Plant Essential Oil as Immune Boosters

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Abstract

The potential role of plant based essential oils (EOs) as immune boosters has gained great importance in recent years. This chapter elaborates the major immunomodulatory properties of EOs and their bioactive compounds. To probe into the mechanism through which EOs affects innate and adaptive immune responses, the chapter explains the potential therapeutic benefits of these natural products. Different EOs have exhibited anti-inflammatory, antioxidant, and antimicrobial activities, which together chip into their immune-boosting effects. Furthermore, the chapter debates about the current research findings, highlights the challenges in standardization, and highlights the importance of stringent clinical trials to validate the efficiency and protection of EOs in immune modulation. The synergy between EOs and conventional treatments, along with the prospects of personalized EO-based therapies, underlines the promising future of these natural compounds in enhancing human health. This panoramic review aims to provide a groundwork for future work and development in the field of EOs as immunity boosters.

Keywords: Essential oils, Immunomodulatory characteristics, Anti-inflammatory, Antimicrobial, Bioactive

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Introduction

EO origins are persuade to be from ancient China and Egypt, recouped from a diversity of plant components, including the stem, bark, leaves, and wood. Additionally, the employment of natural or plant-based medicinal solutions is becoming more popular in recent years. Comparing these plant-based labors to other plant-based medicines, the use of EOs is the greatest at 70%. According to an evaluation by (Osaili et al., 2023), upto 3000 EOs have been discovered thus far, primarily including *Lamiaceae, Rutaceae, Myrtaceae, Zingiberaceae*, and *Asteraceae* families.

EOs are volatile liquids obtained from aromatic flowers and different parts of plants having many medicinal benefit so got much recognition in the last decade. Most of the EOs obtained by steam distillation, hydro distillation, solvent extraction, or super deprecatory fluid extraction (Kaya et al., 2024). Many plants, particularly aromatic spices, can provide EOs, which range in flavor and scent based on the kind and quantity of chemicals they possess. The enhanced consumers desire for natural, safe, and effective health products has made EOs the scientific community's first priority (Ni et al., 2021).

The distinctive fragrance, taste, or both of plants are attributed to EOs, which are blends of aromatic volatile secondary metabolites. They could be found as liquid droplets in different parts of plants and are formed and kept in secretory structures like glands. Fragrance hydrocarbons, terpenoids, terpenes, esters, acids, and alcohols are among the many different compounds that make up EOs, even though they have two or three main components at concentrations of 20–70%. The oil's precise medicinal properties are determined by the proportion of each ingredient. Geographical location, soil type, season, extraction technique, and storage all have an effect on the chemical composition of EOs. Since EOs are generally thought to be safe and have the ability to combine with other compounds, which are both appealing qualities for their use as bioactive molecules, there is a lot of interest in studying their diverse biological and therapeutic properties (Kiki, 2023).

By focusing on the phospholipid bilayer, the enzymatic mode of generation of energy and metabolism, the proton motive force, DNA, and signal mechanism, EOs have been shown to limit microbial growth and eventually harm the formation and functionality of the bacterial plasma membrane. The antimicrobial qualities of several EOs, including citrus oils, olive oil, tea-tree oil, and orange oil, are primarily responsible for the phenolic components with polar functional groups. (Al-Nabulsi et al., 2015).

Active principles, that are combinations of compounds that have pharmacological action working in concert, are responsible for the therapeutic benefits of medicinal plants. According to (CRISTA & BUTNARIU, 2023), plants are the major source of raw materials used in the uprooting of active principles and volatile organic compounds (VOs), which are mainly invaluable to the pharmaceutical, cosmetic, and medical industries. Numerous antibacterial, antiviral, antioxidant, anticancer, and anti-inflammatory effects along with pharmacological features such of EOs have been described and examined. Thus, during the past 20 years, EOs have drawn the interest of scientists because of their distinct biological activities and physicochemical characteristics (Kiki, 2023).

