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Complementary and Alternative Medicine: Essential oils

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PREFACE

Essential oils have been cherished for centuries, known for their diverse applications in traditional healing, wellness, and more recently, their potential in integrative health practices. As science delves deeper into their properties, essential oils are finding renewed significance, especially as complementary and alternative solutions in medicine and veterinary care. *Complementary and Alternative Medicine: Essential Oils* explores this fascinating realm, showcasing the therapeutic versatility of essential oils across a broad spectrum of health applications, from stress management to infection control and immune support. The book begins by examining essential oils' roles in therapeutic practices and aromatherapy, where they are used for their calming, uplifting, and health-promoting properties. It details the mechanisms through which essential oils like jasmine and peppermint impact brain activity, stress relief, and mental well-being. The efficacy of these oils in aromatherapy illustrates the powerful connection between scent and mental health, shedding light on natural ways to support cognitive functions and reduce anxiety. Moving beyond human health, this book covers essential oils' applications in animal care and veterinary medicine, including their roles in nutrition, disease management, and pest control. Essential oils present a natural, eco-friendly approach to disease control in both terrestrial and aquatic environments. Chapters dedicated to ruminant and poultry nutrition demonstrate how essential oils can promote growth, improve health, and serve as natural antioxidants in feed. In aquaculture, these oils offer a sustainable method to enhance aquatic health without inducing resistance in pathogens, providing insights into eco-friendly disease control practices. The antimicrobial and antiviral properties of essential oils are also explored, positioning them as potent alternatives to synthetic medications in both human and animal healthcare. With growing concerns about antibiotic resistance, essential oils offer promising solutions against various pathogens. Their effectiveness in controlling parasitic infections, treating skin ailments like *sarcoptic mange*, and supporting respiratory health highlights their potential as holistic remedies. Additionally, essential oils like coconut and olive oil are discussed for their role in treating specific conditions, such as mastitis in livestock and arthritis in humans, offering a bridge between traditional and modern therapies. Essential oils' larvicidal and insecticidal properties are explored, particularly in mosquito control, which is crucial for preventing vector-borne diseases. The book provides insights into using lemon balm and scented geranium oils as natural repellents, addressing public health concerns with sustainable solutions. Furthermore, essential oils like thyme and oregano are covered for their use in food preservation, highlighting how these compounds contribute to food safety by reducing spoilage and extending shelf life. From their anti-inflammatory and antioxidant effects to their roles in veterinary medicine and aquaculture, essential oils are proving to be versatile, cost-effective tools with minimal side effects. This book aims to provide a comprehensive understanding of essential oils' therapeutic applications, blending traditional knowledge with scientific research to offer readers a nuanced perspective on their potential in complementary and alternative medicine. *Complementary and Alternative Medicine: Essential Oils* is intended for healthcare professionals, veterinary practitioners, researchers, and those interested in natural health solutions. By bridging ancient wisdom with contemporary research, this book invites readers to explore essential oils' expanding role in holistic health, offering a window into nature’s powerful solutions for both human and animal wellness.

Editor

Contents

Chapter 01

Essential Oils: Potential Therapeutic Compounds for One Health

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ABSTRACT

Essential oils are volatile fragrant chemicals that can be acquired from natural plants in different ways. They can be obtained from roots, flowers, stems, leaves, seeds, and gums. Many plants are used for this purpose nowadays, like cinnamon, mint, lavender, etc. All these plants have different chemical procedures to extract their oils in the laboratory. Many old and emergent methods have been used nowadays. The most common methods are steam distillation, cold pressing, solvent extraction, superfluid extraction, ultra-sound, and microwave-assisted extraction. Known till now, the microwave-assisted extraction method is recognized as the optimal method for extracting premium quality oils. All above listed essential oils have great potential to resolve medical issues like neurodegenerative disease, cancer, cardiovascular disease, gut related issues. These oils also have a vast power to treat illness and have antimicrobial and antibiotic properties. Moreover, these oils are commercially used as Nano-medicine particles that guarantee their regular distributions and solubility in water. The extraction of essential oils and their application in the medical field constitute a significant human discovery.

KEYWORDS
Essential oils, Extraction, Chemicals, Methods, Plants

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INTRODUCTION

The volatile aromatic liquids known as essential oils (E0s) are derived from natural plants. According to Soliman et al. (2022), the plant components that are gathered encompass their roots, bark, wood, flowers, leaves, seeds, peels, branches, gums, and oily resin. Secondary metabolites are a collection of compounds that aid plants in controlling their growth and facilitating communication with other plants and species. The complex makeup of essential oil (EO) mostly consists of alcohol, ester, aldehydes, oxides, which are phenols, the coumarins ether and various other constituents (Camele et al., 2021). Essential oils (EOs) are widely utilized in an extensive range of goods for purposes including anti-parasitic, fungicidal, cosmetic, sterilizing, and destroying viruses. Essential oils (EOs), such as lavender, rose, and peppermint oils, are frequently used in the cosmetics sector because of their pleasant scent (Sharmeen, et al., 2021).

Given their pharmacological and psychological properties, essential oils (EOs) have a long history of use and recognition as therapeutic agents. To the indigenous people, they had magical powers that could cure physical, emotional, and spiritual ailments (Ayaz et al., 2017; Lizarraga-Valderrama). Analgesic, neuroprotective, antidepressant, anxiolytic, and sedative effects are just a few of the many CNS-targeted pharmacological effects that EOs have been shown to have in animal and human studies. Dementia, sleeplessness, depressive disorders, dementia, Alzheimer's disease (AD), and other CNS-based disorders can be alleviated or stopped with the use of EOs as an adjuvant treatment. The fact that they occur naturally means that they are also safe and non-toxic in the correct doses, as studies done in the last decade have shown (Lizarraga-Valderrama, 2021).

Chemical Composition of EOs

Essential oils are volatile organic composites that are complex combinations of several compounds, often exceeding 500 in number. Linalool and camphene are two of the many chemicals found in essential oils extracted from plants.

Particular essential oils contain compounds like camphor and menthol. One of the most popular essential oils, lavender, contains eucalyptus, linalool acetate, linalool, and perillyl alcohol among its primary components. Sesquiterpenes, flavonoids, lacton, myrrh alcohol, famesene, tea matzolin, genistein, and volatile oil are present in both varieties of chamomile. Peppermint mostly consists of menthol, menthol acetate, and mentholone. Plant secondary metabolism results in the production of secondary components such as tannins, caffeic acid, 1,8-eucalyptol, propanone, and bitter chemicals. All sorts of plant components, such as blossoms, roots, leaves, bark, seeds, fruit, resins, and so on, produce and contain these compounds. Essential oils derived from various parts of plants also range in their chemical composition. Fragrances, terpenoids, ketones, aldehydes, ethers, epoxy compounds, and other compounds provide the basis for identifying each of these essential oils (Wani et al., 2021). Fig. 1 shows the chemical structures of some Eos.

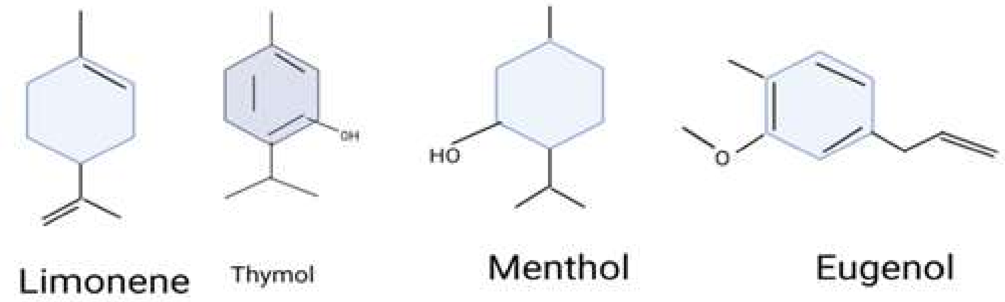

Fig. 1: The Chemical structures of some Eos.

Types of Essential Oils

Peppermint Oil

One of the most common and frequently utilized EOs is peppermint (Mentha piperita) oil. Of the essential oils derived from Menthyl ester and Menthofuran, menthol is the primary constituent (Saharkhiz et al., 2012). Peppermint oil has been shown to have an inhibiting effect on staphylococci growth (Witkowska and Sowińska, 2013).

Melaleuca Alternifolia (Myrtaceae)

Another name for it is Tea Tree Oil, or TTO. Among its components are 1,8-cineole, α-terpinene, γ-terpinene, p-cymene, α-terpinene, γ-terpinen-4-ol, and α-pinene (Pereira et al., 2014). One of its names is Tea Tree Oil, or TTO for short. The clinical investigation found that melaleuca gel inhibited the growth of numerous colonies of bacteria and dental biofilms (Santamaria et al*.,* 2014). Against oral infections, it exhibits potent antibacterial activity (Takarada et al., 2004). The most potent ingredient in Melaleuca alternifolia's antimycotic action is terpinene-4-ol (Terzi et al., 2007)

Lemon EOs

It mostly consists of oxygenated terpenes and terpenes that are nearly exclusive (Trombetta et al., 2005). Therapeutic action shows antifungal potential against three species of Candida: the albicans strain, the tropical Candida species, and *Candida glabrata*. One effective treatment for candidiasis brought on by Candida albicans is lemon essential oil (Trombetta et al., 2005; Białoń et al., 2014).

Cinnamon Oil

The volatile oils derived from various parts of the plant, such as tree bark, foliage, and roots, have very different chemical compositions. Three major constituents comprising 82.5% of the essential oils extracted from the bark of Cinnamomum zeylanicum are trans-cinnamaldehyde, eugenol, and linalool. Studies indicate that the primary and most active ingredient in cinnamon essential oil is cinnamonaldehyde (Naveed et al., 2013).

Inhibition of the growth of several bacterial isolates, including both Gram-positive and Gram-negative strains, as well as fungal isolates (Ooi et al., 2006). It can prevent spontaneous mutations in human cells by acting as an antimutagenic (King et al., 2007). Furthermore, Cabello et al. (2014) found that cinnamaldehyde (CA) had a significant anti-melanoma impact when administered orally. Cinnamomum zeylanicum (CZ) has antiparasitic, antioxidant, and free radical scavenging properties, according to the study (Ramage et al., 2012).

Eucalyptus Oil

It is appropriate for use as an anticariogenic drug since it exhibits a negative y impact on oral bacterian such as *Lactobacillus acidophilus* (Serafino et al., 2008).

Lavender Oil

Linalool, linalyl acetate, 1,8-cineole, Β-ocimene, terpinen-4-ol, l-fenchone, camphor, and viridiflorol are the main constituents identified (Benabdelkader et al., 2011; Végh et al., 2012). However, the relative level of each of these constituents varies in different species. Lavender oil is most commonly found in the following compounds: linalyl acetate, linalool, 1,8-cineole, camphor, lavandulyl acetate, and 3,7-dimethylocta-1,6-dien-3-ol, all of which are obtained by distillation with steam from the flowers of the Lamiaceae family plant *Lavandula angustifolia*. Since linalool's effects are felt throughout the oil, it's reasonable to assume that it's the active component of lavender oil (Prashar et al., 2004).

Lavender EO is described to decrease stress, anxiety, and expand mood when inhaled or orally administered (Lehrner et al., 2005; Kim et al., 2011). It is not very effective in cases of high anxiety (Bradley et al., 2009). *Lavandula luisieri* essential oils have an inhibitory effect on strains of Aspergillus, dermatophytes, and yeast (Zuzarte et al., 2012).

Essential Oils Extraction

For use or analysis, Eos needs to be removed from the plant matrix. Many techniques, including popular ones like solvent extraction, steam distillation, hydro-distillation (HD), cold pressing (CP), and simultaneous distillation-extraction techniques, can be applied for this purpose. Even though Eos have been extracted using these methods for many years, numerous disadvantages have been identified by their application, such as the loss of some volatile compounds, less efficiency, the potential for hazardous solvent residues in extracts or EOs, and the breakdown of ester or unsaturated molecules by thermal or hydrolytic processes. As the "Green Era" approaches and energy prices rise, the extraction industries for extraterrestrials (Eos) concentrated on creating emergent extraction techniques (Bousbia et al., 2009). Many novel techniques, due to the shortcomings of conventional extraction techniques, a variety of techniques are currently available for extracting essential oils (Eos) from plants, such as solid-phase micro-extraction, membrane-assisted solvent extraction, pressured liquid extraction, solid-critical fluid extraction (SFE), microwave-assisted and ultrasound-assisted extraction, and others. (Flamini et al., 2007). By using fewer solvents and fossil fuels, producing fewer hazardous substances, and using less energy overall, the environment may be protected and production efficiency increased with these alternatives to conventional extraction techniques (Chemat et al., 2010). Composition and chemical makeup of extra virgin olive oils are greatly influenced by the extraction techniques used (Nakatsu et al., 2000). The most representative traditional and emerging techniques of extracting essential oils (Eos) are provided in the following sections. Give careful thought to the best feasible and suitable technique for concentrating the intended biologically active ingredient into the EO.

Extraction Methods

Primitive Methods of Extraction

Cold Pressing

Cold pressing, sometimes referred to as expression, is the earliest technique for obtaining essential oils; it predates human discovery of the distillation process by many years. Although this method produces low yields, the process produces little to no heat, which is an advantage (Van, 2013). Because the aldehydes in citrus fruit peel oils are rather thermally unstable, it is primarily employed to isolate the oils from the fruit (Kubeczka, 2010). Citrus peels are used in the mechanical cold pressing method, which involves applying pressure or abrasion to rupture the oil glands, causing the oil to be ejected and then cleaned away with a water spray. Because of the shortcomings of this approach, which include low yield extraction and low purity, enzyme pretreatments have been investigated as a means of enhancing the quality and amount of extracted essential oils (Eos). Using a combination of enzymatic hydrolysis and CP, Soto et al. (2007) were able to extract oil from Borage (Borago officinalis) seeds; Collao et al. (2007) was able to enhance the resultant evening elder oil (Oenothera biennis) extraction; and A study conducted by Anwar et al. (2013) examined the impact of several enzyme preparations on the production of cold-pressed flaxseed oil. The results showed that cold-pressed flaxseeds treated with enzymes had a much greater output (38% vs. 32%).

Distillation

Distillation is the conventional process used to extract volatile materials, such as essential oils from plant matter. Fragrant plants that come into touch with steam or boiling water during the distillation process evaporate and release their essential oils. Three different methods of distillation have been suggested: steam distillation, hydrodynamic distillation (HD), and water/steam distillation. The categorization is predicated on how well the water interacts with the initial matrix. The HD technique involves immersing the plant material in boiling water. What differentiates this approach is the direct contact of the raw material with the boiling water. While steam and water are used in steam distillation, the plant material and the water do not come into indirect touch (Mendes et al., 2007).

The plant material is positioned on a tray with holes at the bottom of the container, and steam is forced through a pipe after being produced in a boiler. Water and oil are combined to create the condensed distillate; the oil and water are separated by using a Florentine flask, which does this by using the differences in their densities. The plant material is positioned on a tray with holes at the bottom of the container, and steam is forced through a pipe after being produced in a boiler. Condensed distillate is made by combining water and oil; the oil and water are separated using a Florentine flask, which uses the variations in their densities to do this (Sell, 2006). The material is only ever exposed to steam, never boiling water, and the steam is constantly moist and completely saturated thanks to this process (Hu¨snu and demerici, 2012).

Solvent Extraction

EOs can be extracted using organic solvents, particularly those derived from fuel, due to their hydrophobic and nonpolar properties (Attokaran, 2011). A solute is distributed between two immiscible liquid phases that are in contact with one another; this process is known as solvent extraction (Cox and Rydberg 2004). Using a liquid in which the material is soluble, a substance is transferred from a matrix in this process. Leaching is the process used when the part that can be extracted is a solid, like plant materials. Batch percolation at room temperature is the most straightforward of these procedures. To extract the plant material, it is first ground into a powder and then put into a vertical vessel that has a false bottom. The oil's micelles are kept from passing through by a cloth covering the bottom. Richer extracts are extracted early on and used in the distillation process to create essential oils. The weaker micelle that follows is directed toward the percolator that holds freshly ground plant material. There will be a solute exchange with a weak micelle at this point because the solute concentration is at its highest. Micelles that are progressively weaker and weaker pass through plant material that has been partially extracted. Ultimately, the process is finished when a new solvent is poured through almost all of the extracted material (Attokaran, 2011).

Emergent Methods of EO's Extraction

The chemical, food, and pharmaceutical industries have recently placed a considerable emphasis on developing novel separation processes because of rising energy prices and the need to lessen CO2 emissions (Bousbia et al., 2009). Oil extraction methods being researched include supercritical fluid extraction (SFE), ultrasound-assisted extraction, and microwave-assisted extraction.

Microwave-Assisted Extraction (MAE)

Several Eos have been extracted using microwaves by various researchers in recent years. The results show that Eos extracted in 30 minutes or fewer are qualitatively and quantitatively comparable to those extracted using some traditional techniques, like HD or Soxhlet extraction, that take twice as long (Camel, 2001).

Vacuum microwave HD is one of many methods that have emerged as a result of developments in microwave extraction (Abert-Vian et al., 2011), microwave HD (Golmakani and Rezaei, 2008), solvent extraction and distillation with microwave assistance (Ferhat et al., 2007), solvent-free microwave extraction (Bendahou et al., 2008), microwave accelerated steam distillation (Chemat et al., 2006), and microwave hydro-diffusion and gravity (MHG) (Vian et al., 2008).

In this method, radiations of microwave are used to heat the sample combination. Because of two peculiarities of matter, namely ionic conductance and dipole rotation, microwave heating occurs instantaneously inside the sample, leading to very short extraction times. The breaching of weak hydrogen limits is one benefit of microwave heating. It is different from the extractive procedures used in conventional approaches because electromagnetic waves induce changes in cell structure that result in MAE extraction. Since microwaves automatically reduce the extraction time and solvent amount, they reduce the impact on the environment by expelling less carbon dioxide into the atmosphere (Périno-Issartier et al., 2011).

Ultrasound-Assisted Extraction (UAE)

The phytopharmaceutical extraction industry has acknowledged the potential industrial application of ultrasound for a variety of herbal extracts (Vilkhu et al., 2008). Compared to conventional methods, UAE shortens processing time, reduces solvent volume, and boosts the yield of the extract by employing organic solvents to separate volatile chemicals from natural products at room temp (Alissandrakis et al., 2003). At low frequencies, at 18–40kHz, its effect is substantial; at higher frequencies, between 400 and 800 kHz, it is almost insignificant (Cravotto et al., 2008).

Super-critical Fluid Extraction

Plant components such as essential oils, flavors, and lipids can be extracted with SFE (Wang, 2008); Reverchon (1997) states that SFE has the makings of a profitable industrial technique. When compared to conventional extraction techniques, this emergent method is superior in terms of speed, compound selectivity, and environmental friendliness.

Supercritical fluid extraction (SFE) relies on subjecting solvents to temperatures and pressures higher than their critical points to use them in their supercritical condition. The content, temperature, and pressure of a supercritical fluid (SCF) define its unique properties, which lie between those of a gas and a liquid. These liquids are efficient and selective solvents because they combine the gaseous penetrating ability with the liquid density. The non-toxic nature and ability to achieve supercritical operation at pressures similar to ambient temperature while maintaining relatively low concentrations of carbon dioxide make it the ideal supercritical solvent for chemical extraction from plants (Zizovic et al., 2007).

Extraction of Essential oils from different Plants

Lavender

As everyone is aware, lavender is a fragrant and therapeutic plant that yields a range of plant essential oils used in medicine, food processing, cosmetics, and other sectors (Zhao et al., 2006).

A novel technique was used for obtaining lavender essential oil: steam distillation with microwave assistance. Steam distillation and general microwave-assisted extraction are two methods from the Chinese Pharmacopoeia that were combined to achieve this. Supercritical CO2 extraction experiments have been used to determine the ideal extraction conditions for lavender essential oils, and gas chromatography has been used to assess and evaluate the quality of lavender essential oils extracted using two distinct methods (XI et al., 2002). Furthermore, vacuum distillation has been used to refine lavender essential oil that was obtained through supercritical CO2 extraction. The resulting data serves as a source for the industry of lavender essential oils.

Supercritical CO2 Extraction
Procedure and Conditions

Add powder of lavender to the extraction tank, set the analytical pressure to 6.5MPa and temperature to 45°C, and flow 20 liters per hour of CO2 into the tank. Extract the lavender powder at a predetermined time after the tank is released from the excerpts of the analysis. Vacuum distillation was used to extract supercritical CO2 from pressure products after atmospheric distillation, followed by condensation through cold water and an ice-water bath to accept bottles. The temperature was progressively rising to 90°F for distillation after the pressure leveled out at 20mmHg.

Microwave-assisted Steam Distillation

A 500ml round-bottom flask was filled with precisely 25g of lavender powder, 300ml of saturated salt water, and allowed to soak for two hours. Regarding the microwave reactor, two milliliters of petroleum ether were added to the volatile oil extractor. After two hours of microwave heating, adjust the temperature to 105 so that 1-2 drops per second are produced.

Cinnamon (*Cinnamomum zeylanicum)*

According to Chinese texts, *Cinnamomum zeylanicum* is one of the oldest known herbal remedies, with a history that spans four thousand years. Both the leaves and the bark of the cinnamon tree have many medicinal and culinary applications. Steam distillation and Soxhlet extraction were employed to obtain the essential oil.

Steam Distillation Method

According to Chinese texts, *Cinnamomum zeylanicum* is one of the oldest known herbal remedies, with a history that spans four thousand years. Both the leaves and the bark of the cinnamon tree have many medicinal and culinary applications. Steam distillation and Soxhlet extraction were employed to obtain the essential oil.

The essential oils were allowed to volatilize for five to ten hours at 100°C in boiling water. Following a settling period for the recovered mixture, the oil was extracted 9–10. Utilizing a separatory funnel, the product was gathered and separated following the steam distillation process. The essential oils were separated multiple times until there was no more oil in the separatory funnel after they settled into the bottom layer.

Soxhlet Extraction Method

A thimble made from heavy filter paper was filled with 100g of crushed cinnamon sticks, which were then put into the main chamber of the Soxhlet extractor. Ethanol was the extraction solvent used. For five to ten hours, the solvent was brought to a temperature above 100°C for reflux. Following extraction, the products were gathered and refined utilizing a rotating evaporator to maintain a steady temperature of 50°C. After the rotovap process, the samples were placed in a fume hood for an hour to ensure that any remaining ethanol in the crude oil had completely evaporated into the atmosphere.

Basil (Mint)

One popular culinary herb and source of essential oils is Oregano basilicum that is used to flavor food, oral health products, and fragrances. Steam distillation is used to remove essential oils from the leaves and flowering tops of the plant. Next, essential oils were extracted from known weights of stems, flowers, leaves, or an equal portion of both (200g fresh weight and 75g dry weight). The samples were oven-dried for three to seven days at 30°C. The dry weights of the samples in the experiments with varying sample amounts were 75, 20, 15, and 10g. There were three approaches taken.

Hydro-distillation

To extract the essential oil, the plant material was dropped into a 2-liter round-bottomed flask along with 1000ml of distilled, deionized water for every 75g of dry matter and 400ml for every 200g of fresh material. A modified clevenger trap was then used for the water distillation process (ASTA, 1968). Water was added in proportion to the size of the plant samples (13.3ml of water to 1g of dry material). The fresh samples were distilled for one hour, while the dried samples were distilled for one hour and fifteen minutes. The ratio of oil volume to tissue weight was used to determine the essential oil content.

Steam Distillation

The process of steam distillation involved collecting the condensate, which is made up of combining oil and water in a flask and then applying steam for ninety minutes to a 3-liter flask filled with either dried or fresh plant material. To fully extract the essential oil, ethyl ether was used three times to extract the condensate. To eliminate moisture, ethyl ether was mixed with sodium sulfate. Following rotary evaporation for ethyl ether removal, the number of essential oils in the base was calculated by dividing the volume by the weight of the tissue (fresh/dry).

Solvent Extraction

Essential oil was extracted using a solvent using Burbott and Loomis's (1967) method. Ten milliliters of yellow extract were obtained by extracting plant material four times with hexane in a mortar that also contained anhydrous Na2SO4. Each extract received a tiny quantity of Norit Just enough charcoal to remove the yellow pigment—which was subsequently extracted using slow centrifugation. After that, the clear solutions were concentrated at room temperature under an air stream. Samples of essential oils were kept at 2°C in the dark in Teflon-sealed caps contained in silica vials. The stated contents of essential oils are derived from three separate extraction processes.

Mechanism of Action

The chemical makeup and the placement of functional groups on molecules determine the ways of action of essential oils (EOs) (Dorman and Deans, 2000). According to Prashad et al. (2004), the primary mode of action is thought to be damage to the membrane. In terms of their antibacterial action, EOs' solubility in the phospholipid double layer of cell membranes appears to play a significant role. Research has shown that terpenoids present in EOs can disrupt the enzyme processes involved in energy metabolism. Specifically, clove oil has been shown to decrease the amount of ergosterol detected in the cell membranes of fungi (Pinto et al., 2009).

Therapeutic Applications

The volatile constituents of essential oils (EOs) are being widely used to treat and prevent human diseases. The mode of action and significant role of these natural products are discussed regarding the treatment and prevention of many diseases (Edris, 2007). The following are the therapeutic applications of essential oils:

Neurodegenerative Diseases

The potential of Essentials oils (EOs) against neuro-protective and anti-ageing being widely evaluated around the world. Neurodegenerative disorders are frequently characterized by strong evidence of oxidative stress in their pathogenesis, as a result unregulated (ROS) reactive oxygen species formed. Neurodegenerative disorders are mostly incurable, and their therapies only just control symptoms and elongate the growth of disease. Now EOs have been used in the treatment strategies for neurodegenerative and anti-aging disorders (Abd Rashed et al., 2021). An increase in the microglia M1/M2 ratio and a rise in inflammatory processes in the cerebral cortex (inflammation) are both associated with aging and increase the risk of neurodegenerative disorders.

In the post-mortem of an individual, the increase of astrocytes in neural tissue has also been reported. The distinguishing feature of neurodegenerative disease is the accumulation of proteins within neurons and in the extracellular space. (Avola et al., 2024). Huntington's disease (HD), Alzheimer's disease (AD), amyotrophic lateral sclerosis (ALS), and Parkinson's disease (PD) are the four age-related neurodegenerative illnesses that are most frequently researched. Huntington's disease (HD), Parkinson's disease (PD), Alzheimer's disease (AD), and amyotrophic lateral sclerosis (ALS) are the four age-related neurodegenerative diseases that are most frequently researched. Deficits in episodic memory, visuospatial abilities, language, executive functions (organization and planning), and apraxia are the various features of AD. Amyloid plaquesnd neurofibrillary tangles are associated with reactive astrocytes and activated microglial cells in addition to neuronal loss (Abd Rashed et al., 2021).

Aromatherapy and Massage

Aroma is a fragrance or pleasant smell, while therapy is a treatment. These two terms are combined to form the word "aromatherapy." The essential oils' usage for physical and psychological well-being through massage or inhalation is known as aromatherapy and massage therapy. Aromatherapy is the application of pure essential oils from aromatic plants (such as rose, sweet marjoram, and peppermint) to alleviate various health issues and enhance overall quality of life. Aromatherapy is said to have therapeutic benefits that include easing pain, promoting sleep and relaxation, and lessening symptoms of depression. As a result, aromatherapy has been used to lessen disruptive activity, encourage sleep, and increase motivated behavior among dementia patients (Forrester et al., 2014). As a result, aromatherapy cannot be applied to massage essential oils. Aromatherapy is limited to the inhalation of aromatic materials to produce either physiological or psychological benefits. However, the application of essential oils and their volatile components in medicine through massage or inhalation has grown all over the world. When working with essential oils in massage, caution should be used. Certain essential oils may pose a risk of toxicity.

Inhalation

The three basic methods of using essential oils are ingestion (via the digestive system), topical absorption (through the skin), and inhaling (via the respiratory system or olfactory nerves). The biological activity and aroma of essential oils are determined by their chemical composition, which is a blend of many organic components. They can be divided into some types based on their aroma, including citrus, herbaceous, camphorous, flowery, woody, earthy, minty, and spicy (Aćimović, 2021). The oils inhibited neurons in the central nervous system via the GABA-ergic neuromodulation pathway. This outcome is caused by elevated amounts of GABA in the brain (Edris, 2007). One of the prevalent psychological and behavioral issues that college students face is test anxiety, which can lead to subpar academic performance or even failure. College students may find aromatherapy to be a helpful way to lessen test anxiety, however, its exact effectiveness has not yet been thoroughly established (Luan et al., 2023).

Essential Oils Against Cancer

Constituents of natural essential oils are crucial I the treatment and prevention of cancer. When tested on various cancer cell lines of humans, including colon cancer, breast cancer, gastric cancer, tumors in the human liver, glioma, lung tumors, leukemia, and others, essential oils and their distinct fragrance components show cancer-decreasing effects. One of the most dangerous tumors in humans is glioma. Sesquiterpene hydrocarbon element, which is present in trace levels in many oils, has been shown to have a major impact on the treatment of gliomas. It extended the quality of survival time of glioma patients (Edris, 2007). Their chemopreventive properties come from a variety of mechanisms, including antimutagenic, antioxidant, anti-proliferative, immune function and surveillance enhancement, enzyme induction and enhanced detoxification, modulation of multi-drug resistance, and synergistic mechanism of volatile constituents (Bhalla et al., 2013). The antimutagenic properties of essential oils are ascribed to specific processes, one of which is the reduction of mutagens' ability to penetrate cells (Kada and Shimoi, 1987). Thymus vulgaris, Carum copticum, origanum, and oregano all have volatile oils that contain carvacrol, a phenolic monoterpene.
Various targets of EOs for cancer prevention are represented in Fig. 2.

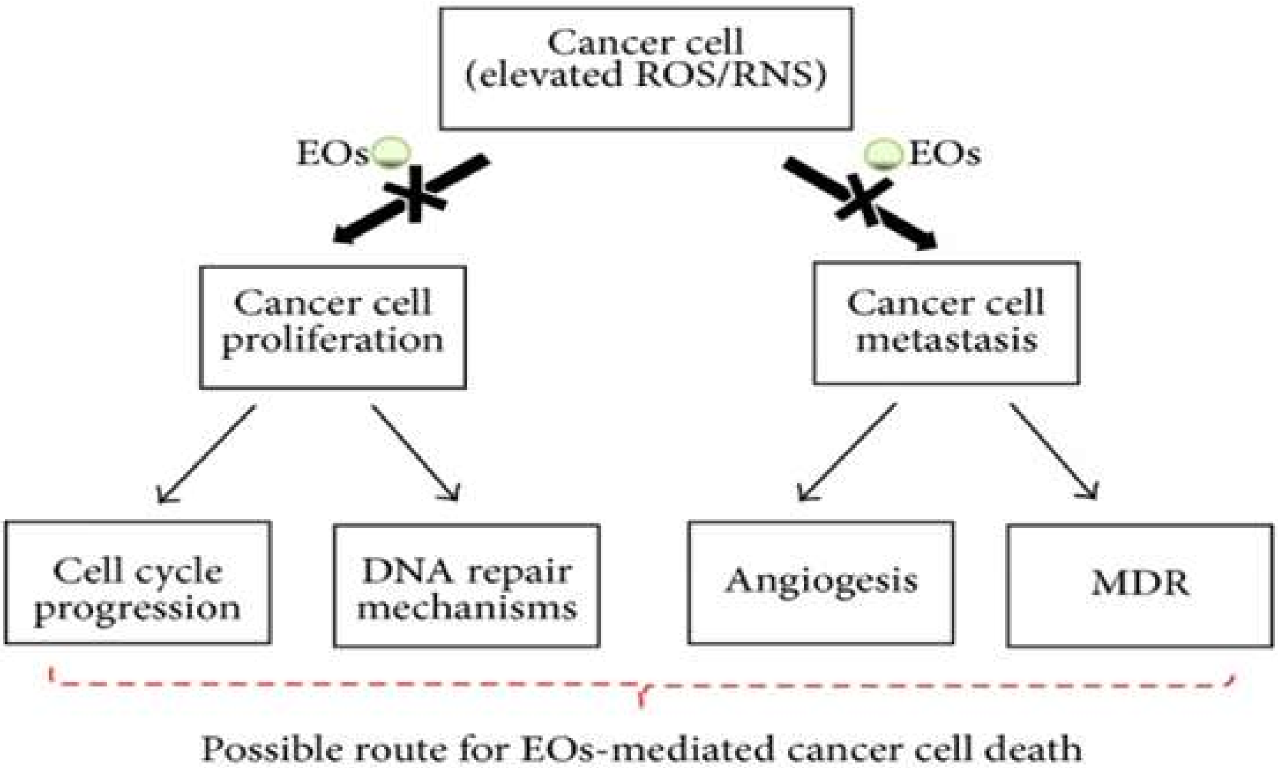

Fig. 2: Targets of EOs

Treatment of Cardiovascular Diseases

Atherosclerosis is a process in which plaque deposits accumulate in the intima, the artery's innermost layer. Over time, plaque can severely reduce blood flow, which might result in major health issues. An important factor in the onset of disease is elevated levels of oxidatively damaged (LDLs) low-density lipoproteins in cholesterol. The volatile components present in essential oils and their scent have demonstrated having antioxidative properties against LDL oxidation. One monoterpene hydrocarbon that is particularly effective at preventing the oxidation of LDL's protein and lipid components is terpinolene. The prolonged degradation of the basic carotenoids of LDL is the actual reason of this inhibition, not the safeguarding effect of intrinsic α-tocopherol like with certain flavonoids. Essential oils rich in phenolic substances, such as thymol and eugenol, have the strongest antioxidant action against LDL oxidation and can change the affinity of LDL particles for the LDL receptor (Naderi et al., 2004).

Antimicrobial Activity against Microbes (bacteria, Virus, and Fungi)

EO chemicals' antibacterial action has been well studied. It was discovered that a number of *Clostridium perfringens* strains were sensitive to thymol, citral, limonene, carvacrol, and cinnamondehyde when grown in anaerobic environments. According to in vitro research, combining various EO compounds may have a stronger antibacterial impact than taking each one alone, suggesting a synergy between separate actions. One benefit of several essential oils is their ability to prevent the growth of possible infections. The many components present in essential oils (EO), such as terpenes, phenylpropanoid, and aldehydes, confer reactivity on each EO based on its composition and nature, rendering it effective against a broad spectrum of infections (Aljaafari et al., 2021). Two groups of different biosynthetic origins are among the key constituents of essential oils that define their biological qualities. One group is terpenoids and terpenes and another is made up of aliphatic and aromatic components that have lower molecular weights. Terpenes are hydrocarbons that are created when numerous isoprene units (C_5H_8) are joined. Acetyl-CoA starts the process of terpene synthesis in the cytoplasm of plant cells, which then moves through the mevalonic acid pathway. Terpenes can be reorganized into cyclic structures by cyclases, which have a hydrocarbon backbone. This can lead to the development of either monocyclic or bicyclic structures.

Terpene biosynthesis consists of the following steps: synthesizing isopentenyl diphosphate (IPP) precursor; adding IPPs one after the other to form the prenyldiphosphate precursor of the various classes of terpenes; modifying allylic prenyldiphosphate by terpene-specific synthetase to form the terpene skeleton; and secondary (redox reaction) enzymatic modification of the skeleton to confer functional properties on the various terpenes. The primary two types of terpenes are sesquiterpenes ($C_{15}H_{24}$) and monoterpenes ($C_{10}H_{16}$), although there are longer chains like triterpenes ($C_{30}H_{40}$) and diterpenes ($C_{20}H_{32}$). Among the components of essential oils having antimicrobial activity are limonene, eugenol, p-cymene, estragole, menthol, geraniol, anethole, thymol, cinnamonyl alcohol and γ-terpinene (Chouhan et al., 2017). The capacity of EO to inactivate or inhibit bacterial development is referred to as its antibacterial activity. Clove extract demonstrated the strongest antibacterial activity, but grape seed cinnamon, pomegranate peel, clove and oregano were also found to be beneficial (Aljaafari et al., 2021).

Different essential oils work in different ways; some attack the outer membrane of bacteria, while others go after the efflux system of proteins in that membrane. Since EO are hydrophobic, they can pierce bacterial cell walls, which in turn causes the walls to break down, increasing permeability and releasing intracellular contents. Several studies demonstrated that the constituents of essential oils (EOs) target the cellular membrane, as demonstrated by the effects of applying oregano and thyme EO on the membrane of L. monocytogenes. This process is known as membrane disruption. Since EO compounds are hydrophobic by nature, this increases the permeability of bacterial membranes and increases the possibility that bacterial contents may leak out (Nazzaro et al., 2013).

Essential oils obtained from plants could be used for treating the viral diseases. A virus is a tiny particle (20–300 nm) that is made up only of genetic material encased in proteins and lipids. They carry out self-replication by infecting host cells. Viral disease continues to be a major global health concern. The usual method for figuring out the mechanisms of action of EOs, including their component parts, against viruses is to manipulate time-of-addition assays. The EOs are applied to cultured cells one hour before the virus is introduced (pre-viral infection). A negative result means that host cell receptors are not blocked by EOs, which would impact viral attachment. As an alternative, viruses are pretreated for one hour with EOs and then incubated with host cells at the same time (simultaneous viral infection). If the test is successful, it means that EOs disrupt free virions by changing the structure of the virus envelope or hiding the viral proteins that are required for the virus to bind to its surface and enter the host cell. Alternatively, EOs are added at several points to the infected cells (post viral infection) during the viral infection lifecycle (from penetration to progeny production). It is possible to approach the point in the viral infection cycle where EOs can combat viruses. To date, the most popular method for examining the general intracellular and intercellular inhibitory qualities of EOs is the time-of-addition experiment (ma and yao, 2020).

Compared to bacterial infections, fungal infections are caused by eukaryotic organisms, which makes it more challenging to identify their existence and administer the proper therapeutic therapy. The chitin structure found in the cell walls of fungi, which is lacking in human cells, makes them an ideal target for highly toxic antifungal medicines. The natural product for inhibiting fungi is essential oils (EOs). In actuality, a variety of essential oils that are derived from several herbs and plants demonstrated potent antifungal characteristics. Similar to other phytochemicals, EOs have the ability to prevent the growth of microbes and the development of biofilms through specific mechanisms. This is a particularly valuable aspect: Microorganisms are known to initiate a certain mechanism that results in the synthesis and manufacturing of chemicals, signals of microbial communication, and also the development of pathogenicity parameters, like the formation of biofilms, in addition to a specific growth threshold value. Many essential oils have broad antibacterial qualities that make them useful for preventing microbiological deterioration, maintaining quality and food safety, and extending the shelf life of food. The lipophilic and smaller molecular weight characteristics of terpenoids/terpenes may account for the antibacterial or antifungal activity of essential oils. These characteristics can cause a cell to rupture and die, or they can stop food-spoilage fungi from proliferating and germinating. Antifungal agents have the ability to deactivate fungi by interfering with the function and structure of the organelles and its cell's membranes, as well as by blocking the creation of proteins or nuclear material (Nazzaro et al., 2017).

Essential Oils and Antibiotic Agents

Many essential oils (EOs) have antibacterial qualities. Lavender essential oil demonstrated antiviral efficacy against the Herpes simplex virus type 1, but it also exhibited far stronger antibacterial action. Lavender essential oil (EO) is used in dermatology to treat ulcers, burns, and scars that are hard to heal.

Since thyme EO was effective against Herpes simplex, it demonstrated antiviral action. Additionally, after 30 minutes of exposure, this EO showed 100% inhibitory efficacy against the influenza virus in the liquid phase. However, thyme essential oil's primary impact is related to bacteria. The thymol chemotype of T. vulgaris L. exhibits particularly significant bacteriostatic activity against most Gram-negative and Gram-positive bacteria.

Nanomedicine Formulation of Essential Oils

The usage of natural prodrugs derived from plants is growing across many industries, including the cosmetic, pharmaceutical and food ones. These volatile, oily liquids that are biologically active are produced by aromatic and medicinal plants and have a unique smell. Although EOs have a great deal of promise for anticancer, antibacterial, antiviral, and antioxidant effects, they are frequently characterized by high volatility, low stability, and a significant risk of degradation when exposed to moisture, light, heat, or oxygen. The use of nanotechnology in medicine, or nanomedicine, may provide effective answers to these issues. The technique is based on building nanostructures in which the natural prodrug is attached to or enclosed in submicron-sized capsules or nanoparticles that guarantee their regulated distribution, solubility in water, and targeting characteristics. When compared to either free EO or a nanoemulsion, nanocapsules demonstrated a greater anticancer impact against the HepG2 liver cancer cell line. (AbouAitah and Lojkowski, 2022).

Future Prospective

An increase in the permeability of the pathogen cell membrane and the subsequent leakage of internal components can have a negative impact on cell metabolism, according to the functional groups of the EOs. To fully understand the potential of EO, determine the optimal dosage, and discover any potential side effects, additional research is needed to conduct clinical studies and long-term examinations to determine its efficacy in vivo. Essential oils also play a major role in reducing the prevalence of bacteria that are resistant to antibiotics.

Comprehensive studies may be conducted in the future to assess or forecast how microorganisms may respond to EO following prolonged or subchronic exposure. In order to better understand the pathways and mechanisms involve in the development of essential oils as prospective antimicrobial agents, several researchers proposed that the antibacterial action of EO should be examined during the lag phase in bacterial growth. Therefore, specialists from a variety of fields are required for the development of more potent therapeutic drugs; these fields include genetics, structural biology, genomics, and bioinformatics. Furthermore, for successful mitigation, it is essential to build extensive epidemiological networks that can report the emergence of novel microorganisms and raise public awareness.

Conclusion

The purpose of this chapter is to explain the essence of oils and their function in human health. Essential oils are substances that are inherently flammable. Essential oils have various uses beyond just adding flavor and aroma. The medicinal potential of essential oils is immense. Essential oils enhance the activation of white blood cells, making them more effective in flushing out germs and other pathogens.

As a result, essential oils, like many other plant-based medications, have multiple therapeutic effects for various illnesses, including cancer. More new essential oils and unidentified compounds should be screened for potential anticancer activities. Depending on where they originate, they each have distinct methods that contribute to lessening the severity of the condition. Essential oils are employed more often in the field of health, primarily on the body's exterior tissues. It is widely utilised worldwide, and as a result of its increased use, the market for essential oils is expanding quickly and gaining significance every day.

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Chapter 02

Holistic Healing: The Modern Role of Essential Oils in Therapeutic and Aromatherapy Practices

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ABSTRACT

Essential oils in aromatherapy form a powerful synergy with the body and mind, facilitating to alleviate stress, enhance mood, and support overall health and vitality. Various essential oils had history of use in aromatherapy such as eucalyptus, lavender, nutmeg, peppermint, clove, and tea tree oils. Eucalyptus oil, sourced primarily from *E. citriodora*, is globally recognized for its economic extraction and diverse therapeutic applications, owing to its high 1,8-cineole content. Lavender oil, known for its antibacterial properties dating back to World War I, offers sedative and anti-inflammatory benefits. Nutmeg oil, extracted from *Myristica fragrans*, displays antimicrobial, anti-inflammatory, and hepatoprotective properties, utilized traditionally for various ailments. Peppermint oil, rich in menthol and menthone, serves multiple purposes including gastrointestinal relief and mental alertness enhancement. Clove oil, containing eugenol, demonstrates strong antimicrobial and antioxidant effects with notable anticancer properties. Tea tree oil is important for its antimicrobial prowess, addressing skin infections and respiratory issues. This chapter highlight the multiple roles of essential oils, detailing their chemical compositions, pharmacological activities, and therapeutic applications.

KEYWORDS
Essential oils, Aromatherapy, Holistic healing, Alternative medicine

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INTRODUCTION

Aromatherapy originates from "aroma," referring to fragrance or scent, and "therapy," indicating treatment. It is a holistic approach to healing, nurturing the mind, body, and soul through natural ways (Worwood, 2000).

For over 6,000 years, civilizations such as Egypt, China, and India have embraced aromatherapy as a prevalent complementary and alternative therapy. It has proven effective in addressing a wide range of ailments and conditions (Alok et al., 2000). Historical accounts indicate a surge in interest during the late 20th century, and its popularity continues into the 21st century. Given its significance, widespread use, and acknowledgment as an aromatic science therapy, aromatherapy holds a prominent place in modern healthcare (Klein et al., 2014; Svoboda and Deans, 1994).

Aromatherapy employs essential oils as its principal therapeutic agents, purportedly deriving from highly concentrated substances extracted from various botanical sources such as flowers, leaves, stalks, fruits, and roots, with additional distillation processes involving resins (Dunning, 2013).

Aromatherapy has been classified into many classes as depicted in (Fig. 1).

Mechanism of Action

Essential oils have become essential in various realms, including therapy, cosmetics, aromatics, fragrances, and spiritual practices (Figure 2) (Evans, 2009).

These oils, known for their enduring potency, possess specific energetic properties resembling hormones. Their ability to penetrate tissues is crucial to their therapeutic effect. Upon inhalation, they integrate with nasal receptor cells, triggering signals to the brain, which release neurotransmitters like serotonin and endorphins. Different oils evoke distinct effects, influencing both mind and body (Kumar et al., 2000).

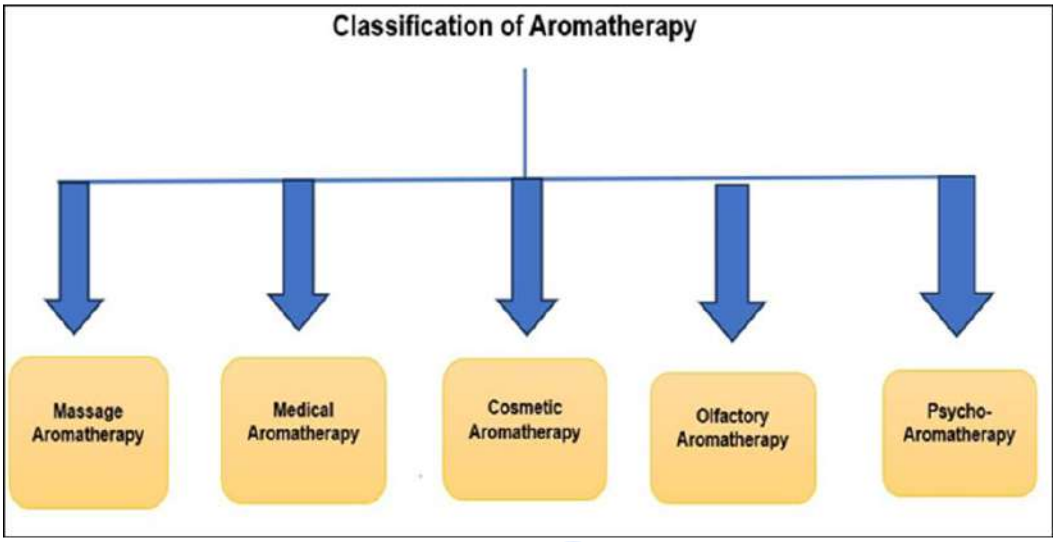

Fig. 1: Classification of Aromatherapy.

