), 254-263. https://doi.org/10.1080/10412905.2017.1308456

Mancini, E., Russo, R., & Iorio, G. (2020). Essential oil blends and their potential for therapeutic use: A review. *Phytotherapy Research, 34*(5), 953-968. https://doi.org/10.1002/ptr.6627

Mattioli, R., Koster, R., & Beckett, T. (2013). Bergamot oil and its interactions with drugs: A review. *Phytomedicine, 20*(10), 900-908.

Miller, J. M., & Goff, T. (2018). Supercritical fluid extraction of essential oils: A review. *Food Chemistry, 249*, 22-29. https://doi.org/10.1016/j.foodchem.2017.12.083

Morris, G. M., Huey, R., Lindstrom, W., & Sanner, M. F. (2019). AutoDock4 and AutoDockTools4: Automated docking with selective receptor flexibility. *Journal of Computational Chemistry, 30*(16), 2785-2791. https://doi.org/10.1002/jcc.21256

Mubashir, A., Ghani, A., & Mubashar, A. (2022). Common medicinal plants effective in peptic ulcer treatment: a nutritional review. *International Journal of Agriculture and Biosciences 11*(2): 70-74.

Patel, A., Patel, S., & Patel, S. (2018). Nanotechnology and its applications in essential oil research. *Journal of Nanobiotechnology, 16*(1), 15. https://doi.org/10.1186/s12951-018-0392-3

Perry, N. S. L., Perry, E. K., & Perry, M. R. (2000). Aromatherapy in the treatment of dementia: A systematic review of the evidence. *Journal of Clinical Nursing, 9*(3), 447-454. https://doi.org/10.1046/j.1365-2702.2000.00344.x

Pietta, P. G. (2000). Flavonoids as antioxidants. *Journal of Natural Products, 63*(7), 1035-1040. https://doi.org/10.1021/np990450a

Rattanachai, N. (2020). Phytochemical and pharmacological research on basil (Ocimum basilicum L.): A review. *Journal of Medicinal Plants Research, 14*(5), 161-172.

Rice-Evans, C., Miller, N. J., & Paganga, G. (1996). Antioxidant properties of phenolic compounds. *Trends in Plant Science, 1*(9), 300-305. https://doi.org/10.1016/S1360-1385(96)10010-2

Rohde, J., Rieder, S., & Menke, T. (2002). Menthol and peppermint oil: Their role in pain management. *Journal of Pain Research, 5*(3), 123-128.

Santos, C., Silveira, D., Sampaio, F., & Almeida, A. (2013). Essential oil analysis of aromatic plants using modern techniques. *Journal of Chromatography A, 1292*, 50-58. https://doi.org/10.1016/j.chroma.2013.03.040

Schilcher, H. (2000). Phytotherapy of the respiratory tract. *Phytomedicine, 7*(3), 292-298.

Takahashi, T., Kaneko, M., & Nakai, T. (2010). Menthol suppresses pain-related behavior by blocking TRPM8 channels. *Frontiers in Pharmacology, 1*, 1-6.

Giannenas, I., Sidiropoulou, E., Bonos, E., Christaki, E., & Florou-Paneri, P. (2020). The history of herbs, medicinal and aromatic plants, and their extracts: Past, current situation and future perspectives. In *Feed additives* (pp. 1-18). Academic Press