For the past ten years, consumers' top health worry has been immunity. According to recent reports, plant-based products can help reduce coronavirus infections and boost immunity (Arshad et al., 2020). Because of their potential health advantages, plant-based products that boost immunity are gaining attention. One of the main elements that will both prevent and promote recovery from any infection is the strengthening of the body's defensive mechanisms (Babich et al., 2020). Furthermore, natural immune response is an extremely intricate organic matrix which developed to tolerate harmless creatures and nutrients while defending the host against a variety of pathogens, including bacteria, viruses, parasites, fungus, and cancer cells (Lange & Nakamura, 2020).

Among other things, different varieties of foods and herbal medicines can act as immunity boosters by improving gut micro flora, inflammation, viral infections, and dietary disproportion (Dong et al., 2022). Bay laurel *(Laurus nobilis*), black cumin (*Nigella sativa*), clove *(Syzygium aromaticum*), fennel (*Foeniculum vulgare*), lemon balm (*Melissa officinalis*), lemongrass (*Cymbopogon citratus*), marjoram (*Origanum majorana*), peppermint (*Mentha piperita*), rosemary (*Rosmarinus officinalis*), sage (*Salvia officinalis*), and thyme (*Thymus vulgaris*) are among the most widely used medicinal herbs and relative EOs that may cause modification in immune system (Pelvan et al., 2022).

Composition of Plant EOs

According to the chemical composition of EOs, all essential oil samples had more than 95 percent of ingredients identified, with the exception of laurel (94.0%). The chemical compositions of the EOs under study appeared to have no commonalities. The chemical makeup of certain oils is quite basic. For instance, fennel, clove, and coriander EO made up a mixture of five, seven even eight chemicals. However, some oils were quite complicated like laurel and nutmeg were carried up to 20- 40 compounds in the EOs (Abd Algaffar et al., 2024).

The primary components of several EOs, such as clove oils (eugenol), coriander (linalool), and cinnamon (trans-cinnamaldehyde), made up over 90% of the overall oil. Trans-anethol was the primary constituent of fennel EO, caryophyllene was the primary constituent of black pepper, and thujene was the primary constituent of sage EO. The primary constituents of other EOs make up less than half of the overall oil. These last ones' principal constituents were a-cedrene, a-pinene, and 2-methylcyclohexyl-pentanoate in everlast oil; neomenthol and isomenthone in mint oil; 1.8-cineole and linalool in laurel oil; terpinen-4-ol, g-terpinene, and a-terpinene in marjoram oil; and sabinene, a-pinene, myristicine, and b-pinene in nutmeg oil (Balasubramaniam et al., 2024). The EOs mentioned below are routinely used in diet supplements having antioxidant properties mainly due to their composition, which attributed either to a high percentage of the main constituents or synergy among different oil constituent (Table 1).

Table 1: Main Components of various EOs used as Immunity booster (Politeo et al., 2023)

Serial No.	EO	Main Component	Percentage
1	Cinnamon	Trans-cinnamaldehyde	94.0%
2	Coriander	Linalool	92.0%
3	Clove	Eugenol	91.2%
4	Fennel	Trans-anethol	77.6%
5	Black Pepper	Caryophyllene	57.6%
6	Sage	Thujone	56.5%
7	Basil	Estragole	24.7%
		Linalool	23.5%
8	Mint	Neomenthol	44.1%
		Isomenthone	30.9%
9	Laurel	1.8-cineole	34.9%
		Linalool	13.5%
10	Marjoram	Terpinen-4-ol	40.8%
		g-terpinene	16.3%
		a-terpinene	11.0%
11	Everlast	a-cedrene	18.3%
		a-pinene	11.3%
		2-methylcyclohexyl-pentanoate	10.5%
12	Nutmeg	Sabinene	25.4%
		a-pinene	15.8%
		Myristicine	14.8%
		b-pinene	13.4%