Fig. 2: Importance of essential oils in aromatherapy.

Essential oils are used for treatment of many diseases and common problems such as memory loss, pain management, anxiety, stress, fatigue, insomnia ,spasms and behavioural issues (Ali et al., 2015).
Several important aromatic oils have been discussed below for their therapeutic potential.

Eucalyptus Oil

Eucalyptus oil is especially helpful since it can be extracted economically (industrial value) and has many desirable qualities that can be used to treat a wide range of illnesses. Eucalyptus oil is obtained from leaves of plant. (Sharma et al., 2023).

Distribution and Botanical Description

Eucalyptus comprises more than 500 species that are widely distributed in Australia, India, southern Europe, North

Africa and South (Patel et al., 2018). The plant has a totally unique habit. Eucalyptus timber have unmarried stems and big trunks of their herbal shape. With a median top of 30 m, this tree is medium-sized to tall, even as a few writers file timber as tall as 45 m. Grey-blue, alternating, drooping, eight–22 cm lengthy, 1-2 cm wide, often curved or sickle-shaped, tapering, and short-pointed at base are the traits of the leaves (Sabo et al., 2019).

Chemical Compounds

More than 70% (v/v) of 1,8-cineole may be present in eucalyptus leaf essential oil. Other compounds are monoterpenes, macrocarpals, phenols, alkaloids, flavonoids 6,8- dimethylkaempferol-3,7-dimethyl ether, eucalyptin, 8-desmethyl-eucalyptin, oleanolic acid, terpenoid phenolaldehydes, verbenone, and tannins oil (Dhakad et al., 2018). There has been a successful report on fifty constituents of the essential oil from *E. globulus* cultivated in the Cangshan mountain region of Yunnan Province, China (Liu et al., 2009). The essential oils of *Eucalyptus camaldulensis* had a more intricate composition, with fifty-four compounds accounting for 95% of the total oil found in the leaves. However, the average yield of oil recovered from various distillation techniques was a very low 0.25% (w/w). Twenty-two elements, or 95.95% of the primary components of the essential oil, have been discovered based on the chemical makeup of E. grandis oil. These constituents are distinguished by a high amount of 1,8-cineole (Sewanu, 2012).

Pharmacological Activities

Several researchers have investigated the antibacterial properties of eucalyptus essential oil. The main components of eucalyptus essential oils are toxic to a variety of microorganisms, such as bacteria, fungus and soil-borne pathogens. Eucalyptus essential oils exhibits antidiabetic, antioxidant, hepatoprotective (Noumi et al., 2022), anticancer (Abiri et al., 2022) and nerve blocker activities (Cavalu et al., 2021).

Therapeutic Uses

Eucalyptus is used by traditional healers to cure a wide range of ailments, including neuralgia, soreness, stiffness, bronchitis, pneumonia, colds, and flu (Ridouh and Hackshaw, 2022) and (Madankar et al., 2021). The wound healing activity of ethyl acetate and ethanolic extracts of *E. citriodora* in Wister albino rats validated the wound healing activity of eucalyptus. Numerous studies have shown that eucalyptus oil has analgesic, anti-inflammatory and antinociceptive properties (Owemidu et al., 2020).

Lavender Oil

Lavender essential oils are used in numerous over-the-counter alternative medicines and cosmetic items as a complementary medicine. It is collected between late June and August from flowers. Medicines prepared from the lavender have been utilized for medicinal purposes from ancient times. (Saeed et al., 2023).

Distribution and Botanical Description

There are 41 recognized species in the genus Lavandula L. (Lamiaceae), which are either native to Arabian Peninsula, Macaronesia, Northern and North-Eastern Africa, the Mediterranean basin, South-Western Asia, Central and Southern India, or were brought to Australia, New Zealand, and Eastern Europe (Kiprovski et al., 2023). Lavender is an evergreen drooping shrub with strong aromatic properties. The flower-bearing stems are tetrahedral with a protracted higher internode, and the decrease lignified branches are closely branched, rising, and bearing many younger shoots. Leaves: opposite, sessile, oblong-linear, inexperienced or gray-inexperienced from drooping, with curled margins, 2–6 cm long. False whorls of plant life are collected to shape spike-fashioned inflorescences. Corolla: pubescent, usually bluish-purple, two-lipped, approximately 1 cm long. The ultimate cup carries 4 nuts that make up the fruit.(Fakhriddinova et al., 2020)

Chemical Compounds

The majority of lavender essential oils contain camphor,1,8-cineole, thymol, borneol, linalool, ρ-cymene, α-pinene, and β-pinene as their primary ingredients (Dong et al., 2020) separated 40 compounds in lavender essential oil that were shown to be responsible for 92.03% of the compositions of the essential oils by using GC-MS. Column chromatography was used to separate the 19 monomers in this study.

Pharmacological Activities

Studies using isolated components from lavender essential oil, such as linalyl acetate and linalool, have demonstrated hypnotic, anesthetic, and antispasmodic properties. Components including camphor, terpineol, 1,8-cineole, and linalool have been shown to possess anti-inflammatory, antimicrobial, and antioxidant properties (Blažeković et al., 2010). Moreover, linalyl acetate, 1,8-cineole, and linalool have antispasmodic properties. Linalool has been shown to have certain insecticidal properties, and linalyl acetate has been shown to have narcotic properties (Lechat et al., 2015).

Therapeutic Uses

Lavender oil has been shown in numerous studies to promote and enhance sleep while lowering tension and anxiety. Additionally, research indicates that lavender may be used to treat dementia. Because lavender essential oil has significant pharmacological properties as an antioxidant, antibacterial, anti-inflammatory, and anticholinesterase agent, other research recommends using it to treat a variety of health issues (Cardia et al., 2018).Lavender essential oil can potentially help with neuropathic pain since it has been shown to effectively lower pain perception when applied topically to patients suffering from carpal tunnel syndrome. Lavender essential oil has been shown to be a great substitute for liver disease treatment due to its significant anti-inflammatory properties that protect liver and kidney damage, lower inflammation, and suppress oxidative stress (Kozics et al., 2017) .

Nutmeg Oil

Nutmeg is an evergreen tree with height up to 20–25 ft high belongs to family Myristicaceae. It yields seeds with red arils (mace) and brown kernels (nutmeg) used in oil is obtained from seed kernels in June to August in Pakistan.

Distribution and Botanical Description

Nutmeg is native to Indonesia, but recently cultivated across various regions including Grenada, USA, India, Mauritius, Sri Lanka, South Africa, and Pakistan. Its sweet flavor makes it a popular choice as a flavor enhancer especially in baked goods, dairy products, meats, sauces, and beverages. Additionally, nutmeg oil, valued for its fragrance, is utilized in both the flavoring and perfumery sectors (Khanam et al., 2023). The nut possesses an oval or broadly ovate shape, encased in a tough, coarse, dark-brown shell that appears glossy on the outside and smooth and light-colored within, measuring about half a line in thickness. (Nikolic et al., 2021) .

Compounds

Nearly all parts of nutmeg like leaves, mace, seed, and kernel contain substantial amount of essential oils (Ashokkumar, Simal-Gandara, Murugan, Dhanya, and Pandian, 2022). Previous studies showed that nutmeg leaf oil contains compounds like sabinene (17.2%), eugenol (16.6%), and myristicin (9.1%), while mace oil (8.1% v/w) is rich in sabinene (38.4%) and α-pinene (8.2%). Factors like soil type, season, cultivars, and location influence essential oil yield in regions like India and Pakistan (Ashokkumar et al., 2022). .

Pharmacological Activities

Clinical studies confirmed the antioxidant, antimicrobial, anti-inflammatory, anticancer, antimalarial, anticonvulsant, hepatoprotective, antiparasitic, insecticidal, and nematocidal (Khanam et al., 2023) activities of nutmeg essential oil as shown in (Figure 3). It has antimicrobial activities which have been documented in research.

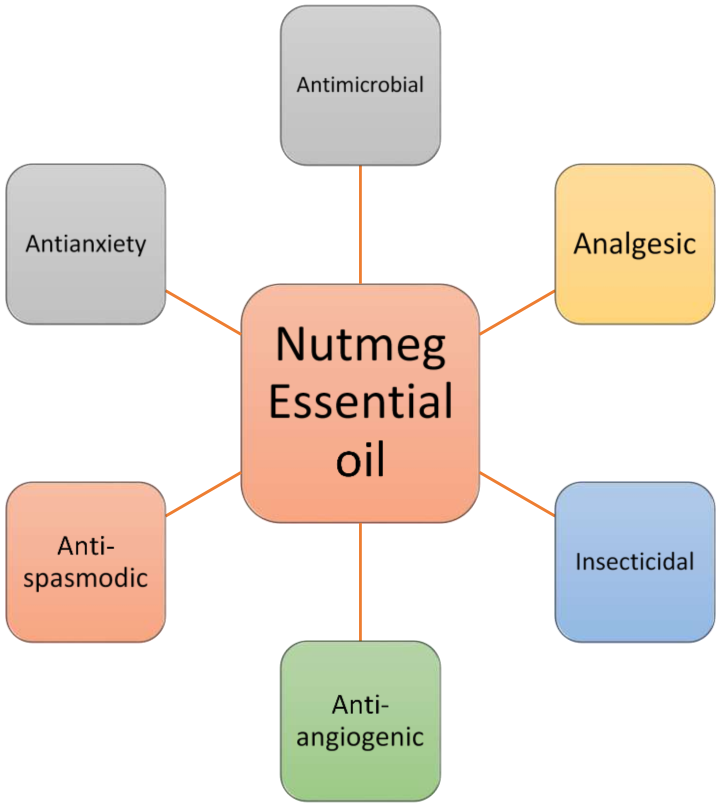

Fig. 3: Pharmacological activities of Nutmeg oil

Therapeutic Uses

Currently nutmeg essential oils gaining interest due to protection from food-borne bacteria and fungi. The demand in food industries is increasing due to safe, cheap and environmental friendly potential as compared to synthetic antibiotics. Spice also contains different essential oils have been reported to inhibit growth of microorganisms. Different studies reported that essential oils with a 0.5% concentration found in nutmeg sufficient to completely suppress the growth of different bacteria like *E. faecalis* and *S. mutans* Some studies also reported that 0.2% concentration was enough to prevent the growth of *P. multocida* (Ashokkumar et al., 2022). Topical study determined the analgesics potential by inhibiting COX. The insecticidal properties were also found for the management of *M. domestica* and *C. albiceps* (Zhang et al., 2016). MFEO exhibited significant antiangiogenic property and it can be utilized as an anticancer agent as it limits the formation of new blood vessels and inhibits the growth of tumours (Kholibrina and Aswandi, 2021). Traditionally it is also used to cure several other problems like anxiety, nausea, diarrhea, cholera, stomach cramps, parasites, paralysis rheumatism and aphrodisiac (Ashokkumar et al., 2022). Nutmeg plant widely used in Pakistan to treat hypertension and hypertension associated disorders (Malik et al., 2018).

Peppermint Oil

Peppermint essential oils (PEO) of *Mentha piperita L.* and *Mentha arvensis* leaves from Labiatae family, is esteemed for its therapeutic attributes Worldwide, *Mentha arvensisis* well known as field mint, wild mint or corn mint (Balakrishnan, 2015).

Distribution and Botanical Description

Mentha is widely distributed globally in the topical, subtopical and temperate regions. *Mentha arvensis* possess leaves with curled edges. Each pair of leaves grows in opposing directions from one another. Mints display flowers in hues such as soft purple, pink, and white (Kholibrina and Aswandi, 2021). Oil is sourced from the undersides of leaves through steam distillation and is typically subjected to rectification and fractionation before being utilized. Exhibiting a colorless to pale yellow or greenish-yellow hue, this aromatic substance bears a distinct odor and taste, often followed by a pronounced sensation of cold (Sharma et al., 2013).

Active Compounds

PEO principal active compounds include menthol, menthone, menthyl acetate, limonene, cineole, and pulegone. Menthone and iso-menthone undergoing substantial synthesis as the epidermal oil glands during the rapid growth phase of young Mentha plants (Sachan et al., 2013).

Pharmacological Activities

Menthol, one of the major constituents of peppermint oil, has been extensively studied for its various biological activities. It has been shown to possess antimicrobial, antiviral, analgesic , anti-inflammatory (Mogosan et al., 2017), and antioxidant properties as depicting in (Figure 4). Menthone, another important component, has demonstrated antibacterial (Diler et al., 2021) and insecticidal activities . Cineole and limonene, two monoterpenes present in peppermint oil, have also exhibited antimicrobial, anti-inflammatory (Chao et al., 2005),and antioxidant effects.

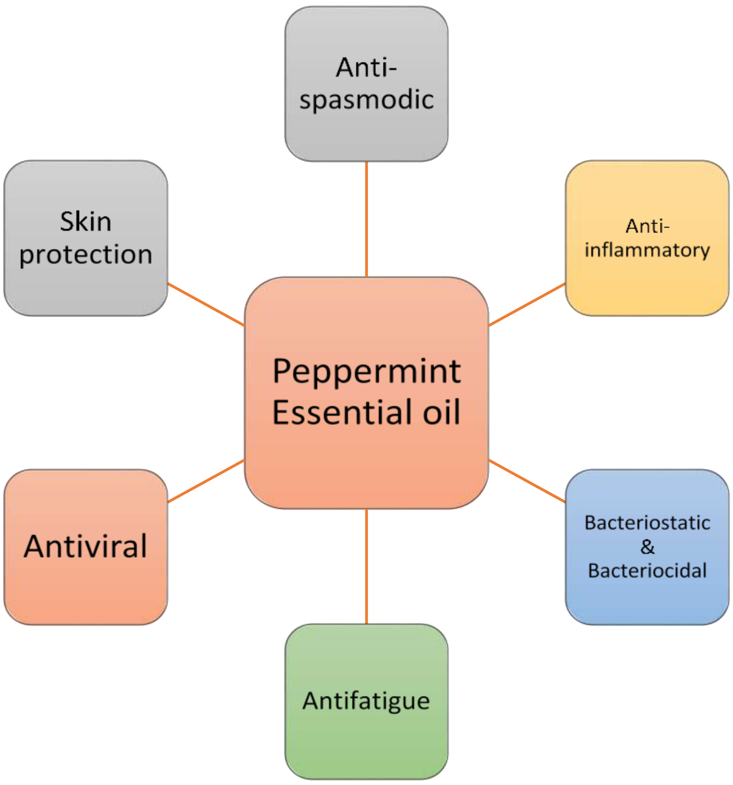

Fig. 4: Pharmacological activities of peppermint oil

Therapeutic Effects

PEO is reported to alleviate gastrointestinal spasms and abdominal pain by functioning as a smooth muscle calcium channel antagonist. This mechanism involves blocking calcium influx through endomysial L-type calcium channels, thereby potentially reducing the contractility of gastrointestinal smooth muscle (Smith et al., 2018; Zhao et al., 2022).

PEO acts as a choleretic by reducing intrahepatic cholestasis. It can be widely used to treat wounds, skin infections, inflammation, eczema, hives, psoriasis, scabies, and insect bites, among other dermatic disorders (Štefanidesová et al., 2019). Topical PEO relieve itching sensations through the activation of A-delta fibers and k-opioid receptors , Furthermore, it has been observed to alleviate pregnancy-related pruritus (PG) resulting from hormonal changes (Amjadi et al., 2012; Elsaie et al., 2016). It enhances alertness and mental refreshment while also modulating the brain's olfactory pathway to alleviate anxiety, reduce pain and impulse, and improve sleep quality, thus contributing to its antifatigue effects. PEO exhibit bacteriostatic and bactericidal properties against a various species of microbes (Rasooli et al., 2009). PEO effectively alleviates inflammation and oxidative stress (Kim et al., 2021).

Clove Oil

Clove (*Syzygium aromaticum*) a precious herb belongs to family Myrtaceae. Clove essential oil (CEO) obtained from flower bud has long history of use in medicine and food.

Distribution and Botanical Description

Clove encompassing approximately 1200 to 1800 flowering plants species extensively found in Asia, Africa and Madagascar regions (Cock and Cheesman, 2018). *Syzygium aromaticum* is an evergreen tree that can reach heights of 8 to 12 meters, characterized by its sizable square-shaped leaves and clusters of vibrant flowers. Initially pale in color, the young flower buds gradually transition to green before turning a vibrant red when they are ripe for harvesting (Milind and Deepa, 2011).

Active Compounds

The handsome amounts of essential oils are found in the aerial parts of clove which contain chemical profile analysed by GCMS (Milind and Deepa, 2011). These chemical constituents including volatile oil (15 to 20%) comprising eugenol (70 to 85%), eugenyl acetate (10 to 15%), and beta-caryophyllene (5 to 12%), methyl amyl ketone, kaempferol and gallotannic acid (Milind and Deepa, 2011) .

Pharmacological Activities

CEO exhibited various pharmacological activities (Figure 5) such as anti-oxidant (Radünz et al., 2019), anti-inflammatory, anti-Alzheimer's, antiarthritic, cardiovascular, anxiolytic , analgesic , antibacterial, anti-viral, wound-healing effects, dental anesthetic and hepato-protective activity (Thuwaini et al., 2016).

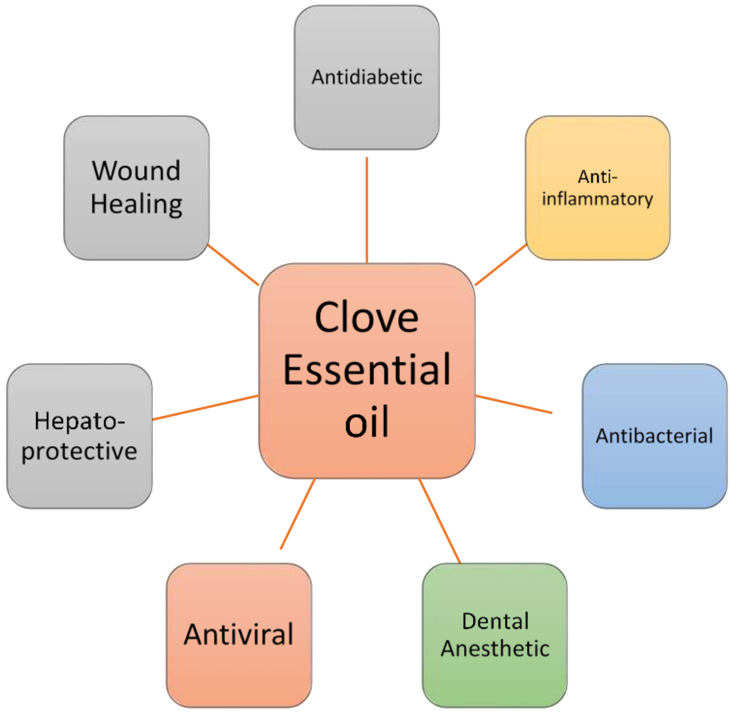

Fig. 5: Pharmacological activities of clove oil

Therapeutic Effects

It demonstrated cytotoxic effects against colon cancer, oesophageal cancer, breast cancer and prostate cancer (Abd El Azim et al., 2014). It acts as antidiabetic agent by dose dependent inhibition of alpha glucoside thus block the absorption of carbohydrate in small intestine (Adefegha et al., 2014). CEO serves a dual purpose of pain relief and infection clearance for abscesses. For individuals with an earache, it is advisable to dilute clove oil with a carrier oil (avoiding water), mixture is applied to a cotton ball, and carefully insert it into the ear canal. SAEO oil derived from the leaves is renowned for its potent antimicrobial properties. It has found application in wound dressing, the formulation of mouthwash, and the prevention of postnatal sepsis (Chah et al., 2006).

CEO has been added as a main constituent in different formulations due to its antioxidant, anti-inflammatory, antimicrobial, antifungal and antiviral properties. It is also used to treat burns, wounds and pain (Batiha et al., 2020).

Tea Tree Oil

Melaleuca Alterfolia belongs to the *Myrtaceae Family* and is commonly named Cheel Plant, an Australian native. Melaleuca (tea tree) oil has become increasingly commonly used in recent decades. Leaves of this plant are most widely used to extract tea tree oil with 100 % Natural IngredientsIt may be yellow or colorless and fragrances like camphoraceous (Borotová et al., 2022).

Distribution and Botanical Description

Australia is the country where tea tree plants are cultivated in a large hierarchy, other countries like China, South Africa, and New Zealand produce large quantities of *Melaleuca alterfolia* (*M.alternifolia*) due to increasing global demand for tea tree oil. The tea tree has a most morphological top of round 7 metres. Leaves have a linear shape, are easy and velvety, and degree among 10 and 35 mm in duration and 1 mm in width. Plant blooms in the course of the spring and early summer. Along the branches are little, 2-three mm diameter, cup-fashioned, woody fruits.(Mathematics et al., 2023)

Chemical Composition

Tea Tree oil (TTO) contains almost 100 ingredients, including major compounds Terpinen-4-ol, γ-Terpinene, 1,8-cineole, α-Terpinolene, α-Terpinolene, α-pinene and P-Cymene (Kasujja, 2021).

Pharmaceutical Activities

TTO has been extensively studied for its various biological activities. It has been shown to possess antimicrobial, antiviral, analgesic , anti-inflammatory, and antioxidant properties (Borges et al., 2019).

Tea Tree oil affects fungi cells' permeability by suppressing mycelium's conversion into germ tubes. It is used without adverse effects or irritation to treat yeast-causing dandruff. It kills the eggs that cause head lice due to the presence of a naturally occurring substance, Nerolidol. Components of tea tree oil bind within the viral lipid bilayer and increase the thickness of the membrane, causing a change in protein correlation. Its lipophilic activity enables its penetration into the skin, making it easy to treat cutaneous infections (Brun et al., 2019).

Therapeutics Uses

TTO possess anti-inflammatory properties that help to cure inflammation, swelling, and redness. It is used for treating acne problems, eczema, and psoriasis. It is a natural antiseptic that prevents infection from burns, cuts, and scrapes (Romeo et al., 2022). The topical use of tea leaves is beneficial for quick wound healing. It effectively repels insects from surfaces such as mosquitoes and ticks. TTO treats respiratory symptoms like cough, sinusitis, and mucus expulsion. It also relieves itching and skin irritation from insect bites. (Kairey et al., 2023)

Rose Oil

Rosa indica is a woody perennial plant belongs to the Rosaceae family and the genus Rosa. Oil is obtained from petals. It have 200 species and over 18,000 cultivars.(Desta et al., 2022).

Distribution and Botanical Description

The plant of rose is cultivated in many countries such as Iran, Turkey, China, South Italy, Libya, South Russia, and Ukraine etc. The traditional uses of rose oil have been found in food, cosmetics, and medicine. (Seify et al., 2018). It is a tall shrub that can reach a height of 2.5 metres. When fully developed, it produces 500–600 flowers during its yearly bloom, which occurs in May or June..(Galal et al., 2022)

Chemical Compounds

The chemical compounds of rose oil can be divided into different categories, such as phytochemicals, flavors compounds, and mineral contents. Numerous chemical components have been identified in rose flowers and leaves. Geraniol, heneicosane, citronellol, linalool, β phenylethyl alcohol, nerol, neral, geranial, eugenol, methyleugenol, nonadecene, eicosane, and tricosane are the main ingredients of the essential oil. Using gas chromatography (GC), the essential oil's quantifiable contents of citronellol, n-nonadecane, n-heneicosane, geraniol, nerol, citral, and eugenol can be determined. Certain components, such as α, β-unsaturated aldehydes, and alcohols like linalool and eugenol, are known to be abundant in the leaves, while flowers contain 2-phenylethanol. In the cosmetic and perfume sectors, floral oil appears to be more suitable. (Verma et al., 2020).

Phytochemicals

Phytochemicals analysis of Rose oil revealed a cluster of important bioactive constituents like kaempferol, Geraniols (5.5–18%), β-citronellol (14.5–47.5%) and nonadecane (10.5–40.5%) (Alom et al., 2021). The active constituents of *R. damascena* essential oil are β-damascenone, β-damascone and β-ionone obtained from degradation of carotenoid (Kant et al., 2023).

Pharmacological Activities

Rose has a wide range of medicinal uses due to diversity of several active constituents which are biologically active and responsible for medicinal properties (figure 6) (Akram et al., 2020).

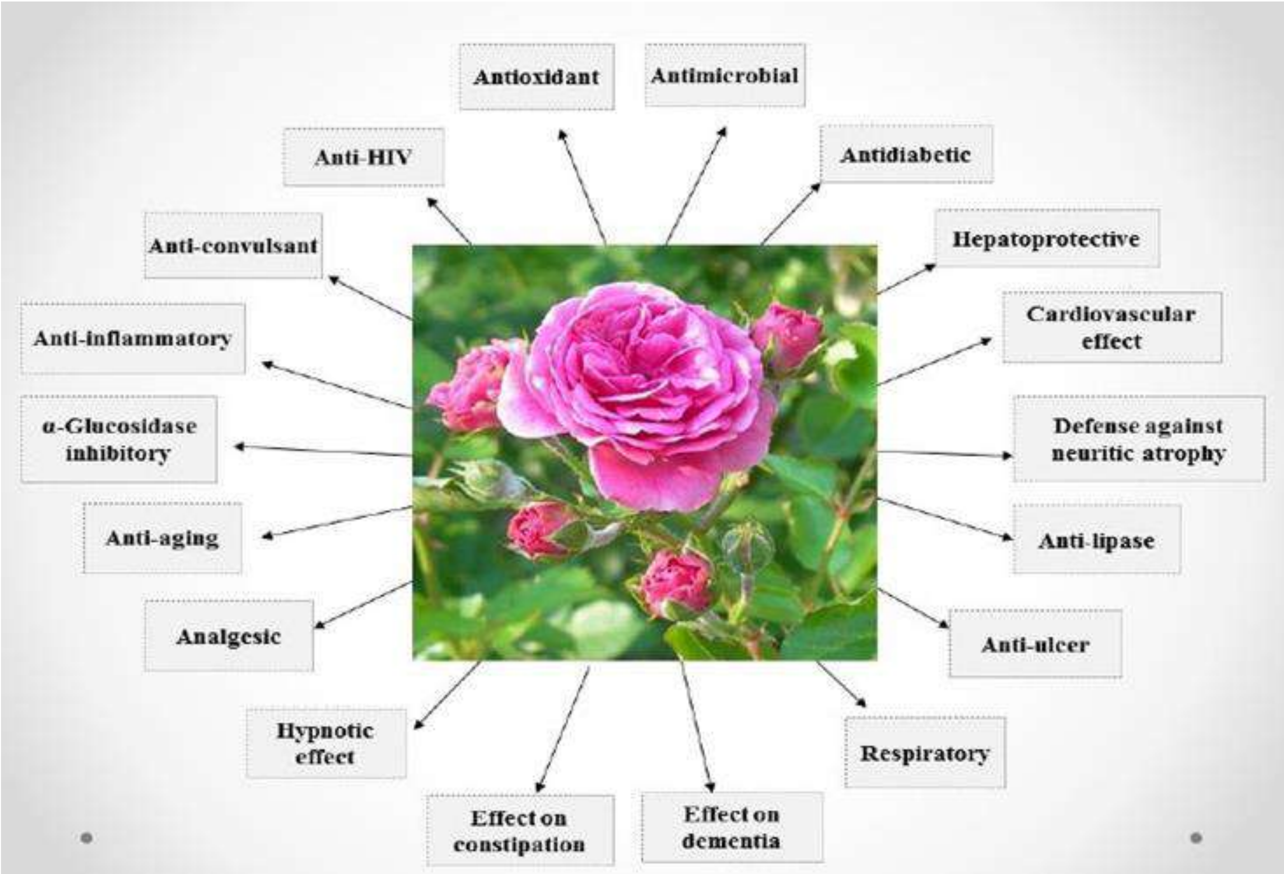

Fig. 6: Pharmacological activities of Rose oil

Clinical studies have been documented in research and proved antimicrobial, anti-inflammatory, anticonvulsant, hepatoprotective and anti-oxidant properties (Fig 6) of rose essential oils (Labban and Thallaj, 2020).

Therapeutic Uses

Rose oil is a nervine tonic, and it is prescribed for patients who are suffering from depressive disorders to elevating mood. Rose oil is very famous alternative herb used from thousands of years against various disorders like gastric ulcers, analgesics properties, cosmetic issues, antibacterial potential and cardiovascular diseases. Rose tea increases the digestion process by supporting the normal flora of gut. Rose oil is very effective for irregular periods and relieve from uterine congestion (Akram et al., 2020).

Conclusion

In conclusion, aromatherapy is a natural, non-invasive therapy that alleviates disease symptoms and rejuvenates the body, promoting overall well-being. It serves as both a preventive measure and a treatment for various conditions. The effectiveness of essential oils depends on the proper selection and collection of plant parts, affecting their active compounds. They can be used alone or complementary conventional medicine, provided safety and quality are considered. The growing scientific interest in complementary and alternative medicine suggests that essential oils could enhance the effects of drugs, especially for CNS diseases, offering significant patient benefits. Aromatherapy's potential, if fully explored, could provide a valuable synergy between natural remedies and modern medicine.

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Chapter 03

Aromatherapy in Healthcare: Harnessing the Power of Essential Oil

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ABSTRACT

Currently, the utilization of alternative and complementary therapies in conventional medicine has experienced a surge in popularity. Aromatherapy is a form of complementary therapy that uses essential oils as the primary therapeutic agent for the treatment of various ailments. Various methods are used to extract essential or volatile oils from different sections of the plant, such as flowers, barks, stems, leaves, roots, and fruits. The discovery of the antibacterial and skin permeability qualities of essential oils led to its creation. The primary techniques employed in aromatherapy to allow these oils to permeate the human skin surface and create a noticeable aura are inhalation and local application baths. After entering the body, the oils adjust themselves and perform harmoniously at the location of dysfunction or the area that is impacted. This therapy employs many combinations and variations to alleviate a wide range of disorders such as depression, indigestion, headache, sleeplessness, muscular discomfort, respiratory issues, skin conditions, swollen joints, urinary complications, and more. The efficacy of essential oils is enhanced when one takes into account other factors of life and diet. This chapter provides an overview of therapeutic, medicinal, cosmetic, psychological, olfactory, massage aromatherapy, safety, and botanical studies. The data was obtained from electronic databases such as Academic Journals, Google Scholar, Ethnobotany, library search, PubMed, Web of Science, and Science Direct.

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INTRODUCTION

The term "aromatherapy" comes from "aroma," meaning fragrance or perfume, and "therapy," meaning treatment. An organic strategy to revitalizing mental, physical, and spiritual health is described above (Mollica et al., 2022). For a minimum of 6,000 years, India, Egypt, and China have employed this form of medicine known as complementary and alternative medicine (Lichtenthaler et al., 2006). Aromatherapy has been shown to cure several conditions. The literature study shows that this therapy was popular in the late 20th century and remains so now. Aroma science treatment is appreciated for its relevance, popularity, and widespread use (Turek and Stintzing, 2013). Essential oils are used for medicinal, cosmetic, aromatic, fragrant, and spiritual applications. The major therapeutic agents in aromatherapy are essential oils, concentrated chemicals taken from flowers, leaves, stalks, fruits, roots, and resins (Schmidt, 2010).

Saturated and unsaturated hydrocarbons, terpenes alcohol, aldehydes, ketones, esters, oxides, ethers and phenols are the components that make essential oils. Terpenes are also a small component of essential oils. The aforementioned components have the potential to generate one-of-a-kind aromas (Tian et al., 2020). These compounds are clear, fragrant liquids that are distinguished by a high refractive index. These oils possess high potency and concentration, allowing them to precisely target pressure points and efficiently stimulate rejuvenation.

Aromatherapy is based on the core principles of using inhalation and applying essential oils externally to produce a state of mental and physical balance. There is substantial evidence that these oils can inhibit the growth of bacteria, viruses, and other microorganisms. Several scientific publications and traditional healers have suggested the possible application of these remedies in treating a range of illnesses, including cardiovascular disorders, Alzheimer's disease, labor pain during pregnancy and cancer (Sikkema et al., 1995). Presently, there is an increasing tendency to utilize this therapeutic method in the treatment of cancer and sleep disorders. These oils are frequently employed in phytotherapy to rejuvenate and energize the body to combat weariness (Astani et al., 2014).

Aromatherapy has experienced substantial expansion in the realm of holistic medicine in recent years. A survey of the research on this medication reveals that many investigations into its impact on the human brain and emotional state have been conducted. Recently, the scientific community has been involved in a vigorous discussion on the influence of the mood, attentiveness, and mental stress levels of those who are in good health (Deng and Lu, 2017).

How Aromatherapy Works

Aromatherapy with essential oils has a long history of use for physical, mental, and spiritual well-being. Fragrances kill bacteria, viruses, and fungus with their volatile chemical molecules (Dewick, 2002). These compounds have been extensively studied for their antibacterial, antiviral, anti-inflammatory, immune-enhancing, emotional, hormonal, glandular, circulatory, relaxing, memory, and alertness properties (Paulpandi et al., 2012). Multiple pilot projects and research studies on humans have examined their intrinsic features and their function in sickness and disorder. These oils have an energy-specific property since they continue to work with age. This therapy is unique for its oils' ability to penetrate subcutaneous tissues (Leite et al., 2007). In response to these impulses, the brain releases feel-good neurochemicals like serotonin and endorphins, which improve nerve impulse transmission to other parts of the body, bringing about the desired change and alleviation. The release of serotonin, endorphin, and noradrenalin, respectively, is what gives soothing oil, euphoric oil, and stimulating oil their respective effects on the mind and body (Lichtenthaler et al., 2006; Amorati et al., 2018).

Categorization of Aromatherapy

Aromatherapy in Cosmetics

This therapeutic modality employs specific essential oils in the formulation of cosmetic goods designed for the enhancement of the hair, face, skin and body. The aforementioned items are utilized for their diverse capabilities, including cleansing, moisturizing, desiccating, and toning. Incorporating essential oils into facial cosmetics can potentially promote the achievement of optimal skin health. Engaging in cosmetic aromatherapy through full-body or foot baths can individually enhance one's experience straightforwardly and effectively. Similarly, a small amount of suitable oil produces a revitalizing and rejuvenating sensation (Ampadu et al., 2022).

Massage Aromatherapy

Previous studies revealed that the utilization of pure vegetable oil in conjunction with almond, grape seed or jojoba oils during the massage process has been shown to yield exceptional outcomes. According to Wani et al.'s research from 2020, massage therapy is frequently referred to as healing touch.

Olfactory Aromatherapy

The practice of inhaling essential oils has resulted in the development of olfactory aromatherapy, which has been shown to increase emotional well-being, as well as tranquility, relaxation, and renewal of the internal organs of the human body. Both the reduction of tension and the activation of olfactory memories are accomplished through the combination of pleasant aromas (Astani et al., 2010). Essential oils are frequently used in conjunction with medical therapy, and they should not be considered a replacement for the treatment that is being administered.

Medical Usages of Aromatherapy

René-Maurice Gattefosse, the pioneer of contemporary aromatherapy, utilized essential oils to massage patients during surgical procedures. He did this by leveraging the expertise of medical aromatherapy regarding the impact of essential oils on enhancing and managing medical conditions that have been scientifically diagnosed (Chen et al., 2018).

Psycho-aromatherapy

The practice of using essential oils to elicit specific states of mind and feelings, such as sensations of relaxation, revitalization, or pleasant recollections, is known as psycho-aromatherapy. An infusion is administered to the patient in their room, and the oils that are used in this treatment are inhaled directly. Psycho-aromatherapy and pharmacology are two fields that concentrate on the study of scent and its effects, regardless of whether the aroma is natural or artificial made. Since its inception, the field of psycho-aromatherapy has been restricted to the study of natural essential oils (Choi. 2018).

Some Plants used in Aromatherapy

The use of a variety of plants in aromatherapy has been documented, primarily as a result of the presence of essential or volatile oils produced by these plants. As organic phytochemicals, the scent molecules demonstrate a significant level of efficiency, effectively eliminating pathogens, fungi, bacteria and viruses from the environment in which they are found (De Cássia et al., 2017). Researchers have extensively reported on the various properties of these substances, which include their ability to fight against bacteria and viruses, reduce inflammation, enhance the immune system, and regulate functions related to hormones, glands, emotions, circulation, relaxation, memory, and alertness (Feijó et al., 2014). One remarkable aspect of this therapeutic procedure is the ability of these oils to effectively penetrate the subcutaneous tissues. These chemicals have complicated and subtle effects because of their chemical properties and complex composition. Scientists experience the desired alteration and a sense of comfort when these impulses drive the brain to release neurochemicals like serotonin and endorphins. These chemicals improve the communication between nerves and other bodily systems. Noradrenalin, Serotonin and endorphin can be released by stimulating oil, soothing oil, and euphoric oil, respectively (Pourghanbari et al. 2016). Certain effects on the brain and body are brought about by these chemicals.

Table 1: Different plants producing essential oils

Essential oils	Parts of plant
Bergamot, lemon, lime, sweet orange, tangerine, mandarin	Fruit peel
Cinnamon	Bark
Citronella, lemongrass, petitgrain, palmarosa, patchouli	Leaves
Geranium, lavender, rosemary, spike lavender	Entire plant
Ginger, vetiver	Roots
Jasmine, neroli (orange blossom), rose, ylang ylang	Flowers

Clary Sage

The Clary sage, scientifically known as *Salvia sclarea* Linn., belongs to the Lamiaceae family of plants (Fig. 1). The perennial clary sage plant's large, purple-hairy green leaves provide most of its essential oil. It differs from ordinary sage, Salvia officinalis. Its bigger leaves and late summer blue-white hue distinguish it from other varieties. Linalyl acetate, geranyl dominate, alpha-terpineol, Linalool, and germacrene D (Costa et al., 2020). Studies have shown that it regulates menstrual cycles, relieves stress and muscle cramps, and is appealing and aphrodisiac. It helps to control the production of sebum, making it excellent for both dry and oily skin. Additionally, it can be used to treat acne, wrinkles, and cellulite (Pandey et al., 2023). Recent research has demonstrated the strong effectiveness of this oil in controlling cortisol levels in women, as well as its ability to combat microorganisms (Chatzivasileiou et al., 2019).

Fig. 1: *Salvia sclarea* Linn. (© 2024 - Jora Dahl [Non-Commercial and Educational purpose only])

Eucalyptus

Eucalyptus globulus, a tall and long-lasting plant, belongs to the Myrtaceae family of plants. At its full maturity, it can attain a height of 250 feet (Fig. 2). The compound's composition, consisting of cineole (70%–85%), aromadendrene, phellandrene, limonene, cymene, terpinene, and pinene, is what distinguishes it (Zhang et al., 2018). The plant's oils have been used to treat neuralgia, headaches, and debility by stimulating and regulating a number of systems, including the neurological system. The immune system fortifies defenses against illnesses like chickenpox, measles, influenza, and the common cold. It also works well in the treatment of genitourinary system-related cystitis and leucorrhea. The plant's oils have been used to treat illnesses of the respiratory system, including sinusitis, asthma, bronchitis, coughs, and throat infections. Additionally, it can be used as an insect repellent and to treat a variety of skin diseases, including burns, scrapes, herpes, lice, and wounds (Cedrowski et al., 2016). The therapeutic properties of the plant's essential oils have been widely recorded in the management of rheumatoid arthritis, as well as discomfort and inflammation in muscles and joints (Feriotto et al., 2018). The efficacy of eucalyptus oil in treating various metabolic and infectious problems has been extensively established by researchers, who have documented its anti-allergic, antioxidant, anti-apoptotic, and antibacterial qualities. The findings demonstrate significant promise and have the potential to be utilized in the management of multifactorial illnesses in individuals (Butnariu and Sarac, 2018).

Fig. 2: *E. globulus* Labill. (This figure is reproduced from Ali et al. (2015) under a Creative Commons Attribution-Non-commercial License [CC BY-NC]).

Geranium

Within the Geraniaceae family, geranium is sometimes referred to by its scientific name, *Pelargonium graveolens* L'Herit (Fig. 3). The perennial, hairy shrub grows up to 1m in height and is native to South Africa. Moreover, this plant has a wide range of geographic distribution and is grown in many countries, including Egypt, France, Italy, Spain, Central America, Japan, and the Congo. The essential oil produced by this plant is highly valued. Numerous chemical components, including eugenol, citronellol, geranic acid, geraniol, linalol (linalool), terpineol, citral, methone, citronellyl formate, myrtenol, and sabinene, are present in this substance's essential oil (Chami et al., 2004). Because of its exceptional properties that are unaffected by the alkaline nature of soaps, geranium oil is a highly concentrated natural scent that is frequently used in soaps and detergents. According to De Sousa et al. (2015), this oil is also used for treating throat infections, controlling blood illnesses including diabetes, relieving menopausal symptoms, and calming and nerve-strengthening qualities.

Studies have been done to investigate the efficacy of supportive therapy in the treatment of breast and uterine cancer, as well as its capacity to ease patients' distress. Furthermore, this oil is becoming more and more well-liked as a treatment choice for infections, cancer, diabetes, and microorganisms (Amorati et al., 2017).

Fig. 3: *P. graveolens* L' Herit.

Lemon

Lemon, scientifically known as *Citrus limon* Linn. (*C. limon*), is a member of the Rutaceae family (Figure 4). Citrus limon is a tall, arboreal shrub that can reach a maximum height of 15 feet. The plant consistently yields lemon fruits with a delightful fragrance all year round. The oil consists of a substantial quantity of terpenes, notably D-limonene and L-limonene, which collectively make up approximately 90 percent of the oil's content. In addition, Lu et al. (2013) found evidence of phellandrene, pinene, and sesquiterpene.

The remaining 10 percent of the oil consists of a valuable fraction, primarily composed of oxygenated chemicals, with a notable presence of the aldehyde citral. This component is predominantly responsible for the fragrance of the oil, comprising around 3.5%–5% of the oil's overall scent. This specific essential oil has components that include antibacterial, astringent, and detoxifying properties. These properties are advantageous for treating blemishes commonly linked to oily skin (Saranraj and Devi, 2017). Citric acid, which aids in digestion by encouraging the production of potassium, calcium Carbonates and bicarbonates, is also used to avoid acidity and ulcers. In a recent study, the effectiveness of citrus oil in reducing pain during the first stages of labor was established through a double-blind, randomized, controlled clinical experiment. It effectively manages nausea and vomiting, and also improves mood (Reichling et al., 2009).

Peppermint

Peppermint, scientifically referred to as *Mentha piperita* Linn. (M. piperita), belongs to the Lamiaceae family (Figure 5). Presently, a total of 600 distinct varieties of mints have been cultivated from 25 precisely delineated species. According to Do et al. (2015), *M. piperita* and *Mentha spicata* are the two most notable types. Spearmint possesses a prominent aroma that is defined by its pleasant sweetness, complemented by a noticeable hint of menthol. The primary constituents of its oil composition comprise limonene, menthol, carvacrol, carvone, menthone and methyl acetate, Menthol, the primary constituent of peppermint oil, is accountable for the pharmacological effects. Peppermint oil has a minimum concentration of 44% of menthol that is not bound to other compounds. The impact of temperature, latitude, and plant age on the sensitivity of components is apparent. The act of breathing in and topically applying menthol to the skin triggers a reaction in the skin (Vigan, 2010). The actions described encompass anti-inflammatory, antiseptic, analgesic, antibacterial, antispasmodic, anti-infectious, digestive, carminative, astringent, fungicidal effects, vasoconstrictor, nerve stimulant and decongestant properties.

Fig. 4: *C. limon* Linn. (© Organic Edible Garden 2024 [Non-Commercial and Educational purpose only])

Fig. 5: *M. piperita* Linn. (© 2023 HealthJade.net. [Non-Commercial and Educational purpose only])

Roman Chamomile

Roman chamomile, or *Anthemis nobilis* Linn., is a member of the Asteraceae family (Figure 6). The plant, which has daisy-like blossoms on it, has been highly valued for generations for its ability to elevate, soothe, and balance emotions. Esters from tiglic acid, angelic acid, and 2-methylbutanoic acid make up the majority of the ingredients in Roman chamomile oil (Vimalanathan and Hudson, 2014). The presence of the sesquiterpenoid chamazulene imparts a blue colour to the newly extracted oil. Chamomile-infused products are widely acknowledged for their efficacy in addressing a range of human health conditions, including hay fever, inflammation, menstrual problems, muscular spasms, sleeplessness, ulcers, digestive disorders, wounds, haemorrhoids, and arthritis. The material's anxiolytic characteristics are utilised in the fields of aromatherapy and cosmetics (Reichling, 2022).

Tea Tree

The tea tree, formally referred to as *Melaleuca alternifolia* Cheel, is a plant classified under the Myrtaceae family. It is typically found in wet or marshy regions. It is distinguished by its yellow or purple flowers and needle-shaped leaves. The cultivation of this crop on plantations is motivated by its substantial economic worth. Terpinen-4-ol, an alcoholic terpene, is the main constituent of its oil and has a unique musty aroma. Alpha-sabine exhibits antiviral activity due to its antifungal and antibacterial characteristics. Terpinen-4-ol improves the functioning of the immune system, whereas cineole helps its ability to fight against bacteria (Allahverdiyev et al., 2004).

Ylang Ylang

The scientific name for the plant species is *Cananga odorata*. Hook. F. and Thoms is the name given to the little Annonaceae tree, ylang-ylang. Its natural habitats are in Madagascar, the Philippines, and Indonesia (Figure 9). There are a lot of substances in this combination. Beta-caryophyllene, Benzyl acetate, linalol, geraniol, methyl chavicol, eugenol, pinene, farnesen and farnesol are some of these chemicals. Women who have postmenopause syndrome and low self-esteem fare better. According to Schnitzler et al. (2001), this plant greatly raised self-esteem.

Fig. 6*:* *Anthemis nobilis* Linn. (By H. Zell - Own work, CC BY-SA 3.0)

Fig. 7: *Melaleuca alternifolia* Cheel. (This figure is reproduced from Neelakantan et al. (2011), which allows unrestricted use and reproduction)

Essential Oil Safety Issue

It is generally accepted that essential oils are safe to use, and there are very few instances in which they have adverse consequences. It has been determined by the Food and Drug Administration of the United States that a number of these compounds have been granted approval to be used as food additives and are categorized as being generally considered to be safe (Kong et al., 2022). When exposed to oils that contain aldehydes and phenols, the most detrimental effects include irritation and sensitization of the skin, mucous membranes, and eyes. This is especially true when the chemicals are present in oils. Documentation has also been gathered regarding the prevalence of phototoxicity in essential oils that include furocoumarins, such as those found in citrus bergamia. Contact sensitization is a process that is more likely to occur as a consequence of the oxidation of monoterpenes, which is frequently attributed to storage conditions that are not sufficient.

Pharmacological Actions of Essential Oils

A study including a vast number of essential oils looked into the possible pharmacological effects of a wide variety of essential oils. Table 2, available here, provides an overview of the most significant pharmacological effects of essential oils.

A few of the pharmacological effects of essential oils on the body will be discussed in the paragraphs that follow.

Antibacterial

To determine the antibacterial efficiency of several essential oils against Gram-positive and Gram-negative bacteria, as well as the possible antifungal effects of these oils, a complete study was carried out. Previous investigations have resulted the antibacterial characteristics of these essential oils, and the outcomes have demonstrated that they are highly effective against oral infections caused by salmonella, staphylococcus and other infectious agents. Basil essential oil is a good example of this type of oil because it has been demonstrated to possess substantial antibacterial capabilities. It has the capacity to eliminate microorganisms classified as Hydrophila, Aeromonas, and Pseudomonas fluorescens. The antibacterial effects examination yielded promising results, showcasing the drug's potential efficacy against these microorganisms (Garozzo et al. 2009. The antibacterial properties of manuka oil were shown to be superior to those of rosmarinus oil, tea tree oil, and eucalyptus oil (Baschieri et al. 2017). According to research, a total of 161 oral bacteria isolates belonging to 15 different genera demonstrated sensitivity to *Melaleuca alternifolia* (tea tree) oil, indicating that this material has the potential to be used as a healthcare agent to boost oral hygiene (Kallel et al., 2019).

Fig. 8: *Cananga odorata* (© molfoto under a Creative Commons Attribution-Non-commercial License [CC BY-NC]).

Antifungal

The in vitro antifungal activity of *Melaleuca alternifolia* (tea tree) oil is of great importance. Many of the ingredients found in tea tree oil have been found to have a variety of antifungal effects, particularly against filamentous fungi and dermatophytes (Garozzo et al., 2011). One of the findings showed that the sprouted spores of Aspergillus niger were more susceptible to non-sprouted spores. Various plant species, such as *M. piperita*, *Brassica nigra* (black mustard), *Cymbopogon nardus*, *Angelica archangelica*, *Skimmia laureola*, *Cuminum cyminum*, and *Artemisia sieberi* have undergone testing and demonstrated positive outcomes regarding their ability to combat fungal infections. If the results are consistent with the expected results, it could be a suitable alternative to currently used antifungal drugs that are not commonly used because of their harmful effects on the body (Balusamy et al., 2018).

Anti-inflammatory

Administering tea tree oil led to a decrease in histamine reactivity in both weal and flare responses in human participants. Within ten minutes, topical use of 100% tea tree oil may successfully lessen histamine diphosphate-induced irritation. Prior studies have demonstrated that certain essential oils, when administered at noncytotoxic dosages, can effectively reduce inflammation by promoting the synthesis of interleukin-10.

Anti-tumor

The proliferation of M14 adriamicin-resistant cells and WT cells with human melanoma was observed to be inhibited by both tea tree oil and terpinene-4-ol. In melanoma cells, the observed impact was associated with apoptosis via a caspase-dependent mechanism. The efficacy of 5-fluorouracil therapy in human colon cancer cells is enhanced when the plant-based essential oil geraniol is believed to have a function. Interesting evidence has been found by polypharmacology researchers to support the potential anti-tumor effects of cardamom essential oils (Jaeger and Cuny, 2016).

Antioxidant

In lab settings, *Nigella sativa* L. seeds yield an essential oil with potent antioxidant qualities that efficiently scavenges hydroxyl radicals. The antibacterial and antioxidant properties of the plants known as Manuka (*Leptospermum scoparium*), Kanuka (*Kunzea ericoides*), and *Leptospermum petersonii* are noteworthy. By changing the parameters of superoxide dismutase and increasing the amounts of vitamin E and C, the essential oil derived from M. armillaria has shown its antioxidant ability (Haddad et al., 2019).

Table 2: Essential oils for common problems

Essential oils for common problems	
Condition	Essential oils
Anxiety, agitation, stress, challenging behaviors	Angelica archangelica rad. (angelica) (nervous), Cistus ladaniferus (labdanum) (chronic), Citrus aurantium var. amara (neroli bigarade), Citrus paradisi (grapefruit) (exhaustion), Coriandrum sativum (coriander) (including mental), Cymbopogon nardus (citronella), Eucalyptus radiata (black peppermint), (chronic), Eucalyptus smithii (gully gum), Juniperus communis ram. (juniper twig), Mentha spicata (spearmint) (mental), Pelargonium graveolens (geranium), (nervous), Pinus sylvestris (Scots pine), Rosmarinus officinalis ct. cineole, ct., camphor, ct. verbenone (rosemary), Salvia sclarea (clary) (nervous), Zingiber officinale (ginger)
	Lavandula angustifolia (lavender), Santalum album (sandalwood), Boswellia carteri (frankincense)
End-of-life agitation	Angelica archangelica rad. (angelica) (nervous), Cistus ladaniferus (labdanum) (chronic), Citrus aurantium var. amara (neroli bigarade), Citrus paradisi (grapefruit) (exhaustion), Coriandrum sativum (coriander) (including mental), Cymbopogon nardus (citronella), Eucalyptus radiata (black peppermint) (chronic), Eucalyptus smithii (gully gum), Juniperus communis ram. (juniper twig), Mentha spicata (spearmint) (mental), Pelargonium graveolens (geranium) (nervous), Pinus sylvestris (Scots pine), Rosmarinus officinalis ct. cineole, ct. camphor, ct. verbenone (rosemary), Salvia sclarea (clary) (nervous), Zingiber officinale (ginger)
Fatigue	Angelica archangelica rad. (angelica), Cananga odorata (ylang ylang), Chamaemelum nobile (Roman chamomile), Citrus aurantium var. amara (nerolibigarade),Cistus ladaniferus (labdanum), Citrus bergamia (bergamot), C. Limon (lemon), Citrus reticulata (mandarin), Citrus sinensis (sweet orange), Cuminum cyminum (cumin), Juniperus communis fruct. (juniper berry), Lavandula angustifolia (lavender), Litsea cubeba (may chang), Melissa officinalis (lemon balm), Myrtus communis (myrtle), Ocimum basilicum (basil) (nervous), Origanum majorana (sweet marjoram), Ravensara aromatica (ravensara), Thymus vulgaris ct. geraniol, ct. linalool (sweet thyme), Valeriana officinalis (valerian)
Insomnia	M. piperita (peppermint), Ocimum basilicum (basil), Helichrysum angustifolium (everlasting)
Mental exhaustion, burnout	Litsea cubeba (may chang), M. piperita (peppermint), Rosmarinus officinalis ct. cineole (rosemary)
Memory loss	
Pain management	Eucalyptus smithii (gully gum), Lavandula angustifolia (lavender), Matricaria recutita (German chamomile), Leptospermum scoparium (manuka), Origanum majorana (sweet marjoram), Pinus mugo var. pumilio (dwarf pine), Rosmarinus officinalis ct. camphor (rosemary), Zingiber officinale (ginger)

Insect/mosquito Repellent Action

The essential oils derived from *Nepeta parnassica* have demonstrated promising outcomes in terms of repelling insects and exhibiting toxicity against Culex pipiens molestus (Kalemba and Kunicka, 2003).

Hormonal Analysis and Aromatherapy

Geranial, neral, geraniol, nerol, and trans-anethole have all been shown to increase the estrogenic response, whilst eugenol has been shown to have anti-estrogenic properties. In recombinant yeast cells, Gómez et al. (2013) showed how well geraniol, nerol, and eugenol worked together to remove [3H]17b-estradiol from estrogen receptors.

Conclusion

From the previously described findings and studies, it can be deduced that aromatherapy is a natural and noninvasive intervention that provides benefits to human beings. Utilizing fragrance not only alleviates the symptoms of illness but also rejuvenates the entire body. Aromatherapy has a vital role in enhancing physical, spiritual, and psychological well-being during the transitional phase of life. That investigation assesses the efficacy of eco-friendly, alternative, and natural medicine in treating diseases caused by microbes and metabolic processes.

These essential oils have the potential to enhance the speed at which medications take effect and their ability to be absorbed by the body.

After thorough examination, it can be concluded that these volatile oils can have a synergistic impact that augments the efficacy of pharmaceutical medications used to treat disorders of the central nervous system. If safety and quality factors are properly taken into account, essential oils can be a useful alternative to medicine or used in conjunction with traditional treatment for some medical issues. When properly researched and used, this treatment has the potential to greatly improve the health of those receiving it as well as the public.

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Chapter 04

The Healing Power of Aromatherapy: Essential Oils in Medical Sciences

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ABSTRACT

Essential oils are known for their varied therapeutic properties and are concentrated extracts that are increasingly popular as complementary medicine. Furthermore, Egypt, China, and India which are the early civilizations utilized aromatherapy thousands of years ago, and the term itself was devised in the 20th span. The essential oils' work is observed through modern research investigation whether inhaled or applied topically and affects the nervous and immune systems by influencing mood and physiological processes. These oils are complex mixtures primarily composed of terpenes and phenolics and demonstrate antibacterial, antifungal, and antioxidant properties by addressing conditions like anxiety and pain. The increase in chronic illnesses grows their interest in further research essential to standardize quality by understanding their interactions with medications and exploring innovative delivery methods like nanotechnology. Overall, aromatherapy provides the potential to enhance human health and well-being because it emerges as a promising field blending historical wisdom with contemporary scientific exploration. The chapter showcases the wide history, diverse applications and promising future of aromatherapy through an ancient practice utilizing plant- derived essential oils for therapeutic benefits.

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INTRODUCTION

Aromatherapy is derivative of "aroma" meaning fragrance or smell, and "therapy" meaning treatment. This practice is natural healing and focuses on the mind, body, and soul (Halder et al., 2018). Early civilizations including Egypt, China, and India used aromatherapy as a complementary and alternative treatment for over 6,000 years. Nowadays, it is modified for treating various conditions and achieved significant popularity in the late 20th century. In the 21st century, meaning recognition is an aroma science therapy. Aromatherapy contains essential oils as its central are extremely focused constituents extracted from plant parts like flowers, leaves, stalks, fruits, and roots (Pan et al., 2014). They incorporate a mix of saturated and unsaturated hydrocarbons, alcohols, aldehydes, esters, ethers, ketones, oxides, phenols, and terpenes that offer distinctive odors. Essential oils contain no color, pleasant-smelling liquids with high refractive indicate valued for their various uses like therapeutic, cosmetic, aromatic, and fragrant (Malabadi et al., 2021). Essential oils are applied to pressure points for rejuvenation due to their potency. Furthermore, various plant structures store these oils like pockets, reservoirs, glandular hairs, specialized cells, or intercellular spaces. These essences protect plants through evaporation from bacterial attacks and temperature fluctuations (Bayantassova et al., 2022). These are administered through inhalation, massage, or simple skin application. The primary use of aromatherapy is to restore mental and physical balance, relieve stress, and rejuvenate individuals (Hedaoo and Chandurkar, 2019). A sense of well-being of the body is promoted due to the organic nature of aromatherapy and its combined effects. Many studies demonstrated that inhalation of herb essential oil is significantly used in phytotherapy to combat exhaustion and enhance the mice's locomotor activity. Recently, aromatherapy has had essential growth in holistic medicine. Many studies on the emotions and brains of humans explore its effects (Sivaphongthongchai, 2021).

Aromatherapy is mostly used other than human-made and typically contains triggers such as solvents and power sources that can irritate. A debate on the topic always remained that synthetic fragrances lack the natural vitality of essential oils among odor psychologists and biochemists. Essential oils have been important for centuries due to their fragrance (Franco et al., 2017). These potent organic plant chemicals aid in eliminating disease-causing bacteria, viruses, and fungi and purify the environment. Furthermore, their properties like antibacterial, antiviral, and anti-inflammatory effects as well as boosting the immune system and benefiting hormonal, glandular, emotional, and circulatory functions. Moreover, many scientists documented that these also enhance memory and alertness. In addition, their effects on diseases and disorders on humans have been explored by conducting many projects and studies. These oils also maintain their potency over time and age enabling them unique their stimulating properties are due to their structural resemblance to actual hormones, and their ability to penetrate subcutaneous tissues is a key feature of therapy (Ali et al., 2015).

Aromatherapy is gaining importance as a growing complementary therapy globally. The National Institutes of Health National Center for Complementary and Integrative Health suggested that the United States spend over $30.2 billion annually on this therapy and estimated that the global market is projected to reach $5 trillion by 2050 (Farrar, 2020). Integrative medicine is another term used for aromatherapy and is particularly important for frontline nurses to understand the complex and subtle effects of alternative and integrative therapy. Furthermore, nursing healthcare aromatherapy forces into the group of mind-body therapy. Essential oils play a role in complementing therapeutic interventions and reducing anxiety in nursing health care. In contrast, assessing anxiety levels before and after interventions can help to measure the application effects of plant-based essential oils (Bunse et al., 2022).

Worldwide Historical Evolution of Aromatherapy

For thousands of years, aromatherapy has been practiced in various fields. Hippocrates who promoted aromatherapy usage, believed that aromatic baths and scented massages were essential for good health and he was known as the father of medicine (Agnihotry et al., 2024). However, in the current era, there's a growing inclination towards consuming food items as perceived as natural and minimally processed. These qualities can affect the food choice of food consumers due to their association with health. Subsequently, the World Health Organization examined approximately 600 million cases of foodborne illnesses and 420,000 related deaths occur globally each year in the 2015 report (Lee and Yoon, 2021). Moreover, food spoilage is a metabolic process that alters sensory characteristics and renders food undesirable or unacceptable for consumption despite being potentially safe. Fruits and vegetables globally post harvesting can reach losses of more than 30 to 40% which can emphasize the need to reduce such losses to ensure food security for all (Alegbeleye et al., 2022).

In modern times, the prompting efforts to secure and safeguard food through food safety is a paramount concern thereby ensuring the availability of fresh and healthy produce. Food preservatives are used by food manufacturers to extend shelf life, without concerns about the health implications of consuming food additives like synthetic preservatives. Plant extraction is used to isolate specific plant components and is gaining attention for its potential as a source of natural antimicrobials (Rudra et al., 2020). Furthermore, the basic utilization purpose of essential oils in medical science across different cultures for millennia is that are highly concentrated hydrophobic liquids containing volatile compounds from plants. The essential oils are obtained from fruit peels by various extraction methods like steam distillation and hydro distillation that can exhibit antibacterial and antiviral properties and can be explored as potential alternatives to chemical preservatives for food preservation (Bhavaniramya et al., 2019).

Historical Background

In the late 20th century, the exploration of aromochology originated and was spearheaded by Japanese scientist Shizuo Torii who delved into the relationship between aroma and emotions. The research of Torri suggested the relaxation-enhancing properties of lavender and chamomile fragrances. The Institute secured the term "aromachology" in 1982 by the sense. Aromas contain a unique ability through our physical, mental, and emotional well-being are influenced by a practice dating back over 3500 years to ancient Egyptian rituals (Thangaleela et al., 2022). In our modern lifestyles, a quest for improved holistic health was reflected through the resurgence of aroma usage. Aromachology determines the internal connection between aroma and psychology and the study of how scents affect the brain. Moreover, it determines the induced subtle neurological and behavioral shifts (Bercik et al., 2021).

Aromatherapy is an ancient concept practiced by civilizations such as the Chinese, Egyptians, and Romans that gained recognition in the 1920s through incense, baths, and embalming when French chemist Rene-Maurice Gattefosse coined the term (Sowndhararajan et al., 2016). The secondary metabolites of aromatic plants are the essential oils that comprise complex mixtures of volatile organic compounds (VOCs) and plants store these oils in various structures including in reservoirs, glandular hairs, and special cells that protect against pathogens and environmental fluctuations. A range of EOs encompasses chemical groups extracted from different plant parts through methods, steam distillation, solvent extraction, and advanced techniques (Machado et al., 2022). The therapeutic effects enable them for extensive investigation that serve as additives in the food industry and air quality enhancers. Phytoncides are volatile organic substances derived from plants that contain antimicrobial properties used to enhance immune functions. The oldest forms of natural herbal remedies are represented as Oils with roots tracing back to ancient civilizations (Franco et al., 2017).

History explores that various medicinal substances derived from herbs, animals, and minerals have been employed to address ailments. Although, the traditional medical systems predominantly emphasized medicinal herb usage. These remedies were typically administered individually or in combinations like pills, powders, or extracts (Tiwari et al., 2018). The pharmaceutical applications of medicinal oils are extensively detailed by the historical Persian medical texts prepared from various herbs for therapeutic purposes either topically or systemically. These formulations are known as "Dohn" or "Adhaan" and are meticulously described in pharmaceutical manuscripts like the "Qarabadin," which play the role of repositories of drug compounds, formulas, and indications (Sharifi-Rad et al., 2017).

Other than their historical significance medicinal oils are often overlooked in contemporary medical research. However, their use for medicinal purposes going back to traditional Chinese and Egyptian medicine with massage therapy using herbal oils remaining prevalent in several East Asian countries. Additionally, aromatherapy help to improve immunological and physiological conditions through the usage of volatile oils (Thangaleela et al., 2022).

Mechanism of Action of Essential Oils in Aromatherapy

The method by which essential oils work comprises of their interactions with the receptor cells in the nose when they are inhaled, triggering biological signals. The olfactory bulb plays a role in transmitting these signals to the limbic system and hypothalamus. The neurotransmitters like serotonin and endorphins are released through this process by triggering the brain by linking the nervous system with other body systems to induce a desired change and provide relief. The response to calming, euphoric, and stimulating oils and others respectively can release Serotonin, endorphins, and noradrenaline to achieve specific effects on the mind and body. Moreover, several beneficial outcomes like increased neurogenesis, regulation of hormonal levels, selective stimulation of certain brain regions, and changes in blood biochemistry that affect mood and emotions are the products of essential oils (Fung et al., 2021).

These outcomes are coming due to the inhaling of volatile elements in these oils and when these are inhaled, act through two main pathways, known as olfactory stimulation and respiratory stimulation. The olfactory nerve activation predominantly works in the inhalation aromatherapy via olfactory by extending from the nose to the brain. Their structural similarity to physiological neurotransmitters and hormones can cause the therapeutic effects and similarity enables them to stimulate olfactory chemoreceptors in the nasal passage by activating olfactory signaling. However, these signaling ends in the higher cerebral cortex where olfactory sensory neurons convey electrical impulses to the brain's limbic and hypothalamic regions via the olfactory bulb and upper olfactory cortex (Sattayakhom et al., 2023).

The olfactory signaling entirely bypass through some highly volatile molecules that directly entering the brain and regulate neuronal pathways upon inhalation. These pathways have a surge result of neurotransmitters and neuromodulators that produce a sense of calmness and alleviate anxiety and depression symptoms. Beyond olfactory stimulation, the essential oils alter the brain function through alveolar absorption and this process allows essential oil molecules to enter the blood circulation and interact with specific brain regions. In the respiratory system, the gaseous exchange controls the diffusion of essential oils to enter the systemic circulation and the brain. Lipophilic essential oil molecules activate specific central nervous system regions and can cross the BBB. These also inducing positive psychological and physiological effects that help alleviate mood disorders that is explained in figure.1.

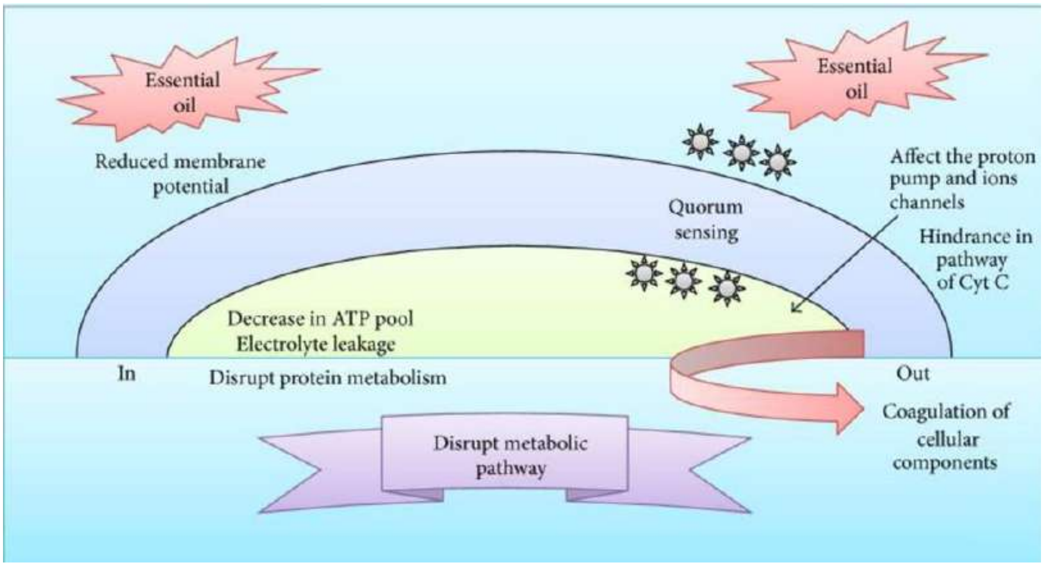

Fig. 1: Mechanism of action of essential oils (Nguyen et al., 2023)

The integumentary system is influenced by the topical application of essential oils. The rapid release of endorphins and certain pain modulators due to the topical use of Essential oils can cause analgesic effects and a sense of well-being. The skin penetration by dissolving in the skin's cell membrane lipid constituent are involved in the topical use of essential oils. The chemical composition of essential oils influenced the depth of oil penetration into the skin. For example, on the upper epidermis are limited oils such as jojoba, avocado, soybean and the oxygenated terpenes can penetrate deeper layers (de Andrade et al., 2022). Some essential oils serve as penetration enhancers in internally and topically by enhancing drug partitioning, disintegrating highly ordered intercellular lipid structures, and inducing conformational changes in intercellular protein domains (Herman and Herman, 2015).

The delivery to the brain of essential oils from different routes is determined by the molecular size of these molecules. Moreover, the smaller formulations can increase the inhalation rate and delivery success. However, the proper brain penetration may also hinder by the non-uniform size of these molecules. The absorption of essential oils by utilizing the encapsulated nanoparticles in the nanotechnology presenting a promising therapeutic future (Rai et al., 2017). The impact of essential oils on the central nervous system also induced the emotional response changes and some molecules can pass through sensory neuron cells or the olfactory mucosa. The respiratory system play role in exchange of gases and to allow the essential oils to diffuse into the bloodstream and circulate in whole the body. The given medium is used for therapeutic interventions in respiratory diseases and mood disorders and to utilize olfactory interventions (Horvath and Acs, 2015). The essential oils can affect the brain by three major mechanisms, the first involves activating nasal olfactory chemoreceptors and the related impact of olfactory signals on the brain with the olfactory system directly linked to the brain's limbic regions by affecting mood. Moreover, the second mechanism involves in which the olfactory nerve influences the cellular and molecular events due to the penetration of essential oils. The third mechanism involves in essential oils absorption into the blood circulation crossing the BBB to interact with brain regions (Cui et al., 2022).

The volatile mixture of compounds is present in the majority of aromatic plants that can be extracted to form essential oils and these plants typically produce various secondary metabolites such as terpenoids, alcohols like geraniol and menthol, acids such as benzoic and cinnamic acids, aldehydes are citral and benzaldehyde, ketones are thymol and eugenol, and phenols are ascaridole and anethole. The composition of essential oils is significantly influenced by Terpenes, terpenoids, and aromatic (Koul et al., 2008). The mevalonic acid and shikimic acid pathways play a role in synthesizing the Terpenoids and aromatic polyterpenoids. Terpenoids are a vast category of secondary compounds found in aromatic and medicinal plants which play a crucial role in providing resistance against pathogens. Furthermore, monoterpenoids contain antimicrobial properties that disrupt the growth and development of microorganisms and interfere with their physiological and biochemical processes. Several botanical constituents are azadirachtin, carvone, menthol, ascaridol, methyl eugenol, toosendanin, and volkensin which have demonstrated potential in combating bacterial, fungal pathogens and insect pests (Pandey et al., 2017).

Chemical Composition and Properties of Essential Oils

As discussed above Essential oils give the complex combination of volatile compounds that are plant derivatives and primarily composed of terpenoids and phenolic compounds. The specialized cells can synthesize these aromatic constituent types found throughout various plants such as leaves, flowers, and roots, and may depend on the plant species. Furthermore, these parts like glandular trichomes, adduct cavities, and osmophores can offer sites for the biosynthesis and accumulation of these compounds. Plants contain the ability to extract to produce these aromatic compounds which are obtain essential oils, and are referred to as aromatic plants. Aromatic plants are distributed widely across the plant kingdom but are not restricted to a particular group. Moreover, it's noticed that the composition of essential oils differs from one plant taxonomic group to another (Fokou et al., 2020). Additionally, essential oils' chemical composition can vary due to factors such as abiotic and biotic effects, postharvest treatments, extraction methods, and storage conditions within the same species. The synthesis of secondary metabolites in plants affected by Abiotic factors contains all nonliving components and the factors are soil characteristics like hydrology, pH, and salinity, as well as overall climatic conditions with particular emphasis on the microclimate surrounding the plant (Duarte et al., 2017).

On the other side, the biotic factors involve living organisms that influence plant metabolite production and this segment contains the soil organisms, microorganisms, and inherent plant characteristics. The secondary metabolites of essential oils play many roles like defending against plant invaders, interacting with symbiotic organisms, and attracting pollinating insects, among others. Postharvest treatments are conducted between the plant collection and essential oil extraction. However, the drying plant materials before extraction has been observed to significantly increase extraction yields and it may also trigger biochemical reactions among secondary metabolites by leading to changes in the chemical composition of the resulting essential oil compared to its original state in the plant (Taghavi et al., 2018).

Conservation method can encompass the processes from extraction to chemical analysis and can influence the nature of essential oils. Essential oils are achieving importance due to their diverse biological properties that are impacting humans, animals, plants, insects, and microorganisms. In human applications the essential oils find use in nutrition as preservatives or flavorings and in cosmetics as fragrances, and in pharmacology as active ingredients. Their pharmacological properties influenced the both transmissible and non-transmissible diseases (Roca-Saavedra et al., 2018).

Therapeutic Properties

The World Oral Health Report suggested that although oral health has improved significantly in many countries the challenges persist especially among disadvantaged populations in developed and developing nations. The major global oral health concerns were identified as periodontal and dental caries diseases which also have adverse effects on overall health, quality of life, and work capacity (Anushri et al., 2019). However, the antibacterial agents used to treat oral health issues with various side effects like diarrhea and vomiting and there is growing concern over bacterial resistance to these drugs. Moreover, the mentioned adverse effects are increasing resistance and high costs of standard therapeutic approaches and the need to explore alternative therapeutic agents and further investigate traditional medicines derived from various plant sources (Aware et al., 2022).

Table 1: Historical evolution of essential oils

Country	Cultural therapy of essential oils	References
Egyptian culture	Resins, Balms and fragrant oils Papyrus Ebers wrote a famous manuscript about Aromatic Medicines around 2800 BC and proved essential oils therapeutic properties.	(Agnihotry et al., 2024)
France	Shirley price authored Aromatherapy for Health care professionals, known for clinical use of essential oils for surgery and spa treatment.	(Cartwright and Armstrong, 2020)
German	In 1919, Gattefossé, a famous chemist, was burned in an explosion in his laboratory. The wounds became infected. Wound rinsing with essential oils eradicated the infection. He coined the term, aromatherapy, and was known for the medical use of essential oils with their antibacterial and healing properties of essential oils. Jean Valnet, an army physician, wrote the first aromatherapy book by a doctor.	(Scuteri et al., 2022)

Table 2: Nursing theoretic frameworks for health care aromatherapy

Theorist Name	Application to Clinical Practice	References
1. Florence Nightingale Environmental	Cleanliness, rest, and relaxation properties	(Ahmad et al., 2020)
2. Myra Estrin Levine Holistic	Transformation process preventing stress	(Thakral et al., 2019)
3. Hildegard Peplau Interpersonal relations	Supports interpersonal relations; promotes personal growth	(Zhang and Shuai, 2021)
4. Martha Rogers Unitary human beings and their environment are one	Interrelationship between people and plants	(Harris, 2021)
5. Sister Callista Roy Adaptation	Assist coping and adaptation	(Gavrilescu, 2023)
6. Wanda de Aguilar Horta Basic human needs	Restore balance, thereby decreasing depression and stress	(Choudaj and Wankhade, 2023)

Many traditional remedies are analyzed for infections by conducting clinical trials to assess their efficacy and potential side effects. Among all these natural remedies, essential oils (EOs) have been a surge of interest for many years (Aljaafari et al., 2021). Approximately 3000 EOs are currently known and have been used since ancient times to treat a range of medical and dental issues. These secondary metabolites possess antibacterial, antifungal, and antioxidant properties. The systematic literature purpose is to analyze various Eos therapeutic properties (Freires et al., 2015).

Clinical Applications

In the past, there has been a growing demand for phytotherapy with alternative medicine. Phytotherapy is a practice shown by both healthcare professionals and practitioners of traditional medicine that refers to using herbs and herbal preparations (like infusions, decoctions, and tinctures) along with phytochemicals for medicinal purposes. The scientific importance of phytotherapy evaluated through extensive clinical and experimental studies has validated the effectiveness of herbal remedies (Khan and Ahmad, 2019).

Phytotherapy contains many subsets and one of them is aromatherapy. The bindings essential oils produced by plants are secondary metabolites that work as a defense mechanism against challenges including diseases with environmental conditions such as high temperatures and droughts. Humans are using essential oils due to their advantageous biological properties in various aspects like medicine, cosmetics, and the food industry other than their botanical origin. These are also used due to their primary impact on mental and physical well-being (Lawn et al., 2020)

Inhalation aromatherapy is the most prevalent method associated with aromatherapy and offers a fast, convenient, and safe means of administering essential oils. This approach contains various methods including vapor balms, nasal inhalers, lamp diffusion, room sprays, and direct inhalation through tissues or cotton balls infused with essential oils. Despite this, aromatherapy does not cure major illnesses and promotes relaxation, stress relief, mood enhancement, balance, well-being, and minor discomfort relief, and boosts the immune, respiratory, and circulatory systems. However, their common applications are stress management, pain relief, mood enhancement, and relaxation. Moreover, aromatherapy differs from herbal medicine in practice. The essential oils are commonly used by researchers like botanists and they prefer whole plant applications for human benefits. Traditionally, aromatherapy is used for holistic mental health and the care of mind and body (Vora et al., 2024)

Essential Oils for Public Health Therapy

In developed countries, an increase in diseases occurrence by modern lifestyles that are largely attributed to poor dietary habits and inadequate physical activity. Since 2014, the USA witnessed a decline in life expectancy through prevalent measures such as hypertension, heart diseases, diabetes mellitus chronic liver diseases, and obesity (Raleigh, 2019). These increases in the disorders related to lifestyle have propelled a growing preference for natural remedies among consumers and patients and are driven by perceived lower side effects compared to synthetic alternatives. Notably, these were used historically in the middle Ages due to their diverse biological activities and are comprised of volatile mixtures primary terpenes, and aromatic structures and such oils are synthesized in different ways from plants. Moreover, Eos are extracted through steam distillation or cold pressing and were originally produced by plants for protective benefits. Well-known effects include antimicrobial, antiseptic, analgesic, anti-inflammatory, spasmolytic, and sedative impact through which EOs have garnered increasing global interest in herbal medicine (Elshafie et al., 2017).

In developing nations, almost 80% of individuals rely on traditional herbal medicine and there is a rising trend in industrialized countries as well. Many prominent health concerns like depression, obesity, diabetes, and allergic disorders are addressed by EOs reflecting their therapeutic potential against a spectrum of modern public health issues. The increasing prevalence of lifestyle illnesses underscores the Immediacy for effective therapeutic interventions. More than 264 million individuals were affected by depression globally in 2017, which poses a significant burden on public health systems (Moitra et al., 2022). Similarly, obesity affected 600 million individuals in 2015 and contributes to various secondary illnesses such as diabetes and cardiovascular diseases. Furthermore, about 20% population is affected by allergies of the global population which presents additional challenges (Yeshi and Wangchuk, 2022).

Future Directions and Research

In the past, a remarkable interest was experienced in essential oils research that provided crucial results for new inventions and advancements the resurgence of interest in aromatherapy has been increased over the past few decades and can make it one of the most commonly used complementary medicines. The increase in cultivation of aromatic plants has been noted by the International Federation of Essential Oils and Aroma Trades (IFEAT) with lavender emerging as the most widely purchased raw material for essential oil (EO) extraction. EO are complex mixtures of volatile chemical components and are obtained by many extraction techniques including distillation or cold pressure that avoids the use of chemical solvents. In the early 1900s, the French chemist Gattefosse discovered the accidental discovery of lavenders by calming effects. Lavender aromatherapy has gained popularity as an alternative or complementary use from antiemetic to pain relief and more recently sedative and cognitive effects (Makeri and Salihu, 2023).

The physician Jean Valnet was inspired by the Gattefosse works and enabled to pioneer of plant-based medicine. In contrast, he initially used lavender EO to soothe the wounds of veterans in Indochina in 1948 and later to manage agitation in psychiatric patients (El-Sagheer, 2020). Recently, the globally, ethnopharmacological studies are highlighted lavender EO's efficacy in treating stress, anxiety, and depression globally. The lavender's anxiolytic effects through linked to cognitive enhancement from a cognitive perspective which is observed with certain anesthetic drugs. Many illnesses are treated and managed by aromatherapy efficacy and often when pharmacological interventions fall short. Furthermore, the discovery of the antiseptic and skin-penetrating properties of essential oils are followed by their inception that are highly concentrated plant extracted from leaves, fruit peels, and flowers. Essential oils contain therapeutic properties when inhaled or applied to the skin and are broadly classified based on aroma families such as citrus, herbaceous, floral, minty, camphoraceous, spicy, musky, and woody (Jaruzel et al., 2019).

In the available literature definition of precise mode of action is very poor. Therefore, a systematic review is needed to evaluate whether different lavender EO compositions, a systematic review is needed that can be explored to affect core cognitive functions and to consider EO phytochemical parameters and administration methods (Zhong et al., 2019).

Conclusion

In conclusion, aromatherapy is a general practice that marks the mind, body, and soul through the use of essential oils. This practice has its earliest roots in civilizations like Egypt, China, and India. In the current era, aromatherapy has evolved and is gaining significant popularity. Furthermore, is recognized as a scientific therapy involving the use of highly concentrated essential oils extracted from different plant parts. Essential oils contain distinctive odors and therapeutic properties and are applied through methods including inhalation, massage, or direct skin application to restore mental and physical balance, relieve stress, and rejuvenate individuals. Moreover, essential oils encompass biological effects like antibacterial, antiviral, anti-inflammatory, and immune-boosting properties. In contrast, inhalation aromatherapy is a fast and safe method of administering essential oils to promote relaxation, stress relief, mood enhancement, and minor discomfort relief. In the mechanism of action, the essential oils affect the brain and body through olfactory and respiratory stimulation and skin absorption. The signals are transmitted to the brain through the olfactory system and can influence neurotransmitter release and induce calming or stimulating effects. As an increasingly complementary therapy, aromatherapy is achieving importance globally furthermore, the continuous research and experimental activities underscore that use of essential oils offers numerous health benefits through making it a valuable complementary therapy in contemporary healthcare.

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Chapter 05

Aromatherapy and Jasmine Oil Inhalation in Improving Brain Activities

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ABSTRACT

Aromatherapy is the therapeutic usage of aromatic compounds for psychological well-being, most commonly essential oils. The neurological system is stimulated by the actions of jasmine oil. The research findings demonstrated that both the anterior center and the left posterior region had increased beta wave power (13–30 Hz). On one hand, jasmine oil enhances pleasant emotions like feelings of well-being, activity, freshness, and romance. On the other hand, unpleasant feelings like feeling drowsy were also significantly reduced. Jasmine oil is helpful in the treatment of severe depressive episodes and relaxes the nerves, eliciting feelings of assurance, enthusiasm, and euphoria while revitalizing and replenishing energy and enhancing memory. Jasmine oil mostly consists of β – linalool, Benzyl propionate, and Benzyl acetate. The reported properties of volatile oils include being carminative, aromatic, antidepressant, antispasmodic, astringent, antimicrobial, and stimulatory. Theta and alpha waves increased in response to the jasmine lactone odor, reflecting a calming impact. By the stimulating effect on brain activity, methyl jasmonate, and cineole, a key ingredient in jasmine oil, enhanced beta waves while suppressing theta and alpha waves, resulting in improved brain functionality. Psychoactive drugs used to treat mood disorders can have a variety of adverse effects. Research on how aromatherapy affects mood could help scientists create drugs with fewer side effects.

KEYWORDS		
Aromatherapy, Jasmine oil, Euphoria, Antidepressant, Antispasmodic, Psychoactive drugs	Received: 05-Jun-2024 Revised: 18-Jul-2024 Accepted: 21-Aug-2024	A Publication of Unique Scientific Publishers

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INTRODUCTION

Complementary and alternative medicines (CAMs) are being used by more than 80% of people worldwide, and these treatments are becoming a finer part of the US healthcare system. Over 70% of Americans have used CAMs at least once, and if used yearly CAMs can cost highly approaching $34 billion. There has been a substantial advancement in complementary medicine, in the science of complementary and alternative medicine, helping to integrate treatments that have not only held out the test of time but have also been validated (Mainardi et al., 2009).

There are numerous broad areas of complementary and alternative medicine, including alternative medical systems, manipulative therapies, physiologically based treatments, energy therapies, and mind-body therapies (Heimall and Bielory, 2004). intrinsic hazards should be taken into account when assessing the possible danger of a drug and these may include predicted and expected adverse responses (type A) and idiosyncratic reactions (type B). Despite being considered natural, CAM also carries these same risks (Studdert et al., 1998). The common notion is that because such products or services are "natural," they are safe. The idea that "naturalness" guarantees harmlessness is innocent and false. The universal availability of complementary medicines in health food stores and supermarkets, as well as the low incidence of complaints against CAM practitioners, has been referred to as proof of safety (Mills, 1996).

These, however, cannot be regarded as suitable safety measures, and the scientific literature is increasingly presenting more suitable ways. This is frequently supported by hard statistics in traditional medicine, with accurate figures indicating the proportion of patients suffering a negative event relative to those who benefit. However, healthcare professionals should have a schema for thinking about safety problems until more complementary and alternative medicine therapies and products are thoroughly evaluated (Barnes, 2003). Unfortunately, in contrast to medication, an extensive list of probable and possible side effects has been lacking regarding use of complementary and alternative medicine (Myers et al., 2004).

In addition to the previously mentioned intrinsic and extrinsic risks, there are other risks associated with using complementary and alternative medicine (CAM), such as discontinuing conventional therapies due to a lack of perceived necessity or direct interference with therapeutic actions, and not acknowledging treatment precautions due to incorrect assumptions that the products are "natural" and thus "safe" (Angell and Kassirer, 1998).

The practical application of aromatherapy dates back thousands of years. The father of modern medicine, Hippocrates, encouraged aromatherapy because he thought that scented massages and baths were beneficial for good health. Leaders in essential oils arose, endorsing aromatherapy as a valid and efficient treatment for the mind, body, and soul. Eight leading nursing theorists accept the historical development of essential oils use in medicine, clinical practice, and holistic healing. The use of clinical aromatherapy as a patient-centered, holistic strategy for balancing physical health, spiritual requirements, and well-being is reflected in their theoretical frameworks and ideas. The acceptance of aromatherapy by the eight scholars attests to its credibility as a complementary therapy in healthcare (Farrar and Farrar, 2020). Essential oils are the "volatile, organic constituents of fragrant plant matter that are extracted by steam distillation or expression." Aromatherapy is the regulated, therapeutic use of essential oils. There are no other extraction techniques that provide an essential oil. Aromatherapy transforms into a therapeutic practice when essential oils are utilized to treat certain illnesses and the results are measured. As a supplementary therapy, aromatherapy is recognized as one of the instruments of holistic nursing (Buckel, 2001).

The field of complementary and alternative medicine is seeing speedy growth in the area of aromatherapy. A possible interpretation of this term is "the therapeutic use of fragrances, or at least of ordinary volatiles, to cure, mitigate, or prevent diseases, infections, and indispositions exclusively through inhalation" (Buchbauer, 1995). Not even the most conventional physician could practice natural medicine without plants; in fact, they serve as the bridge that connects natural and conventional, the ancient and the innovative (Steflitsch and Steflitsch, 2008).

There are several reasons why essential oils should be added to the arsenal of disease-fighting weapons. They have numerous attractive features and benefits, with few adverse outcomes. They can be anti-inflammatory, antiseptic, appetite-stimulating, carminative, choleretic, circulation-stimulating, deodorizing, expectorant, granulation-stimulating, hyperaemic, insecticidal, insect repellent, and sedative. They are natural antimicrobial agents capable of acting on bacteria, viruses, and fungi, and several studies have been conducted in this area. Tropical countries have always employed a variety of spices in their meals, not just for taste, but also to kill microorganisms that thrive in hot climes. Essential oils are supposed to have antibacterial properties because of their lipid solubility and surface action (Rideal et al., 1928). The global health system is heavily burdened by neurological illnesses. According to the most recent estimates, 3 percent of the global burden of disease is caused by neurological disorders that were included in the Global Burden of Disease (GBD) Study. These disorders include Parkinson's disease, migraine, medication-overuse headache (MOH), multiple sclerosis, epilepsy, and dementias including Alzheimer's and other types. Dementia, epilepsy, migraine, and stroke are among the leading 50 causes of disability-adjusted life years (DALYs), even though this is a relatively low total proportion (Murray et al., 2012). India has had a considerably greater growth in the prevalence of mental, neurological, and drug use disorders than many other Asian nations, with a 44% increase from 1990 to 2013 (Patel et al., 2016).

Jasmine

The Persian term "Yasmin", which means "gift from God", is where the name "Jasmine" originates. The jasmine flower represents power, humility, purity, and simplicity in the language of flowers (Dhanasekaran, 2019). Damascus, in Syria, is referred to as the "City of Jasmine." Every home in Damascus was believed to have a jasmine plant before the most recent conflict broke out, and during waning moons, the streets would be filled with the aroma of blossoms (Mansour, 2015). China's mild areas and the Himalayas are the origins of jasmine. There are over 200 distinct species; the Arabian Jasmine, or *Jasminum sambac*, was the first to be given a name. Trade routes brought jasmine from Persia (modern-day Iran) to Europe, but for millennia, people in the East and West have been enthralled with these blossoms. The plant gained immense popularity due to its distinct and delightful scent (Jarrett, 2003).

There are around 200 different kinds of jasmine, and depending on the kind, they can resemble anything from an erect shrub to a sprawling vine. Jasmine plants like growing in well-drained soil and prefer full sun over partial shade. While most jasmine plants are deciduous, losing their leaves in the autumn, some can be evergreen, meaning they retain their leaves throughout the year. Jasmine can be deciduous, with leaves that fall in the fall, or evergreen, with leaves that remain green all year (Boning, 2010). Although jasmine leaves can have many different patterns, they usually feature trifoliate leaves, in which each leaf splits into three leaflets, or pinnate leaves, in which the leaves grow in opposite pairs along the stem. Jasmine has been grown for its euphoric odour for hundreds of years. It may be employed in numerous ways, from essential oil to fresh blossoms (Sharangi, 2021).

Morphological Characters

The genus Jasminum had roughly 200 species that were extensively dispersed throughout tropical and subtropical climates. They come originally from Eurasia, India, and the Mediterranean. Ancestral character state reconstruction of taxonomically important traits (leaf shapes, leaf arrangement, and blossom colour) used to differentiate genus parts demonstrating homoplasy. Our findings indicate that since the split form the las common ancestor there have been at least four reversals to the unifoliate state.

Fig. 1: Arabian Jasmine flower and foliate

Jasmine Species

More than 200 jasmine species have been identified so far. Some of the most often cultivated and discovered are mentioned in Table 1.

Table 1: Different varieties of Jasmine flowers and their characteristic features

Common Name	Scientific Name	Floral characters	Ref.
Arabian jasmine	*Jasminum sambac*	White three forked cymes flowers	(Widowati et al., 2018)
Spanish jasmine	*J. grandiflorum*	Five petalled terminal or axillary flowers	(Arun et al., 2016)
Star jasmine	*J. multiflorum*	An evergreen, twinner shrub with young branches clothed with velvety pubescence flowers seen in terminal and axillary cymes	Ganatra et al., 2013)
Rosy jasmine	*J. beesianum*	Pink to deep rose colored flowers	(Green, 1997)
Gold coast jasmine	*J. dichotomum*	Vigorous climbing woody vine, red tinted outside pure white inside flowers	(Yilangai et al., 2015)
Yellow jasmine	*J. humile*	Semi-evergreen shrub holding yellow golden flowers	(Nain et al., 2011)
Juhi jasmine	*J. auriculatum*	Star shaped flowers having many flax cymes	(Bahuguna et al., 2009)
Pink jasmine	*J. polyanthum*	Evergreen strong vine with masses of intensely fragrant long-tubed white flowers opening from pink buds	(Prakkash et al., 2019)
Wild jasmine	*J. fruticans*	Yellow corolla calyx with slender lobes	(Guitian et al., 1998)

Phytoconstituents and Essential Oils in *Jasminum* Species

Several studies investigated the phytochemical contents of several *Jasminum* species. Antioxidants, coumarins, cardiac glycosides, essential oils, phenolics, saponins, and steroids were discovered during a preliminary phytochemical screening. The isolation and characterization of chemical components such as volatile oils, jasmine, indol, iridoids, secoiridoids, volatile oils, phenolics, tannins, and flavonoids, which have been determined to be significant constituents of *Jasminum*, is noted (Tharakan, 2021).