Mechanism of Action

Antibacterial Activity

A number of findings were prompted by the relationship between the relative efficacy of various EOs components and the antibacterial activity of the components under test, as well as their chemical structures. Many plant-based phenolic chemicals, including thymol, eugenol, and carvacrol, have strong antimicrobial properties. Contrasting the carvacrol activity with its methyl ether form allowed for the confirmation of the significance of the hydroxyl group in the phenolic structure. Furthermore, the function of the hydroxyl group affects how effective the two isomers of terpenes thymol and carvacrol are. Whereas, the relevance of the phenolic ring was proven by contrasting the activity of thymol to p-cymene, a cyclic monoterpene hydrocarbon. Compared to their parent compounds (geraniol and borneol), which destroy bacterial cell membranes, resulting cell disruption and death, the occurrence of an ester group in the structure of geranyl acetate and bornyl acetate enhances

their function against the majority of microbes under study, whereas p-cymene was exhibit a very weak activity. Notably, EOs such as cinnamon, clove, thyme, and eucalyptus have demonstrated strong repressive effects against both Gram-positive and Gram-negative bacteria (Butnariu & Sarac, 2018).

Antifungal Activity

There is a chance to gain from the synergy between components because of the intricate chemotype composition of EOs. Nonetheless, some experts prefer to examine a single component so that they may then compare it to the oil's total activity. Testing EOs for fungi-static activity against separate components suggests that the essential oil's chemical makeup directly affects this activity. Furthermore, in contrast to the function of isolated aromatic components, it suggests that certain chemical functionalities within the examined components are also necessary to prevent fungal growth. Although acids (cinnamic and hydrocinnamic acids) also show significant fungi-static qualities, phenols (eugenol, chavicol, and 4-allyl-2-6- dimethoxyphenol) are specifically more antifungal. Conversely, prevention of fungal growth by the aforementioned components (eugenol and 4-allyl-2-6-dimethoxyphenol) does not appear to be much enhanced by the methoxy groups. The antifungal activity of the separated components against certain fungi allows for their classification. The length of growth inhibition ascertained by a straightforward macroscopic observation is used to measure this activity. According to (Saad et al., 2013), the antifungal effectiveness diminishes with the kind of chemical function: phenols > cinnamic aldehydes alcohols > aldehydes ≥ ketones > ethers > hydrocarbons.

Antioxidant Properties

The strong antioxidant qualities of plant EOs are well known, and they are crucial for shielding cells from oxidative stress and harm. Free radicals are unstable atoms that may harm cells, causing inflammation and aging. Antioxidants are chemicals that counteract these atoms. The antioxidant properties are characteristic of EOs including cinnamon, clove and rosemary. Their use as natural antioxidants in different kind of food preservation, cosmetics, and nutritional supplements is determined by their capacity to scavenge reactive oxygen species (ROS) (Table 2).

Table 2: Antioxidant Properties of different EOs and their common uses (Liu et al., 2023)

Serial No.	EO	Antioxidant Activity	Use
1	Lavender	High	Stress relief, skin care
2	Cinnamon	High	Blood sugar regulation, warming
3	Clove	High	Pain relief, oral health
4	Frankincense	High	Anti-inflammatory, spiritual practices
5	Sandalwood	Moderate	Skin care, relaxation
6	Lemon	High	Mood enhancement, cleaning
7	Eucalyptus	Moderate	Respiratory support, pain relief
8	Rosemary	High	Cognitive support, hair care
9	Peppermint	High	Digestive aid, headache relief
10	Tea Tree	Moderate	Acne treatment, immune support