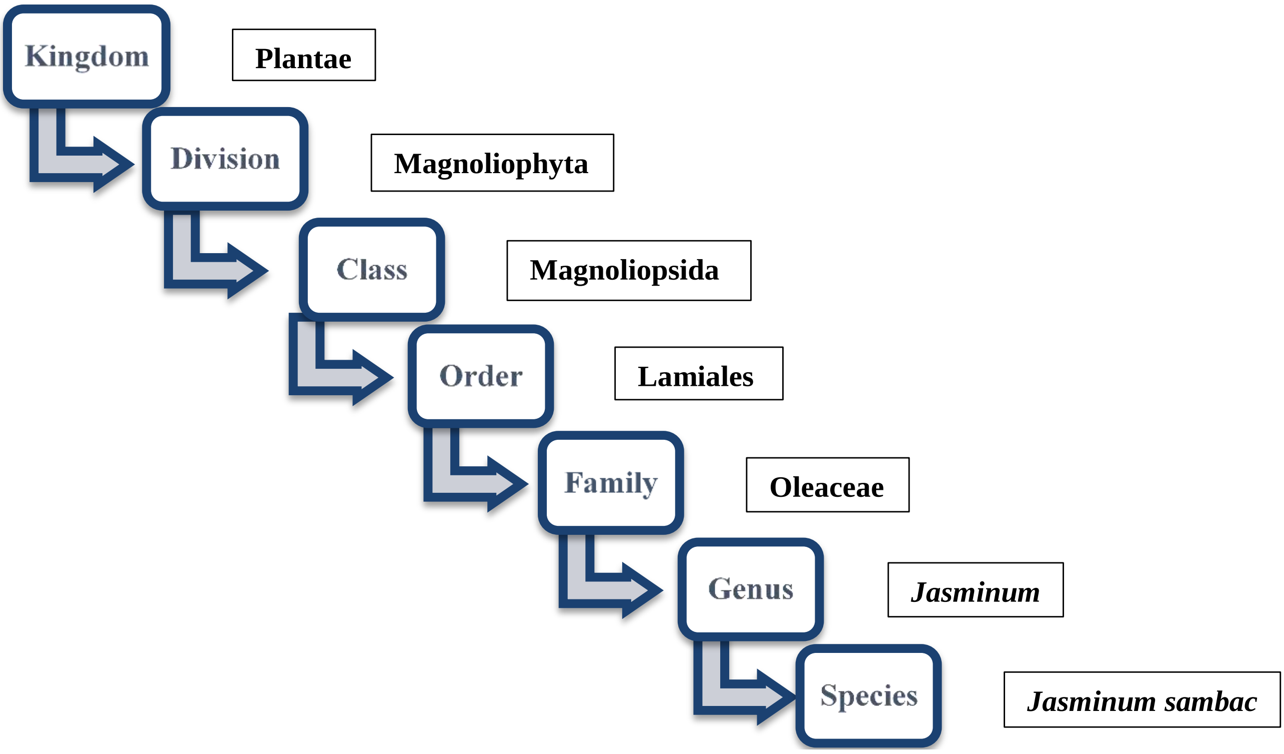

Fig. 2: Taxonomical Classification of *Jasminum sambac*

The leaves and flowers contain a high concentration of phytochemicals such as alkaloids, phenols, flavonoids, tannins, and others that can treat a variety of ailments. In this context, an experiment was carried out to determine the phytochemical components and antioxidant activity of *Jasminum multiflorum* leaves and flowers. For phytochemical screening, several solvents can be used, including methanol, ethyl acetate, ethanol, chloroform, aqueous extracts, and petroleum ether, and for antioxidant analysis methanol, ethanol, ethyl acetate, and aqueous extracts were also used. The DPPH, ABTS, and chelating potential of leaf and floral extracts were measured as part of an antioxidant experiment. The presence of alkaloids, carbohydrates, tannins, sterols and terpenoids, cardiac glycosides, flavonoids, proteins, and amino acids was indicated by phytochemical analysis of leaf and flower extracts. The quantitative determination of total phenolic, total flavonoids, and different antioxidant activities (DPPH, ABTS, and chelating potential) was carried out by the use of the colorimetric technique, and the results evaluated that total phenolic and total flavonoids were highest in the ethanol extract of leaves. The antioxidant activity was measured using the EC50 value, and the ethanol extract of leaves showed the highest decreasing percentage (Kumaresan et al., 2023).

Table 2: Phytoconstituents in various parts of *Jasminum* plant and their therapeutic effectuality

Plant Parts	Phytoconstituents	Therapeutic Effects	Ref.
Flower	Methyl jasmonate (essential oil), indole, methyl Dihydrojasmonate, isophytol, methyl palmitate, geraniol, benzyl benzoate, myrcene, alkaloids, terpenoids	Anticancerous, antileprotic, otalgia, aromatherapy	(Sandeep and Paarakh, 2009; Sharma et al., 2000)
Leaves	salicylic acid, oleanolic acid, 40-dihydroxyacetophenone, resin, isoquercitrin, oleacein, 3,4-dihydroxy benzoic acid	Anti-inflammatory, antiulcerative, antimicrobial, antioxidant	(Rastogi and Mehrotra, 1990; Arun et al., 2016)
Seed	phenyl propanoid glycoside, Iridoid glucosides	Antileishmanial, Immunomodulatory	(Tuntiwachwuttikul et al., 2003; Banerjee et al., 2007)
Bark	Alkaloids, secoiridoid glucosides	Anti-microbial	(Singh and Vyas, 2018; Solanki et al., 2021)
Stem	Loganin, sesquiterpenoids, phenylethanoids	Analgesic, anti-inflammatory	(Lyubetska,2002; Gupta and Chaphalkar, 2015)
Root	Triterpenes, saponins, flavonoids	Astringent, antiseptic, suppurative, thermogenic	(Tadiwos et al., 2017; Singh and Sharma, 2020)

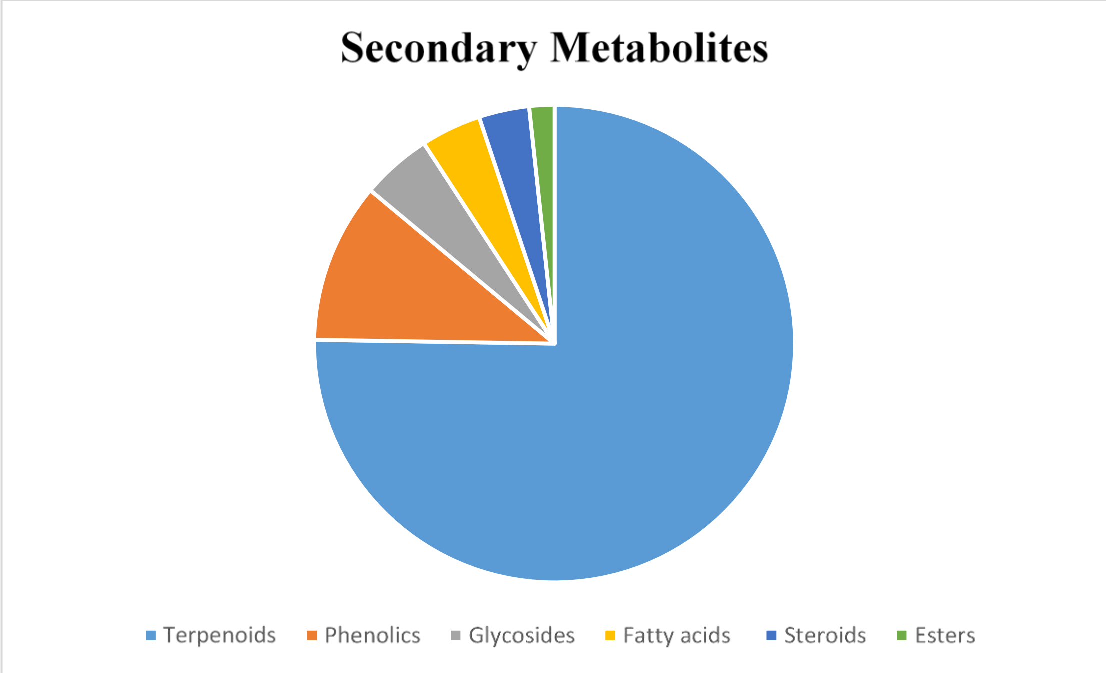

Fig. 3: Secondary Metabolites in *Jasminum*

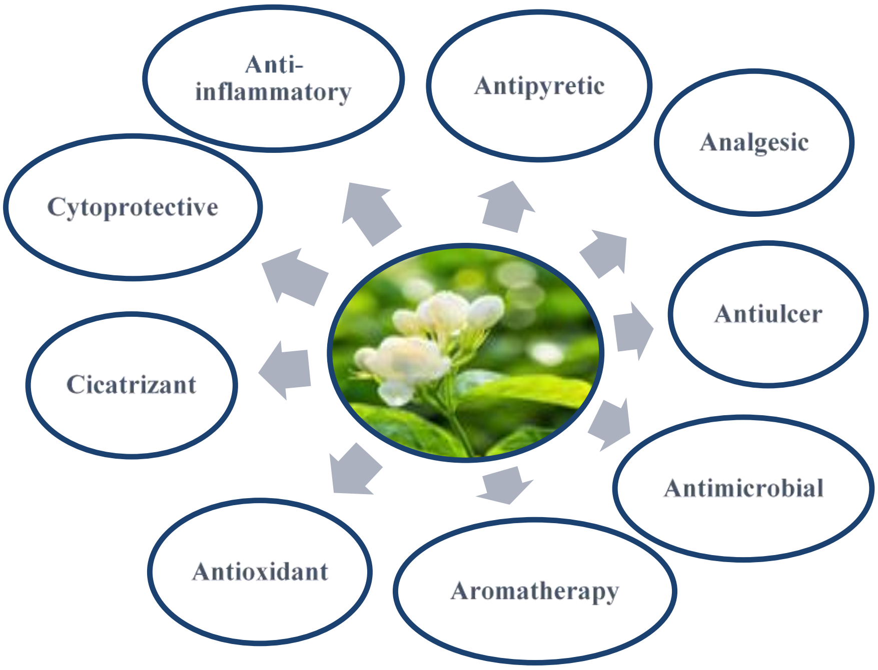

Fig. 4: Medicinal effects of *Jasminum* plant

Essential Oils in *Jasminum* Flower

Alkaloids, flavonoids, cardiac glycosides, glycosides, saponins, coumarins, phenolics, quinones, betacyanins, steroids, terpenoids, and tannins were among the phytochemical test findings acquired from the jasmine flower extract used in this study (Suaputra et al., 2021). The volatile jasmine oil comprises over 100 aromatic compounds, including linalool, benzyl acetate, benzyl alcohol, indole, benzyl benzoate, cis-jasmone, geraniol, and methyl anthranilate. Additionally, trace amounts of p-cresol, cis-3-hexenyl benzoate, farnesol, eugenol, cresol, nerol, benzoic acid, and benzaldehyde are also present in extract from jasmine (linalool, for example). Various quantities of linalool can be found in several essential oils. Jasmine is fundamentally mostly comprised of linalool, a monoterpenoid alcohol (Paibon et al., 2011).

Hexanal Extraction

Typically, jasmine essence is produced by hexane extraction. To isolate aroma molecules from undesirable extractives such as paraffins and fatty acid methyl esters, the extraction results in the formation of a "concrete" and it is then subjected to further processing (Reverchon et al., 1995). In the commercial extraction of jasmine volatile oil Hexanal extraction is the preferable method. However, this approach works against the "green" notion of modern industrial processing systems, which demands minimal emissions of carbon dioxide and energy saving (Sonobe, 2011).

Solid-phase Microextraction (SPME)

The extraction phase, often referred to as ab/adsorption of the chemicals on a fiber coated in a polymer, is the foundation of the SPME. Today, a variety of polymers with varying polarity are accessible, and thermal desorption of substances is often accomplished in gas chromatography. Polar and nonpolar substances are adsorbed on different types of fibers (Mejías et al., 2002). This method offers several benefits, such as a shorter extraction time, the elimination of the need for organic solvents, automation potential, ease of coupling with gas chromatography (GC), simplicity, sensitivity, and selectivity (Mohammad Hosseini, 2015). The variability of fibers from batch to batch, the fragility of fiber coatings, and possible matrix effects are some drawbacks of SPME (Huang et al., 2019).

Power Control Microwave Hydrodiffusion and Gravity (PC-MHG)

One of the most innovative uses of solvent-free microwave extraction is microwave hydrodiffusion and gravity (MHG). Hydrophilic phytoconstituents can be extracted from the reactor matrix with "in situ" water. Additionally, matrix is weakened and phytochemical storage cavities are ruptured. Bioactive chemicals are carried out of the plant tissues by heating in situ water in fresh marix (Mustafa et al., 2022). Using the benefit of green microwave technology, the PC-MHG extraction system may shorten the processing period while consuming less energy, both of which are favourable for the environment. With PCMHG, a significant yield of jasmine volatile oil was obtained in about 6 minutes, while SSDE took around 5 hours to get the same volatile oil. With MAE, the environmental effect was substantially decreased; at 500 and 100 W, respectively, around 50 and 100 g of carbon dioxide (CO2) had been released into the atmosphere (Sommano et al., 2015).

Simultaneous Steam Distillation Extraction (SSDE)

An effective technique for separating volatile organic compounds (VOCs) from intricate liquid mixtures. The method extracts the essential oils from the plant by combining solvent extraction (using an organic solvent like pentane) with steam distillation. According to the concept of the steam distillation process, heating a combination of two or more immiscible liquids causes the vapor pressure of the system to rise because of the combination of the vapor pressure of the two immiscible liquids (Chen et al., 2006). Steam distillation aids in the decrease of temperature-sensitive chemicals' breakdown by reducing the boiling point. For steam distillation heat must be used to produce the steam which can be energy-intensive and raise production costs (Gomez et al., 1993).

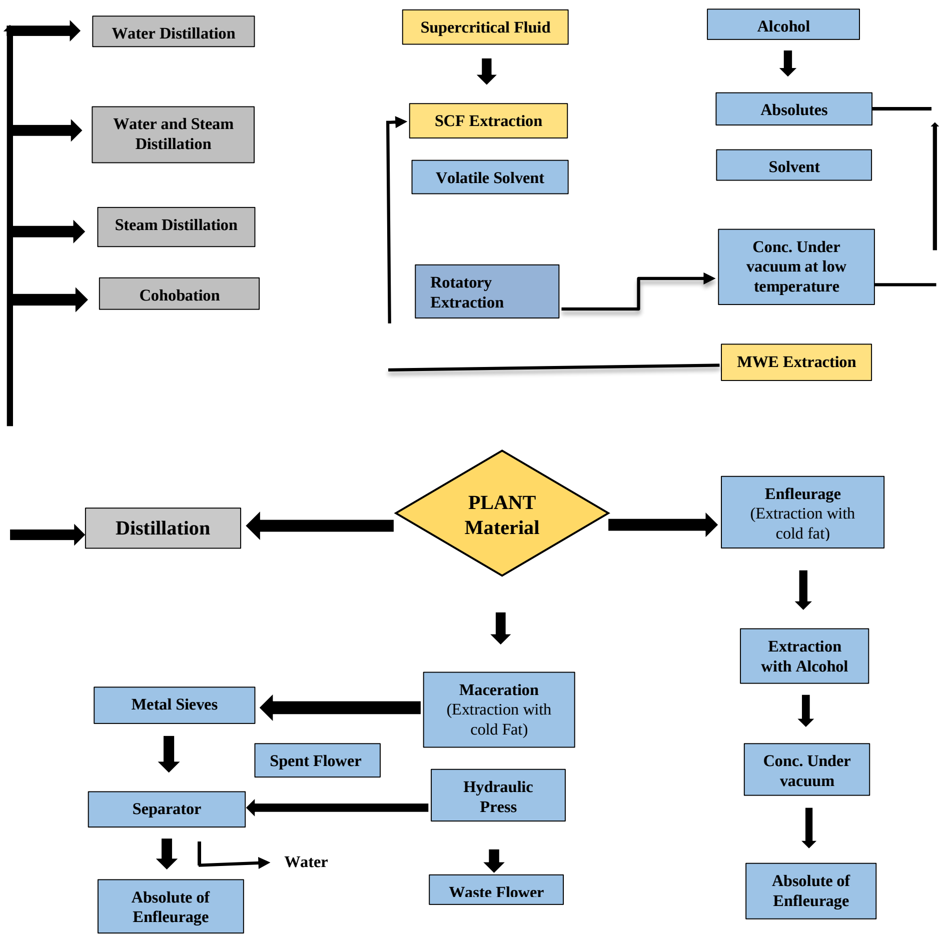

Fig. 5: Schematic flow diagram of plant material extraction

Aromatherapy

The art and science of using naturally derived aromatic essences from plants to balance, integrate, and improve the health of body, mind, and spirit is commonly referred to as aromatherapy, sometimes known as essential oil therapy. To support an individual's natural healing process, it attempts to encompass physiological, psychological, and spiritual processes (Hedaoo and Chandurkar, 2019). The history of aromatherapy was influenced by the Greeks. The main ingredient of the perfume Megallus is Myrrh. A Greek perfumer was created and named Megaleion. Hippocrates, the "father of medicine," is credited with using aromatherapy for therapeutic purposes long before the term was coined. Greek mythology put forth that the gods were endowed with the ability to smell and create perfumes (Lawless, 1995).

Little is known about the origins of aromatherapy and where it started precisely, however, the Egyptians are credited as the ones who constructed the earliest distillation machines for extracting oils from particular plants, such as cedarwood, cinnamon, and clove which were used to embalm the dead. The practice of employing infused aromatic oils to improve mood is considered to have originated in China. The Egyptian culture was among the first to gain a deeper awareness of fragrant plants. They used plants for spiritual, cosmetic, therapeutic, and mortuary purposes (Wildwood, 2006).

French chemist Rene-Maurice Gattefosse was the one who used the name "aromatherapy" originally in 1937, who became interested in the therapeutic properties of essential oils (Khan et al., 2023) after suffering a burn. Following Gattefosse's "discovery" that his burn was healed by lavender oil, French surgeon Jean Valnet also employed essential oils to treat troops' wounds during World War II and it further demonstrated the therapeutic advantages of aromatherapy (Ali, 2015). "The best therapy for health is to infuse the brain with pleasant aromas" Alexis (Lyubetska, 2002).

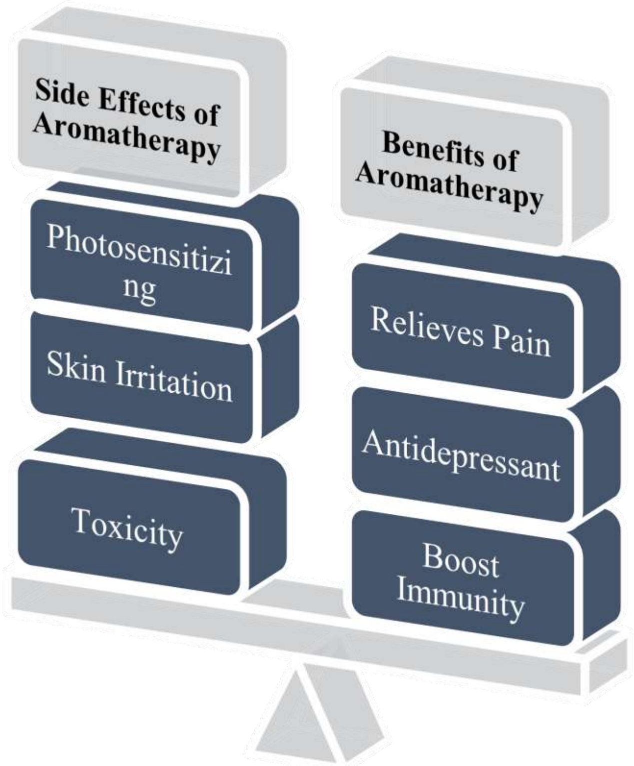

Fig. 6: Pros and cons of Aromatherapy

Jasmine Oil in Aromatherapy

Humans who use aromatherapy essential oils have physiological and psychological changes, including altered mood and sleep patterns. It is thought that pharmacological and psychological systems work together to elicit the effects of essential oils. While the psychological process functions through the sense of smell and may thus have physiological consequences, the pharmaceutical mechanism acts directly on the physical organism. The impacts on the body and mind are completely different, even though they frequently happen at the same time (Jellinek, 1997). The use of jasmine oil, particularly in aromatherapy, as a medicinally effective substance has increased significantly. In aromatherapy, Jasmine oil is incorporated as a holistic remedy for depression, fear, hysteria, and apathy, and to balance, uplift, and inspire confidence (Lis-Balchin, 2006).

Stimulating the Impact of Jasmine Essential Oil

Experiments on human attention revealed that lavender essential oil has soothing properties and jasmine essential oil has stimulating properties. Numerous essential oils are thought to be sedatives because they have been demonstrated to lower contingent negative variation (CNV) brain waves in human volunteers. Others are regarded as stimulants and raise CNV. Given that CNV amplitude elevated in individuals exposed to jasmine, it appeared to have stimulated consequences (Ilmberger et al., 2001).

Changes in the electroencephalogram were employed as indicators in research conducted at the University of Occupational and Environmental Health in Kitakyushu, Japan, for measuring the effects of essential oils. Their findings showed that the pleasant odor of jasmine had a stimulating impact, as seen by the notable rise in beta brain wave activity that occurred when the fragrance was presented (Kubota et al., 1992).

Transdermal jasmine oil administration was performed on healthy volunteers. The arousal state of the autonomic nervous system was measured using autonomic measures, such as systolic blood pressure (SBP), diastolic blood pressure (DBP), pulse rate (PR), blood oxygen saturation (BOS), breathing rate (BR), and skin temperature (ST). To measure subjective behavioral arousal, individuals were also required to score their state of mental and emotional health in terms of alertness, vigor, tranquility, attentiveness, mood, and relaxation (Andreassi, 2000).

The systolic and diastolic blood pressures of the jasmine oil group were consistently higher. Since the activity of the sympathetic branch of the ANS controls blood pressure, an upsurge in blood pressure indicates an increase in sympathetic tone, or autonomic i.e. By increasing systolic and diastolic blood pressure, blood oxygen saturation, and breathing rate, transdermal absorption of jasmine oil intensified the ANS' state of consciousness. In addition to this, massaging jasmine oil caused behavioral activation, meaning that the respondents felt less relaxed, more attentive, and more active as compared to the previous administration. Based on self-evaluation, this finding implies that arousal has gotten higher. The idea of stimulating/activating effects may thus be used to characterize the effects of jasmine oil massage. Our analysis justifies the use of jasmine oil in medications intended to treat depression as well as enhance mood in people by showcasing the stimulating and activating properties of the oil (Hongratanaworakit, 2009).

In addition to relieving anxiety and inducing feelings of confidence, optimism, and happiness, jasmine oil is excellent in treating severe depression. It also rejuvenates and restores energy and strengthens memory (Sayowan et al., 2013). The number of alpha and theta waves was increased by the jasmine lactone smell, suggesting that the chemical composition had a calming effect (Hongratanaworakit, 2004). The findings indicated that following inhalation, the respondents felt improved, more energetic, fresher, and more amorous. Negative feelings, like drowsiness, have consequently diminished (Hongratanaworakit, 2010).

To investigate the underlying processes of the key components of jasmine oil, it is important to know that the second messenger for certain serotonin receptors is as well cAMP, and serotonin is thought to be involved in emotion modulation within the central nervous system. Inhaling jasmine vapor is likely to have a stimulating effect due to its absorption and subsequent pharmacological activity inside the brain, or it might simply stimulate odor receptors (Lis Balchin et al., 2002).

It is widely documented that cortisol levels are elevated in response to pain, fretting, and distress (Kurina et al., 2004). The study on animals found that long-term oral ingestion of jasmine essential oil drastically reduces anxiety, discomfort, and itching in mice (Kuo, 2017). The research found that 5 minutes of JEO inhalation per day for 10 days can considerably reduce anxiety in people with a generalized anxiety disorder (Arhanthkumar, 2013). The recommended technique of aromatherapy is inhalation, which allows for direct absorption of essential oil components via the nasal mucosal membranes into circulation (Starkweather, 2018). According to one of the study findings, a one-hour inhalation of JEO can considerably lower mean blood cortisol levels and mean anxiety scores in patients having laparotomy. This suggests that essential oil may be useful in lowering preoperative anxiety (Yadegari et al., 2021).

The effects of jasmine oil on the central nervous system were looked into after inhalation. The power beta (13-30 Hz) rose dramatically in the frontal center and left posterior brain locations. This finding demonstrated that aromas influenced cortical brain wave activity. Brain waves have been shown to alter quite sensitively depending on the subject's degree of consciousness (Sayowan et al., 2013). Jasmine essential oil works physiologically to increase the non-rapid eye movement (REM) sleep state by inducing slow delta and beta frequency oscillations in the hippocampus region. The mice that were given 0.03% jasmine essential oil were found to explore the center arena of the apparatus more than the mice in the control group, in accordance with the locomotor tracking (Cheaha et al., 2023).

Conclusion

Thus we can conclude that aromatherapy is a growing practice of people today to help reduce stress and invoke certain moods and feelings. The studies conducted using jasmine essential oil as an intervention render mesmerizing neuroprotective benefits including, modulation in the sleep-wake cycle, stimulating brain activities, revitalizing memory, degrading neuro oxidants, and eliciting pleasing neuronal effects. The study of aromatherapy is relatively new and unexplored. More research must be done to make scientific conclusions about the use and effect of aromatherapy so the field may emerge as revolutionary in contemporary scientific society.

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Chapter 06

Role of Aromatherapy in the Management of Stress and Depression

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ABSTRACT

Since ancient times, man has depended on natural products, especially those derived from plants, for the cure and treatment of various diseases. Aromatherapy refers to the therapeutic use of essential oils. These essential substances are extracted from different plants using different methods such as steam distillation, solvent extraction and expression. The concentrated form of these essential oils is used for therapeutic use by inhalation or topically. Essential oils have a positive effect on the physical, emotional and mental state. Essential oils also target stress and depression, which are major issues today, as essential oils have the potential to affect the central nervous system. The main mechanism by which essential oils are involved in managing stress and depression is through direct transmission through the olfactory nerves and the release of neurotransmitters such as serotonin and dopamine. Lavender, chamomile, bergamot, jasmine, rose, sandalwood, frankincense and lemon are the main essential oils used in aromatherapy. Thanks to their specific properties, these essential oils have therapeutic effects including anxiolytic, stress and antidepressant effects.

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INTRODUCTION

Aromatotherapy be a complementary exercise like singular is defined as the helpful use of urgent oils taken out of flora to guide bodily, emotional, or spiritual health (Cho et al., 2017). Essential oils should be volatile liquids extracted from plant material by steam distillation and distillation. It is usually obtained from any part of the plant, including leaves, seeds, resin, roots or stems. These incredibly targeted oils can be used for relaxation and local healing by pulling on the mucous membranes and skin: using oiled cloths, nasal sticks or through nasal sprays or chamber attachments to ensure inhalation when used topically, the essential oils are diluted in a hard solution. To concentrate the oil with little concern for some of the time spent in the treatment. Mucosal and skin sensitivities may require dilution due to potency, associated tissue and skin disease, and phototoxicity of citrus oil Essential oils should be volatile liquids extracted from plant material by steam distillation and distillation. It is usually obtained from any part of the plant, including leaves, seeds, resin, roots or stems. These incredibly targeted oils can be used for relaxation and local healing by pulling on the mucous membranes and skin: using oiled cloths, nasal sticks or through nasal sprays or chamber attachments to ensure inhalation when used topically, the essential oils are diluted in a hard solution. to concentrate the oil with little concern for some of the time spent in the treatment. Mucosal and skin sensitivities may require dilution due to efficacy, associated tissue and skin disease, and phototoxicity of citrus oil (Hedigan et al., 2023).

Aromatherapy is based on the idea that these oils, with their premium scents, are private recuperatives that can improve physical, intellectual and emotional well-being. In the context of critical care, aromatherapy provides a non-invasive, patient-centered method that could possibly augment conventional medical remedies. Despite the fact that aroma therapy for mental health is not a revelation, academic studies have been gaining interest in aromatherapy as an alternative to conventional medicine for its amazing effectiveness in reducing tension and melancholy and improving brain health. Aromatherapy has been performed in many areas including maternal hygiene, treatment of anxiety, chemotherapy sequelae, skin and hair hygiene, wound treatment, control of epileptic condition, discounting of breathing problems and bargain of tension and despair (Cao et al., 2023).

Mechanism of Aromatherapy in the Management of Stress and Depression

A fundamental important mechanism for remedying tension, stress, and depression is the bioactive effect of essential oils on the precious worry tool (CNS). Known, EOs exerts their feasible neuropharmacological results generally through blood movement (blood pathway) or direct olfactory nerve transmission (nerve course).

Essential oils are excellent because they can have low polarity, we should EO molecules effortlessly pass through physiological barriers such as mucous membranes, pores and pores and skin, blood and mind restrictions and so on. Aromatic massage supporting a calm body and mind through the delivery of living components of vital oils into the bloodstream through the pores and skin and mucous membranes, reaching the mental tissues through the bloodstream, showing neuropharmacological results.

Essential olives are breathed through the nostril, passing the slimy membrane where they adhere to the pointed receptors of smelly sensor organs. Unique signals are transmitted to the brain's convoluted structure. The brain becomes excited to release brain fluids such as serotonin and dopamine, which can help regulate mood by controlling the nervous system (Zhang et al., 2023).

The aromatic molecules of critical oils can influence the hypothalamus, the autonomic frightened instrument and endocrine gadget. When inhaled, these molecules create a calming response by means of calming, balancing, and stimulating, which can reduce the phases of the stress hormones cortisone and cortisol in the frame (Ma'arif et al., 2023).

Determining the most essential basic feature is a difficult undertaking. Although numerous researches have highlighted the high-quality effects of essential oils on mood disorders and explored the mechanisms of their abilities, more research is needed to better understand the complex and multiple essential oils in the primary fearful device (Cao et al., 2023).

Essential Oils in Aromatherapy

Lavender

Lavender (*Lavandula* spp.), a member of the *Lamiaceae* family, is one of the most discussed medicinal plants, well known for stress-reducing properties. The plant is native to the Mediterranean basin, including southern Europe, northern Africa, the Middle East, and into some parts of Asia. With a very varied taxonomy comprising over 30 species, numerous subspecies, and hybrids, *Lavandula* is a botanical mosaic in terms of genetic diversity. Of the most common species, there is *Lavandula angustifolia*, or English lavender, which presents very delicate flowers and subtle fragrance. Another one is *L. Stoechas*, or French lavender, with a very strong aroma and a late blooming period. *L. Latifolia* is another species with a grassland appearance that is native to the Mediterranean region. *L. Intermedia* is another key species that is a sterile hybrid between *L. Latifolia* and *L. Angustifolia*. It combines characters of both parents, shaping the botanical identity of this species.

The beauty of lavender, represented by the lavender oil in Figure 1, is only one side of this botanical mosaic. The other side is the health benefits it brings to the human body. Lavender finds widespread use not only in herbal medicine but also in cosmetics and perfumery, culinary applications, and in the new field of aromatherapy. This is why this multi-faceted botanical gem constantly amazes and fuels various aspects of human life, as it has profound effects on the body both physiologically and psychologically (Ghavami et al., 2022).

The number one ingredients observed in lavender include essential oils (linalool), limonene, perillyl alcohol, linalyl acetate, cis-jasmone, terpene, coumarin tannin, caffeic acid, and camphor. However, the relative distribution of these compounds varies among many species. Linalool has sedative effects by affecting gamma-aminobutyric acid receptors within the valuable irritating gadget. Inhaling essential oils for aromatherapy or restorative functions is a common method to reduce pressure because it has minimal consequences. It can also help reduce stress and promote relaxation through the limbic gadget, especially with the help of the amygdala and hippocampus (Ghavami et al., 2022).

The aromatic oils extracted from flora and herbs is utilized by aromatherapy to deal with varying sicknesses. Lavender is of those herbs which can be utilized in aromatherapy. Lavender essential oil has anti-pain antianxiety and anti-depressant, and sleep improvement results. The mechanism of this plant is not completely known, but it has been taken into consideration that this plant probably had a comparable feature to benzodiazepines and improved GABA (gamma aminobutyric acid) within the amygdala (Algristian et al., 2022).

The scientific college students, in particular all through examination seasons undergo stress, however no vast distinction was located for gender regarding degree of stress at some point of tests. The remedy namely aromatherapy, hydrotherapy and homeopathy are used extensively to lessen stress now-a-days (Algristian et al., 2022).

Fig. 1: Lavender Essential Oil

Chamomile

The term "chamomile" comes from the Greek words Chemios Melody, translating to "earth pear" because of its pear-like scent. There are different forms of chamomile and they will be diagnosed using a lot of names together with baboon chamomile, German pot, Roman fence, mystery chamber, Hungarian chain, simple champagne, camouflage, krami, maggots, sweet false chamber pot and fragrant chaos. Chamomile is decided in different places and is properly documented as a common international plant. Chamomile, additionally known as *Matricaria chamomilla L*., is an important medicinal plant that belongs to its own family *Asteraceae* (formerly known as Compositae) and originates from Europe and Asia. It is grown in areas of southern and Japanese Europe, northern Africa, valuable and western Asia, and western North America. Hungary is the largest producer of plant biomass. The Mughals added herbs to India and they would be grown in the northernmost regions of the US. The seeds need bare soil to grow nicely to germinate regularly near roads and in areas with landmines or cultivated fields where they may be considered weeds. Many styles of botanical species are referred to as the butler (Figure 2), which includes German Rail, Wild Chapati (*Matricaria discoidea DC*.), Valley Maze (*Matricaria octagon G*.), Matricaria aurora Loafers, Edge or Corn Generator (*Archive Anthemis L*.), stinking chandelier (*Anthemis cutlet L.),* odorless or scaleless chamber (*Tripleurospermum inordinate L*.), dyer's chamber (*Coda tincture L.)* and larger. To avoid confusion, *Matricaria regatta L.* (additionally referred to as *Matricaria chamber* or *chamber regatta*) is now diagnosed because bot (Sah et al., 2022).

The number one two types of chamomile typically used for medicinal purposes are German chamomile. True Chamomile (*Matricaria Chamomilla L.)* Roman Chamomile or English Chamomile (*Chamaemelum nobile* syn. *Anthemis nobili*s, also Roman Chamomile (L.). *Ormenis multicaulis* Braun-Blanq, three species often used in the gloss and perfume industry (Sah et al., 2022).

Fig. 2: Chamomile Oil

Chamomile, known to have mild hypnotic properties, is believed to be due to binding of the flavonoid apigenin to benzodiazepine receptors in the brain, which, in turn, affect the outcome of sleep. Although initial studies showed the presence of central nervous system depressant properties with possible antiepileptic effects, clinical trials are still far from enough. Of interest are findings on ten patients with coronary disease who showed sleep induction within ninety minutes of ingesting chamomile tea suggestive of benzodiazepine-like sedative effects. Other studies indicate that inhalation of chamomile oil prevents the increase in plasma adrenocorticotropic hormone (ACTH) brought about by inhalation of stress-inducing substances. Adding diazepam to the volatile chamomile oil further increased this effect, although flumazenil, a benzodiazepine antagonist, negates the effect of volatile chamomile oil on ACTH levels. Paladini et al. postulate that the dissociation index of diazepam was 3, and for apigenin, 10, showing that the two have a different potency. Apart from apigenin, other constituents of chamomile extract also bind to benzodiazepine (BDZ) and gamma-aminobutyric acid (GABA) receptors in the brain, which may account for its hypnotic effects. However, these mechanisms have not yet been fully elucidated and will need further study (Srivastava et al., 2010).

Bergamot

Bergamot oil, derived from Citrus *Bergamia*, is a member of the genus citrus in the *Rutaceae* family and is mostly grown in Italy and Morocco. Constituents of bergamot oil include bergaptene (5-methoxypsoralen), linalool, and linalyl acetate, which are mainly extracted from the fruit peel and have potential mood-enhancing and relaxing features. Several studies have shown that plasma melatonin levels can be increased by bergamot essential oil, mainly because of penta-methoxypsoralen. Melatonin is known to regulate circadian rhythms and is involved in improving mood as well as sleep quality by enhancing sleep initiation and improving sleep architecture in animals. In addition, linalool, a monoterpene alcohol, has some antimicrobial, analgesic, anxiolytic, and antidepressant effects and is found in many other essential oils in minute volumes. It possesses these properties potentially because of the mood-enhancing properties of the essential oil. Linalyl acetate, which is another major constituent, causes nitric oxide to be released, thus inducing relaxation in smooth muscle tissue. Studied in the context of postpartum depression and sleep disturbances, researchers have identified a need for strategies to improve mood disturbance, sleep quality, and relaxation in postpartum women. In an animal study, bergamot oil constituents were found to improve postpartum depression and sleep disturbances, thus indicating its potential to improve postpartum care and relaxation for sleep quality (Mei-Ling et al., 2022).

Fig. 3: Bergamot Oil

Lavender and bergamot are popular essential oils that can be effective for insomnia. Both were said to promote restful sleep by stimulating the parasympathetic startle machinery. Bergamot has been recognized as a surge of unhappiness emotions (Bragamot oil has shown in figure 3). As a result, using bergamot essential oil can also help reduce mental tension and improve sleep and morning alertness. High levels of insomnia and misery among Japanese university students have been caused by reduced opportunities for social interaction, leading to emotions of hysteria and isolation, approximately Japanese universities have been hit hard by the COVID-19 pandemic. Universities were forced to close their physical campuses, leading to a shift from one-on-one lectures to online tutorials. Measures including the banning of conventions, the cancellation of organizational sports, and the restriction of socialization limited the daily life of university students, and as a result, most students missed out on opportunities to participate in men's or women's courses at the university. In addition, part-time job opportunities have been eliminated to help cover living expenses due to reduced demand and reduced working hours in the food industry. This scenario has created a harsh environment that is difficult for many students. As a result, a number of college students suggested that they had mild symptoms of depression and a variety of psychological problems, including insomnia and trouble getting up during the morning workload. So we used bergamot oil to study university students on the way to determine its effectiveness in treating insomnia and despair (Wakui et al., 2023).

Jasmine

Jasmine or Jessamine is a member of the *Jasmine* genus, which belongs to the *Olaceae* family. In Arabic, the plant goes by the name Yasmin. In Iran, *Lonicera japonica* is commonly referred to as "Yass" or "Gole Yass" by locals. It can be sugar, white, pink or brown. The strong scent of jasmine activates the parasympathetic nerves. This document has been successful in stopping allergic reactions in animals.

One observer found that the aroma of jasmine tea had an effect on the frightened autonomic system and calmed the mind. Important volatile compounds in jasmine tea are linalool, benzyl alcohol, benzyl acetate, (Z)-tri-hexenyl-benzoate, indole, methylanthranilate, and α-forene. wave activity. Another study in the healing homes of jasmine critical oil (shown in Figure 4). The use of jasmine vital oil in aromatherapy can alleviate depression and improve cognition in members In addition, Vidayati et al conducted the results of aging and physical disorders on sleep problems in the elderly. adults If it helps to use New experimental findings highlight the importance of screening other for the effect of aromatherapy as an easy and smooth drug with minimal results to improve sleep in untreated dialysis patients (Sultani et al., 2023).

Fig. 4: Jasmine Oil

J. Multiflorum and *J. Mesnyi* contain high levels of secoiridoids, lactones, flavonoids, and diverse terpenoids and triterpenoids. Studies have indicated that plants belonging to the *Jasminum* genus are esteemed medicinal herbs in various areas of India and other locations. These are commonly utilized in folk medicine for a range of issues like cuts, ailments, skin disorders, brain disorders, and sores. Both flowers have antioxidants and can be used to enhance someone's emotions. Both *J. Multiflorum* and *J. Mesnyi* stems were selected for evaluation as potential antidepressants based on their abundance of terpenoids and flavonoid compounds. The present research assessed and contrasted the efficiency of antidepressants across different species. The research employed experimental techniques like the forced swim test, tail suspension test, head twitch test triggered by 5-HT, tetrabenazine blocking, and chronic unpredictable mild stress (Garg et al., 2024).

Rose

Rose the members of the *Rosaceae* family, roses, are among the most well-known and most cultivated medicinal plants worldwide, even though their home is in the Middle East. The essential oil of the petals of Rosa species, in particular, *R. Damascena* and *R. Centifolia*, commonly known as rose oil, is of great importance. Written evidence shows that rose oil has been produced since ancient times in Greece, and today, production mainly takes place in Bulgaria, Turkey, and Morocco. This valuable oil (Figure 5) is pale yellow and partially crystallized; therefore, it is also very expensive (Mohebitabar et al., 2017).

A study in Kashan province, Iran revealed 95 compounds in *R. Damassena* essential oil, with β-citronellol, nonadecane and geraniol being the most abundant. It has been shown to have effects on the critical worried system of reducing morphine withdrawal symptoms Rose oil from exceptional sources has additionally been studied for its sedative and sedating properties. One example is when Hongratanaworakit (2009) investigated the cooling effects of rose oil (obtained from Rosa damascena Mill, *Rosaceae*) in humans after transdermal absorption (Mohebitabar et al., 2017).

Sandalwood

Sandalwood oil from the *Santalum* album plant, belonging to the *Santalaceae* family, has been utilized in India for its medicinal properties for centuries. Oil is extracted from sandalwood by either hydrodistillation or steam distillation, obtained from the wood and roots. India ships out this oil (depicted in figure 6) in large quantities. It is believed to enhance the oxygen flow to the pineal and pituitary glands. The primary chemical compounds consist of α and β santolol and santenone. It is utilized for alleviating depression, anxiety, stress, nervousness, and insomnia. It has also been researched for its role in helping to fight against herpes simplex virus by blocking its ability to reproduce. The primary components of sandalwood oil consist of tricyclic α-santalol and β-santalol. Sandalwood essential oil enhanced neurological rehabilitation (Younis et al. 2020). Decreased oxidative stress, and mitigated inflammatory reactions in mice subjected to middle cerebral artery occlusion (MCAO) surgery (Murugesh et al., 2024).

Fig. 5: Rose Oil

Fig. 6: Sandalwood Oil

Administering methanol extracts of sandalwood to albino mice proved to have inhibitory effects on acetylcholinesterase and showed superoxide radical scavenging abilities by α,α-diphenylβ-picrylhydrazyl (DPPH), indicating its ability to potentially hinder the advancement of dementia and memory loss in Alzheimer's patients. Furthermore, a study from 2016 with 32 human subjects demonstrated decreases in both blood pressure and salivary cortisol levels, indicating its ability to decrease stress (Murugesh et al., 2024).

Frankincense

Boswellia resin extraction. This resin is derived from trees belonging to the *Boswellia* genus, primarily from five species: *Carterii, serrata, papyrifera, sacra, and frerana*. Chemical analysis shows that it contains more than 200 diverse natural compounds such as terpenoids, polyphenols, and tannins. It aids in reducing stress and improving sleep. Figure 7 depicts the presentation of Frankincense essential oil.

It is also utilized for lessening the severity of labor pains and asthma to assist with breathing. In a recent animal experiment, adult male rats deprived of sleep were given frankincense essential oil to test its potential for reducing anxiety and impacting their sleep and wake patterns (Murugesh et al., 2024).

Stress and depression can affect the occurrence of epilepsy in individuals with epilepsy. Stress and anxiety can shrink the tumor and reduce the risk of acne. In addition, the emotional burden associated with epilepsy can increase feelings of anxiety and sadness, leading to stronger interactions between these factors in controlling epilepsy and glutamate) and affected the density of muscarinic (M1, M2) and dopaminergic (D2) receptors in the striatum and hippocampus. Despite significant efforts to find effective treatments for SE, uncontrolled epilepsy occurs in up to 30% of individuals with epilepsy. Therefore, SE wants to act immediately to prevent its own harm and death (Hosny et al., 2020).

Fig. 7: Frankincense Oil

Lemon

Lemon oil, an essential oil of Citrus *limon L. Osbeck*, is considered useful for both culinary and medicinal applications, due to its association with the *Rutaceae* family. Studies have shown its efficacy in animal models, particularly in the pressurized swimming test (PST), where inhalation of lemon oil causes a rapid reduction in immobilization time, thus presenting potential antidepressant effects. However, in concurrent results, it reduced locomotion and exploration in the open field test, indicative of a sedative effect.

The composition of *Citrus limon L. Osbeck* oil, with limonene at 53%, geranyl acetate at 10%, and trans-limonene oxide at 7% as major components, determines its action in pharmacological evaluation. Studies have validated the dose-dependent variations in antidepressant, anxiolytic, and hypolocomotor effects in animal models. However, the effect of monoterpenes such as limonene decreases after acute treatment in the forced swim test. Limonene, after a 15-day treatment, showed its potential in reducing the immobility time in the FST paradigm in neuropathic pain-induced rats. Citrus limon *L. Osbeck*-derived lemon oil causes complex pharmacological effects, which are under monoterpenes' control. Limonene plays a central role in the modulation of neuropathic pain-related behaviors. (De Sousa et al., 2017).

Fig. 8: Lemon Oil

A possible mechanism of the antidepressant effect of LO involves the modulation of neurotransmitter transmission, particularly serotonin (5-HT) and dopamine. Pretreatment with a variety of pharmacological agents, including buspirone, DOI, myaserin, apomorphine, and haloperidol, reduced the depressive effect of LO. In addition, acute exposure to LO resulted in increased levels of 5-HT and dopamine within the hippocampus and prefrontal cortex, parts of the brain responsible for emotional response. Because of the critical role of 5-HT and dopamine in mood modulation and the importance of the hippocampus and prefrontal cortex in regulating mood, it is likely that limonene, a principal component of CLLO, may mediate the antidepressant effect of LO. It is possible that the observed antidepressant effects of LO may be mediated by regional levels of serotonin and dopamine, since both play key roles in mood modulation and since the hippocampus and prefrontal cortex play active roles in mood-related behaviors (De Sousa et al., 2017).

In the ultramodern era, there has been an immense demand to explore and use plant-derived compounds against the growth of microorganisms and oxidative processes in foods. However, information on the in vivo effectiveness of the antimicrobial activity of flower-derived essential oils, especially in meat, is still lacking. The in vitro response to different food microorganisms, including bacteria, molds, and yeasts, and the antibacterial action of Citrus limon essential oil against food microorganisms, are yet to be clearly defined. The present study is therefore an original contribution designed to evaluate the chemical composition of Tunisian lemon essential oil (ClEO) (as shown in figure 8) using Gas Chromatography-Mass Spectrometry (GC-MS) analysis. The objectives of the research were to evaluate the antioxidant and in vitro antimicrobial activities of ClEO, analyze its effect on the quality parameters of refrigerated stored unheated ground beef, and estimate its ability to inhibit the growth of Listeria monocytogenes in raw ground meat stored under refrigerated conditions.(Ben Hsouna et al., 2017).

Precautions and Limitations of Aromatherapy

Certainly! Aromatherapy, which involves the usage of vital oils for healing purposes, can be quite beneficial. However, like all practice, it has its precautions and obstacles. Let’s dive into the ones:

Toxicity OF Essential Oil

Essential oils are robust and ought to in no way be ingested or carried out undiluted to the pores and skin. Swallowing them may be dangerous, and direct skin utility may additionally purpose infection.
Always dilute crucial oils with a provider oil (like sweet almond or olive oil) before making use of them on your skin. Remember, natural doesn’t always mean safe.

Inhalation Caution

Be cautious when using vaporized oils if you have asthma or are prone to nosebleeds. Don't use aromatic plant oils in sensitive areas, such as the ears, mouth or vagina.

Long-Term Use

Some essential oils can be hard on the body with extended use. This may cause damage to the liver or kidneys. Always follow recommended guidelines and consult a health professional about their use.

Interaction with Medications

Essential oils can interact with medications and cause problems. Always consult your doctor, especially if you're on medications.

Dilution Matters

Dilution ratios are very important. In most cases, you'll want to use a few drops of essential oil in a carrier oil (like almond oil or olive oil). Patch test by placing a few drops on a small area on your forearm before using it in larger amounts.

Conclusion

Aromatherapy, the therapeutic use of essential oils has shown promising effects in treating stress, anxiety and depression by means of both olfaction and cutaneous routes. Essential oils like lavender, chamomile, bergamot, jasmine, rose, sandalwood, frankincense, and lemon are neuroactive and exert their action on the central nervous system by enhancing the activity of the neurotransmitters serotonin and dopamine. These essential oils thus help to overcome mood disorders, improve sleep, and foster emotional well-being. However, in spite of its therapeutic benefits, caution with its use is needed because of possible toxicity and skin irritations, as well as interactions with other medications. Dilution and proper application and consultation with healthcare professionals are important to ensure its safety and efficacy. Further research is necessary to fully elucidate the mechanisms and make the applications of these natural remedies in modern medicine more extensive.

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Chapter 07

Sustainable Strategies: Integration of Essential Oils in Ruminant Nutrition

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ABSTRACT

Essential oils (EOs) have shown capacity to adjust rumen ferment action and heighten nutrient usage, impacting critter vigor and doingness. Albeit hopeful, their utilization confronts obstacles such as likely antifeed nutrient effects and alterations in the flavor of beast yields, which might impinge on dry matter consumption. Plus, inconsistency in measurement and the chemical makeup of the EOs utilized, alongside variances in feedstuffs and beastly physiognomy, present difficulties. The future is seen in nutrigenomics to direct cud-chewer foodstuff crafting, aiming at evaluating existent hurdles and suggesting fresh pathways for the domain. Henceforth, this passage gifts a broad view of EOs blended into cud-chewer sustenance through these points: impacts on ruminal fermentation plus microbial ecosystem; antimicrobe potency, influence on ruminant outputting, antibiotic substitutes; also, methane management.

KEYWORDS		
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INTRODUCTION

Chemical Composition of Essential Oils

In a vast spectrum of vegetation, essential essences (EOs) are located, with notably essential vegetal families including Lamiaceae, Lauraceae, Asteraceae, Myrtaceae, and Rutaceae standing out. To derive essential essences from various plant parts such as bark, seeds, roots, stems, flowers, and leaves, steam distillation, solvent extraction, cold pressing, and expression techniques are commonly used. The chemical blend of EOs is recognized for being complex, consisting of small molecules such as long-chain hydrocarbons, acids, alcohols, aldehydes, phenols, non-ring esters, and lactones, which may vary within the same plant species (Kim et al., 2022). However, certain species possess signature compounds, such as Cinnamomum verum, where Cinnamyl acetate is listed in Table 1.

Several studies have focused on evaluating the chemical composition of essential oils, as it plays a crucial role in their potential use in ruminant nutrition and production. According to Wells (2023), 28 species of essential oils have been used in ruminant feeding, grouped into 15 botanical families, with the most representative being the Lamiaceae family, which includes six species: Oregano (*Origanum vulgare*), Mexican oregano (*Lippia berlandieri*), Poliomintha longiflora, Thyme (Thymus vulgaris), Peppermint (*Mentha* x *piperita*), and Lavender (*Lavandula angustifolia*) (Table 1).

Oil extracts are paramount from three species*: Lippia berlandieri*, *Poliomintha*, or *Origanum vulgare*, which are critical sources of terpenoids such as carvacrol, thymol, p-cymene, γ-terpinene, limonene, caryophyllene, myrcene, and humulene (Noriega et al., 2022). Garlic essential oil (*Allium sativum*) contains disulfide components including sulfur-like disulfide, trisulfide, and diallyl tetrasulfide dimethyl, along with trisulfide (Saharan et al., 2023). These compounds present in essential oils impart antibacterial qualities directly related to methane reduction when introduced into the diets of ruminant creatures as part of their routine food intake (Kholif et al., 2017).

Within the genus of plants known as Cymbopogon, an extraction process for essential oils takes place among three varieties: *C. citratus*, *C. nardus*, and *C. martini*. The substances extracted include aldehydes (such as Citral and Citronellal), alcohols (such as Geraniol and Linalool), esters (with Geranyl acetate present), as well as Limonene, β-Caryophyllene, and Elemol. These compounds have a specific ability to affect rumen activities while also acting as antioxidants and addressing hyperammonemia conditions (Kholif et al., 2017).

Table 1: Major plant species, compounds, method of application, and biological activity of essential oils (EOs) used in Ruminants (Source: adapted and modified from Wells, 2023).

Plant Species	Main Compounds:	Mode of Use	Biological Activity:	Ruminant Type
Allium stavium	Diallyl disulfide Diallyl trisulfide Sulfur compounds	feed additive	antimicrobial, anti- parasitic	Bovine, sheep
Artemisia afra	α-thujone 1,8-cineole β-thujone Camphor	oral drench	anti-parasitic	Bovine
Azadirachta indica	Azadirachtin Nimbin Salannin Nimbidin	external	acaricidal	Bovine
Capsicum spp	Capsaicin Dihydrocapsaicin Nordihydrocapsaicin Homocapsaicin	food additive, external, fumigation	milk production, ruminal function, heat stress, methane reduction	Bovine, sheep
Cedrus atlantica	α- Himachalene γ- Himachalene δ-Cadinene α-Cadinol	external	anti-parasitic	Bovine
Cinnamomum verum	Eugenol Cinnamyl acetate α- Transcinnamaldehyde β- Caryophyllene	feed additive	mastitis	Bovine
Citrus spp.	Limonene Citral Linalool Octanal	feed additive, external	antimicrobial, rumen function, mastitis	Bovine
Coriandrum sativum	Linalool Camphor α-Terpineol g-Terpinene	feed additive	rumen function, methane reduction, heat stress	Bovine
Cymbopogon citratus	Citral Geraniol Limonene Citronelal	external	anti-parasitic	Bovine
Cymbopogon martini	Geraniol Geranyl acetate Linalool β-Caryophyllene	external	anti-parasitic	Bovine
Cymbopogon nardus	Citronellol Geraniol Elemol Citronellol	food additive	ruminal function, methane reduction, heat stress	Bovine, sheep
Foeniculum vulgare (hinojo)	Linalool Estragole Fenchone Limonene	intranasal (BRD), food additive	Antimicrobial.	Bovine
Juniperus communis	α-Pinene β-Myrcene δ-3-Carene Terpinolene	food additive	milk production	Bovine
Lavandula angustifolia	Linalool Linalyl acetate 1,8-cineole Borneol	external mammary, infusion	Antimicrobial, acaricidal.	Bovine
Melaleuca alternifolia	Terpinen-4-ol γ-Terpinene α-Terpineol 1,8-cineol	external	acaricida	Bovine

Mentha x piperita	Menhtol Menthone Menthyl acetate Limonene	food additive	milk production, heat stress, antiparasitic. External: antiparasitic	Bovine, sheep
Origanum vulgare, Lippia berlandieri, Poliomintha longiflora	Carvacrol Timol 1,8-Cineol Estragole Borneol	feed additive, externa	antimicrobial, milk production, rumen function, methane reduction, heat stress	Bovine
Pelargonium graveolens	Citronellol Geraniol 10-epi-γ-eudesmol Guaiol	external	antiparasitic	Bovine
Pimpimella anisum	Anethole Estragole Methylchavicol Foeniculin	food additive:	antimicrobial, milk production	Bovine
Salvia rosmarinus	1,8-cineol α-pinene β-pinene Camphor	food additive	antimicrobial, ruminal function	Bovine
Senecio barbertonicus	Santolinatriol Sentequinone Senecionanetin Senecionine	oral drench	antiparasitic.	Ovinos
Sonchus congestus	Germacrene D β- Caryophyllene δ-cadinene Camazulene	oral drench	antiparasitic.	Sheep
Syzygium aromaticum	Eugenol β- Caryophyllene Eugenyl acetate α-Humulene	food additive, external, fumigation	antimicrobial, milk production, ruminal function, methane reduction, heat stress.	Bovine
Thymus vulgaris	Thymol Carvacrol p-Cimene γ-Terpinene	external mammary infusion, external, intranasal (BRD), external (mastitis)	antimicrobial, ruminal function, methane reduction.	Bovine
Zingiber officinale	Zingiberene Ar-curcumene 1,8-cineole β-bisabolene	external	antiparasitic, bactericidal	Bovine

Let's journey into the realm of cinnamon essential oil, where we're discussing the species known all fancily as *Cinnamomum verum*. It's rich with Aldehydes, featuring α-Transcinnamaldehyde, the classic spicy-smelling Cinnamaldehyde, and its cousin, (E)-Cinnamaldehyde. Let's not overlook those Esters making their mark, with "Cinnamylish" acetate taking the stage in its alternate universe version, ((E)-Cinnamamide acetate). There's also a gathering of Terpenoids here, with β-Caryophyllene joining Pinene, Phellandrene, Limonene, Copaene, and Caryophyllene oxide. All wrapped up under the observation of Farag et al. (2022), this cinnamon ensemble is gearing up nicely against threats like Aspergillus and Candida albicans. They've positioned themselves as contenders, potentially outshining conventional disinfectants in the ongoing battle within livestock production systems.

Nevertheless, it is important to recognize that the density of substances within the EO can fluctuate based on elements like Geographic location, developmental phase of the plant, type of plant, method used for extraction, and also the amount and technique used in its application (Schären et al., 2017).

Effects on Ruminal Fermentation and Microbial Ecology

Oils of essence underwent examination for impacts on population's microbial rumen and procedures fermentative. It was demonstrated that essential oils, due to its active compounds, impact the fermentation of ruminal microbial and nutrient flow (Paraskevakis, 2018). These components can sway the creation of by-products fermentation like acetate, butyrate, formate, lactate, hydrogen, and ammonia by bacteria gram-positive in the rumen showing that oils essences possibly change fermentation in rumen by bettering efficiency use energy plus lessening emissions methane (Zhou et al., 2020). Yet, several writers signal that outcomes are erratic concerning the influence of essential essences on stomach fermentation and beast efficiency. This could stem from inconsistency in portioning and chemical makeup of the vital essences applied, as well as fluctuations in feedings and creature science (Schären et al., 2017).

A concoction of critical extracts from clove, marjoram, cinnamon bark, and citron shows potent anti-life action towards rumen single-celled life forms and gram-positive microbes, impacting the generation of assorted fermentative side-products such unmixed propionic acid derivative esterified additive $C_2H_3O_2^-$ anion radioactive carbon series liquid antecedent nitriles ammonia mixed (Lin et al., 2013).

Oil extracts mixtures trim down the occurrence of ancient one-celled organisms protozoa's specific small living entities within stomachs altering ruminant microbial assembly. Adding strong scents to lamb sustenance influences tummy agitation by lessening grub cell partition digestion (Barreto-Cruz et al., 2023).

Several studies have explored the effects of essential oils on digestion, ruminal fermentation, microbial populations, as well as milk production and composition in dairy cows. These studies emphasize the adaptation of rumen microbes to essential oils over time and discuss potential limitations in improving nutrient utilization and milk production in dairy cows (Benchaar, 2021).

Antimicrobial Activity

Significant attention has been attracted by essential oils within the domain of ruminant nutrition for their antimicrobial traits and potential influence on ruminal microbial fermentation, nutrient usage, and efficiency in milk production. Active elements are contained in essential oils which show antimicrobial functions across a broad spectrum of microorganisms that includes bacteria (gram-negative and gram-positive), protozoa and fungi (Benchaar et al., 2008). These antimicrobial effects have been attributed to various small terpenoid and phenolic compounds present in essential oils. Additionally, essential oils have been suggested as alternatives to traditional antimicrobials such as monensin, aiming to enhance feed efficiency, nutrient utilization, and milk yield in ruminants (Benchaar, 2020).

Investigations unveil that EO mixtures might sway the microbial brewing in the rumen by tweaking elements like the complete sum of volatile chunky acids (VFAs) and propionate turnout. Besides, discoveries denote that crucial oils along with their terpenic parts sway the metabolism within the rumen, microbial tribes, and eventually bear upon parameters linked with milk yielding (Lejonklev et al., 2016). Such influences on ruminal fermenting and microbe groupings underscore the promising use of essential essences as fodder enhancements for cud-chewing beasts. Moreover, exploring has been done on how vital scents adjust bacterial colonies engaged in fatty acid biohydrogenation inside the rumen which might provoke shifts in fatty acid profiles within dairy and flesh outputs from cud-munchers (Liu et al., 2020). While critical aromatic compounds exhibit promises in exerting anti-microbic actions and amping up certain slices of ruminal operation, divergent outcomes have been logged concerning their impact on fermentation inside ruminants' stomachs, consumption rate of nutrients, plus dairy generation among milking bovines (Benchaar, 2021). These disparities could be pinned to variables such as distinct essential scent blends utilized doses put into feed-specific nourishment practices for animals altogether clubbed with trial surroundings.

Impact on Ruminant Production

In general, the addition of EOs to the diets of small ruminants (goats and sheep) improves the Average Daily Gain (Andri et al., 2020). It has also been suggested that essential oils could potentially influence ruminal fatty acid biohydrogenation, thereby affecting the quality of milk and meat produced (Zhou et al., 2020). This effect is partly related to the antimicrobial activity of essential oils, which reduces the population of ruminal protozoa, potentially increasing microbial protein and energy supply, ultimately enhancing the growth rate of small ruminants (Soltan et al., 2018).

The addition of a supplement of EOs from anise, cinnamon, garlic, rosemary, and thyme in pre-weaned calves improves immunity and lower fecal scores in the pre-weaning phase. Hence, essential oils are a healthy additive option for modern production systems and could be used as an alternative to enhance calf health and performance (Palhares et al., 2021).

The essential oil of Greek oregano (*Origanum vulgare*), provided at doses starting from 1 mL in lactating Alpine goats, increases the activity of the enzymes glutathione peroxidase and reductase in both blood and milk, enhancing the antioxidant system and helping to minimize oxidative damage during lactation (Paraskevakis, 2018). In dairy cows, supplementation with oregano EO may alter the organoleptic characteristics of milk, without showing effects on feed conversion (Lejonklev et al., 2016; Hadrová et al., 2021). Supplementation with garlic extract (*Allium sativum*) in goats and sheep can increase milk production, protein content, and non-fat solids. However, it decreases the percentage of fat and non-protein nitrogen in milk (Ding et al., 2023).

The inclusion of rosemary essential oil (*Salvia rosmarinus*) in goats' diet improved nutrient digestibility, ruminal fermentation without affecting pH, daily milk production, fat and protein content, and at a dose of 230 g/animal/day in goats reduced milk coagulation time, decreased C10:0 and C14:0 fatty acids content, and increased the percentage of C17:0, C18:2 fatty acids, and polyunsaturated fatty acids (Smeti et al., 2021). This effect is similar to that reported by Kholif et al. (2017) when using lemongrass (*Cymbopogon citratus*) as a supplement in goats' diet.

In dairy cows, the addition of rosemary extract to their diet increases production and content of fats, proteins, and lactose, while reducing the number of somatic cells (white blood cells and epithelial cells) present in milk (Kong et al., 2022).

Moringa oleifera leaf extract at doses of 10 to 40 mL daily improves milk production by up to 6% in Nubian goats and increases total solids, non-fat solids, fats, proteins, and lactose in milk (Kholif et al., 2019).

The incorporation of rosmarinic acid, a chemical compound present in various plants, especially in the Lamiaceae family, in combination with probiotics as a food additive can increase average daily gain, starter intake, and total dry matter intake (Stefańska et al., 2021).

Alternative to Antibiotics

In intensive animal production for feed, antibiotics are used to prevent and treat various bacterial diseases. However, they are also used as a food additive to enhance the effectiveness of ingested foods in products for human consumption, such as milk and meat. This excessive and inappropriate use of antibiotics has led to the emergence of bacterial resistance, posing a threat to global health (Benchaar et al., 2020; Haulisah et al., 2021).

The most used antibiotics are a) tetracyclines, such as oxytetracycline, which are commonly used due to their broad-spectrum activity against a wide range of Gram-positive and Gram-negative bacteria (Almaraz-Buendía et al., 2019); b) penicillin, such as amoxicillin, frequently used in the treatment of respiratory and skin infections in ruminants; c) macrolides, particularly azithromycin, are commonly prescribed due to their anti-inflammatory and immunomodulatory properties, which are beneficial in managing respiratory diseases in ruminants (Montoya et al., 2022).

EOs are proposed as a sustainable alternative to antibiotics in the livestock sector, due to their antimicrobial properties and safety. For example, thyme and oregano oils exhibit strong antimicrobial and antioxidant activities. It is important to note that the antimicrobial activity of EOs is influenced by their chemical composition, and certain components such as carvacrol, thymol, and eugenol which play a significant role in determining their effectiveness against microorganisms (Redondo et al., 2021).

Below, studies on the use of essential oils that have proven to be effective in controlling bacteria and nematodes are discussed, suggesting their potential for disease control in ruminant livestock.

EOs from *Rosmarinus officinalis* (rosemary), *Melaleuca alternifolia* (tea tree), and *Cinnamomum cassia* (cassia) have high antimicrobial activity (Abers et al., 2021).

Extracts from *Caesalpinia spinosa* showed antimicrobial effect on antibiotic-resistant strains of *Staphylococcus aureus*. This study is relevant as it demonstrates the potential of extracts as an alternative to antibiotics and their potential application in animal health (Coral et al., 2022).

The essential oil of *A. sativum* has been shown to be effective in controlling nematode parasites in sheep, presenting the same effect as the synthetic agent albendazole at 10% (Masamha et al., 2010).

There are other EOs that have only been evaluated in vitro, such as the plants *M. afra* and *M. longifolia*, which are candidates for the treatment of gastrointestinal larval infections (Wells, 2023). Similarly, extracts from *Tithonia tubaeformis* have antioxidant and antibacterial effects on *Escherichia coli*, *Salmonella typhimurium*, *Salmonella enteritidis*, and Listeria (García-Vázquez et al., 2023). However, in both cases, the mechanisms of their in vivo efficacy have not yet been evaluated, and it is considered necessary to conduct in vivo safety and toxicity studies to determine the minimum non-lethal concentrations required for the treatment of infections in ruminants.

Methanogenesis Control

Methanogenesis is a biological process by which methane (CH_4) is produced by microorganisms called methanogens. This process is crucial in the degradation of organic matter in anaerobic environments, such as the rumen of ruminant animals and aquatic sediments. Methanogens are microorganisms belonging to the Archaea domain and are capable of synthesizing methane from organic substrates, such as hydrogen and carbon dioxide, or simple organic compounds, such as acetic acid.

Oregano oil and carvacrol are two essential oils that have been extensively studied for their ability to inhibit ruminal methanogenesis both in vitro and in vivo. These essential oils contain active compounds that can modulate ruminal microbial fermentation, potentially reducing methane emissions by affecting fermentation pathways and promoting alternative hydrogen sinks such as propionate production (Benchaar, 2020).

As evidenced by reports, aromatherapy fluids could enhance ruminant digestion by boosting volatile fatty acid production and decreasing methane emission by inhibiting the operations of bacteria responsible to produce methane. Ingredients like tannin compounds, soap-like materials, and ion transporters are likely causes of reducing methane levels in cud-chewing livestock through inhibiting methane-producing processes or dissolving digestion pathways. These agents can radically improve microbial populations within the stomach cavity, reducing emissions of gas and increasing feed utilization (Becker et al., 2023).

Challenges and Future Perspectives

Since EOs are hydrophobic and lipophilic, they could influence the ruminal environment in a similar way to antibiotic admixtures. The effects of EOs on bacterial membranes have been established in many studies and reduce microbial populations, contributing to a potential increase in the response. Other limitations include EOs' antinutritional qualities, modification of the product's palatability following animal acceptance, which might decrease dry matter intake (Almeida et al., 2021). Future perspectives lie in nutrigenomics, where ruminant nutrition engineering can be guided by assessing current challenges and proposing new directions for the field (Kizilaslan et al., 2022).

EOs, as volatile secondary metabolites of plants, are gaining popularity as alternatives to traditional growth-promoting antibiotics, offering a sustainable approach to improving ruminant nutrition (Nel et al., 2021). They have the potential to reduce ruminal protozoa populations, increase microbial protein and energy supply, and ultimately improve growth rates in small ruminants (Andri et al., 2020). The use of EO may contribute to methane mitigation in ruminant production systems, aligning with sustainable practices (Durmic et al., 2021). By harnessing plant bioactivity to reduce methane, strategies involving low-methanogenic forage species and plant-derived by-products can offer renewable solutions with minimal impacts on forage digestibility, especially if complemented with EO positively impacting ruminal fermentation and microbial communities, to enhance the health attributes of animal products (Zhou et al., 2020).

Conclusion

One potential perspective is nutrigenomics, as the application of essential oils in the nutrition of ruminants is a substitute for chemosynthesis drugs, increases the animal's well-being and productivity. The overall daily increase in weight with a EO does not harm feed intake and FCR. Their use influences animal products as the acids in milk can contribute to meat preservation, reducing the need for additives. One significant effect of EO use is the reduction of enteric methane production. However, there are still controversial outcomes as ruminal microbiota can adapt to EO presence, diminishing antimicrobial and antiparasitic effects or reducing food degradation by minimizing volatile fatty acid production, thus making certain essential nutrients less accessible for animal development.

The generation of new *in vivo* research is essential, considering parameters such as dosage, addition method to the diet, duration of use, age and species of the animal, as well as the synergistic effect with other compounds like phenolics or animal diet ingredients.

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Chapter 08

Balancing Act: Essential Oils as Cost-Effective and Eco-Friendly Disease Control in Aquatic Environments

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ABSTRACT

Aquatic environments, critical to both ecological balance and human industry, face significant threats from pathogenic microorganisms. Conventional chemical treatments, though effective, often lead to environmental degradation and high costs, prompting the need for sustainable alternatives. This study explores the potential of essential oils as cost-effective and eco-friendly agents for disease control in aquatic systems. Essential oils, derived from various plants, exhibit potent antimicrobial properties against a broad spectrum of pathogens. Our research focuses on evaluating the efficacy of essential oils such as tea tree, eucalyptus and thyme in controlling common aquatic pathogens, including Vibrio spp., Aeromonas spp., and Pseudomonas spp.

KEYWORDS
Conventional, Sustainable, Degradation, Microorganisms, Pathogens

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INTRODUCTION

The farming of aquatic plants and animals, at a 4.5% annual growth rate, has established aquaculture as a rapidly expanding industry and its yearly value is put at $243.26 billion. Aquaculture is important in meeting the high protein requirements of the world's increasing population, contributing to 50% of the total fish used globally and at the same time is a source of employment and income. Nevertheless, super-intensive techniques have led to the environment being destroyed in aquatic ecosystems because they use much more stock densities and provide more artificial feed (Dawood et al., 2021). Medicinal plants are used in more quantities for aquaculture due to their biodegradability, accessibility, and lack of residues in animal tissues. Essential oils are secondary metabolites of plants that have bioactive qualities that make them excellent phytotherapeutic agents for sustainable aquaculture (Magouz et al., 2021).

Both specialized and generalist parasites inherently live in fish hosts; certain parasites can easily adapt to aquaculture environments and present health problems when infection levels are high. Furthermore, the problem becomes more complex when these parasites find their way into wild stocks after first being reared in captivity as in aquaculture (Buchmann 2022). Since parasitic infections affect the entire population in addition to the individual, the community as a whole must be the target of the response, not the individual. These issues have prompted research into using herbal plants as a substitute for treating parasite illnesses in fish kept in aquaculture. Fish aquaculture may benefit from herbal medicine as an alternative, since it may be less expensive and more efficient than chemotherapy (Soares et al., 2017).

Essential oils are any volatile oil or oils with aromatic elements that can alter a plant's flavor, odor, or scent. The phrase "Essential Oil" was first used by Swiss medical reformer Paracelsus von Hohenheim. It comes from the Latin "Quinta essentia," which refers to a potent medicinal ingredient. These oils are mostly found in glandular hairs or secretory cavities inside plant cells, as fluid droplets at different plant parts like roots, stems, barks, leaves as well as fruits or flowers. They are made up of terpenes comprising monoterpenes, diterpenes, and sesquiterpenes as well as terpenoids but also oxygenated derivatives such as phenolic compounds alcohols, ketones, esters, aldehydes, ethers, or oxides. Moreover, they have compounds belonging to phenylpropanoid and phenolic groups of chemicals, whose biosynthesis starts with the acetate-mevalonic and the shikimic acid pathways, respectively (Sil et al., 2020).

To fight infections and boost immune responses, antibiotics are widely used in aquaculture. However, this approach carries several concerns, such as the emergence of drug-resistant microbes and environmental dangers. This procedure may result in microbial population imbalances, weakened host immunity, and bacterial resistance, all of which could harm aquatic animals' general health. In fish farming, the use of chemicals like formalin, sodium chloride, and copper sulfate could lead to the selection of resistant organisms as well as the accumulation of dangerous residues that put the environment and human health at risk. Therefore, there is a need for sustainable alternatives in aquaculture given the high cost of conventional anthelmintic medicines. It is well-recognized that medicinal herbs are a good, sufficient, and environmentally safe substitute for antibiotics.

Biological and chemical methods to control diseases, for example, probiotics or prebiotics; also, medicinal plants are used. Keeping certain disease-causing agents out of a specific system is made possible by aquaculture biosecurity measures. It's common for Aquafeed to include a variety of supplements such as prebiotics, probiotics, or herbal ingredients aimed at promoting animal health and well-being. Incorporating medicinal plants and their extracts into Aquafeed serves multiple physiological purposes due to the active metabolites they contain acting as functional components (Dawood et al., 2022).

This chapter will delve into essential oils as a potential solution, exploring research findings, their effectiveness, and the mechanisms by which they act on pathogens. Additionally, it will discuss future directions for safely utilizing essential oils on aquatic organisms.

Overview of Common Diseases Affecting Aquatic Environments

Certain diseases are specific to aquatic organisms, for instance, fish, but other diseases are widespread within the entire aquatic environment (Stuart et al., 2018). Common diseases that affect aquatic environments are;

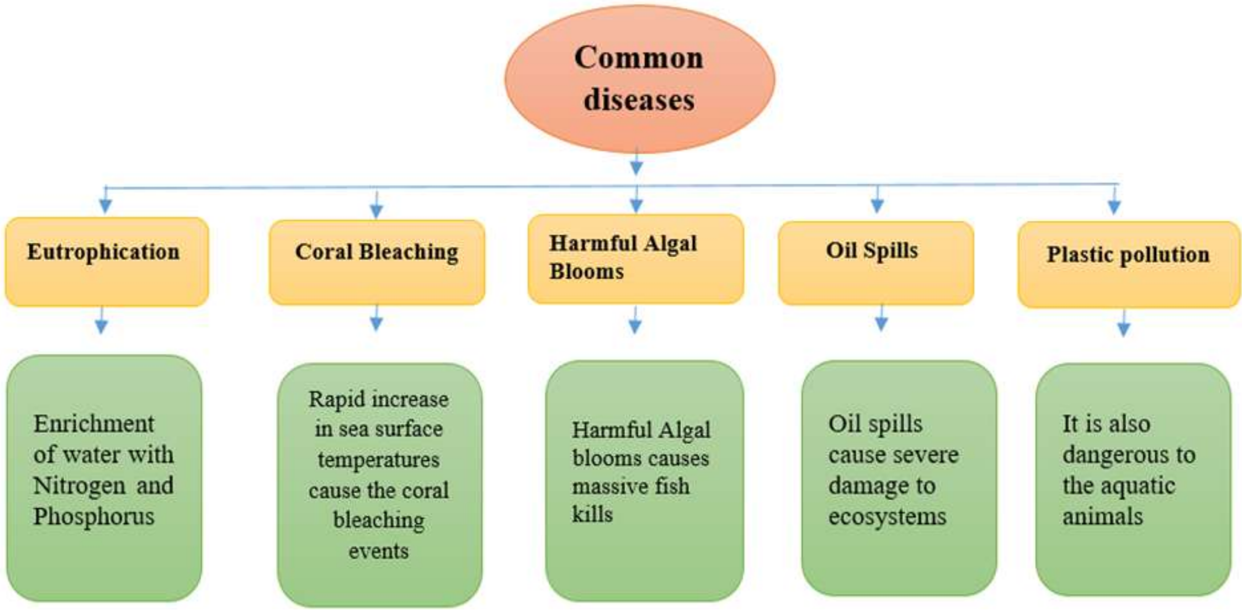

Fig. 1: Overview of common diseases

Impact of Diseases on Aquatic Ecosystems and Industries

The environment in the aquatic system is very complex since all food resources are supplied in the same system where waste and by-products of excretion are also present. Aquatic environments are not static because they are affected by changes that may happen both “within and without.” Especially “Physico-chemical changes” make fish diseases complex as the fish environment is dependent on several other factors like plants, soil, and other animals living in the water. The most common cause of environmentally induced diseases is “poor water quality” because changes in water parameters result in direct or indirect effects on fish.

The aquatic ecosystems are ultimate absorbers of contaminants. Water pollution is caused by human actions like urbanization, industrialization, and agriculture. Abundant application of pesticides and fertilizers as well as sewage leads to infections that include “dysentery, diarrhea, and jaundice”.

In the ecosystem of water, contamination is one of the types of pollution that is extremely detrimental to human health concerns. “Water is naturally capable of neutralizing contamination”, but when pollution is beyond our control, water loses its ability to self-generate. Industrial spills and leakages contribute to the initiation of the process of “water pollution”. Most aquatic ecosystems have a “natural ability to dilute pollution” but severe pollution leads to a change in the “fauna and flora” of a community.

Current Methods of Disease Control and their Limitations

Pharmaceutical products are a major factor in “the improvement of quality of life”. Many active organic and inorganic compounds have been used for the "treatment and cure of numerous diseases".

The risk of "epidemic transmission" especially due to global warming has heightened. Identifying the "pathogen types, epidemic season, temperature variations, and environmental conditions" that cause the transmission of diseases is critical for prevention or treatment strategies (Jiang et al., 2023).

Methods of Disease Control

The prevention and control of aquaculture health by a single approach is not successful in itself. The mixture of different strategies, rather than the usage of a single strategy, is effective. Establishing a national or regional information exchange between farmers and responsible parties might be advisable. "Prevention is often better than treatment", thus it is recommended to concentrate on the prevention of disease rather than treatment. These are methods of controlling aquatic diseases;

- Antibiotics
- Vaccination

Antibiotics are "chemotherapeutic agents" that prevent or inhibit the growth of microorganisms, such as bacteria, viruses, and fungi. These are used as "antibacterial or antifungal". Their frequent release in water becomes the main concern in the continuing spread of "multi-resistance" in bacteria, which is a precursor for serious health-related problems (Torres et al., 2017).

Vaccination is a major factor in "avoiding and managing infectious disease in fish". There are some recent developments in fish vaccination recently. Vaccination is being used in large numbers for almost all food animals. In fish farming, it can prevent infectious diseases. It also prevents the risk of "drug resistance". Vaccines are so widely accepted because there is no risk of drug resistance development. Modern vaccines are classified as "killed, attenuated, DNA and genetically modified".

Limitations and Challenges

- The important challenge in diagnosing the disease of fish is "the individual fish is the unit of interest". The use of antibiotics is under restriction due to "drug resistance".
- "Formulation of vaccines towards intracellular bacterial and viral pathogens" would be among the major challenges for the next few years.
- Probiotics too can acquire antibiotic resistance because live bacteria are added in high numbers, which have high levels of antibiotic resistance genes (Watts et al., 2017).

Introduction to Essential Oils

Essential oils (EOs) can be defined as any type of volatile oils that contain aromatic components and can give variation in aroma, odor, or flavor to the plant. These are primarily a by-product formed during plant metabolism, also called volatile secondary plant metabolites. The term "Essential Oil" is supposed to be originated in the sixteenth century coined by Paracelsus von Hohenheim, which is a Swiss reformer of medicine, from the term "Quinta essential", which means an effective constituent of a drug (Sil et al., 2020).

In general, EOs account for less than 5% of vegetable dry matter, which is a very small part of the plant's total composition. All plant organs, especially the buds, flowers, leaves, stems, seeds, and fruits, synthesize EOs. EOs can be stored in secretory cells, cavities, epidermal cells, or glandular trichomes. EOs are usually liquid, volatile, colorless at ambient temperature, highly soluble in fixed oils, organic solvents, and alcohol but poorly soluble in water. A total of 3000 types are identified as EOs, from which only 300 are found to be of industrial importance for use in the food industries, often for the fragrances and flavors market. For plants, EOs perform many important functions in nature, particularly chemical and aromatic characteristics, such as

- Attracting beneficial pollinators and insects
- Protecting plants from environmental stress (cold, heat, etc.)
- Shielding plants from microorganisms and/or pests

EOs are globally known for their biological activities, including antifungal, antioxidant, antiviral, antimicrobial, insecticidal, antiparasitic, and antimycotic properties. Due to these activities, many EOs are used in agriculture (repellent and bio-pesticide), in cosmetics (make-up products and perfumes), as natural remedies in aromatherapy and sanitary products (aromas in cleaning products for household) (Falleh et al., 2020). EOs can be used as food additives in industry and bioactive packaging due to their antimicrobial properties, especially for the preservation of cereal grains, fruits, legumes, and meat products (Almeida et al., 2024).

Previous research has revealed that essential oils and their major components, such as carvacrol and thymol, are active against *Salmonella* spp. *Staphylococcus aureus*, *Escherichia coli,* and *Bacillus cereus* but are less efficient against *Pseudomonas* spp. due to the formation of exopolysaccharides that increase resistance to these compounds. Due to variations in the composition of cell membranes, most EOs have a greater bactericidal impact on Gram-positive bacteria than on Gram-negative. For example, an experiment revealed that the administration of essential oils (such as carvacrol, thymol, anethole, and limonene) as feed additives offer protection in Rainbow Trout against *Aeromonas salmonicida* infection. Higher survival rates in White Shrimp post-larvae were shown by dietary supplementation of neem (*Azadirachta indica*) or oregano (*Lippia berlandieri Schauer*) extracts when exposed to *Vibrio parahaemolyticus* infection as compared to the control group (Perez-Sanchez et al., 2018).

The Efficacy of Essential Oils in Disease Control

EOs are intricate blends made up of more than 300 distinct substances. They are made up of organic volatile substances, most of which have small molecular weights. EOs are generally found in the vapor state at room temperature and atmospheric pressure due to their suitably high vapor pressure (Dhifi et al., 2016).

Bacterial membranes and their cytoplasm can both be impacted by EOs. The breakdown of cell walls, harm to membrane proteins and the cytoplasmic membrane, as well as decreased ATP production and proton motive force, are some of the pathways of action of EOs. Because EO chemicals are lipophilic, they can pass through cell membranes and stay in the space between phospholipids. EOs primarily enter bacterial membranes and operate on their cytoplasm and membranes to change the morphology of their cells and the abnormalities of their organelles, thereby blocking their action mechanisms. The heightened sensitivity of gram-positive bacteria to essential oils (EOs) compared to gram-negative bacteria often stems from the presence of lipoteichoic acids in their cell membranes. These acids may facilitate the penetration of the hydrophobic compounds found in essential oils (Zanetti et al., 2015).

Chitin plays a vital role in constructing the fungal cell wall, which is indispensable for fungal survival. This cell wall is crucial for the growth and vigor of fungi. Inhibiting chitin polymerization can impede cell division and growth, affecting the maturation of cell walls, septum development, and bud ring formation. Essential oils (EOs) emerge as one of the most promising natural products for inhibiting fungi. Similarly, arginine is converted into nitric oxide (NO) by bacterial nitric oxide synthases (bNOS). The NO produced by bNOS gives bacteria a wider range of antibiotic resistance, enabling the bacteria to coexist and share environments with microorganisms that produce antibiotics. NO-mediated resistance is attained by reducing the oxidative stress that many antibiotics inflict, as well as by chemically altering harmful substances. EO oil has the potential to be used in the treatment of oxidative damage since it can lower nitric oxide levels, restrict the synthesis of H2O2, and inhibit NO synthase (Nazzaro et al., 2017).

Research on the utilization of herbal remedies as additives in aquatic feeds for the prevention and treatment of illnesses has seen significant growth since the 1990s (Valladao et al., 2015). By adding myrcene, menthol, and 1, 8-cineole to its diet, the growth performance, immune status, antioxidant status, and resistance to environmental ammonia of Common Carp *(Cyprinus carpio)* were improved. Furthermore, Dawood et al. (2020) showed that Nile Tilapia-fed diets supplemented with carob syrup *(Ceratonia siliqua)* exhibited improved immunity, tolerance to ammonia exposure, and growth performance. Lately, exposure to dietary menthol essential oil has had a positive impact on the growth rate and anti-oxidative capability, as well as an anti-inflammatory response among Nile tilapia suffering from chlorpyrifos toxicity.

Several studies have highlighted the antimicrobial efficacy of essential oils and their primary *constituents, such as thymol and carvacrol, against Salmonella spp., Bacillus cereus, Staphylococcus aureus*, and *Escherichia coli*. However, their impact on Pseudomonas species is less pronounced due to the development of exopolysaccharides, which enhances tolerance to certain substances. Due to alterations in the structure of cell membranes, most essential oils exert a stronger bactericidal effect on Gram-positive bacteria compared to Gram-negative bacteria, although the specific mechanism of action varies depending on their chemical composition (Perez-Sanchez et al., 2018).

A new study has proven that Channel Catfish *(Ictalurus punctatus)* increases feed intake and growth as well as mean corpuscular hemoglobin (MCH) content when reared in low temperatures with flax seed oil supplementation as opposed to the supplemented diet (Thompson et al., 2015). A comparative study has further revealed that administrating dietary extract of papaya *(Carica papaya)* significantly increases the growth rate and helps in the maturation of gonads in both male and female Tilapia.

Economic Considerations of Using Essential Oils for Disease Control

The considerations that comprise all the factors like money-making, presence of resources, prices, etc. which were involved in the act of deciding by the individuals which are the basis of elevation of good economic outcomes are called economic considerations.

Some essential oils have attributes to curb parasitic diseases in fish, to test these attributes, in vitro studies were used. The main factors of utilizing in vitro studies are:

- Their cheap price.
- Their speedy outcomes.
- Their eventuality of an apparent act of screening.
- Presence of certain essential oils (Tavares-Dias, 2018).

Potential Cost Savings of Using Essential Oils

A remarkable number of plants were required to extract essential oils in minute quantities. For example, one drop of Rose Otto essential oil is formed by using rose petals of thirty to fifty roses.

While buying essential oils, some of the points given below assist in money saving:

- A small quantity of essential oil lasts for a long time because of its concentrated appearance.
- Prefer to buy essential oil aggregates than a single particular aromatic oil.
- Buying pre-diluted aromatic oils.

➢ When well-known companies or brands offer discounts, it is better to purchase essential oils from those brands or companies.

Examples of Essential Oils and Benefits of Using These Essential Oils
Example no. 1, Thymol Essential Oil

Thymol essential oil is given to fish and poultry animals because of its numerous advantageous components that are beneficial for the body of the animals. The Thymol essential oil is used to ameliorate:

- Functionality variables
- Sexual performances
- Utilization of nutrients
- Working of immunity cells of the body
- Prohibiting the body from pathogenic agents and diseases.

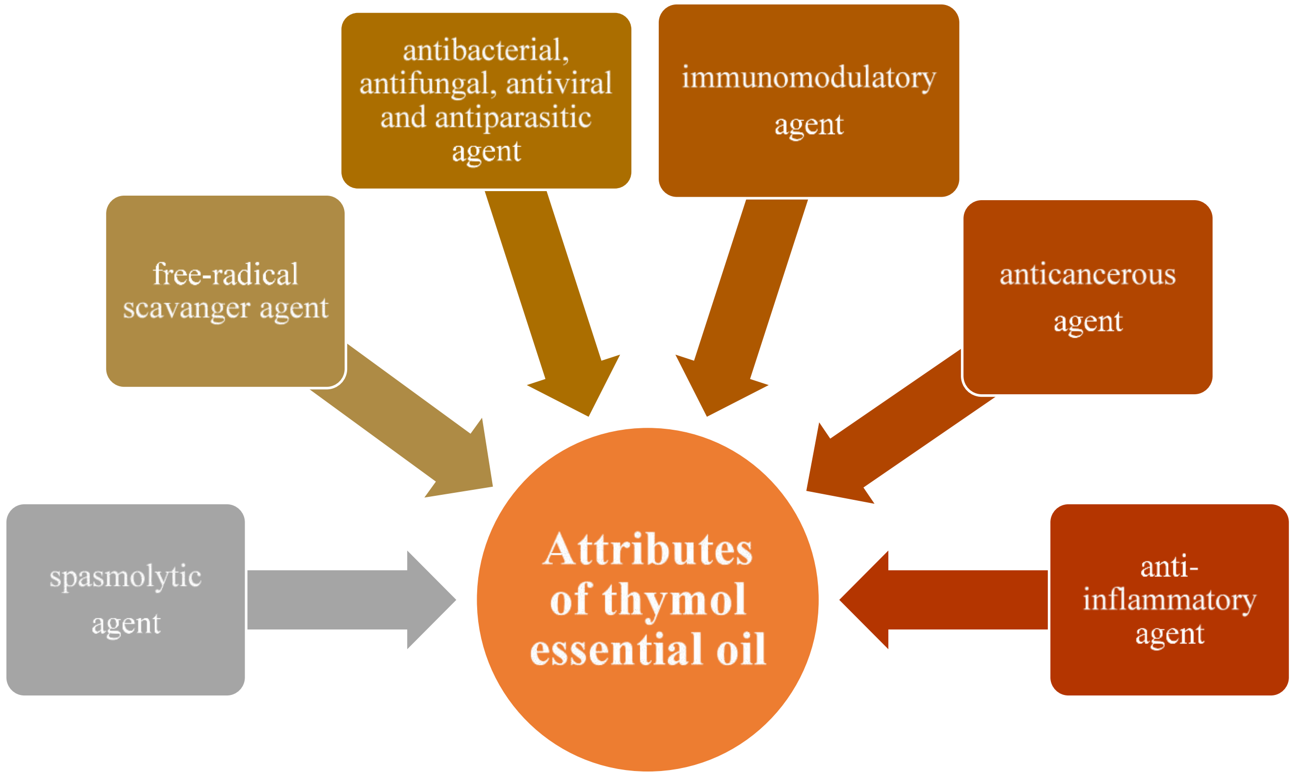

Fig. 1: Some attributes of thymol essential oil (Ezzat Abd El-Hack et al., 2016)

Example no. 2, Clove Oil

To perform small-scale surgical operations on the fish, a small amount of clove oil is applied to anesthetize the fish. Applying this oil in large quantities is responsible for fish assassination.

Comparative Cost Analysis with Conventional Disease Control Measures

The deed of splitting the cost of a summary into its parts and then analyzing and describing every factor is termed cost analysis.

Environmental Impacts of Traditional Disease Control Methods

Specific kinds of physical deeds that cause variations in the man-made and innate environments and these modifications have disastrous impacts on aquatic organisms, terrestrial organisms, birds, mammals, invertebrates, and other residents of the environment are termed as environmental impacts.

➢ The quality of soil is influenced by regular sowing, plucking, and gathering of food crops and many trees were demolished to collect the sap to get the resins which is responsible for the origination of essential oils, so the formation of essential oil is the root cause of removal of trees.

➢ **In vitro studies of using essential oils to control fish parasites**: These studies are used to overcome parasitic diseases in fish due to monogeneans that were the main cause of huge amounts of fish loss.

➢ **In vivo studies of using essential oils to curb fish parasites:** These studies are used to medicate fish infected with external parasites and they are separated from the body of fish by the application of short-duration or long-duration baths in which seeking essential oils were used.

- The quality of water is ameliorated by the insertion of essential oils.
- For the betterment of the physical condition of fish, essential oils were added.
- Parasites were also removed from the body of fish by the inclusion of essential (Tavares-Dias, 2018).

Table 1: Cost analysis, dose and duration, and impacts of different essential oils on immunity, growth, and infectious diseases of fish species

Fish species	Essential oils	Dose and Duration	Cost per 10ml (according to Pakistani currency)	Effects (growth, immunity, and infectious diseases)	References
Mozambique tilapia (*Oreochromis mossambicus*)	Bitter lemon (*Citrus limon*)	0.5, 0.75, and 1% for 60 days	*Rs. 690 for 10ml*	Growth indices and feed utilization increase Nitroblue tetrazolium (NBT), white blood cells (WBCs), Blood total protein, lysozyme, and myeloperoxidase activity (↑) – Serum glucose and triglycerides (↓) Resistance against *Edwardsiella tarda* (↑)	(Baba et al., 2016)
O. mossambicus	Sweet orange (*C. sinensis*)	0.1, 0.3, and 0.5% for 60 days	Rs. 550-570 for 10ml	Growth indices and feed utilization (↑) – Lysozyme and myeloperoxidase activity, hematological and biochemical variables, i.e., hemoglobin (Hb), hematocrit (Htc), albumin, and globulin (↑) - Blood glucose and cholesterol (↓) – Resistance against *Streptococcus iniae* (↑)	(Acar et al., 2015)
O. niloticus	*Origanum vulgare*	5 and 10% for 8 weeks	Rs 1,750 for 10ml	Growth indices and feed utilization (↑) Antioxidant activities (↑) Resistance against *Vibrio alginolyticus* (↑)	(Abdel-Latif and Khalil, 2014)

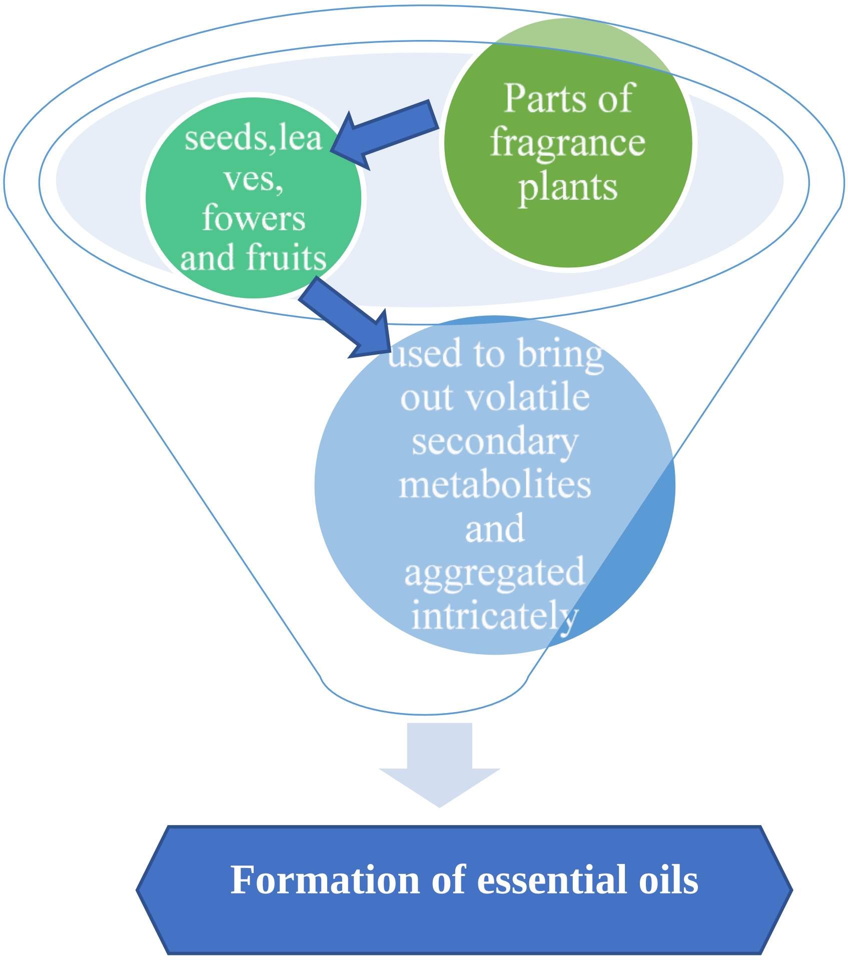

Fig. 2: Extraction of essential oils (Raghuvanshi et al., 2023)

Eco-Friendly Aspects of Essential Oils

Ecologically safe additives were used to keep away from the immediate and non-immediate influences on the aquatic environment and physical condition of humans. Some essential oils were operated as a natural pesticide. To protect the crops from pests, some essential oils worked as preventive and prohibitive agents to keep the insects away from plants.
For humans, essential oils are used for:

- Making skin products
- Betterment of mood and alleviating pain by scent therapy.
- Wiping homes, schools, and offices by using harmless essential oil-based cleaners to prevent these places from air pollution and water pollution.