Immunomodulatory Effects

Certain EOs have the ability to excise the growth of immune-competent cells, such as B and T lymphocytes, natural killer cells, dendritic cells, macrophages, and polymorphonuclear leukocytes. For example, constituents in eucalyptus EOs enhance macrophage phagocytosis, but *Nigella sativa* essential oil inhibits CD4+ and CD8+ lymphocyte growth in vitro. They are thus regarded as prospective therapeutic agents in union with their contents, which may present as a supplement or substitute for the antibiotics and other medications already in use. Reports from the professional literature persuade that EOs may have immunomodulatory qualities that are even better than those of prescription medications. So, always keep in mind that EOs may have adverse consequences if misused. At low doses, however, they never cause cytotoxicity (Grazul et al., 2023). Immunomodifiers can be stimulate, suppress, or enhance different immune cells and signaling routes to regulate immune homeostasis (Figure 1) (Balasubramaniam et al., 2024).

Immunomodulatory Activity Effects of EOs in Cells and Animals

The immune system's complicated reaction to several dangerous substances is inflammation. The host benefits from an acute inflammatory response that is triggered by pathogenic bacteria, irritating substances, or damaged tissue and may last for a brief period. Nevertheless, chronic inflammation is a condition that predisposes the host to several illnesses including cancer, cardiovascular disease, neurological disease, and metabolic problems if the inflammation is not sufficiently resolved or the stimulation continues. Several signaling pathways are triggered during a chronic inflammatory response, which results in the overexpression of pro-inflammatory proteins and genes such the NF-κB transcription factor and cytokines like TNF-α and IL. Reactive nitrogen species (RNS) and ROS release and buildup are also linked to this inflammation. Oxidative stress can damage DNA, proteins, and lipids when ROS generation exceeds the antioxidant capability of the cell. Because of their anti-inflammatory and antioxidant qualities, EOs (EOs) are particularly interesting in this regard and might be used to create functional meals (Valdivieso-Ugarte et al., 2019).

The in-depth comparative analysis of various EOs showed their influence on the immune system. Different essential oils grouped together on basis of their immunomodulatory properties, illuminating specific mechanisms by which they boost or regulate immune responses. The main therapeutic applications of each EO in boosting immune health are offering perception into their potential roles in both preventative and therapeutic contexts. The data presented here is taken from current scientific research and traditional medicinal practices as mentioned in Table 3.

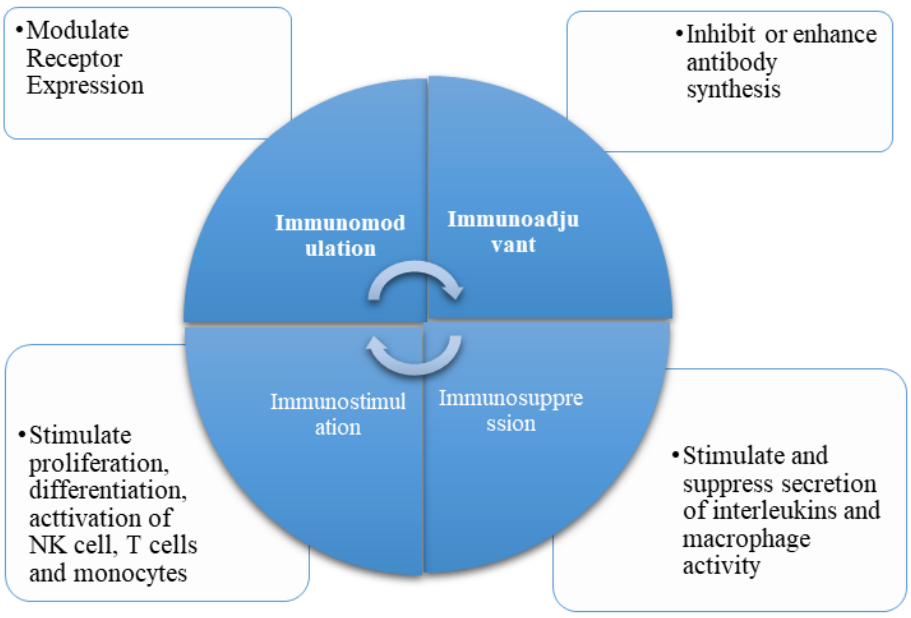

Fig. 1: Procedure of Immunomodulation in traditional plants.

Dosage, Bioactive Metabolites, Therapeutic, and Adverse Effects of EOs

EOs extracted from a diversity of sources, including peppermint, chamomile, fennel, rosemary, fenugreek, garlic, cumin, and lavender, have been analyzed for their potential stimulating consequences, dose value, and potential side effects against a range of illnesses, including microbial infections, obesity, diabetes, increase blood pressure, and dyslipidemia (Osaili et al., 2023). According to prompt research, using 225 mg of peppermint EO daily may help people with IBS have less microbial dysbiosis and a lower overall symptom score. In animal models, consuming 100 mg/kg/b.w. of chamomile EO reduces weight growth and improves lipid profiles, kidney and liver functions, hence preventing obesity and dyslipidemia. Furthermore, in individuals with type 2 diabetes, 3 g of chamomile EOs reduced the blood HbA1C, TAG, TC, LDL, and HOMA-IR index (Das et al., 2019).

Through their anti-inflammatory and antioxidant properties, fennel and rosemary EOs (15 mg/kg/b.w. and 7.5 mg/kg) protect against hypertension and enhance cardiac and renal function (Rafya et al., 2024). Furthermore, by decreasing the body weight increase and adipose tissue weight brought on by an HFD, the administration of 50 mg/kg/. w of garlic EOs had anti-obesity and anti-hyperlipidemic effects. Polyphenols, flavonoids, tocopherols, menthone, tanins, luteolin, apigenin, transanethole, terpenoids, estragole, fenchone, limonene, diallyl disulfide, cuminaldehyde, α-pinene, γ-terpinene, linalool, and linalyl acetate are the bioactive components that give EOs their medicinal properties. Most of these bioactive substances, including phenolic compounds, terpenoids, luteolin, apigenin, estragole, fenchone, and limonene, have potent antioxidant properties (Ozma et al., 2023).

However, there are certain negative consequences linked to EO intake. Therefore, before utilizing EOs, it's crucial to understand their potential impacts. According to earlier research, EOs function as an exogenous substance known as an endocrine-disrupting chemical (EDC), which disrupts the body's hormone production, action, storage, and metabolism. However, EO may induce endocrine disruption, operate as an antagonist to the androgen receptor (AR), and act as an agonist to the estrogen receptor alpha (ERα). Frequent exposure to tea tree and lavender oils is linked to early gynecomastia and aberrant breast development in teenagers. In individuals with type 2 diabetes, chamomile tea drinking was linked to mild skin irritation (Osaili et al., 2023).

Potential Risks and Limitation while using EOs as Immune Boosters

It's critical to understand the possible hazards and restrictions while utilizing plant Eos as immune enhancers (Lacerda et al., 2023)

1. Skin Sensitization and Irritation: EOs are strong chemicals that, if improperly diluted, can result in skin irritation, redness, itching, and even chemical burns. Prior to usage, always do patch tests and adhere to safe dilution requirements.
2. Allergy Reactions: Some people, particularly those who already have allergies, may experience allergic reactions to certain EOs. Respiratory problems, edema, and itching are possible symptoms.
3. Drug Interactions: The efficacy of pharmaceuticals may be impacted by interactions between EOs and drugs. If you are on medication, it is imperative that you speak with a healthcare provider before utilizing EOs.
4. Toxicological Concerns: Some EOs might have dangerous to pets and children. Around these susceptible populations, oils such as eucalyptus and tea tree should be taken with safety.
5. Endocrine Disturbance: Hormone-related health proteins have been connected to several EOs, including tea tree and lavender. They might intervene with the body's normal hormone synthesis by using as endocrine disruptors.
6. Ingestion Problems: Essential oil ingestion may be harmful and should avoid unless managed by a trained healthcare provider.
7. Attributes and Purity: EOs can differ considerably in manner of quality and purity. Intense effects might be more likely when using inferior or as tainted oils.