Lemon and Peppermint essential oils and mixtures of oils like Purification are usually inserted in fish aquariums. These oils are used for the removal of microorganisms and other pathogenic components from the water to shield the fish.

Lavender, orange, and tangerine essential oils are given to fishes. They are sometimes protective but sometimes they are not protective of all fishes. Some of them are responsible for ameliorating and conferring immunity to some infections or diseases when taken up by fish.

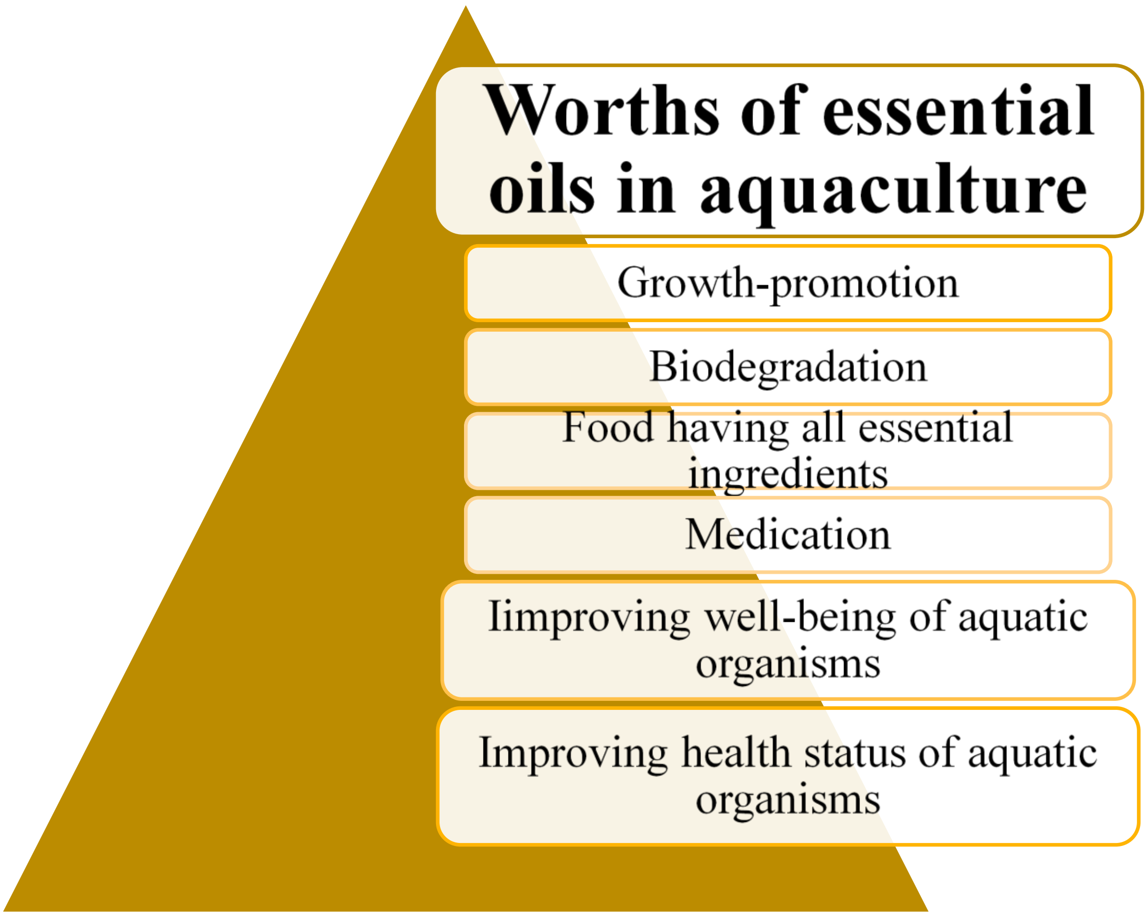

Fig. 3: Usefulness of essential oils for aquatic (Dawood et al., 2022)

Sustainability Aspects of Essential Oil Usage in Aquatic Environment

The potentiality to conserve, restore, or reinforce an activity eventually is known as sustainability. Three fundamental concepts of sustainability are:

1. Profitable
2. Ecological
3. Communal

Using Diffusers

The extremely frequent means to apply essential oils for peacefulness is with a diffuser. To protect the aquatic organisms, it was suggested by the fish owners to place the aquarium away from the diffusers because sometimes specific types of essential oils were harmful to the body of fish so their toxic diffused vapors could become the fundamental cause of death of fish.

Inclusion of Essential Oil in Glass Aquarium

Insertion of essential oils in an aquarium made of glass is much more secure and reliable than adding it in a tank made of plastic because the reaction between the chemicals present in the essential oils and the plastic tank poses disastrous impacts on the fish. Start adding essential oils in small quantities and then increase their quantity with time so that the fish can become habitual of these oils.

Practical Applications and Case Study

Essential oils have diverse properties that can improve the welfare, growth, and health of animals, as well as lessen the stress processes that's why these are used in aquaculture studies. Recent studies revealed that EOs can reduce or eliminate stress caused by varying stocking densities. In Silver Catfish, exposed to a stressful environment of high stocking density, dietary administration of 0.50mL/kg *Lippia alba* EO prevents the cortisol levels from rising. Similarly, a diet containing *Myrcia sylvatic* (2.0mL/kg) EO for ninety days decreased the levels of cortisol in Gilthead Seabream after 22 days at high stocking density (40kgm^{-3}) (Souza et al., 2019).

Studies demonstrated that the disease resistance to *Vibrio parahaemolyticus* of Pacific White Shrimp remarkably increased by adding 0.3gkg^{-1} essential oils and organic acids blend into the control diet. Similar results were observed in shrimp-fed diets containing plant extracts and citric acid. Also, enhanced disease resistance by dietary essential oils against bacterial pathogens has been reported in Mozambique Tilapia, Rainbow Trout (*Oncorhynchus mykiss*), and Channel Catfish (*Lctalurus punctatus*) (He et al., 2017).

The antimicrobial activity of essential oils from *Mentha piperita, Lippia sidoides, Lippia alba, Zingiber officinale*, and *Ocimum gratissimum* was investigated against *Streptococcus agalactiae*. With minimum bactericidal concentration (MBC) ranging from 416.7-2,500µgmL^{-1} and minimum inhibitory concentration (MIC) ranging from 312.5-2,500µgmL^{-1}, all tested essential oils revealed bactericidal action against *S. agalactiae*. In this study, essential oil *L. sidoides* demonstrated better findings against *S. agalactiae* (Majolo et al., 2018)

Recently, it has been observed in many species that EOs can be used as sedatives or anesthetics to reduce possible harm to fish during handling. Lower levels of EOs can be used that cause light sedation and tranquilization for minor procedures such as collection of blood samples and biometry to reduce stress and minimize cortisol levels of plasma. In handling processes, the suggested concentration is 10-30mgL^{-1} for clove oil (extracted from *Syzygium aromaticum* or *Eugenia aromatica*) (Souza et al., 2019).

Challenges and Limitations

The use of antibiotics or vaccines is an effective way to prevent diseases in the aquaculture industry, but the mass killing of beneficial aquatic bacteria is also involved in it (Ahmad et al., 2021). Several researchers found out that essential oils cause fish toxicity and that affected "its embryotoxicity, mortality, developmental abnormalities, the hatching rate of embryo and swimming activities of fish" (He et al., 2018).

Opportunities for Further Research and Development

Many essential oils are highly instrumental in the process as they "enhance the defense system of the aquatic organisms". The research on the transcriptomic profiles of fish is still ongoing to see the effects of botanical EO concentrations on the immune response or disease resilience (Dawood et al., 2022).

Future Trends and Potential Advancements in the Field

EOs are going to be significant for the creation of products exhibiting "antibacterial characteristics". The essential oils have been examined for their capability to be used as bio-pesticides, which are highly degradable in the environment and comparatively safe (Pintong et al., 2020).

Studies on the "cytotoxic activity" of plant extracts and essential oils in tumor cells have produced promising results for "new cancer therapies or enhancement of the effectiveness of existing cancer drugs". Plant-derived essential oils have surfaced as an "eco-friendlier" method of producing metal nanoparticles in more recent times (Salehi et al., 2020).

New Perspectives on the use of Essential Oils and Plant Extracts

The toxicity of essential oils and plant extracts to insects that damage crops and their potential use as bio-pesticides have been the subject of numerous studies in recent years, making this one of the most researched potential uses of these substances. Utilizing nano-emulsion and essential oils (EOs) or other herbal remedies to treat microbiological illnesses is seen to be "a novel and sustainable aquaculture strategy". EOs serve as "natural preservatives, stress relievers, herbal anesthetics, and immunomodulatory medicinal plants" in the fisheries and aquaculture industries (Gonzales et al., 2020).

Conclusion

The international community acknowledges the existence of alternative approaches to address some of the most prevalent illnesses in fish farming. Nevertheless, the knowledge gained from previous experiences holds valuable insights, and new research has further substantiated the importance of using environmentally sustainable methods to implement disease control measures in aquaculture. Therefore, the task is to accomplish it. Previous encounters with different types of animal husbandry have demonstrated that antiparasitic drug resistance has emerged consistently when stringent control methods have been implemented. This has led to the ineffectiveness of the majority of traditional anthelmintics. Thus, chemotherapeutics will be used less frequently in fish farming as herbal products, including essential oils, are more widely used. The usage of these natural compounds, together with other preventive measures, will gradually rise to decrease disease outbreaks. In addition, fish metabolic pathways often flush EOs out of the body rapidly due to the components' sensitivity and low molecular weight.

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Chapter 09

Fungitoxic Properties of Essential Oils to Treat Tinea

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ABSTRACT

Dermatophytes responsible for causing various skin diseases confined to keratinous tissues in humans are divided into three genera, i.e. Trichophyton, Microsporum, and Epidermophyton. Pathologic clinical manifestations caused by these microbes are divided into tinea pedis, tinea corporis, tinea cruris, tinea capitis (head), tinea faciei (face), tinea barbae (beard), tinea corporis (body), tinea manus (hand), tinea cruris (groin), tinea pedis (foot), and tinea unguium (nail), depending on the affected place. Essential oils, characterized as concentrated, volatile, fragrant, hydrophobic, oily liquids with diverse functional groups, exhibit potential as treatments for tinea owing to their absence of side effects and the escalating antifungal resistance. Monoterpenes and sesquiterpenes (alcohols, ethers, phenols, polysaccharides, aldehydes, and ketones) and terpenes (phenolic compounds) are responsible for the antimicrobial activity of essential oils. Essential oils of *Melaleuca alternifolia* (tea tree oil), *Azadirachta indica* (neem), *Eucalyptus citriodora*, *Cymbopogon martini* (palmarosa), *Foeniculum vulgare* (fennel seed oil), and *Citrus bergamia* (bergamot) individually and in various essential oil combinations have demonstrated their high efficacy in dermatophytosis therapy.

KEYWORDS		
Essential Oils, Dermatophytosis, Antifungal Resistance, Natural Remedies, Synergistic Effects, Clinical Trials	Received: 17-May-2024 Revised: 23-July-2024 Accepted: 13-Aug-2024	A Publication of Unique Scientific Publishers

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INTRODUCTION

The growing prevalence of serious human pathogenic infections caused by dermatophytes, particularly among low-immunity persons, has prompted significant attention and calls for proactive measures in recent decades (Arif et al., 2009). Trichophyton, Microsporum, and Epidermophyton are the only known genera of dermatophytes responsible for causing various skin diseases in humans, such as athlete's foot, ringworm, and jock itch. The human body's hair, skin cells, and nails are significant components rich in keratin. Dermatophytosis, a condition caused by dermatophytes, is confined to areas of the human body containing one or more of these keratinous tissues (Saxena, 2021).

Tinea pedis, tinea corporis, tinea cruris, and other pathologic clinical manifestations are caused by these microbes that metabolize keratin (Sahoo and Mahajan, 2016). They are clinically classified into various types of tinea, comprising tinea capitis, tinea faciei, tinea barbae, tinea corporis, tinea manus, tinea cruris, tinea pedis, and tinea unguium, depending on the specific location of the infection. Majocchi granuloma, tinea imbricata, and tinea pseudoimbricata are other clinical variations. The most common of these is tinea pedis, or athlete's foot, which causes discomfort in the afflicted areas. Firstly Pellizari characterized it in 1882 (Pellizzari, 1888). While tinea pedis is not a fatal illness, it can significantly affect lifestyle of those affected. It is imperative to recognize that when the immune system is weakened by illnesses or certain treatments like AIDS and immunosuppressive medications, tinea pedis can progress into more dangerous secondary infections (Houghton et al., 2006). Adults are often less susceptible to tinea pedis due to their increased ability to defend against fungal infections of triglycerides in the sebum produced after puberty. However, postmenopausal women are more susceptible to developing tinea pedis due to their lower levels of triglycerides compared to other people (Gupta and Summerbell, 2000). Human feet are common sites for tinea pedis infections, which can spread from soil, animals, and humans. These infections play a significant role in causing superficial mycoses, often leading to frequent relapses and proving resistant to therapy (Gupta, and Cooper, 2008).

The escalation of resistance to antifungal agents as a consequence of pharmacological pressure represents a mounting global concern (Revie et al., 2018). Antimicrobial resistance fosters the survival and propagation of pathogens by conferring the ability to withstand antibiotic eradication (Nainu et al., 2021). This resistance has engendered heightened complexity in the treatment of fungal maladies, resulting in protracted morbidity and mortality. Prolonged administration of antifungal therapeutics may elicit substantive deleterious effects on human tissues (Gnat et al., 2020).

Researchers are increasingly interested in developing novel antimicrobial medications from natural materials due to their diverse chemical properties (Orchard et al., 2019). Essential oils (EO) have shown promising potential in effectively combating both fungal and bacterial pathogens, indicating their potential as a valuable treatment for superficial fungal infections (Orchard et al., 2017). EOs are hydrophobic, concentrated, volatile, fragrant, oily liquids having different functional groups, can be extracted from a variety of plant parts, including flowers, seeds, leaves, branches, bark, fruits, and roots. Crucial terpenoids, often known as volatile oils because of their propensity to readily diffuse into the atmosphere, are typically the molecules that give herbs, spices, and perfumes their distinctive flavour and aroma. Monoterpenes and sesquiterpenes, which include alcohols, ethers, phenols, polysaccharides, aldehydes, and ketones, are the primary components of EOs and are also responsible for their aroma and biological activity. Essential oil’s phenolic constituents have also been identified as antibacterial bioactive ingredients (Chanthaphon et al., 2008).

Essential oils derived from medicinal plants have shown potential as alternative agents to combat fungal infections (Khan and Altaf, 2020). Essential oils of *Melaleuca alternifolia*, *Azadirachta indica*, *Eucalyptus citriodora*, *Cymbopogon martini*, *Foeniculum vulgare* and *Citrus bergamia* have been used to treat tinea due to their antimicrobial and antifungal activity. Furthermore, scientific evaluation of various essential oil combinations has demonstrated their high efficacy in dermatophytosis therapy.

Tinea Corporis

Fungi known as dermatophytes infiltrate and proliferate within keratinized tissues, such as the skin, hair, and nails, resulting in infection (Weitzman and Summerbell, 1995). Dermatophyton (causing infections on all keratinous tissues), Epidermophyton (causing infections on skin and nails), and Microsporum (causes skin and hair infection) are the three groups into which dermatophytes can be divided on the basis of genera. These have been divided into three categories: geophilic, zoophilic, and anthropophilic, depending on how they spread. Ultimately, these have been clinically divided into tinea capitis (head), tinea faciei (face), tinea barbae (beard), tinea corporis (body), tinea manus (hand), tinea cruris (groin), tinea pedis (foot), and tinea unguium (nail), depending on the affected place. Majocchi granuloma, tinea imbricata, and tinea pseudoimbricata are other clinical variations.

This field has frequently had little research done in it, despite the fact that cutaneous dermatophytosis is growing increasingly prevalent globally, especially in tropical areas. In reality, the American Academy of Dermatology's recommendations for treating tinea corporis and cruris date back almost two decades (Drake et al., 1996), and in the modern world, they seem, at best, insufficient. With little mention of tinea corporis/cruris, the updated guidelines, which were released by the British Association of Dermatology and the British Medical Journal have mostly concentrated on tinea capitis and tinea unguium (Ameen et al., 2014; Fuller et al., 2014). Updated Cochrane studies on topical treatment for tinea corporis, cruris, and pedis have helped close this knowledge gap, but there aren't many on oral medications. Nonetheless, there are noticeably lacking well-planned studies, national and/or international evidence-based guidelines, and suggestions about the amount and length of time to use systemic antifungals for tinea corporis/cruris (Bell-Syer et al., 2012; El-Gohary et al., 2014). To bring attention to some of the management difficulties that remain unclear, the current review will go over some of the latest developments in the pathophysiology and treatment of tinea corporis, tinea cruris, and tinea pedis.

A superficial dermatophyte infection of the skin, tinea corporis, sometimes referred to as "ringworm," is not the same as tinea manuum, tinea pedis, scalp capitis, bearded areas, face, groin, or nails (onychomycosis or tinea unguium) (Weitzman and Summerbell, 1995). The three genera of dermatophytes that cause tinea corporis—Trichophyton, which infects skin, hair, and nails, Microsporum, which infects skin and hair, and Epidermophyton, which infects skin and nails—are the most common sources of the condition. Dermatophytes are categorized as anthropophilic, zoophilic, or geophilic according on whether their primary source is soil, animals, or people, respectively, this is shown in Fig 1. Doctors need to educate themselves since tinea corporis is a prevalent fungal infection that can mimic many different annular diseases.

Fig 1: Typical annular lesions of ringworm (Source: https://dermnetnz.org/topics/tinea-corporis)

History

Histological observations include modest superficial perivascular infiltration in the upper dermis, hyperkeratosis, parakeratosis, and minor acanthosis. Periodic acid, methenamine silver, or hematoxylin-eosin. The stratum corneum contains yeast, as shown by the "spaghetti and meatballs" pattern revealed by Schiff staining (Hattori et al., 1984). More hyphae and spores are typically found in hyper-pigmented lesions than in hypo-pigmented ones. The horny layer of hypo-pigmented lesions is often slightly hyperkeratotic, and the stratum spinosum may have fewer melanosomes (Gupta et al., 2003)

Clinical Findings

The hallmark of tinea versicolor is mildly scaly hypo-pigmented or hyper-pigmented macules/patches. These are most frequently seen on skin regions with high sebum production, such as the upper arms, neck, trunk (particularly the top portion), and shoulders Adults are less likely to make facial gestures. However, in youngsters, facial involvement is prevalent and may be the only place affected. Usually, facial involvement occurs on the forehead (Katz et al., 2008).

Etiology

The predominant causative agents of tinea corporis are *Microsporum canis*, *Trichophyton rubrum*, and *T. tonsurans* (Adams, 2002; Takenaka et al., 2020). *T. rubrum* is widely recognized as the primary cause of dermatophytosis on a global scale and is notably prevalent as the leading cause of tinea corporis in North America (Kelly, 2012; Costa et al., 2015). *T. tonsurans* is commonly the cause of tinea corporis subsequent to tinea capitis. However, *M. canis* frequently causes tinea corporis that results from intimate contact with dogs or cats. Additional organisms that cause harm are *T. interdigitale* (formerly known as *T. mentagrophytes*), *T. verrucosum*, *T. violaceum*, *T. concentricum*, *Epidermophyton floccosum*, *M. audouinii*, and *M. gypseum*. In Southeast Asia, *T. interdigitale* has supplanted *T. rubrum* as the most frequent cause of tinea corporis in recent times. Some uncommon organisms that cause problems are *T. erinaceid*, *T. equinum*, *T. simii*, and *T. schoenleinii*, *Nannizzia gypsea*, *N. nana*, and *M. gallinae* and *M. fulvum* (Leung et al., 2020).

Tinea Corposis causes

Most regions of the world are home to tinea corporis, although hot, humid areas are where it is most common. People of any age, including newborns, can be affected, although the majority of instances include children and young adults.

Among the Medical Risk Factors are:

- Tinea infection in the past or concurrently
- Diabetes type I
- Lack of immunity
- Overheating
- Ichthyosis Xerosis

Among the Environmental Risk Factors are:

- Overcrowding in households
- Infection of family members
- Keeping animals indoors
- Doing recreational activities that require close social interaction, such as sharing changing rooms, while wearing occlusive apparel (Shelley et al., 2005)

Tinea Corposis clinical variation

The following kinds of tinea corporis can occur as clinical variations. A severe pustular inflammatory response brought on by zoophilic fungus is known as keremia.

Tinea gladiatorum

It is a condition that occurs when skin-to-skin contact occurs in contact sports like martial arts or wrestling. Usually, *T. tonsurans* is the reason.

Tinea Imbricate

Caused by *T. concentricum*, large concentric rings that form polycyclic plaques with thick scale. It itches quite badly.
The Pacific Islands and other equatorial tropical regions are home to this kind. Because topical corticosteroid or calcineurin inhibitor therapy suppresses the inflammatory response.

Tinea incognito is characterised by the absence of the characteristic symptoms of tinea corporis. Lesions typically lack size and erythema and have widely dispersed, poorly defined edges (Chong et al., 2013).

Majocchi granuloma

A variation that affects the subcutaneous tissue and hair follicles; typically discovered on the limbs after shaving. It appears as pustules or papules within the hair follicles. The typical organism is *T. rubrum* (Ansari et al., 2016; Veraldi et al., 2018). These clinical variations are shown in Fig 2.

Kerion **Majocchi granuloma** **Tinea incognito**

Fig. 2: Clinical variants of tinea corporis
(Source: https://dermnetnz.org/topics/tinea-corporis)

Signs and Symptoms

The symptoms of ringworm may manifest as follows:

- A circular area of scales that typically induces itching on the trunk, arms, legs, and buttocks.
- Enlarging, slightly raised rings accompanied by a clear or scaly area inside the ring, potentially with a few scattered bumps of varying colors. These colors may range from reddish, purplish, and brown, to grey on different skin tones.
- An overlapping ring of itching on a flat, rounded patch of skin (Katz et al., 2008).

Essential oils

Essential oils are hydrophobic, concentrated, volatile, fragrant, oily liquids having different functional groups, and can be extracted from a variety of plant parts, including flowers, seeds, leaves, branches, bark, fruits, and roots. Crucial terpenoids, often known as volatile oils because of their propensity to readily diffuse into the atmosphere, are typically the molecules that give herbs, spices, and perfumes their distinctive flavour and aroma. Monoterpenes and sesquiterpenes, which include alcohols, ethers, phenols, polysaccharides, aldehydes, and ketones, are the primary constituents of EOs and are also responsible for their aroma and biological activity. Essential oil's phenolic constituents have also been identified as antibacterial bioactive ingredients (Chanthaphon et al., 2008). A wide range of plant materials are believed to possess antifungal qualities, and a multitude of essential oils have demonstrated antifungal activities without inducing any adverse reactions in people or animals (Sokmen et al., 1999).

Terpenes (phenolic compounds) are the main antibacterial components of essential oils. They target infections by attacking their cell walls and membranes. Therefore, a variety of invasive targets may be occupied by active phenolic compounds, potentially leading to the suppression of human pathogenic fungal infections (Sharma et al., 2014).

Tea Tree oil

Tea tree oil, derived from the *Melaleuca alternifolia* plant, has been used in traditional Australian medicine. Its powerful antimicrobial properties have led to its widespread adoption across the globe. As per 'ISO 4730:2004' TTO is extracted from foliage and terminal branches of *Melaleuca alternifolia* (Maiden et Betche) Cheel, *Melaleuca linariifolia* Smith, and *Melaleuca dissitiflora* by using steam distillation. There are significant differences in the yield and chemical composition are reported as these characteristics are strongly reliant on the quality of plant's natural resource (Bejar, 2017).

Chemical Composition

International guidelines govern the chemical composition of TTO, which establishes minima and/or maxima for 14 compounds i.e. Terpinen-4-ol (30-48), γ-Terpinene (10-28), α-Terpinene (5-13), α-Terpineol (1.5-8), p-Cymene (0.5-8), α-Pinene (1-6), Sabinene (tr-3.5), Aromadendrene (tr-3), δ-Cadinene (tr-3), Viridiflorene (ledene) (tr-3), Limonene (0.5-1.5), Globulol (tr-1) and Viridiflorol (tr-1) (International Organization for Standardization, 1996; Zeng et al., 2015; de Groot and Schmidt, 2016).

Antimicrobial Activity

TTO is utilized as a local formulation for a variety of dermatological problems due to its lipophilic nature, which allows for easier skin penetration (Martindale, 2009). TTO contains several medicinal effects, including anti-inflammatory and antimicrobial properties. That is why, it has effectively been utilized as a topical treatment against dermatophytes and *Candida albicans* in human medicine. Its antimycotic action includes modifying cell permeability, limiting respiration and reversibly inhibiting the development of germ tubes. In veterinary medicine, the antimycotic activity of TTO has been effectively proven against many strains of *Malassezia pachydermatis* from seborrheic dermatitis (Nardoni et al., 2010) and more recently in vivo by topically treating horses diagnosed with *T. equinum*. This treatment approach appeared to be effective in this and many other dermatological infections as well as versatile since it could be used right away following a physical examination even before receiving a laboratory response (Nardoni et al., 2010; Thomas et al., 2016; Bezabh et al., 2022).

Neem oil

Neem (*Azadirachta indica*) is commonly called 'Indian Lilac. Owing to its broad range of antibacterial activity, the neem plant is regarded as a dental panacea. It contributes significantly to the cosmetics sector because of its widespread use in hair and skin care products. *Azadirachta indica* fruits and seeds are used to extract vegetable oil, which is known as neem oil. Neem oil comes in a variety of colours: bright red, golden yellow, yellowish brown, reddish brown, dark brown, and greenish brown. Every part of the neem tree has certain therapeutic properties, and can be exploited commercially (Aneesa, 2016).

Chemical Composition

A variety of bioactive phytochemical compounds have been distilled from neem essential oil including triterpenoids (nimbin and azadirachtin), isomargolonone, proteins, tannins, quercetin, coumarin, carbohydrates, glycosides, salannin, margolonone, dihydrochalcone, diterpenoids (like nimbidine), gedunin, margolone, and glycosides (Alzohairy, 2016).

Antimicrobial Activity

Neem and its components can suppress the growth of variety of microorganisms, including bacteria, viruses, and harmful fungi. Methanol and ethanol extracts of neem proved growth inhibitors against *Aspergillus flavus, Alternaria solani*, and Cladosporium. A further investigation additionally shown the antibacterial properties of neem cake aqueous extracts in preventing spore germination from three sporulating fungus, namely *C. lunata, H. pennisetti,* and *C. gloeosporioides* f. sp. mangiferae (Kumari et al., 2013). The ability of neem plants to disintegrate cell walls and prevent microbial development are two indications of its antibacterial qualities (Alzohairy, 2016).

***Eucalyptus citriodora* oil**

The essential oil of *Eucalyptus citriodora* is a natural product with a variety of biological qualities. It is among the most extensively utilized species in the culinary, pharmaceutical, and cosmetics sectors today. *Eucalyptus citriodora* oil is frequently used to treat headaches, fever reduction, body pains, chronic bowel problems, and diarrhea (Tiple et al., 2024).

Chemical Composition

The primary components of *Eucalyptus citriodora* are citronellal, citronellol, and DL-isopulegol. Other significant components include limonene, P-cymene, alpha-pinene, geraniol, and camphene (Tolba et al., 2015).

Antimicrobial Activity

It was found that *Eucalyptus citriodora* oil was highly effective on *Trichophyton rubrum*, antifungal-resistant mutants of *Candida albicans*, and pathogenic microbes. It also demonstrated greater antifungal activity as compared to *Eucalyptus globulus* and traditional pharmaceuticals against zoophilic fungi such as *C. albicans*, *T. mentagrophytes*, and *Microsporum gypseum* (Luqman et al., 2008).

Palmarosa oil

High value essential oil obtained from *Cymbopogon martini* (common name palmarosa) is called palmarosa oil. Palmarosa oil possesses substantial market value due to its versatile applications in perfumery, agriculture, medicine, and environmental contexts (Sinha et al., 2014).

Chemical Composition

According to GC and GC-MS analytical findings *Cymbopogon martini* essential oil is composed of alcohols(geraniol, geranyl acetate) (Padalia et al., 2011), fatty acids, myrcene, b-elemene, linalool, monoterpenes, sesquiterpenes, linalool, E-citral, farnesol, terpinene, and b-elemene (Kakaraparthi et al., 2015). Some other compounds that are present in *C. martini* oil are nerolidol, α-bisabolol, α-terpinene, and terpinen-4-ol (Prasad et al., 2010).

Antimicrobial Activity

The Cymbopogon species shown noteworthy properties such as anthelmintic, anti-inflammatory, analgesic, anti-aging, pesticidal, antibacterial, antifungal, larvicidal, and antioxidant (Kumar, 2000; Raina et al., 2003; Tsai et al., 2011). Scientists discovered that the oils from *Cymbopogon ambrosioides* and *Cymbopogon martini* together may be utilized as a natural treatment for tinea corporis (ringworm) and other superficial fungal diseases in humans, in place of synthetic antifungal drugs (Prasad et al., 2010).

Fennel oil

Essential oil extracted from *Foeniculum vulgare* L. is called fennel oil (Ahmad et al., 2018). *Foeniculum vulgare* L. is an economically significant member of the Apiaceae family that is native to central and Mediterranean Europe. Fennel oil is produced by distilling fennel seeds and is used as an antiseptic, cough medicine, and laxative in the pharmaceutical industry (Damayanti and Setyawan, 2012), as well as in bakery, confectionery, medicines, and cosmetics as an addictive ingredient.

Chemical Composition

GC-MS analysis showed that there are 29 compounds in fennel oil accounting for 98.96%. The most prevalent constituents in the fennel oil were fenchone (8.32%), trans-anethole (63.30%), and pinene (11.11%). There were smaller concentrations of some compounds, including 2, 3-cyclohexen-1-methanol (2.58%), apiole (2.01%), 3-carene (1.44%), 1-methyl-4-(1-methylethyl) benzene (1.32%), methyl chavicol (1.28%), and limonene (1.09%). However, only negligible quantities of other chemicals, including hydrocarbons and oxygenated sesquiterpenes, were discovered (Shahat et al., 2011; Zeng et al., 2015).

Antimicrobial Activity

The mechanism of fennel oil, which demonstrated stronger antifungal activities against *T. tonsurans*, *T. mentagrophytes*, and *T. rubrum*, compared to the ubiquitous antifungal medications amphotericin B and fluconazole. Flow cytometry along with transmission electron microscopic studies were also used to examine the anti-fungal action of fennel essential oil. The outcomes demonstrated that damage to the plasma membrane and cell organelles was the root cause of the inhibitory effect. Fennel essential oil may reduce the activity of mitochondrial enzymes, specifically succinate dehydrogenase, malate dehydrogenase, and ATPase (Zeng et al., 2015).

Research has demonstrated that fennel oil possesses extensive antimicrobial capabilities against an array of diseases, such as Bacillus species, *Staphylococcus aureus*, *Micrococcus luteus,* Pseudomonas species, and *Pseudomonas fluorescens* (Singh et al., 2006; Mohsenzadeh, 2007; Kazemi et al., 2012).

Bergamot oil

Bergamot oil is the essential oil produced by *Citrus bergamia*. Italy is the major producer of bergamot oil (Pizzimenti et al., 1998). This oil is obtained directly from cold-pressed fruit peels, characterized by yellow green colour and also called natural essence.

Table 1: Essential oil combinations proven to be effective in tinea treatment

Essential oil 1	Essential oil 2	References
Allium sativum (garlic)	*Citrus limon* (lemon)	(Orchard et al., 2019)
	Cymbopogon martinii (palmarosa)	
	Melaleuca alternifolia (tea tree)	
Boswellia carteri (frankincense)	*Cedrus atlantica* (cedarwood	
	Citrus limon (lemon)	
Cinnamomum verum (cinnamon bark)	*Boswellia carteri* (frankincense)	
	Citrus sinensis (orange)	
Citrus bergamia (bergamot)	*Cupressus sempervirens* (cypress)	
	Lavandula angustifolia (lavender)	
Citrus limon (lemon)	*Cymbopogon martinii* (palmarosa)	
	Eucalyptus globulus (eucalyptus)	
	Lavandula angustifolia (lavender)	
Coriandrum sativum (coriander)	*Cymbopogon citratus* (lemongrass)	
Cymbopogon citratus (lemongrass)	*Rosmarinus officinalis* (rosemary)	
Cymbopogon martinii (palmarosa)	*Boswellia carteri* (frankincense)	
	Cedrus atlantica (cedarwood)	
	Pelargonium graveolens (rose geranium)	
Eucalyptus globulus (eucalyptus)	*Lavandula angustifolia* (lavender)	(de Rapper et al., 2013)
Lavandula angustifolia (lavender)	*Allium sativum* (garlic)	(Orchard et al., 2019)
	Melaleuca alternifolia (tea tree)	(de Rapper et al., 2013)
Melaleuca alternifolia (tea tree)	*Citrus limon* (lemon)	(Orchard et al., 2019)
	Rosmarinus officinalis (rosemary)	
	Santalum austrocaledonicum (sandalwood)	
Origanum vulgare (oregano)	*Commiphora myrrha* (myrrh)	
	Pelargonium odoratissimum (geranium)	
	Pinus sylvestris (pine)	
Syzygium aromaticum (clove)	*Cinnamomum verum* (cinnamon bark)	
	Citrus bergamia (bergamot)	
	Citrus limon (lemon)	
	Lavandula angustifolia (lavender)	
Thymus vulgaris (thyme)	*Citrus bergamia* (bergamot)	
	Citrus limon (lemon)	
	Rosmarinus officinalis (rosemary)	

Chemical Composition

There are about 80 volatile compounds (such as limonene, linalool, β-pinene, γ-terpinene, and linalyl acetate) that account for 93–96% and non-volatile (like bergamottin, citroptene, psoralens, coumarins, and bergaptene) components that account for 4–7% in bergamot oil formulations (Verzera et al., 2003). Due to the phototoxic properties of furocoumarins, including bergaptene, found in bergamot oil, pharmaceuticals frequently substitute furocoumarin-free, distilled extracts in the place of natural essence.

Antimicrobial Activity

According to (Fisher and Philips 2006), bergamot essential oil is efficient against bacteria. Bergamot oil is a potent antifungal that works well against yeast infections and dermatophytes. Strong evidence is being reported in favor of anecdotal or popular views about the efficacy of bergamot oils in treating skin and mucous membrane infections (Sanguinetti et al., 2007).

Essential oil Combinations

There are a number essential oils and their different combinations have been scientifically tested to treat tinea. Some of the essential oil combinations proven to be very effective in tinea treatment listed in Table 1. (Orchard et al., 2019).

Conclusion

The use of essential oils in the treatment of dermatophytosis represents a promising avenue due to their natural origin, minimal side effects, and potential effectiveness against fungal infections. Essential oils such as *Melaleuca alternifolia* (tea tree oil), *Azadirachta indica* (neem), and *Eucalyptus citriodora* have demonstrated notable antifungal properties attributed to their bioactive compounds, including monoterpenes and sesquiterpenes. These oils exhibit diverse functional groups that contribute to their antimicrobial activity, making them suitable candidates for combating antifungal resistance observed with conventional treatments. Furthermore, combinations of essential oils, such as those including *Cymbopogon martini* (palmarosa), *Foeniculum vulgare* (fennel seed oil), and *Citrus bergamia* (bergamot), have shown synergistic effects in enhancing efficacy against dermatophytosis. Despite their potential benefits, further research is needed to standardize formulations, determine optimal dosages, and assess long-term safety. Additionally, clinical trials comparing essential oils with standard antifungal therapies are necessary to establish their place in dermatophytosis management protocols. Nonetheless, the current evidence underscores the promise of essential oils as alternative or adjunctive treatments for dermatophytosis, providing clinicians and patients with potentially effective options in the face of evolving fungal resistance patterns.

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Chapter 10

Pharmacological Potential of Essential Oils: Exploring Therapeutic Perspectives

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ABSTRACT

Many research has shown the various chemical compositions and pharmacological characteristics of essential oils, which include antinociceptive, anxiolytic-like, and anticonvulsant actions. Essential oils may be inhaled, taken orally, or used topically. They are often used as an additional treatment for those who suffer from anxiety, sleeplessness, convulsions, discomfort, and cognitive impairment. There are a number of detrimental effects linked to the use of synthetic drugs to treat different conditions and symptoms. As a result, there has been a global push for research teams to investigate the effectiveness of natural substitutes such essential oils. This chapter offers a thorough summary of the body of review on the pharmacological characteristics of substances produced from essential oils, as well as the underlying processes causing the effects that are seen. Research in this area is still in its early stages, which emphasizes the need for a more thorough examination of the medicinal benefits of essential oils and their constituent parts. By including essential oils into traditional therapy, diverse treatment regimens may be made more successful and provide a more complete approach to tackling the complex nature of various ailments.

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INTRODUCTION

Throughout the course of human history, essential oils have assumed a compelling and indispensable function, intricately intertwining the fundamental character of nature with the quest for optimal health and restoration. These valuable oils, obtained from aromatic plants using complex extraction methods, have been highly valued for their therapeutic qualities and cultural importance since ancient times (Silva-Correa et al., 2021). This chapter delves into an illuminating exploration of the dynamic realm of essential oils including their significant influence on diverse facets of human existence. The volatile and aromatic molecules known as essential oils are derived from various plant components, such as flowers, roots, stems, and leaves. The oils in question represent the unadulterated essence of the plant, effectively encapsulating its distinct aroma and powerful bioactive constituents (Dagli et al., 2015).

Essential oils have been highly esteemed throughout history because of their wide-ranging applications, encompassing medicinal procedures, religious ceremonies, perfumery, and culinary skills. The therapeutic effects of nature were recognized by the prehistoric cultures of Greece, Egypt, and China, who acknowledged their ability to promote both mental and physical health (Göbel et al., 1994; Wani et al., 2020).

This chapter endeavors to illuminate the current comprehension and progressions pertaining to essential oils, drawing inspiration from our extensive historical fabric. This inquiry explores the most recent scientific investigations and advanced technology that have enhanced our understanding of these natural phenomena. In addition, we examine new viewpoints that have arisen, revealing inventive uses that go beyond conventional limits.

Recent Advances in Essential Oil Research

Recent years have seen an incredible increase in interest in the field of essential oil research, which has resulted in some amazing discoveries and ground-breaking advancements (Kong et al., 2022). This section explores the ever-evolving field of essential oil research today, showcasing the most recent findings in science, creative extraction methods, and an in-depth understanding of the molecular makeup of these jewels found in nature.

Timeline of Current Scientific Research and Advancements

Scientific inquiry into essential oils has surged due to innovations in analytical technologies and a growing emphasis on natural therapies Current research endeavors have been dedicated to elucidating the complex mechanisms that underlie the biological activities and possible therapeutic uses of these substances as shown in Table 1.

Table 1: Current research advancements that underlie the biological activities and possible therapeutic uses of these essential oils

Essential oils and their bioactive molecules		
S/N	Finding/Advancements	Source
1	Identification of new essential oil compounds	(Haddad et al., 2019)
2	Antimicrobial activity of essential oils against Drug- Resistant pathogens	(Jaeger and Cuny 2016)
3	Anti-inflammatory and analgesic properties	(Reichling, 2022)
4	Therapeutic potential of essential oils in neurological disorders	(Saranraj and Devi 2017)
5	Exploration of sustainable extraction techniques for higher essential oil yield	(Tian et al., 2020)
6	Application of essential oils in nanotechnology for targeted drug delivery	(Zhang et al., 2018)
7	Understanding the molecular and cellular mechanisms of action of essential oils	(Sattayakhom et al., 2023)

• Research on Antimicrobial Properties

Promising findings have been obtained from studies on the essential oils owing to their antibacterial effectiveness against viruses, bacteria, and fungi. Numerous studies have demonstrated the significant antimicrobial properties exhibited by oregano oil, tea tree oil, and lavender oil, hence presenting potential avenues for innovative therapeutic interventions targeting drug-resistant bacteria (Force et al., 2000; Balusamy et al., 2018; Kallel et al., 2019).

• Neurological Effects and Mood Regulation

There has been a significant increase in scientific interest in the influence of essential oils on the nervous system. Research is being conducted to explore their potential in reducing anxiety, depression, and stress. According to Ali et al. (2015), certain oils such as bergamot have demonstrated the ability to modulate neurotransmitters, hence providing insights into their potential impact on mental well-being.

• Anti-inflammation and Analgesic Effects

The use of essential oils has garnered significant interest in the realm of pain management and inflammatory conditions due to their proven anti-inflammatory and pain-relieving capabilities. Nevertheless, ginger, peppermint oil, and eucalyptus oil have shown encouraging anti-inflammatory benefits in preclinical tests (Kachkoul et al., 2021).

Novel Extraction Methods and Technologies

Historically, the acquisition of essential oils has been accomplished by the process of distillation or cold pressing. Nevertheless, both the effectiveness and quality of the production of essential oils have been significantly transformed by recent advancements in extraction methods, hence broadening the range of potential aspects (Mollica et al., 2022).

• Supercritical Fluid Extraction (SFE)

Supercritical carbon dioxide extraction produces high-quality essential oils with little residues, making it popular. Sustainable extraction methods include enzyme-assisted extraction. Enzymes break down plant cell walls, releasing oil components and improving extraction efficiency (Pandey et al., 2023)

According to Hyldgaard et al. (2012), Microwave-Assisted Extraction (MAE) speeds up extraction using microwave radiation. This approach reduces extraction time and energy while maintaining crucial oil component dependability.

Enhanced Expertise in Essential Oil Chemistry and Composition

We now know more than ever before about the complex chemical makeup of essential oils owing to cutting-edge analytical techniques such as gas chromatography-mass spectrometry (GC-MS) and nuclear magnetic resonance (NMR) spectroscopy. Biological Component Identification: Scientists have discovered a variety of bioactive chemicals in essential oils, including phenols, terpenes, and aldehydes (Hoffmann, 2020). The recognition of these chemicals' roles in conferring therapeutic properties paved the path for tailored uses (Richa et al., 2020).

The significance of the synergy among different constituents present in essential oils has been emphasized in several studies. Aliaño-González et al. (2022) have identified the entourage effect in specific oils, which refers to the enhanced therapeutic efficacy resulting from the combined effect of numerous components.

In summary, recent advancements in the field of essential oil studies have propelled these naturally occurring aromatic chemicals into a domain of scientific investigation, hence facilitating the emergence of innovative uses across several domains. Essential oils have a wide range of capabilities, including antibacterial effects, mental health assistance, and new extraction processes. These features have attracted the attention of researchers and enthusiasts, leading to a better understanding of their complex nature (Chen et al., 2018).

Discovering Fresh Insights on Essential Oil usage

In this section, we discuss essential oils' unique function in mental health, their potential application to societal and agricultural practices, and the essential oil industry's exciting developments and prospects.

The Benefits of Essential Oils for Mental Health and Stress Reduction

Essential oils' strong scents are known to affect mental health and emotional equilibrium. Inhaling certain essential oils may stimulate the olfactory system, releasing neurochemicals that impact moods and emotions, according to research. For instance, research has demonstrated that lavender possesses the ability to alleviate anxiety and facilitate relaxation, whilst citrus-derived oils such as bergamot and sweet orange have mood-enhancing properties (Fokou et al., 2020).

New Developments and Prospects for the Essential Oil Sector

The essential oil market has experienced significant expansion during last few years, mostly due to the rising consumer interest in natural and holistic methods for promoting health and overall wellness. Entrepreneurs and businesses are leveraging this phenomenon by investigating novel approaches to integrate essential oils into diverse product offerings. Essential oils are being utilized in a wide range of applications, including skincare, personal care products, home cleaners, and aromatherapy diffusers (Kim et al., 2016).

The rise of the sector has been facilitated by advancements technological advances and refinement techniques. Scientists are now studying innovative methods for extracting essential oils, techniques to enhance the efficiency and caliber of essential oil manufacturing, such as microwave-assisted extraction and supercritical fluid extraction (Harris, 2002). Furthermore, the proliferation of digital marketing and e-commerce platforms has facilitated the expansion of micro-distilleries and craft manufacturers' opportunities to access a wider range of customers, thereby cultivating a market that is both inclusive and competitive. As research delve more into the captivating realm of essential oils, it becomes clear that their influence extends well beyond the boundaries of fragrances and odors. Essential oils exemplify the potential of nature's abundance, as they contribute to the enhancement of mental well-being, the transformation of environmental practices, and the advancement of industry trends. Their capacity is limitless, and we eagerly anticipate the thrilling advancements that await us (Puvača and de Llanos Frutos, 2021).

Use of Essential Oils in Healthcare

In this section examination of the many applications of essential oils in healthcare, including their usage in procedures based on evidence in both mainstream and alternative medicine have been documented. It also explores their role in antimicrobial treatments and pain management.

Traditional and Alternative Medicine and Evidence-based Applications

Many civilizations and traditions have long used essential oils for medicinal reasons. Recent academic study has shown that these fragrant miracles work in traditional and alternative medicine. Aromatherapy is a supplement that uses essential oils to enhance healing and well-being. As a prominent illustration of its efficiency. Various research by De Lavor et al. (2018) have demonstrated that aromatherapy helps control anxiety, despair, and stress. Aromatherapy has also been used in hospital and palliative care institutions to improve patient well-being and reduce medication use (Jones et al., 2022). Increasing proof supports the use of essential oils in traditional medicine, spurring more research (Swain et al., 2023).

Latest Research on the Antibacterial Effects of Essential Oils

Given the increasing prevalence of antimicrobial resistance, there has been a notable surge in the investigation of essential oils as a prospective avenue for exploring their full potential as natural antimicrobial agents. Numerous essential oils demonstrate a vast array of antibacterial capabilities, enabling them to effectively attack a diverse array of fungi, viruses, and bacteria (Amorati et al., 2017).

Tea tree oil has been shown to exhibit notable antibacterial properties against a range of bacterial and fungal species. According to Wang et al. (2023), oregano oil is recognized for its significant antibacterial and antifungal characteristics. The present body of study is mostly dedicated to comprehending the underlying mechanisms responsible for these antimicrobial properties, as well as investigating the possible application of essential oils in the development of alternative therapeutic approaches for the treatment of infectious disorders. Nevertheless, it is crucial to acknowledge that additional research is necessary in order to ascertain the safety and effectiveness of these substances when employed in therapeutic environments.