Through staying updated and using EOs precisely, you can be benefited while minimizing potential harms. Always seek advice from a medical professional prior to administer EOs into your health routine, especially if you have pre-existing conditions or are pregnant.

Table 3: The influence of Plant EOs on the immune system (Valdivieso-Ugarte et al., 2019).

Essential Oil	Study Design	Cell/Animal Type	Outcome	Scientific Evidence
Bay laurel	in vitro (tissue culture)	Human neutrophils and complement activation	Enhance suppression of phagocytosis Enhance obstruction of the classical complement pathway Maintain the hindrance of substitutive complement pathway activation	(Perez-Roses et al., 2015)
Black cumin	in vitro (cell culture)	MCF-7 and A375 human cancer cell lines	Volatiles used to enhance and stabilize protein structures AChE and HMGR targeted to check the antitumor activity Expression of POTEF and HSP 90-β depicted the high antioxidant activity by nonvolatile compounds High Enzymatic curbing High Cytotoxic activity in cancer cells	(Silva et al., 2020)
Clove	in vitro (cell culture)	Human neutrophils (flow cytometry) and complement activation (hemolytic assay)	Increases inhibition of phagocytosis by clove oil and eugenol Increases repression of classical complement pathway activation (clove oil and eugenol) Maintain suppression of substitute complement pathway activation	(Perez-Roses et al., 2015)
Fennel	in vivo (animal)	Male Wistar rats with acetic acid-induced colitis	At 200 and 400 mg/kg doses: Decreases macro and microscopic colonic inflammation In colon homogenate: Decreases MPO activity Decreases expression of TNF-α positive cells Decreases expression of NF-κB	(Rezayat et al., 2018)
Lemon balm	in vivo (animal)	Male Wistar rats with carrageenan-prompted paw edema	6 h administration resulted in edema reduction	(Bounihi et al., 2013)
Lemongrass	In vitro (cell culture)	Peritoneal macrophages from BALB/C mice, enhanced with DMSO or LPS	Limit IL-1β and IL-6 formation	(Sforcin et al., 2009)
Marjoram	In vitro (cell culture)	THP-1 human macrophages stimulated with LPS or ox-LDL	Limit IL-1β and IL-6 formation in LPS-stimulated macrophages Limits TNF-α, IL-1β, IL-6, and IL-10 formation in ox-LDL stimulated cells	(Arranz et al., 2019)
Peppermint	In vitro (cell culture)	Murine macrophages RAW 264.7 stimulated with LPS, 0.1 μg/mL	At 100 μg/mL: Limits Phagocytosis by 42% Slow down IL-6 production Maintain iNOS production	(Lang et al., 2019)
Sage	In vivo(animal)	Male BALB/c mice with circular full-thickness surgical wounds	Accelerated wound healing: Limit expression of IL-1β, IL-6, and TNF-α Limit expression of FGF-2 and VEGF-1	(Farahpour et al., 2020)
Thyme	In vitro (cell culture)	Human monocytic leukemia THP-1 cells stimulated with 1 μg/mL of LPS	Slow down IL-1β, IL-8, and TNF-α formation	(Tsai et al., 2015)

Conclusion

The plant EOs as effective as immune boosters reveals a promising avenue to enhance human health by using natural herbs. This chapter has elaborated different pathways by which EOs can boost the immune system due to their antimicrobial, anti-inflammatory and antioxidant properties. Cinnamon, Clove, Thyme, Lavender, Lemon, Fennel, and Peppermint are prominent herbs. The potential for EOs to complement conventional treatments and pave the way for personalized medical approaches presents an exciting future for these natural compounds. As we move forward, recommencing diversified investigation and partnership will be vital in unlatching the full scope of EOs as potent immune boosters, ultimately contributing to a holistic and health-optimized society.

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