The use of Essential Oils in Alleviating Pain and Alternative Treatments

Essential oils have developed as an adjuvant way to manage pain and discomfort, which is a huge difficulty in the healthcare industry. Pain treatment continues to be a significant challenge. Some specific essential oils have analgesic and anti-inflammatory properties, which provide potential alternatives to conventional pain medications. Research has demonstrated that peppermint oil can effectively relieve headaches and migraines. Similarly, studies have shown that lavender oil can effectively treat labor pain in pregnant women (Tan et al., 2022). Various types of essential oils have been used in palliative care to alleviate symptoms and provide comfort to those suffering from chronic pain and terminal diseases. (Herz, 2009). The incorporation of essential oils in complementary therapies, such as massage and aromatherapy, has been increasingly popular due to its perceived efficacy in pain reduction, relaxation enhancement, and overall well-being improvement as shown in Fig. 1 (Nasiri and Mahmodi, 2018; Osaili et al., 2023).

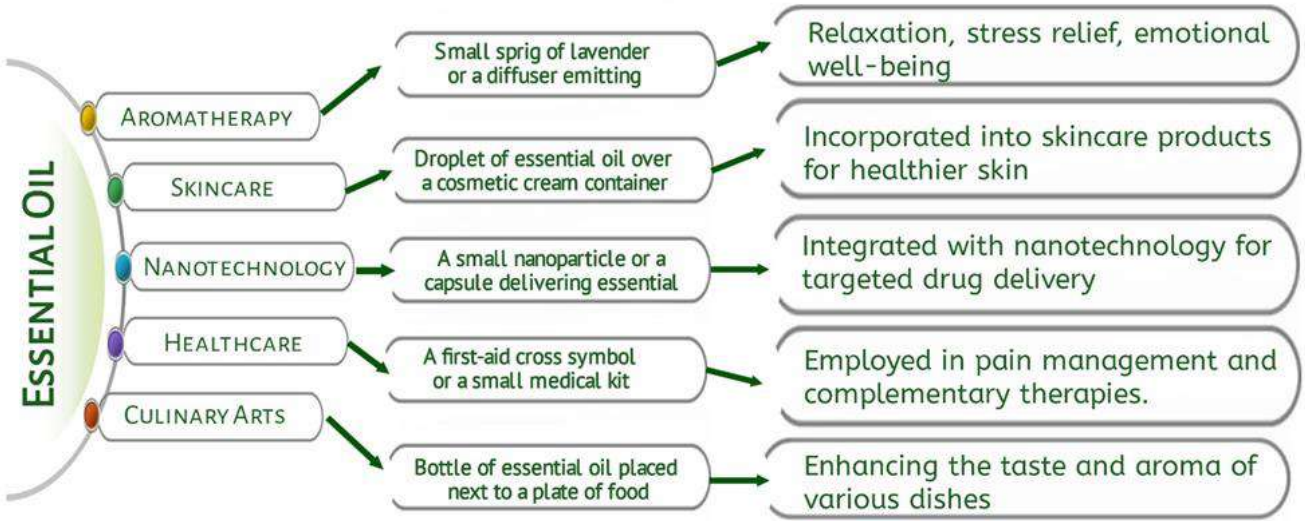

Fig. 1: The wide-ranging uses of essential oils in contemporary enterprises.

Essential oils may play a vital role in future integrated pain therapy plans as this area of study develops. The investigation of essential oils in healthcare is a nod to their history of use in folk medicine, their possible efficacy as antimicrobials, and their mild use in pain relief. As a result of modern research, essential oils are becoming more popular in contemporary healthcare as aromatic companions to support health (Costa et al., 2020).

The Real-world Applications of Essential Oils

Within the enthralling realm of essential oils, there exist a plethora of accomplishments and case studies that exemplify the extraordinary influence these fragrant marvels have exerted across many sectors. This section explores practical instances of incorporating essential oils, showcasing real instances of success that showcase the many inventive uses of these extracts of plants.

Alleviating Well-being in Health Care Amenities

The use of essential oils in healthcare environments has facilitated the adoption of a comprehensive approach to patient treatment and overall wellness. Previous research was undertaken at a hospital's palliative care unit to investigate the use of aromatherapy, including the usage of essential oils such as lavender, chamomile, and frankincense (de Sousa et al., 2023). The purpose of this intervention was to mitigate pain and offer solace to patients suffering from chronic illnesses. The findings exhibited a notable decrease in self-reported levels of pain and an enhancement in the general state of patients' well-being, showcasing the capacity of essential oils to augment the healthcare encounter (Lee and Shibamoto, 2001; Mounira, 2024).

Generating Ordinary and Regenerative Cleaning Solutions

Within the commercial and sanitation sectors, essential oils have shown themselves to be a viable alternative to the standard chemical-based solutions that have been used in the past. Within the context of a hotel chain, Wang et al. (2019) conducted a case study that proved the successful use of essential oils into cleaning solutions. A variety of citrus-based oils, including lemon and orange, were used in the production of multi-purpose cleansers that were both efficient and adaptable. The implementation of this environmentally conscious strategy not only resulted in a decrease in the ecological footprint of the hotel, but it also improved the general satisfaction of the guests by eliminating unpleasant chemical odours found in the establishment.

A Remarkable Revolution in Personal Care and Beauty Products

The integration of essential oils into numerous products has brought about a revolution in the beauty and personal care business. The composition of anti-aging serums and face oils in a case study conducted by Isman et al. (2011)

incorporated essential oils such as rosehip seed oil and chamomile. According to the research carried out by Caamal-Herrera (2016), the usefulness of essential oils in supporting healthy and bright skin has been shown by changes in skin texture and hydration which demonstrates the effectiveness of essential oils.

Sustainable Agriculture and Pest Management

The utilization of essential oils in sustainable pest management has also yielded advantages for the agricultural sector. The case study examined the integration of essential oils, such as neem oil and thyme oil, into pest management tactics within the context of organic farming practices. These natural alternatives have demonstrated efficacy in mitigating pest infestations and minimizing crop damage, hence fostering the adoption of environmentally sustainable and economically feasible agricultural methods (Puvača and Llanos Frutos, 2012).

Scientists have provided evidencesof the diverse range of applications for essential oils, encompassing many sectors such as healthcare, agriculture, and other areas. The incorporation of these technologies into several sectors not only showcases their adaptability but also underscores the importance of sustainable and organic remedies in contemporary society (Do et al., 2015; Ampadu et al., 2022)

To Overcome the Challenges in Aromatherapeutic usages

A rise in the difficulties that are linked with the widespread use of essential oils has been brought about as a result of the rising popularity of essential oils. In this section, the basic factors that pertain to potential safety threats, concerns about sustainable and ethical sourcing, as well as the significance of regulatory constraints and standardization will be discussed.

Possible Safety Consequences and Precautionary Measures

While essential oils have many advantages, their potency may pose safety issues if not handled appropriately. James et al. (2017) and Isman et al. (2011) found that certain essential oils may cause skin irritation or allergic reactions. Some drugs may interact with these oils. To solve these issues, appropriate use and dilution guidelines must be followed. Due to their toxicity, essential oils are debated for consumption. Seek advice from aromatherapists or doctors before taking internally. In order to prevent accidental intake or contact, essential oils must be kept away from children and pets.

Concerns Relating to Sustainable and Ethical Sourcing

The lack of necessary quantities of essential oils has led to challenges regarding the long-term viability and ethical acquisition. Overharvesting of essential oil-producing plant species endangers the plants and the communities that rely on them (Tanner et al., 2018). The lack of laws for harvesting practices has the potential to worsen deforestation, habitat degradation, and biodiversity loss.

In order to tackle these concerns, the essential oil business is placing growing importance on the adoption of sustainable and ethical sourcing processes. Initiatives like fair trade partnerships, ethical growing practices, and certificates for wild harvesting play a crucial role in guaranteeing the responsible sourcing of essential oils and the protection of the associated ecosystems and populations (Feriotto et al., 2018)

Future Perspectives and Research Approaches

This section seeks to elucidate the capacity of essential oils to fundamentally influence the trajectory of diverse businesses and domains, encompassing healthcare, agriculture, nanotechnology, and beyond. By adopting a future-oriented approach, we are able to reveal fresh viewpoints and investigate unexplored areas where essential oils have the potential to revolutionize scientific research, improve overall health, and stimulate groundbreaking applications for future generations.

Diverse Promising Areas for in-depth Research and Development

• The exploration and development of new extraction technologies have significant potential for the future of essential oil research. According to Johnson and Carter (2021), many techniques, including supercritical fluid extraction (SFE), microwave-assisted extraction (MAE), and ultrasound-assisted extraction (UAE), have demonstrated the potential to improve the production and quality of essential oils.
• To fully exploit the potential of essential oils, it is crucial to do a thorough investigation of their chemical makeup. Thorough investigations into the whole chemical composition of essential oils can assist in establishing uniformity and ensuring high standards in quality control protocols (Guzmán et al., 2021).
• The examination of synergistic effects resulting from the combination of several essential oils or their integration with other natural substances is a promising avenue for future investigation. The comprehension of these interactions has the potential to facilitate the development of therapeutic blends that are more effective and customized (Chemat et al., 2020).
• Studying the cellular and molecular mechanisms by which essential oils work is a vital field of study. Conducting research in this sector will provide valuable understanding of how essential oils interact with biological systems, hence promoting the development of new therapeutic methods and pharmacological treatments.
• Conducting detailed safety and toxicological research is crucial for creating evidence-based recommendations on the safe use of essential oils in various applications. It is essential to determine the correct dosages and potential negative

effects in order to ensure the safe incorporation of these substances into healthcare practices.

• The investigation of methods to improve the bioavailability of essential oil components holds significant potential as a research avenue. By using new formulation tactics or encapsulating methods, we may maximize the body's absorption and distribution of essential oil components (El Asbahani et al., 2015)

Conclusion

Essential oils are a large collection of natural substances that have exceptional potential. From historical customary practices to modern scientific advancements, their trajectory has been characterized by ongoing exploration and ingenuity. As we continue to advance in the field of essential oil discovery and development, it is clear that these fragrant extracts will have a crucial impact on current applications, transforming several sectors and enhancing human well-being. By embracing the combination of ancient knowledge and contemporary science, we can fully use the potential of essential oils and promote a future where we responsibly harness the benefits of nature for the improvement of society.

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Chapter 11

Role of Essential Oils in the Treatment of Sarcoptic Mange

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ABSTRACT

The cause of scabies, a highly contagious and itchy skin disease that affects people and animals around the world, is *Sarcoptes scabiei*, a mite that is a member of the *Sarcoptidae* family. The World Health Organization has identified scabies as a neglected disease in recent years, which emphasizes the need for adopting the efficient control measures. Due to issues with resistance and side effects, traditional acaricides have been replaced by other treatments regimens, especially herbal products. An overview of herbal remedies—specifically, essential oils—for managing infestations of *Sarcoptes scabiei* is given in this chapter. The effectiveness, mechanisms of action, and potential uses of important essential oils, such as tea tree, lemongrass, lavender, cinnamon, clove, palmarosa, and neem, in the treatment of scabies are discussed. In addition, the chapter summarizes current studies and clinical trials that assess the acaricidal effects of these essential oils, providing important information for the creation of fresh anti-scabies treatments.

KEYWORDS
Scabies, *Sarcoptidae*, Resistance, Essential oils, Herbals

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INTRODUCTION

The organism *Sarcoptes scabiei*, belongs to the family *Sarcoptidae* (Bornstein et al., 2001) which causes severe infectious, itchy skin disease in animals and humans around the world. In humans, its infection is known as scabies and globally 130 million people are affected from this infection (Figure 1) (Currie BJ, 2015). In 2013, this problem was added in World Health Organization (WHO) in the list of ignored diseases. Scabies is a developing issue and causes death of many animals including cattle, buffalo, dogs and cats (Arlian and Morgan, 2017, Bernigaud et al., 2020). It becomes difficult to control the mites because of the resistance against many acaricides and no availability of vaccines (Van Leeuwen et al., 2010; Absil et al., 2022). Because of these reasons, the world will have to focus on natural products to control mites (Zhu et al., 2020; Liao et al., 2023). The natural products include metabolites obtained from plants or different microorganisms. Essential oils are produced during the metabolism by plants as secondary products and are effective against bacteria, virus, fungi and parasites (Blenau et al., 2012; Peterfalvi et al., 2019; Sandner et al., 2020). Some oils are also very effective against ticks and mites (Selles et al., 2021). Important oils are obtained from tea tree, lavender, lemongrass, cinnamon, clove, tulsi and palmarosa. This book chapter is aimed to offer valuable insights and references for the development of novel acaricidal drugs.

Tea Tree and Lemon Grass for Treating *Sarcoptus Scabies*:

Several chemical drugs having acaricidal effects have been successfully applied to treat mite infestations including scabies but their extensive usage led to the emergence of resistance and presence of residues in animal products (Bezabh et al., 2022). Therefore, traditional and modern medical practices have been employing herbal remedies due to their cost-effectiveness and minimal side effects (Khare et al., 2019; Nardoni and Mancianti., 2022). Plants have therapeutic properties due to the presence of active ingredients like flavonoids, glycosides, vitamins, alkaloids etc. (Koomson et al., 2018).

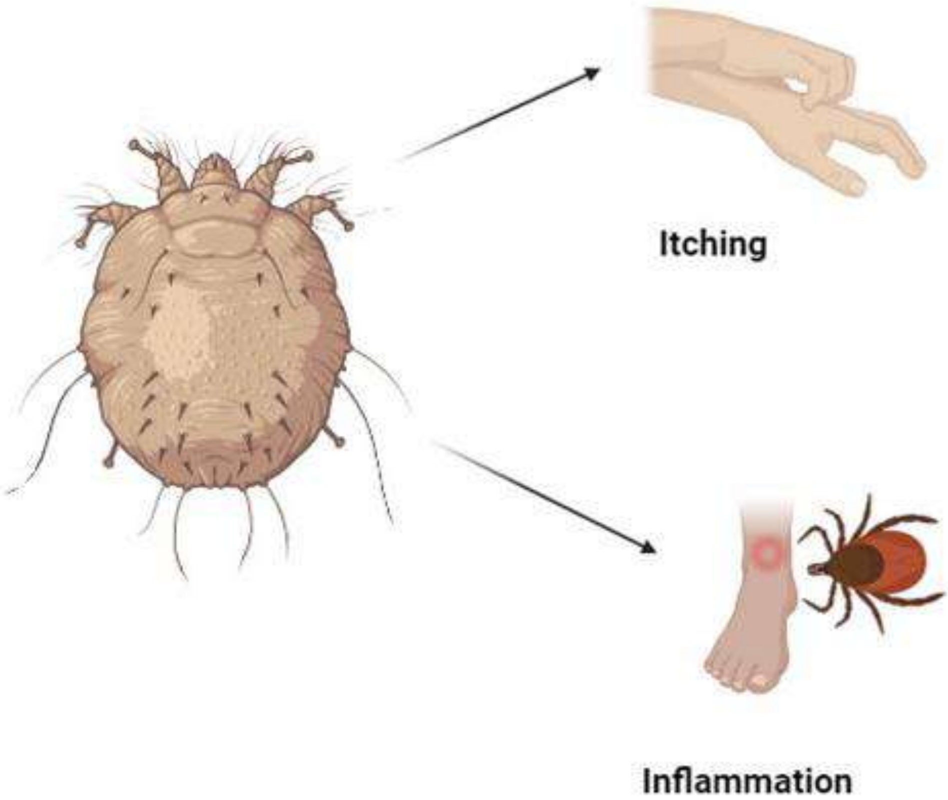

Fig. 1: Clinical signs of Scabies

The tea trees are members of the *Myrtaceae* family, namely *Leptospermum, Melaleuca*, and *Kunzea* genera (Çalışkan and Özfenerci, 2018; Bezabh et al., 2022). Australian Aboriginals has been using *Melaleuca alternifolia* leaves as medicine for different dermal and epidermal disorders for over 90 years, and oils distilled through steam has been extensively utilized by Australian communities for the same purpose (Yürekli, 2022). The tea tree plant leaves contain essential oils that are collectively referred to as "TTO" (Sabir et al., 2014). The TTO have acaricidal, antimicrobial, antioxidant, immunomodulatory and anti-inflammatory properties due to availability of terpinene-4-ol content, γ-terpinene, and α-terpinene as the main bioactive components (Nardoni and Mancianti, 2022). The exact mechanism behind TTO's anti- *S. scabiei var. cuniculi* effect is currently unknown (Gopinath et al., 2018), however 1.8-cineole, T4O, a-terpinene, g-terpinene, and p-cymene's anticholinesterase activity cause the mites muscles to contract and cause spastic paralysis (Li et al., 2023). Additionally, cineole act as repugnant against *S. scabiei* var. *cuniculi* and modifies working of an enzyme involved in the scabies mites nervous system (Hu et al., 2015; Xavier-Junior et al., 2017).

The TTO showed concentration dependent anti-mite effect on *S. scabiei* mites in a study conducted to evaluate the relative efficacy of permethrin and TTO (Zulkarnain et al., 2019; Ajan et al., 2022). It has reported that in Australia, TTO has been used to treat scabies (Thomas et al., 2016). A study conducted to evaluate the efficacy of 5% TTO, 5% permethrin cream and 10% permethrin cream. Among all, 5% TTO successfully treated scabies at higher rate among all. In addition to this, TTOs can also avoid the secondary bacterial infections like secondary sepsis, pyoderma, and other bacterial implications due to their antimicrobial properties. Moreover, the inflammatory response generated due to mite antigen can also be lessened by TTO. This is due to the anti-inflammatory and antipruritic properties of TTO (George and Joseph, 2009; Thomas et al., 2016).

The lemongrass produces essential oils having miticidal, ovicidal, anti-inflammatory and antioxidant properties. It is also known as Cochin grass connected to family *Poaceae*. It is commonly grown in tropical and subtropical climates (Mead, 2012; Mukarram et al., 2021). A variety of pharmacologically active chemicals, involving citral (a combination of neral and geranial), citronellal, germacrene-D, geranyl acetate and elemol, in addition to other bioactive components are present in lemongrass essential oil (LEO). The lemongrass essential oils (LEO) exhibit strong dose dependent miticidal action against all the stages of life cycle of *S. scabies*. A study conducted to test the efficacy of different concentration of lemongrass essential oil against the *S. scabies* adults. Results explored that LEO killed all adults of *S. scabiei* at percentage concentrations of 10% and 5% in 10 and 25 minutes, respectively. The lemongrass oil at percentage concentrations of 10%, 5%, 1%, 0.5% and 0.1% markedly reduced the hatching rate of mite's eggs taken from the naturally infested rabbits (Li et al., 2020). Citral which is main component of LEO has been reported to exert an ovicide effect against *S. scabiei* eggs at 4.8% concentration (Li et al., 2021; Paichitrojjana et al., 2023). Ahibero 1% exhibited mite-killing properties, killing all phases in 62.53 minutes (Andriantsoanirina et al., 2022).

Lavender and Cinnamon

A highly traded essential oil plant species globally, *Lavender angustifolia Mill* (English lavender) ranks among the top 15. It is a small flowering plant that connected to *Lamiaceae* family (Jemimah et al., 2019; Kharraf et al., 2021). The Inalool, linalyl acetate, monoterpenoids, terpinen-4-ol, camphor and β-ocimene are major ingredients of lavender oil in addition to other therapeutically important components like tannins, coumarin, monoterpenes, phytosterols, anthocyanins, valeric acid, glycolic acid, coumarin etc (Gök et al., 2024). The lavender oil acts as an anti-inflammatory, antioxidant, hypnotizing, antidepressant, anticonvulsive, antimicrobial and antifibrotic agent, among other nutritional and medicinal benefits (Rana, 2021; Bokelmann, 2021; Saeed et al., 2023). On *S. scabiei*, *Lavandula angustifolia* EO demonstrated an LD50 at 10% in 20 minutes (Fang et al., 2016).

Since Biblical times, cinnamon has been utilized as a therapeutic and flavoring agent. There are reportedly more than 200 species of *Cinnamomum* including *Cinnamomum zeylanicum* (also known as *C. verum*), *C. burmannii, C. camphora, C. cassia, C. glaucescens, C. iners, C. loureirii, C. pauciflorum, C. tamala* (Sharifi-Rad et al., 2021; Kharisma and Upi Chairun Nisa, 2023). The Cinnamon as essential oil has significant therapeutic effects owing to the attendance of cinnamaldehyde, eugenol, and beta-caryophyllene as its main components (Stevens and Allred, 2022). It has been shown that *Cinnamomum zeylanicum* EO is effective against *P. cuniculi* and has recently shown promising potential against *S. scabiei*. This EO demonstrated a powerful activity, both in contact and fumigant form, killing 100% of mites at 1%. Regretfully, the essential oil did not showed ovicide effect, even though its primary constituents, eugenol and benzyl-benzoate, were thought to be accountable for its mite-killing properties (Andriantsoanirina, 2022). The *Cinnamomum camphora* EO was obtained from two distinct geographical sources: camphorwood from China and *raventsara* from Madagascar. Both sources possessed significant concentrations of 1.8 cineole and limonene, respectively, however the plant only exhibited 5% miticide action when applied topically (for *raventsara*), and both topically and when fumigated (Fichi, 2007; Andriantsoanirina, 2022; Li et al., 2023). Applying this tree's oil on a daily basis for ten days will completely cure the scabies infection (Akram et al., 2020).

Clove and Palmarosa

The *Sygyzium aromaticum* is used to extract clove essential oil (Haro-González et al., 2021; Nardoni and Mancianti, 2022). In a contact bioassay, it was found that 1.56% of clove oil eliminated every scabies mite after 15 minutes (Fang et al., 2016). In a contact bioassay, Fang et al. (2016) also found that 1% clove eliminated every mite in 20 minutes. According to El-Saber Batiha et al. (2020), this oil has multiple biological activities in addition to antibacterial, antiparasitic, and antifungal effects. The clove oil is known to have immunobooster and antioxidant qualities (Sandner et al., 2020; Vasantha Kalyani and PM, 2021). The miticidal effect of eugenols has resemblance with that of tarpenes. The eugenols exhibit potent miticidal effects. This effect is due to the presence of phenolic hydroxyl groups in their structure. The phenolic hydroxyl group in eugenols binds with GABA and octopamine receptors to show miticidal properties (Li et al., 2023). The eugenol and related compounds are active ingredient of the clove oil and all the effects of clove oil are attributed to the presence of these compounds. These terpenes first disturb the cell membrane and then cell organelles in the cells of mites gut and epidermal epithelium. Furthermore, eugenol inhibited the electron transport chain in the oxidative phosphorylation pathway taking place in mitochondria during respiration, with a stopping rate of 60.26% for 100 μg/mL (Shang et al., 2020) and regulated the expression mRNA for catechinic acid, glutathione S-transferase and thioredoxin (Ma et al., 2019). Due to these mechanisms, the eugenol effectively kills *Psoroptes cuniculi* mites. This killed mites in 5 minutes at 1% concentration and successfully stopped fifty percent (EC50) of hatching of eggs at 0.65%; its fumes also produced surprising results (Fang et al., 2020). The eugenol demonstrated an egg killing effect on *S. scabiei* with an EC50 of 0.9%, (Li et al., 2021). This recommends that eugenols can penetrate the surface of eggs and can be used as sole treatment of *S. scabies* (Bernigaud et al., 2019; Thomas et al., 2020).

The eugenols are known to cause skin reactions when used in excessive quantities so EC 50 should be critically considered. The topical administration of eugenol should not exceed 0.5% to prevent these adverse reactions on skin (Nardoni and Mancianti, 2022).

The Palmarosa essential oil is the secondary metabolic product of *Cymbopogon martini*. It killed *S. scabiei* in 50 minutes when used at 1% concentration (Fang et al., 2016; Nikolaou et al., 2021). Fang et al. evaluated the efficacy of ten essential oils against *S. scabiei.* Out of the 10 essential oils, the most effective essentials oils were 1 percent (v/v) clove oil and palmarosa oil as they eliminated every mite in 20 and 50 minutes, respectively (Sharma et al., 2020). The active ingredient of palmarosa oil is geraniol (Smitha and Rana, 2015). Different routes of administrations have tested for geraniol but the results have shown that geraniol have a potent acaricidal effect whenever administered by contact as opposed to fumigant form. The tarpene also exhibit ovicide activity against *S. scabiei* (Li et al., 2020) with an EC50 of 2% and was effective against both the forms (adult and eggs) of *P. cuniculi* mites (Fang et al., 2020). Being 5.3% of the maximum amount advised, it is well acceptable for dermal use, and this EO seems to be a emerging tool for a secure cure (Nardoni and Mancianti, 2022).

Neem Oil

The *Azadirachta indica* is a plant of India that provides us with neem oil (Upadhayay and Vigyan, 2014), this oil is used in various medicines for the treatment of different issues (Benelli et al., 2017). The main element of neem is azadirachtin that is present in the leaves and seeds. It deregulates the growth of parasites, decreases ecdysone levels, changes the development and reproduction, and have negative effect on molting. The acaricidal effect active as larvicide against *S. scabiei var cuniculi* while octadecanoic acid-tetrahydrofuran-3,4-diyl ester, cause damage to the body wall of mites, hinders mitochondrial activity and oxidative phosphorylation pathway, ultimately results in the death of parasites (Chen et al., 2014; Song et al., 2017).

Conclusion

In conclusion, there are encouraging possibilities for the management of *Sarcoptes scabiei* infestations, including scabies in humans and mange in animals, through the use of herbal remedies, especially essential oils. In place of traditional acaricides, essential oils with notable acaricidal activity against *S. scabiei* include tea tree, lemongrass, lavender, cinnamon, clove, palmarosa, and neem, respectively. These essential oils are effective against mites at different stages of their life cycle due to their diverse mechanisms of action, which include neurotoxicity, ovicidal effects, and disruption of mite physiology. Moreover, herbal products made from these essential oils are usually safe for the environment, well-tolerated, and have few side effects. To maximize efficacy and safety, more research is necessary to optimize formulations, dosages, and application techniques. Researcher, medical professional, and policymaker collaboration is necessary to fully utilize the potential of herbal remedies in the fight against scabies and to enhance public health outcomes worldwide.

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Chapter 12

Peppermint Essential Oil: A Tropical Remedy

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ABSTRACT

Essential oils are known to be the concentrated oils, containing substantial compounds due to which a plant takes its particular aroma and flavor. Peppermint oil is also one of the many significant essential oils. Peppermint herb also gains its popularity as it is a natural cross between two different types of mints. Its occurrence expands to many origins including the entire regions of Asia, North America and Europe. The leaves of peppermint are used for many purposes but its oil stands at another level in therapeutics. Peppermint oil is highly effective against gastrointestinal complexities. The use of this oil is quite well known for irritable bowel syndrome (IBS), but it also treats several other medical conditions including digestion, bloating, fatigue, anxiety, memory and spasms. The role of peppermint essential oil as an anti-inflammatory and antimicrobial agent has also been unveiled. The broad spectrum of usage of this oil is given to its efficient pharmacodynamics. It can be used by numerous ways considering the proper way of application in accordance with the suitability and safety of the applicant. A significant amount of research work has been done to disclose the tendencies of this amazing oil but still there is a lot to discover.

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INTRODUCTION

Essential oils (EOs) are basically a concoction of volatile oils extracted from natural aromatic plants (Sattayakhom et al., 2023). Since the antient times of various cultures including Egyptians, Persians, Greeks, and Chinese, essential oils have been used as a common remedy throughout the world. Till this day, EOs are being used in traditional as well as complimentary medicines, massage therapies, aromatherapy, perfumes, cosmetics, and food industries (Lr, 2021). Some common plants from which essential oils are extracted include cinnamon, basil, eucalyptus, oregano, thyme, sage, camphor tree, peppermint, lavender, lemongrass, and others (Sakkas and Papadopoulou, 2017; Yanakiev, 2020; Lee et al., 2022) . EOs extracted from citrus fruits have a great significance as well in the food, beverage, and perfume, industries, in addition to being used in aromatherapy and as potent medicinal agents (Dosoky and Setzer, 2018). These vital oils are also found in a range of other products such as food flavoring, lotions, soaps, shampoos, colognes, hair styling products, laundry detergents, as well as in several insect repellents (Ramsey et al., 2020). Over the past decades, essential oils have greatly risen in their popularity. This might be due to the fact that EOs extracted from numerous plant species contain over 200 constituents. The application of such oils as anti-inflammatory anticancer, antioxidant, antimicrobial, anti-viral, antiparasitic, antiaging, and neuroprotective agents, in addition to other pharmacological responses of nervous system thus leading to anxiolytic, sedative, antidepressant, and anticonvulsant effects are due to their effective properties (Aziz et al., 2018). Currently, the clinical study data available regarding the immunomodulatory effects of essential oils is not enough (Sandner et al., 2020). However, different studies have confirmed that EOs interfere with crucial biological processes via interacting certain biological targets, at both cellular and multicellular levels (de Sousa et al., 2023). Therefore, the therapeutic tendencies of several essential oils are enough to make them a substantial ingredient in novel drugs and modern products.

Background of Peppermint Essential Oil (PEO)

Occurrence

Over the decades, certain plants have made a great mark in the world history due to their remarkable tendencies (Diniz do Nascimento et al., 2020). One of such plants is peppermint. Peppermint (mentha), is a genus belonging to the taxonomic family Lamiaceae (*Mentha piperita* L.) and a cross between two different types of mints (spearmint and water mint) (Fig. 1). It is broadly distributed throughout the temperate regions of the world including Asia, specifically India, Europe, United States, and Mediterranean countries because of their distinct aroma and commercial value (Mahendran and Rahman, 2020). Peppermint is generally a perennial, strongly scented, and glabrous herb. It contains innumerable constituents which are further categorized as PEO and non-essential components (Zhao et al., 2022).

Table 1: Pharmacological significance of some common essential oil extracting plants

Sr. no.	Plant name	Scientific name	Biological activities	References
1	Cinnamon	*Cinnamomum verum*	Anti-inflammatory, antimicrobial, antioxidant, anticoagulant, analgesic, anticancer	(Bhattarai et al., 2021)
2	Basil	*Ocimum basilicum*	Antifungal, antibacterial, antiparasitic, antioxidant	(Sakkas and Papadopoulou, 2017; Tavallali et al., 2019)
3	Eucalyptus	*Eucalyptus cinerea*	Antioxidant, antimicrobial, chemotherapeutic, antiseptic, wound healing, and herbicidal, insecticidal, nematicidal, acaricidal	(Dhakad et al., 2018)
4	Peppermint	*Mentha piperita L.*	Anti-inflammatory, antimicrobial, effective against gastrointestinal disorders, anti-spamosdic activity, antidepressive	(Kehili et al., 2020; Scarpellini et al., 2023; Matsueda et al., 2024)
5	Sage	*Salvia officinalis*	Antimicrobial, anti-inflammatory, anticancer	(Poulios et al., 2020)
6	Caraway	*Carum carvi*	Anti-tumor, antimicrobial, antioxidant	(Aly et al., 2023)
7	Lavender	*Lavandula angustifolia*	Antifungal, antibacterial, carminative, antidepressive, sedative	(Cavanagh and Wilkinson, 2002)
8	Lemongrass	*Cymbopogon citratus*	Antioxidant, antifungal, antibiofilm, anti-hypersensitive potential	(Rhimi et al., 2022)
9	Camphor tree	*Cinnamomum camphora*	Antioxidant, anti-inflammatory, antimicrobial, allelopathic, insecticidal, algicidal	(Lee et al., 2022)
10	Rosemary	*Rosmarinus officinalis*	Antioxidant, antitumor, antiproliferative, anti-inflammatory, antimicrobial	(de Oliveira et al., 2019)

Cultivation Zone

Peppermint is indeed one of the most crucial aromatic crops that is cultivated around the world for the sake of its EOs (Ghotbi-Ravandi et al., 2023). This plant is also widely cultivated in India. This vital plant is expansively cultivated in Himalayan hills, Uttar Pradesh, Haryana, Bihar and Punjab. Out of these regions, Uttar Pradesh is known to be the largest producing state of the country, thus contributing about 80% to 90% of the total production, It is then followed by the regions of Punjab, Bihar, Haryana, and Himachal Pradesh (Muthukumar, 2013).

Fig. 1: Peppermint plant (A) and peppermint essential oil (B)

Therapeutic Efficacy of Peppermint Oil

PEO has long been used to treat innumerable ailments. This oil is specifically known for its gastrointestinal problems, but it also shows several curative abilities in the diseases including abdominal pain, nausea, irritable bowel syndrome, anti-inflammatory activity, antioxidant activity, anti-microbial effects, in addition to the modulation of psychosocial distress and fatigue (Chumpitazi et al., 2018; Wińska et al., 2019; Scarpellini et al., 2023). Some of the basic therapeutic properties of peppermint essential oil have been described (Fig. 2).

Fig. 2: Health benefits of peppermint essential oil

An Anti-inflammatory and Antimicrobial Agent

PEO is a promising anti-inflammatory agent. About 23 compounds have been identified in this oil, with the core chemical component being menthol (approximately 53.29%), thus making it an effective anti-inflammatory and wound healing oil (Kehili et al., 2020). Various studies have showed that such EOs reduce inflammation in vitro by inhibiting the production of pro-inflammatory cytokines, including IL-6 and TNF-α, and also by in vivo methods. Therefore, herbal preparations of peppermint are potent cosmetic and medicinal preparations in case of their use in different products with anti-inflammatory, wound-healing and antimicrobial properties (Hudz et al., 2023).

The widespread use of peppermint is generally related to its pleasant minty flavor and a feeling of coolness that it gives, however, it is supposed that an elevated menthol content in peppermint oil shows increased antimicrobial activity (Orchard and van Vuuren, 2017; Wińska et al., 2019). More recent data involving peppermint oil demonstrate its antimicrobial effects and a capability to downregulate inflammation. Antimicrobial properties of peppermint oil have been determined by the application on various microorganisms by adding in variable amounts to the film samples made of different components. The biodegradable films thus obtained have an increased potential for practice in different fields, especially in food packaging industries (Koşarsoy Ağçeli et al., 2022).

Settles IBS and Gastric Irritation

Around the world, herbal therapy containing PEO is broadly used for patients suffering with irritable bowel syndrome (IBS). This oil is an effective and safe remedy for gastroenterology, thereby having promising scientific standpoints and rapidly escalating practice in clinical trials. PEO as well as its constituents exert anti-spasmodic and muscle relaxant effects on the stomach, lower esophageal sphincter, and duodenum, in addition to large bowel. Moreover, this oil has tendency to modulate visceral sensitivity. These effects suggest the use of peppermint oil for better endoscopic performance and also for IBS (Scarpellini et al., 2023).

As various mechanisms of action described for PEO include relaxation of smooth muscles; modulation of visceral sensitivity; anti-inflammatory activity, anti-microbial effects, and modulation of psychosocial distress, placebo controlled data significantly support the use of this oil in IBS, childhood functional abdominal pain, gastric irritation, postoperative nausea, and functional dyspepsia (Matsueda et al., 2024).

Supports Digestion

Since ancient times, PEO has been used to cure many digestive disorders as it helps to improve digestion (Kligler and Chaudhary, 2007). Drinking a glass of water mixed with few drops of this oil after meals reduce flatulence and helps digestion by relaxing the muscles. It is mainly used to treat issues in the upper digestive system like cramps, indigestion, and nausea for many people (Zhao et al., 2022). There are several evidences showing that PEO exerts effective actions against many gut diseases. It improves stomach and intestinal movements (Matsueda et al., 2024) and relieves feelings of fullness and discomfort, especially in case of functional dyspepsia (Acker and Cash, 2017).

Reduces Gastrointestinal Spasms

PEO has been proved as effective smooth muscle relaxant, and due to this property peppermint oil delivered through enema has been examined in two trials to help ease symptoms of gastrointestinal spasms during different GI procedures like flexible sigmoidoscopy, colonoscopy, administration of barium enema etc. (Asao et al., 2003). During procedure like outpatient flexible sigmoidoscopy, traditional practices cause many problems. Attention has been drawn to the use of peppermint oil as it is a safe substance to produce smooth muscle relaxation (Scarpellini et al., 2023).

Relieves Headaches

Recent research has uncovered specific ways in which PEO can relieve pain. When it is applied directly to the skin, it creates a long-lasting cooling sensation by steric alteration of calcium channels of the cold receptor as well as antagonizes serotonin-induced contraction (Chumpitazi et al., 2018). Moreover, applying PEO to the skin of the forehead increases blood flow, as measured by laser doppler (Kehili et al., 2020).

Tension-type headaches are the most common type of headaches. Solutions containing about 10% peppermint oil in alcohol have been approved for treating tension-type headache in adults and children over 6 years age (Mahendran and Rahman, 2020).

Fight Fatigue and Anxiety

In a recent research study using mice as a model, it has been concluded that injecting PEO into mice can make them walk more, and menthol might help boost energy by stimulating the nervous system and lowering lactate level in the blood (McKay and Blumberg, 2006). It is expected that PEO might help healthy people breathe better by increasing lung capacity, giving their brains more oxygen and reducing tiredness and anxiety (Li et al., 2017). Moreover, PEO fights against anxiety by increasing body alertness and improving mental refreshment. PEO can relieve anxiety, reduce pain and impulse, modify the olfactory pathway of the brain, as well as promote sleep quality, contributing to its antifatigue activity (Mahdavikian et al., 2021).

Improves Memory

PEO is noted to protect brain and nerves. Menthol and menthone in PEO are neuroactive substances. They can block cholinesterase and attach to nicotine and also GABAA receptors, making neurons more active. Using PEO regularly can really help reduce mental tiredness (Lv et al., 2022).

Additionally, PEO has neuroprotective property. Peppermint aroma has been shown to improve tasks related to attentional processes, working memory, virtual recognition memory, as well as visual-motor response (Fang et al., 2019). Administrating drugs through the nose to the brain is a promising method because it bypasses the blood-brain barrier and increases the bioavailability for the treatment of different brain diseases (Kiran Vaka and Narasimha Murthy, 2010). Besides, PEO can ease bronchospasm, by boosting nitric oxide production and opening of K^+ channel (de Sousa et al., 2010).

Pharmacodynamics of Peppermint Oil

The key pharmacodynamic effect of PEO related to the gastrointestinal tract is a dose-related antispasmodic impact on its smooth musculature, given to the interference of menthol component with calcium moving across the cell membrane.

Mode of Action

The numerous preclinical investigations impart light on the possible applicability of peppermint oil to gastrointestinal and other problems and the physiology of the gastrointestinal tract as shown in the Fig. 3.

a) The core mechanism of action of PEO in functional gastrointestinal diseases is thought to be its antispasmodic properties. However, it is unclear how much peppermint oil gives therapeutic benefits (Kearns et al., 2015).

b) PEO relaxes smooth muscles. It inhibits calcium channels in guinea pig ileal smooth muscles in vitro. Menthol has been shown to cause circular smooth muscle relaxation in the human colon by directly preventing contractility by blocking Ca^{2+} inflow via sarcolemma L-type Ca2+ channels (Amato et al., 2014).

c) The enteric nervous system may potentially be directly impacted by this oil. It has been demonstrated that menthol functions via transient receptor potential cation channel to generate membrane potential depolarization in a concentration-dependent manner (Kim et al., 2016).

d) Despite being widely recognized topical analgesic, when taken orally or intraperitoneally, PEO can reduce visceral discomfort (Adam et al., 2006). The transient receptor potential cation channel superfamily's TRPM8 and/or TRPA1 receptors, which are found in the gut, are thought be involved in the alleviation of visceral discomfort (Harrington et al., 2011).

e) Menthol inhibits human monocytes' ability to produce inflammatory mediators in vitro. Peppermint oil's anti-inflammatory properties are thought to be mediated because its activation reduces the symptoms of chemically induced colitis (Ramachandran et al., 2013). Ani-inflammatory property of this oil is also achieved by involvement of certain cytokines.

f) In healthy adults, the impact of PEO upon esophageal function has been investigated. It reduces esophageal spasms utilizing double contrast esophageal barium tests (Mizuno et al., 2006).

g) According to hydrogen breath tests, it has been discovered that this oil slows down orocecal transit (Goerg and Spilker, 2003). Using PEO solution combined with barium reduces intestinal spasm during barium enema treatments (Asao et al., 2003). Peppermint oil has been successfully employed for its anti-spasmodic qualities during ERCP operations as well as upper GI endoscopies and colonoscopies.

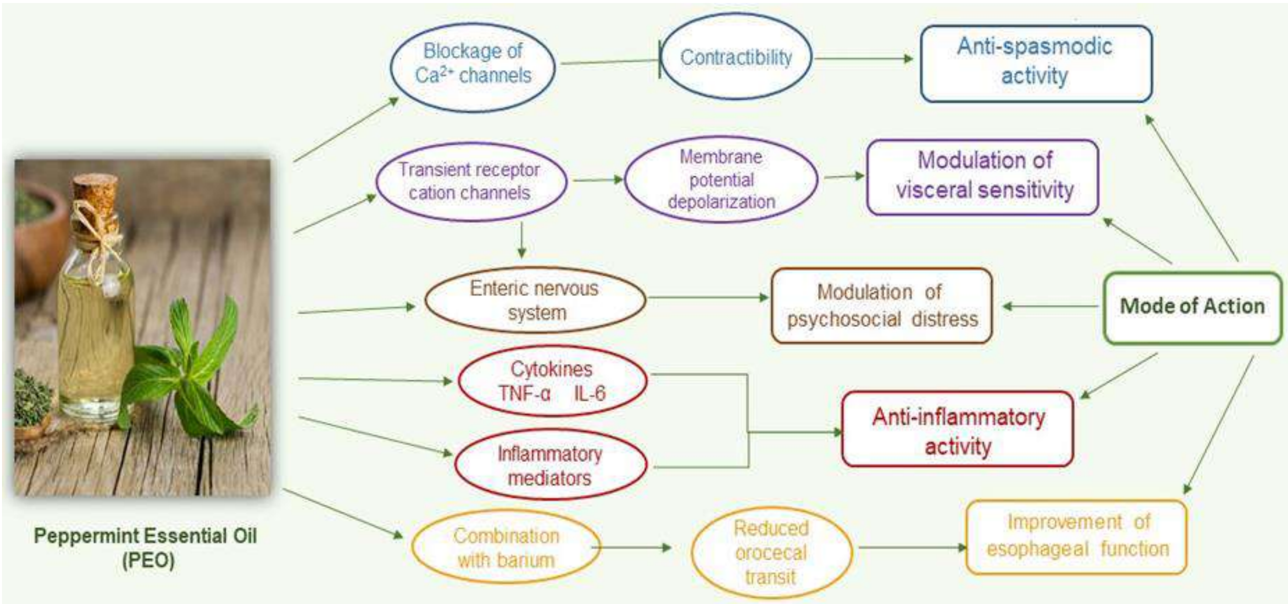

Fig. 3: Mode of action of PEO in various ailments

Combination with other Oils

A combination of peppermint oil and caraway oil is of special interest in FD and IBS since the documented mechanistic investigations reveal a synergistic and additive impact of the combination against the sensation of abdominal discomfort and bloating by a multitarget approach (Alliger et al., 2020; Krueger et al., 2020; Zhang et al., 2021). Both caraway and peppermint oil have been examined alone and in combination using a post-inflammatory visceral hyperalgesia paradigm. When used in combination, the sensitivity to pain was significantly reduced (Adam et al., 2006). Using the disk diffusion method, the antibacterial activity of peppermint, lavender, and their blend have also been evaluated (Park and Yoon, 2018). Because of the antibacterial and antiviral properties, peppermint, eucalyptus, and rosemary oils have also been believed to work in concert to treat certain infectious disorders of both the upper and lower respiratory tracts (Köteles et al., 2018).

Various Ways to use Peppermint Oil

There are various ways to use peppermint essential oils which are described as:

Applied Topically on Skin

One way to use PEO is by its direct application on the skin. Menthol, a component of peppermint plant and known to be effective in external use, is the main ingredient in many ointments and provides a little analgesic and cooling effect (Kligler and Chaudhary, 2007). It has been observed that menthol alters the Ca2+ currents in neuronal membranes, hence increasing the susceptibility of cutaneous cold receptors and can be considered as the most efficient penetration enhancer (Aqil et al., 2007). About 3% peppermint oil allows hair growth by promoting the conservation of vascularization of hair dermal papilla, thus contributing to the improvement of hair growth (Oh et al., 2014).

Applied Intranasally

PEO is also effective when it is applied intranasally. The therapeutic agents administered this way are regarded to reach the brain through the olfactory pathway. However, this pathway is associated with a primary restricting element, the olfactory epithelial barrier. A natural barrier modulating agent, peppermint oil, has been found to enhance the delivery of therapeutic agents via secure and transient permeabilization of the olfactory epithelium. it is most likely that peppermint oil opens the tight junction to enhance the delivery of therapeutic factors (Vaka and Murthy, 2010).

Oral Ingestion (Capsule or tablet form)

It is very well known that the use of peppermint oil is a common method to treat IBS (Nee et al., 2021). ZO-Y60 is an enteric-coated pill, the core factor of which is peppermint oil extracted from the peppermint plant (Asgarshirazi et al., 2015). Peppermint oil ZO-Y60 exert notable impacts on IBS, regardless of its subtypes (Matsueda et al., 2024). Colpermin is also an enteric coated peppermint oil formulation designed to delay peppermint oil release, which seems beneficial in the treatment of irritable bowel/spastic colon syndrome (Khanna et al., 2014). Oral administration of PEO can also prevent xylene caused intestinal infection (From the American Association of Neurological Surgeons (AANS), American Society of Neuroradiology (ASNR), Cardiovascular and Interventional Radiology Society of Europe (CIRSE), Canadian Interventional Radiology Association (CIRA), Congress of Neurological Surgeons (CNS), European Society of Minimally Invasive Neurological Therapy (ESMINT), European Society of Neuroradiology (ESNR), European Stroke Organization (ESO), Society for Cardiovascular Angiography and Interventions (SCAI), Society of Interventional Radiology (SIR), Society of NeuroInterventional Surgery (SNIS), and World Stroke Organization (WSO) et al., 2018). While injected directly into the large intestine during colonoscopy, peppermint oil reduces colonic spasm caused by the process and decreases colonic motility.

Diffused in the form of Essential Oils

Peppermint diffused in the form of essential oil, consisting mainly of menthol, menthone, neomenthol and iso-menthone, is a combination of biologically active secondary metabolites with numerous properties (Zhao et al., 2022). This is the most crucial and potent method to acquire benefits of peppermint plant. It can pharmacologically defend gastrointestinal, liver, kidney, skin, breathing, brain and nervous structures, and also reduces viral infectivity (Civitelli et al., 2014). Colorectal cancer cells proliferation is notably inhibited by PEO, by inducing apoptosis and thus arresting cell cycle at different phases (G1/G0 and G2/M) (Yi and Wetzstein, 2011). Urolithiasis can also be treated by crystal-inhibiting, antioxidant, anti-inflammatory and diuretic effects by PEO (Ullah et al., 2014). Mental fatigue is also known to be eliminated by the continuous administration of PEO.

Repercussions of Peppermint Oil

The common repercussions of peppermint oil are given as:

i. There is a long history of using peppermint oil and also leaves to treat stomach issues.
ii. The impact of this oil on chemotherapy-induced nausea, vomiting, retching, and frequency has also been assessed in some cancer patients (Efe Ertürk and Taşcı, 2021).
iii. The effects of targeted ileocolonic release of PEO and the safety and effectiveness of small-intestinal release of peppermint oil in IBS patients has been confirmed (Matsueda et al., 2024).
iv. Additionally, it is thought to be helpful in the treatment of nerve illnesses and mental exhaustion.
v. The psychological effects of peppermint oil (EO) on animals have also been observed.
vi. The invigorating effects of peppermint have been studied as an objective measure to treat daytime drowsiness (Norrish and Dwyer, 2005).
vii. Inspite of a broad range of health benefits of peppermint oil, few side effects are also taken under consideration such as possibility of nausea, heartburn, and dry mouth if PEO is taken orally.
viii. In rare cases, PEO has a slight possibility to cause some allergic reactions as well. However, a broad range of therapeutic efficiencies of this oil is responsible for its escalating popularity.

Conclusion

This chapter provides a comprehensive analysis of the biological activities of peppermint plant, specifically peppermint essential oil. It is a well-known oil regarding its curing activities in IBS, gastric irritation and digestive problems. However, it has been illustrated that therapeutic efficacy and pharmacological potential of PEO is not just limited to gastrointestinal issues, but also addresses several other ailments including cancer. A number of ways by which this oil can be used is just remarkable, as each type of the practice highlights its curing efficiency in a whole different way. This is one of the reasons due to which pharmacodynamics of peppermint oil is attaining a great deal of attention in medical practices. This escalating popularity is also because it gives multiple advantages with comparatively less side effects. Therefore, if the benefits of PEO, either alone or in synergistic way, are utilized to an advanced extent, it would be a positive step toward modern therapeutics and natural drug discovery practices.

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Chapter 13

Plant Essential Oils as an Alternative Antimicrobial Therapy

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ABSTRACT

Essential oils, natural volatile liquids, are characterized by strong aroma and low mol. weight. They are usually colorless, lipid-soluble, and organic solvents, synthesized by various plant parts including stems, seeds, roots, flowers, leaves, etc. They are typically extracted through processes like steam distillation, cold pressing, or solvent extraction from various plant parts. They may serve as a replacement therapy in treating microbial infection. The antibacterial effects of essential oils can either be bacteriostatic or destroy bactericidal. EO has been employed besides the restricted efficacy of antiviral drugs. Numerous studies have shown the antiviral activity of EO against DNA and RNA viruses by hindering the replication process. EOs exhibited antifungal activity that makes it a therapeutic alternative to synthetic drugs by interfering with chitin synthesis leading to abnormalities in glycoprotein synthesis, mitochondrial structure, and inhibition of sporulation, reducing fungal growth, and suppressing mycotoxin production. Plant essential oils have been employed as an alternative therapy against both endo and ectoparasites due to the increasing resistance of certain parasites to conventional drugs, leading to significant mortality and morbidity rates. Their action mechanism is their effect on the cell wall, cell membrane, respiration, hereditary material, and quorum sensing of micro-organisms. Researchers have extensively studied the antimicrobial effects of EOs and their chemical components.

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INTRODUCTION

Different aromatic medicinal plants constitute a substantial part of the natural ecosystem and have valuable applications in various sectors including pharmaceuticals, perfumery, flavor and fragrance, and cosmetics (Swamy and Sinniah, 2015). Despite the availability of modern medicine, most of the world's population is using traditional herbal remedies to cure various health issues (Sudipta et al., 2012). In the global market, herbal products are currently valued at around 62 billion USD with projections indicating a potential increase to 5 trillion USD by 2050. (Bhattacharya et al., 2014). Approximately 1500 species are identified and recorded for their aroma and flavor, while over 9000 native plants have been found and documented for their medicinal qualities. Annually, more than 250 varieties of essential oils, valued at 1.2 billion USD, are traded internationally (Swamy and Sinniah, 2016). Essential oils, natural volatile liquids are marked by strong aroma and low molecular weight. They are usually colorless, lipid and organic solvents soluble, produced by various plant parts such as buds, stems, bark, leaves, seeds, fruits, flowers, twigs, roots or wood and are stored in specialized structures such as oil ducts, secretary cells, cavities, canals, resin ducts, glands, or trichomes. They are utilized as flavor enhancers in food and beverages, as well as in perfumery, pharmaceuticals, and cosmetics, essential oils possess notable medicinal properties (Bozin et al., 2006). They are widely used in treating various chronic non-infectious diseases such as diabetes, cancer and hypertension as well as various infectious diseases. The antimicrobial properties of essential oil and their chemical composition have been extensively studied by researchers (Ali et al., 2015).

Essential oils are commonly obtained from plants using methods such as hydro distillation, dry distillation, steam distillation or mechanical cold pressing. The Clevenger steam distillation apparatus was utilized in the late 19th century (Arora et al., 2016). Methods such as fermentation, extraction, crushing, or hydrolysis are used to obtain essential oils (Baj et al., 2015). The EOs demand and usage are increasing not only in medicine but also in food, fragrances, and cosmetics. They may serve as a replacement therapy in treating microbial infection. There's a potential for EO to replace antibiotics in the future, although their effectiveness is still under scrutiny. Different mechanisms such as cell wall disruption, interference with metabolic pathways, or lowering cellular membrane potential are involved in inhibiting microbial growth (Swamy et al., 2016).

Chemical Composition

The plant parts from which essential oils are taken determine the chemical composition of oils. These oils contain terpenoids and phenylpropanoids, alongside aromatic and aliphatic constituents. Terpenoids, naturally occurring hydrocarbons, are categorized into various types based on their structure and function, typically organized by units of five carbons. The terpenes contain monoterpenes, sesquiterpenes, hemiterpenes, diterpenes, triterpenes, and tetraterpenes. These terpenes constitute 90% of essential oils (Bakkali et al., 2008). More than 55,000 terpene molecules have been identified. Essential oils also contain aromatic compounds derived from phenylpropane but in lower concentrations than terpenes. These compounds encompass methylenedioxy compounds, methoxy derivatives, aldehydes, alcohols, and phenols (Suzuki et al., 2015). However, various terpenes and aromatic compounds are listed in Table 1.

Table 1: Chemical Composition of different Essential Oils (Bakkali et al., 2008)

	Functional Groups	Compounds
	Carbures	Acyclic: myrcene, ocimene. monocyclic: terpinenes, phellandrenes, p-cymene. bicyclic: 3-carene, camphene, pinenes, sabinene.
	Alcohols	Acyclic: geraniol, linalol, lavandulol, citronellol, nerol. Monocyclic: a-terpineol, carveol, menthol.
Terpenoids		Bicyclic: borneol, chrysanthenol, fenchol, thuyan-3- ol.
	Peroxides	Ascaridole, hydroperoxide, isoborneol peroxide, and d-limonene peroxide.
	Phenols	Thymol, cinnamic acid, and phenethyl alcohol.
	Ethers	1,8-cineole, menthofurane, estragole, safrole, myristicin, anethole
	Esters	Linalyl acetate or propionate, citronellyl acetate, Benzyl acetate, menthyl or a-terpinyl acetate, and bornyl acetate. isobornyl acetate, methyl salicylate, and geranyl acetate.
	Aldehydes	Geranial, neral, citronellal, citral.
	Ketones	Tegetone, menthones, carvone, thuyone, ombellulone, pulegone, piperitone, camphor, fenchone, menthone pinocamphone, pinocarvone.
	Aldehyde	Cinnamaldehyde, benzaldehyde.
Aromatic	Alcohols	Cinnamic alcohol, linalool, geraniol, citronellol, and benzyl alcohol.
Compounds	Phenols	Eugeno, chavicol.
	Methoxy derivatives	Anethole, methyleugenols, estragole, elemicine, safrole.
	Methylenedioxy compounds	Apiole, myristicine, elemicin.

Antimicrobial Effects of Plant Essential Oils

Plant essential oils are well known for their antibacterial, antiviral, antifungal and antiparasitic properties. Currently, there is a wide range of antibiotics utilized to cure different bacterial infections. However, due to increasing multidrug resistance, compromised immune systems in some people and bacteria's ability to form protective biofilms may leads to the death of individuals. Moreover, the administration of multiple antibacterial agents is the major cause of toxicity in humans. In current scenario, plant essential oils and their primary chemical constituent emerge as potent alternatives for antimicrobial activity (Galvão et al., 2012; Raut and Karuppayil, 2014).

Antibacterial Activity

The antibacterial effects of essential oils can be either bacteriostatic or bactericidal. However, distinguishing between these actions can be challenging. The parameters such as minimum bactericidal concentration (MBC) and minimum inhibitory concentration (MIC) are used to assess antimicrobial activity. The agar well diffusion and agar dilution methods are commonly employed to check antibacterial properties of essential oils (Burt, 2004; Faleiro, 2011).

A study reported that certain plants and essential oils (EOs) including rosemary, cinnamon, thyme, clove and oregano demonstrating strong inhibitory effects against different bacterial infections. The phenolic compounds found in essential oils such as carvacrol, thymol, rosmarinic acid, menthol, vanillin, and eugenol play an antimicrobial role against *Bacillus cereus, Streptococcus pneumoniae, Escherichia coli* and *Staphylococcus aureus* (Lopez-Romero et al., 2015). Furthermore, citronellol and carveol exhibit an inhibitory effect on *Escherichia coli* growth due to the penetrating ability of oils into cell wall components leading to disruption in cell wall integrity. Some chemical compounds can inhibit the growth of most Gram-positive bacteria and a few Gram-negative bacteria. (Liu et al., 2017) reported that cardamom from the Zingiberaceae family, anise from the Apiaceae family, and oregano, rosemary, and basil of the Lamiaceae mint family along with parsley, and coriander showed notable antimicrobial properties against saprophytic microbes. This also demonstrated oregano EO's effectiveness against *Yersinia enterocolitica, Salmonella typhimurium* and *E. coli* by slowing down their growth and lactic acid production. Certain EOs have varying levels of effectiveness against both gram-positive and gram-negative bacteria. On the other hand, compounds like eugenol, thymol, citral and carvacrol EO demonstrated efficacy against both Gram-positive as well as Gram-negative bacteria (Swamy et al., 2016). However, the chemical composition of essential oils and their antimicrobial activity against various pathogens are summarized in Table 2.

Table 2: Antibacterial Activity of plant Essential Oils

Scientic Name	Common Name	Parts used	Chemical Composition	Inhibited Microorganism	References
Artemisia longifolia	longleaf wormwood or Indian wormwood	Aerial part	Camphene, Camphor, 1,8-cineole, Sabinene, Alpha-pinene, (Eucalyptol)	*Staphlococcus epidermidis, Escherichia coli, Staphlococcus aureus*	(Lopes-Lutz et al., 2008)
Daucus littoralis	seacoast carrot	Leaves, stems, fruits, flowers, roots	Carotol, acorenone B, Daucol, Caryophyllene, Germacrene D	*S. aureus, B. cereus, S. typhimurium, E. coli*	(Yousefbeyk et al., 2014)
Cymbopogn nardus	citronella grass	Leaves, stems	Carene, beta-citronellal, Geranyl acetate, β-Caryophyllene, Citronellol	*S. putrefaciens, Brochothrix thermosphacta, Listeria innocua, P. putida, S. typhimurium, E. coli, L. monocytogenes*	(Teixeira et al., 2013)
Eugenia caryophyllata	Clove	Buds, leaves, stems	Eugenyl acetate, Phenylpropanoids, carvacrol, thymol, Acetyl eugenol, eugenol, cinnamaldehyde	*L. monocytogene, S. epidermidis, S. aureus, Salmonella typhimurium, E. coli, P. aeruginosa*	(Chaieb et al., 2007)
Foeniculum vulgare	Fennel	Leaves, seeds	Phellandrene, trans-anethole, methyl chavicol, limonene, Camphen, pinene, fenchone fenchyl alcohol, anisaldehyde.	*E. coli, S. typhimurium*	(Bisht et al., 2014)
Nigella sativa	black seed, black cumin, or fennel flower	Seeds	Thymoquinone, α-thujene, thymohydroquinone, limonene, p-cymene, carvacrol, thymol, longifolene	*B. cereus, S. aureus, P. aeruginosa, E. coli*	(Singh et al., 2014)
Origanum vulgare	oregano	Leaves, Arial part	Carvacrol, thymol, γ-terpinene, trans-sabinene hydrate, cis-piperitol, borneol, terpinen-4-ol, linalool	*Escherichia coli, Salmonella typhimurium,* Ampicillin-resistant *Pseudomonas aeruginosa*, *Staphylococus aureus, Bacillus subtilis*	(Béjaoui et al., 2013)
Verbena officinalis	Vervain	Arial part	Borneol, 1,8-cineole, α-pinene, geraniol, β-pinene, α-terpineol, citral,	*S. aureus, E. coli, S. typhimurium, L. monocytogenes*	(Shan et al., 2011)
Warionia saharae	desert wormwood or desert ragwort	Arial part	Eudesmol, trans-nerolidol, linalool, 1,8 cineole, camphor, p-cymene, terpinen-4-ol	*E. coli, S. aureus, P. aeruginosa, B. cerus*	(Sellam et al., 2014)

Antiviral Activity

Antiviral agents, also known as antivirals, are substances or medications employed for treating viral infections by targeting and impeding the processes involved in viral replication. Many antivirals have developed resistance against viral pathogens such as hepatitis B virus (HBV) and human immunodeficiency virus (HIV). Alternative therapeutic compounds, like EO, have been employed besides the restricted efficacy of antiviral drugs. Numerous studies have shown the antiviral activity of EO against DNA and RNA viruses by hindering the replication process Notably, essential oils like oregano and clove were evaluated against non-enveloped viruses such as poliovirus (RNA virus), coxsackievirus B1 (RNA virus), and adenovirus type 3 (DNA virus) (Orhan et al., 2012; Tariq et al., 2019).

Certain compounds in essential oils have demonstrated effective antiviral activity against viruses by exhibiting viricidal activity preventing the viral replication and viral adsorption to host cells. Gavanji et al. (2015) have conducted a study to confirm the antiviral properties of essential oils extracted from Artemisia kermanensis, Eucalyptus caesia, Zataria multiflora, rosemary and Satureja hortensis L against herpes simplex virus-1 (HSV-1). Not all essential oils are effective including thyme EO, which did not yield an effective response against HSV and influenza viruses (Tepe et al., 2004). Furthermore, β-caryophyllene, a constituent found in essential oils showed inhibitory effects against dengue virus (Moo et al., 2020). The compounds such as γ-terpinene and cumin aldehyde exhibited antiviral activity against HSV-1 significantly, while a lower inhibitory effect was noted against parainfluenza virus (Orhan et al., 2012). The 0.5 mg/mL ajwain essential oil showed an effective antiviral response against the Japanese encephalitis virus (JEV) (Roy et al., 2015).

Essential oils exhibit various mechanisms of action to combat viral infection, typically targeting nucleic acid polymerases to inhibit replication. Furthermore, thymol and phenylpropanoids have been recognized as antiviral against herpes simplex virus and Japanese encephalitis virus. Human trials are being conducted to improve efficacy and safety conclusively (Aljaafari et al., 2021). The antiviral effects of different essential oils are summarized in Table 3.

Table 3: Antiviral Effect of Plant Essential Oils

Scientific name	Common Name	Parts used	Chemical Composition	Inhibited Microorganism	References
Achillea fragrantissima	fragrant yarrow or sweet yarrow	Aerial part	2,5,5-Trimethyl-3,6- heptadien-2-ol, yomogi alcohol, eucalyptol, 1,8-cineole, artemisia alcohol, thujone, Cissabinol, Lavandulol	Poliomyelitis-1 virus (POLIO), ORF virus (poxvirus family)	(Zeedan et al., 2014)
Fortunella margarita	kumquat	Leaves	Gurjunene, eudesmol, muuroleneterpineol, t-carveol, limonene, muurolene and cadinene	Avian influenza A virus (H5N1)	(Ibrahim et al., 2015)
Pogostemon cablin	Patchouli	Leaves	α-Pinene, Camphene, 3-octanone, Limonene, Terpinolene, Linalool, and Acetophenone	Influenza A (H2N2) virus	(Swamy and Sinniah, 2015)
Trachyspermm ammi	Ajwain or ajowan	Leaves, seed-like fruit	α-thujene, Carvacrol, Thymol, γ-terpinen, α-pinene, Sabinen, ρ-cymene	COVID-19, Japanese encephalitis virus (JEV) (Flaviviridae)	(Roy et al., 2015)
Melissa officinalis	Lemon balm	Leaves	Caryophyllene oxide, citronellal, β-Ionone, Nerolidol, β-Ocimene, geranial, neral	Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2), Human Immunodeficiency Virus (HIV), Herpes Simplex Virus (HSV), avian influenza virus (AIV) subtype H9N2	(Allahverdiyev et al., 2004)
Ocimum campechianum	Camphor basil	Leaves	Linalool, eugenol, β-Caryophyllene, α-Terpinene, Caryophyllene oxide	Herpes simplex virus type 1	(Wani et al., 2021)
Glechon spathulata	Coastal cudweed or coastal fleabane	Leaves	Caryophyllene, bicyclogermacrene	Herpes simplex virus type 1	(Venturi et al., 2015)
Glechon marifolia	Coastal cudweed	Leaves	Caryophyllene, bicyclogermacrene	Herpes simplex virus type 1	(Venturi et al., 2015)

Antifungal Activity

Plant essential oils exhibit antifungal activity that makes them a therapeutic alternative to synthetic drugs, especially considering the rising prevalence of drug-resistant fungal strains akin to bacterial resistance. Fungal infections can manifest as either superficial or invasive having treatment via oral tablets or topical creams. Treating fungal infection exhibits challenges as compared to bacteria due to the eukaryotic nature of both human and fungal cells. The chitin, a polysaccharide in fungal cell walls, is crucial in antifungal drug development to avoid potential toxicity to human cells and ensure host safety. Eugenol, terpenes, farnesol, menthol, benzoquinone and menthone have antifungal effect against *Candida albicans, Candida tropicalis, Candida neoformans, Candida glabrata* as well as *Paracoccidioides brasiliensis*. Additionally, essential oils can interfere with chitin synthesis leading to abnormalities in glycoprotein synthesis, mitochondrial structure, inhibition of sporulation, reducing fungal growth, and suppressing mycotoxin production (Hu et al., 2017; Nazzaro et al., 2017). Scalas et al. (2018) have conducted a study to demonstrate the utilization of essential oils extracted from *Origanum vulgare*, *Pinus sylvestris*, and *Thymus vulgaris* along with their primary constituents to augment the effectiveness of itraconazole against both azole-susceptible and azole-not-susceptible Cryptococcus neoformans strains and the findings have shown favorable results.

Ksouri et al. (2017) have conducted a study to determine an antifungal property of various essential oils (EO) against *C. albicans.* The essential oils obtained from plants such as rosemary, oregano and thyme exhibited inhibitory effects. Hu et al. (2019) observed the antifungal efficacy of essential oils from anise, peppermint, clove, cinnamon, pepper, citronella, and camphor derived from seven distinct spices was validated using an agar diffusion assay against three fungal strains. Among these Essential oils, cinnamon EO exhibited the most potent antifungal property against fungal strains. Clove EO showed the next highest level of antifungal activity following cinnamon EO. Dias Ferreira et al. (2013) found that essential oil of Curcuma longa exhibited toxicity against *Aspergillus flavus* and effectively suppressed the production of aflatoxin. Aflatoxins are harmful toxins generated by molds, capable of causing liver damage and potentially leading to liver cancer in humans. These mycotoxins occur naturally and are produced by two mold species. *A. flavus* and *A. parasiticus* are the two mold species responsible for aflatoxin production. The potential impacts of essential oils (EOs) on inhibiting aflatoxin production are highly intriguing and warrant further investigation (da Cruz Cabral et al., 2013). However, the antifungal effects of plant essential oils are summarized in Table 4.

Table 4: Antifungal Effect of Plant Essential Oils

Scientific Name	Common Name	Parts used	Chemical Compounds	Inhibited Microorganism	References
Aegle marmelos	Bael or bael fruit	Leaves	δ -Cadinene, δ-carene, α-pinene, trans-2-hydroxycinnamic acid, β-myrcene	*Candida albicans, Aspergillus niger, Fusarium oxysporum*	(Ibrahim et al., 2015)
Cinnamomum zeylancium	Ceylon cinnamon or true cinnamon	Bark, leaves	Cinnamaldehyde, (E)-cinnamyl acetate, benzaldehyde	*C. auris, C. parapsilosis, C. albicans, C. krusei*	(Unlu et al., 2010)
Daucus littoralis	Sea carrot or coastal carrot	flowers, leaves, roots, fruits, stems	Polyacetylenes, Flavonoids, Germacrene D, acorenone B, phenylpropanoids, Carotol, Daucene, Trans-α-bergamotene	*C. albicans*	(Yousefbeyk et al., 2014)
Eremanthus erythropappus	Brazilian Arnica or Candeia	Leaves	germacrene D, (Z)-caryophyllene, viridiflorol, p-cymene, γ-terpinene, carvacrol	*C. albicans, Cryptococcus, C. tropicalis*	(Santos et al., 2015)
Feoniculum vulgare	Fennel	Seed	(E)-anethole, fenchone, methyl chavicol	*C. Albicans, A. Niger, Trichoderma, Metarizium*	(Mimica-Dukić et al., 2003)
Glechon marifolia	Coastal cudweed	Leaves	β-Caryophyllene, bicyclogermacrene	*T. rubrum, E. floccosum*	(Venturi et al., 2015)
Glechon spathulata	Coastal cudweed	Leaves	β-Caryophyllene, bicyclogermacrene	*Trichophyton rubrum, Epidermophyton floccosum*	(Venturi et al., 2015)
Momordica charantia	Bitter melon or bitter gourd	Seeds	α-momorcharin, trans-nerolidol, Catechin, epicatechin apiole, cis-dihydrocarveol, germacrene D	*C. albicans*	(Braca et al., 2008)
Nigella sativa	black seed, black cumin, or fennel flower	Seeds	Thymoquinone, p-cymene, D-limonene, Thymol, Carvacrol, α-thujene, thymohydroquinone	*A. parasiticus, C. albicans*	(Singh et al., 2014)
Syzygium aromaticum	Clove	Leaves	Eugenol, eugenol acetate	*Fusarium moniliforme, Fusarium oxysporum, Aspergillus sp., Mucor sp., Trichophyton rubrum*	(Rana et al., 2011)

Antiparasitic Effect

Plant essential oils have been employed as an alternative therapy against both endo and ectoparasites. This is because certain parasites, like *Plasmodium falciparum* (malaria) and *Leishmania donovani* (leishmaniasis), exhibit resistance to conventional treatments, resulting in notable mortality and morbidity rates. However, studies have shown that essential oils extracted from *Lavandula angustifolia Mill.* and *Lavandula x intermedia* have demonstrated antiparasitic properties against human protozoal pathogens such as *Giardia duodenalis* and *Trichomonas vaginalis*, as well as the fish pathogen *Hexamita inflata* (Ritzefeld et al., 2018; Tariq et al., 2016).

Drawbacks of EOs

Demonstrated potential as antimicrobials is possessed by only limited EOs. In comparison to synthetic compounds (such as antibiotics), their real effect is noticeably weaker. Their high volatility limits the effective duration of action and allows for the modification of properties like encapsulation. Therefore, it is important to emphasize that EO usage for microbial stability is feasible, but each situation must be examined separately (Wińska et al., 2019).

Mechanism of Actions

The essential oils' efficacy mainly depends upon their major chemical components or the synergistic effects among these components. Various antimicrobial agents demonstrated distinct modes of action (Pellerito et al., 2018). Consequently, the antibacterial mechanism of EOs involves the combination of multiple modes rather than a single one (Ju et al., 2019). Different EOs target different sites within organisms which are elaborated in Fig.1.

Effect on Cell Envelope

The outer layer of microbes, the cell wall, plays a crucial role in reducing sensitivity to antimicrobial agents due to major components and enzymes. The bioactive constituents in essential oils can disrupt the peptidoglycan structure or inhibit its synthesis. This leads to cell wall damage and can either deform or kill the bacteria (Meychik et al., 2011; Sun et al., 2020). Moreover, essential oils affect the structure of the cell membrane by altering its permeability. For instance, cinnamaldehyde readily dissolves within the fatty acyl chain of the membrane which results in disrupting its outer layer. This creates leaks in the membrane, allowing essential components like adenosine triphosphate (ATP) to flow out, ultimately killing the bacteria. It can also interact with the phospholipids of the cell membrane, altering the proportion and structure of fatty acids within the membrane. Furthermore, essential oils inhibit the ergosterol synthesis such as eugenol which hinders ergosterol production in microorganisms, compromising cell membrane integrity. Furthermore, EOs can traverse via porins present on the cell membrane resulting in reducing the expression of porin-related genes, and disrupting amino acid transporters (Nazzaro et al., 2013).

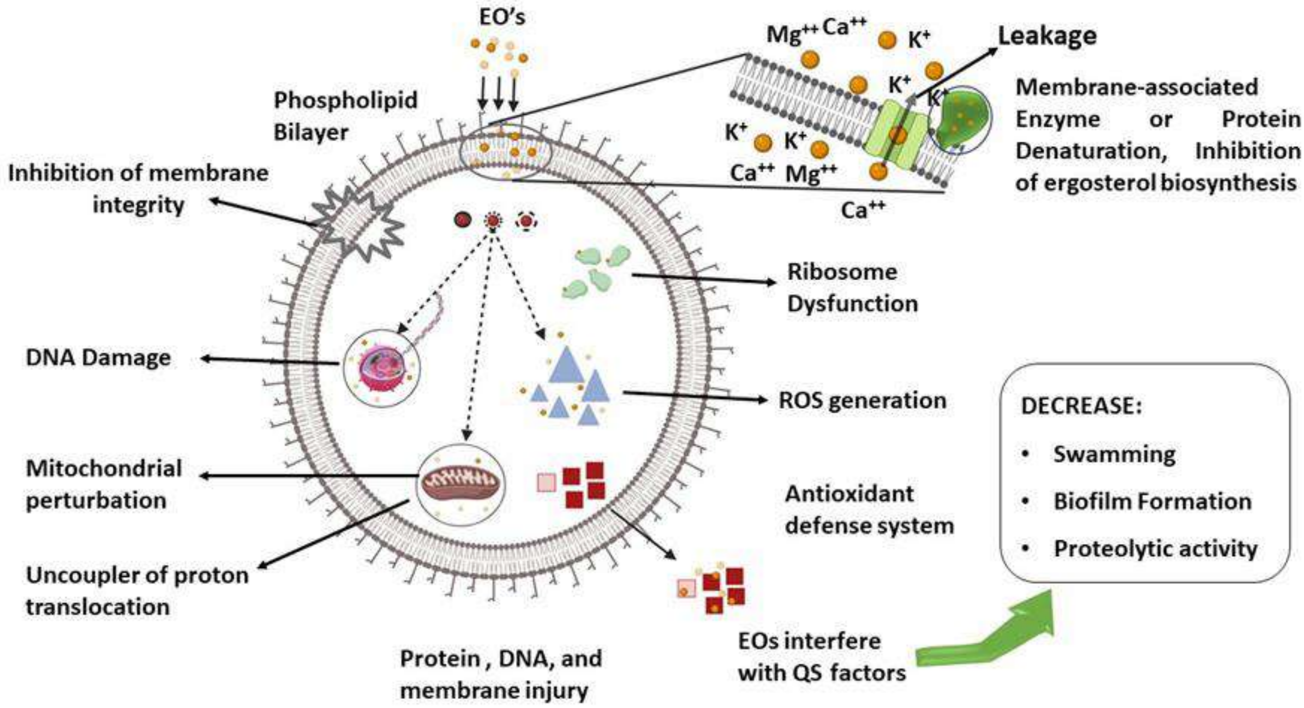

Fig. 1: Different EOs target different sites within organisms

Effect on Respiration

Microorganisms rely on respiratory metabolism to produce energy by oxidatively breaking down carbohydrates. This energy production primarily occurs through pathways such as the Entner–Doudoroff (ED) pathway, the phosphogluconate pathway, and citric acid cycle. When the oxidation and decomposition of sugars are hindered, normal metabolic processes are disrupted, potentially leading to cell death (Ju et al., 2020). Antimicrobial agents target energy production in pathogenic bacteria by interfering with nutrient absorption and transport, thereby impeding their growth and reproduction (Ulanowska et al., 2006). Di Pasqua et al. (2010) observed that thyme essential oil hinders the activity of ATP synthase within *Salmonella typhimurium*, thereby interfering with the tricarboxylic acid cycle pathway.

Effect on Heredity Material

The heredity material, whether DNA or RNA within microorganisms, plays a crucial role in their development, reproduction, mutation, and growth. The accuracy and stability of genetic material are crucial for maintaining consistent inheritance across generations. Additionally, genetic material governs protein synthesis and metabolism. Consequently, any damage to the genetic material can disrupt normal microbial reproduction and self-replication (Li et al., 2014).

Effect on Quorum sensing

Research has demonstrated that cinnamaldehyde can downregulate bcsA and luxR gene expression in *E. coli*, both of which are involved in quorum sensing. Moreover, cinnamaldehyde has shown significant inhibitory effects on quorum sensing in *P. aeruginosa* and *Streptococcus pyogenes* (Brackman et al., 2009; Brackman et al., 2011). It's important to note that different essential oils (EOs) may exhibit varying inhibitory effects on quorum sensing in different types of cells. Discovering novel approaches to inhibit quorum sensing in bacteria presents an intriguing strategy for developing new antibiotics that can mitigate bacterial pathogenicity without inducing drug resistance (Rasko et al., 2008).

Conclusion

In conclusion, EOs have the potential to replace antibiotics, antivirals, antifungals, and antiparasitic drugs in the future by inhibiting microbial growth by interference with different mechanisms such as cell wall disruption, interference with metabolic pathways, or lowering cellular membrane potential, although their effectiveness is still under scrutiny. The growing global issue of multidrug resistance has made diseases more severe caused by these pathogens so further research on EOs can help to combat this problem.

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Chapter 14

Comparison of the use of Essential Oils for the Control of Varroa (*Varroa destructor*) in *Apis mellifera*

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ABSTRACT

Varroasis in *Apis mellifera* is today the most serious problem in beekeeping, since it affects the brood and the adult bee since it feeds mainly on the fat of its host, causing malformations, reducing the lifespan of the bee adult and the mite is considered a transmitter of viral diseases of bees, such as bag brood and acute paralysis. Different alternatives have been sought for its control, among them are: bees genetically resistant to varroa, use of acaricides that can leave chemical residues in the wax and honey, mainly affecting the safety of beekeeping by-products, in addition to generating resistance in the parasite due to the misuse of said chemicals. Therefore, an alternative is the use of natural products of plant origin that have been shown to have significant potential for the control of varroa and to be an alternative to the use of chemical products, so the objective of this study was a systematic review of articles scientists in search engines such as: Google Scholar, Scopus or Web of Science, on the comparative use of essential oils, recommended for the control of Varroa based on previous research.

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INTRODUCTION

Beekeeping is an economic activity of great importance in several regions of our country, since in addition to generating quality products such as honey, royal jelly and propolis, it provides services of undoubted value for the maintenance of ecosystems, since Bees are one of the most important pollinators, which is why it is necessary to keep bees healthy, preventing diseases and parasites from damaging their work (Moreno, 2022).

One of the main parasites of bees is Varroa destructor, a mite that is considered one of the most important dangers for agriculture. It is an external parasite that attacks both adult and baby bees without distinction and whose life cycle is adapted to that of the bee.

Varroa destructor adheres to the body of adult bees, affecting their work and reducing their lifespan. It consumes the fat reserves of the offspring, in addition to causing malformations and transmitting viral diseases, in such a way that the colony sees its population and honey production decimated and this means that, if the presence of this parasite is not attended to in time, production is seriously affected, causing severe economic damage to the beekeeper (Guerra et al., 2010).

The most common treatments are based on chemical substances that eliminate the mite, affecting its development and killing it, but also favoring the appearance of resistance in different parts of the world. Some of the most used compounds to attack this parasite are Amitraz, oxalic acid, formic acid, coumaphos, thymol and pyrethroids (flumethrin and Tau-fluvalinate) (Medici, 2021).

The use of these commercial products which can be purchased without problems, and whose main drawback is that most of these chemical substances can leave residues contaminating the honey and wax, generating problems for the beekeeper, so alternatives must be sought to eliminate this parasite without damaging collaterals to bee products. The bibliography consulted to carry out this research suggests the use of essential oils, which are natural products that do not affect production and are instead harmful to Varroa destructor. Essential oils do not have organoleptic effects on honey and do not affect bees or their products, therefore they can be an alternative for Varroa control (Reyna et al., 2021).

Importance of Varroa in Beekeeping

Varroa Destroyer

Until 1957, Varroa destructor developed the ability to parasitize the western bee Apis mellifera, since then it spread very rapidly in much of the world (Oldroyd, 1999). The species V. destructor was confused with V. jacobsoni until Anderson and Trueman, (2000) verified that they are different species. V. destructor is attributed with the loss of hundreds of colonies and billions of dollars in relation to the benefit of the agriculture, (Guerra Jr. et al., 2010; Padilla-Álvarez and Flores-Serrano, 2011; Hamiduzzaman et al., 2012; Sanabria et al., 2015).

It has been held responsible for the hive depopulation syndrome, which has been occurring worldwide and has not yet been completely explained (Bacci, 2007). No other pathogen, like this mite, has caused as much impact on bees in the entire history of beekeeping (Le Conte et al., 2007; Seeley, 2007; Rosenkranz et al., 2010; Evans and Cook, 2018), having Keep in mind that the losses currently are incalculable.

When the varroa mite interacts with the bee, there is a close relationship between the biological cycle of both species; The life cycle of the mite comprises two distinct phases (phoretic phase and reproductive phase), the phoretic phase occurs on the adult bee and the reproductive phase occurs only within the sealed brood cell (Rosenkranz et al., 2010).

The mite has evolved in such a way that when it invades bee larval cells to reproduce, they avoid being eliminated from them by worker bees thanks to a kairomonal strategy (chemical substance (pheromone) released by one species that is 'detected' by another species that uses it for its own benefit (Traynor et al., 2020). These pheromones help it camouflage itself between larvae and adult bees by capturing chemical signals that help it avoid the bees' defense mechanisms (Nazzi and Le Conte, 2016; Airahuacho and Rubina, 2021).

The parasitized brood become adult bees that spend less time caring for the brood in the hive (Zanni et al., 2018), and will be a possible vector for varroa dispersal to new colonies (Brosi et al., 2017). The first egg deposited that is male will be the one that fertilizes the females (Evans and Cook, 2018). Only mites that have reached maturity (females) survive, males and immature mites die when uncapping occurs.

The varroa females, which just emerged after their cycle in eight days; They exhibit chelicerae as non-functional stumps with mouthparts that allow them to adhere to adult bees. Fertile adult varroas and some juveniles remain attached to the bees, their mouthparts and the varroa digestive system are structured to feed on semi-solid tissue through extraoral salivary digestion (Ramsey et al., 2018).

Ramsey et al., (2019) showed that this parasite not only consumes hemolymph, but also damages host bees by consuming body fat, a tissue more or less analogous to the liver of mammals. Years ago it was mistakenly thought that the mite fed only on hemolymph. However, the mites fed with body fat survived longer and produced more eggs than those fed with hemolymph. After this, the adult varroae detach from the body of the worker and invade a new capped cell. In females, sexual maturity is reached after 24 hours. Males die shortly after mating, so it is difficult to find them outside the cell.

Varroa infestations in cold environments can vary depending on the climatic environment and the size and strength of the colonies. In cold climates, when the availability of brood in weak colonies decreases, there is a greater incidence of mites in the phoretic state, increasing the proportion of varroa in brood as in adult bees, which decimates their metabolic rate and thus the activity productive (Vásquez, et al., 2000).

Negative Effects of the use of Chemicals in Beekeeping

Acaricides can leave chemical residues in honey and mainly in wax (Lensky and Slabeski, 1981; Cruz, 2007; Lanzelotti, 2007) on the other hand, some results could suggest the participation of pesticides as a cause of colony collapse (Vargas-V et al., 2020). There is evidence in Spain that beeswax contaminated by the application of coumaphos and amitraz in hives can contaminate honey and offspring in contact with it, although the levels found by these researchers did not reach the LD50 for brood nor the MRLs (Maximum Residue Limits) for honey, except for amitraz in December in some hives (Albero et al., 2023). The negative effect on bees is the combination of pyrethroids (fluvalinate and flumethrin) and/or other Neonicotinoids can have a synergistic potentiating effect that makes them 100 times more toxic than that of any pesticide individually, for example, fluvalinate and coumaphos (more toxic effect). Toxic multiplier (Medici, 2021).

Chemical Effects of the use of Chemicals in the Presence of Varroa

The fight against varroa began in the 19th century, developing various techniques such as mechanical, chemical and natural procedures to prevent colony losses (Masry et al., 2020, Spivak and Danka, 2021). Unfortunately, beekeepers continue to apply intensively and often without veterinary control a small group of active materials, fundamentally three groups of pesticides: pyrethroids (taufluvalinate and flumethrin), organophosphates (coumaphos) or amidines (amitraz). Mites have developed resistance to previous pesticides (Milani, 1995; Elzen and Westervelt, 2002; Pettis, 2004; Evans and Cook, 2018). The mechanisms responsible for acaricide resistance involved both metabolic changes and target site mutations in Varroa mite populations worldwide (González-Cabrera et al., 2013; Dmitryjuk et al., 2014). Tau-fluvalinate Resistance to tau-fluvalinate has been established with splice variants and mutations in the voltage-gated sodium channel that can potentially lead to a reduction in the interaction of the acaricide with this protein (Wang et al., 2002). Resistance to coumaphos has also been reported in Varroa mites (Elzen and Westervelt, 2002; Pettis, 2004), but the resistance mechanisms are not clear in the mites.

However, esterase-mediated detoxification may be involved (Sammataro et al., 2005). Resistance to coumaphos has also been reported in Varroa mites, but the resistance mechanisms are not clear in the mites. However, esterase-mediated detoxification may be involved. Although the mechanisms of resistance to Coumaphos by the mite are not completely clear, it is known that this product interferes with the activity of acetylcholinesterase that intervenes with nerve signaling. Therefore, they make these acaricides ineffective (Elzen and Westervelt, 2002; Pettis, 2004).

Use of Essential Oils against Varroa

To prevent the development of resistance to chemical acaricides, as well as environmental contamination, the option of developing and using acaricides from organic substances, therefore, natural and ecological, is sought (Karimi et al., 2022). Some of the most outstanding research on the subject is described.

Sublethal effects may be useful in varroa control; Any effect on this mite that interferes with its ability to locate its host may have practical value as a control method. They developed a school in the search for sublethal effects to control bee parasites and proposed a protocol to evaluate plant products.

Table 1: Comparison of the use of essential products and oils and the decrease in the presence of varroa destructor

Name of the product/ author	Mechanism of action	Advantages of use	Disadvantages of use	Application and recommended dosage
Lemon oil Cymbopongon citratus (Sabahi et al., 2018)	Contains properties to kill mosquitoes and mites	acaricidal activity	Low toxicity in adult bees	5 ml It is placed on the interior walls of the hive.
Oregano oil (Origanum Vulgare) (Chambi and Condori, 2016)	Fungicide, acaricide and disinfectant properties.	Low toxicity for bees Parasite death due to water stress or asphyxiation.	Oil volatilization. Oil application temperature.	30 ml of essential oregano oil Spraying in hives
Garlic oil (Allium sativum) (Reyna et al., 2021)	acaricidal activity	Does not damage the hive Low cost	High doses negative effect on bees resulting in mortality in mites and bees	10 ml In hives
Wild thyme (Acantholippia seriphioides) (Ruffinengo et al., 2005)	Antibacterial and antifungal properties, repellent effect on varroa	Low risk for bees and the environment Leaves no residue in honey	May require high concentrations to be effective May be expensive	0.25; 05 y 1 gram Microencapsulation and evaporation.
Eucalyptus oil (Eucaliyptus radiata) (Ahumada et al, 2022)	Insecticidal and repellent properties	Low risk to bees Effective against varroa and other parasites Low cost	May require frequent applications possible impact on honey flavor	20 ml It is placed on the interior walls of the hive.
formic acid (ácido orgánico) (Calderón et al., 2014)	Varroa irritation, pH alteration in brood cells	Effective against varroa in the pupal stage Low resistance of varroa Decomposition into oxalic acid, leaves no residue	- Potentially corrosive and dangerous to handle Requires special application equipment May cause harm to bees in high concentrations	150 gr Organic gel that is placed on the frames of the breeding chamber.
Thymol gel (timol es componente del aceite de tomillo) (Calderón et al., 2014)	acaricidal effect	Low toxicity Low environmental impact	Toxic when using high concentrations	25 gr Gradual release gel
Neem oil (Azadirachta indica) (Gonzalez et al., 2006)	acaricidal effect	Non-toxic to bees It is used on pests in flowering crops.	In low doses they do not cause parasite mortality.	1-2 mg Spray application
Oxalic acid (Vásquez, 2006)	Direct toxic damage to varroa	- Effective against varroa in the pupal state and adult mites Does not leave residues in the wax Low cost	- Requires repeated application for effective control Potentially toxic to bees at high concentrations	50 ml in sugar solution
Peppermint oil (Mentha Piperita) (Cueto and Estevez, 2020)	Repellent and toxic effect on varroa	- Low risk to bees Lower likelihood of varroa resistance Does not leave toxic residues in honey	- May require frequent applications for effective control Possible impact on honey flavor	9.27 ml Infusions

Source: self-made

Different tests were carried out to determine through which method the elimination and/or control of varroa could be more effective, which were: Acute lethality test in varroa and bees (Application of distilled water plus emulsifier, in concentrations corresponding to those used for each dilution treatment), repellency test with choice (If all the varroas remain on zone zero or there is an equitable distribution on both zones, the values of A will counteract those of B; if all the mites remain on the pupae of zone B, the values of A will be zero and the values of B), repellency test without choice (In this case the pupae that were placed in zone Ac and Bc were treated with the corresponding products and concentrations, as well like the witnesses described). In conclusion, it is postulated that the death of varroa females is due to starvation, caused by the inability of the mites to feed on the offered pupae.

Sabahi et al., (Sabahi et al., 2018), carried out a study which evaluated the relative toxicity and selectivity of anethole and lemongrass oil (*Cymbopogon citratus)* and Sweet marigold on Varroa mites and on larvae and adult honey bees. In which the essential oil was obtained from plant tissues by steam distillation. The methodology consisted of six concentrations of the essential oil prepared in 1.5 ml of acetone, using 280 mites in eight replications, under controlled conditions of temperature 26° and 26% relative humidity. The solution was spread on the inner walls of the vials with the mites, covering after 10', the results were read 4 hours post treatment. With the help of a needle, the mites were touched; if they did not move, they were considered dead. It was obtained that anethole and Cymbopogon oil showed significant effects on mites at the same time, high selectivity and safety margins for the honey bee.

Chambi and Condori (Chambi and Condori, 2016) carried out a study, which used oregano essential oil (Origanum vulgare) at 40, 45, 50, 55 and 60% analyzing volatilization in oasis sponge in three surface support areas. It was decided to use the 40% concentration since it contains a greater amount of ethyl alcohol and volatilization increases, although the amount of active product is lower, there is no significant difference with the other concentrations. This concentration was compared against a commercial acaricide, resulting in the use of oregano oil being 23% more efficient than the commercial one.

(Table 1) identifies the main substances and essential oils used to eliminate Varroa in bees. Considering lemon, eucalyptus, oregano, garlic and thyme oil for its low toxicity effect on bees and honey, this being a harmless product for human consumption.

The oils can be applied in different ways such as evaporation, gel or directly to the hive depending on the active substance of each oil, in addition to the fact that some require the use of another component (ethyl alcohol) for their activation and to have the effect of eliminating Varroa. In addition, each oil has a varied action time that can range from hours to weeks where they will be most effective on the parasite (González- Gómez et al., 2006).

As for formic acid, its effectiveness can be in combination with thymol, which is a component of thyme oil, considering other factors such as temperature, ventilation so that the steam is distributed evenly over the hive, its effectiveness can be from the first day. of application until the 30th.

Conclusions

Varroasis is a complex problem for the beekeeping industry worldwide. Adequate varroa control planning should first include the restricted use of chemicals, and second, management techniques that include low levels of parasite infestation. The current trend in animal production lies in the use of practices and use of noble and natural substances that guarantee animal well-being, thus the safety of the product, thus being the bases of food safety. There are many studies related to the use and applications of essential oils on the control of varroa destructor in *Apis mellifera*, however those presented here are for isolated use, that is, they do not combine more than one oil with another to identify if there is a synergistic action. It is proposed to search or carry out studies where two or more essential oils are combined. Likewise, identify through laboratory studies if there is a residual of the active substances of essential oils in honey, thereby detecting if safety is affected or a product with added value can be obtained. The present study offers recommendations for beekeepers interested in using essential oils to control varroa and as a result reduce the use of acaricides that leave residues in the wax and honey and cause resistance in the mite.

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Chapter 15

Use of Essential Oil against Mosquitoes

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ABSTRACT

Diseases spread by mosquitoes are thought to be the cause of one million fatalities worldwide each year. To prevent certain diseases, the environment must be improved (e.g., reduced stagnant water) and managing adult and juvenile mosquito populations. A couple of the main drawbacks of utilizing chemical insecticides are environmental contamination and mosquito resistance. Essential oils are fascinating and potent natural plant products that have been utilized medicinally since ancient times. Essential oils (EOs) have a variety of effects on mosquitoes, such as repellant, ovicidal, larvicidal, pupicidal, and adulticidal effects. EOs are mostly utilized as sources of active ingredients for different repellents when it comes to their ability to combat mosquitoes.

Because of their strong breakdown in the environment little adverse effects on non-target animals and selective action on target. Recently, pesticides based on EO have been presented as artificial insecticide substitutes to keep mosquitoes away. Several investigations about using EOs to repel insects are found in the literature. In this chapter, we summarize the role of EOs in controlling the mosquito population.

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INTRODUCTION

Many people across the world suffer from parasites and parasitic diseases, which provide a variety of difficulties in terms of treatment and management. (Alvi et al., 2020; Alvi et al., 2021; Alvi et al., 2022; Alvi et al., 2023). Among parasites the most significant arthropods for public health are mosquitoes (Sanei-Dehkordi et al., 2018). In addition to encephalitis, dengue, yellow fever, *chikungunya*, malaria, and *filariasis,* they could spread numerous other illnesses. The most significant mosquito-borne illness is malaria; 405,000 deaths and 228 million cases were recorded globally in 2018 alone (Kurtovic et al., 2020). Approximately 400 million dengue infections occur each year, with about 25% of those individuals exhibiting clinical symptoms. Approximately half of the world's population is susceptible to dengue infection (Duarte et al., 2020).

Larval control is a crucial component of the integrated management of most mosquito species (*Diptera culicidae*) and has been achieved by using various pesticides. Disease-endemic nations have a significant financial burden from vector-borne illnesses such as *malaria, dengue fever*, and *filariasis*, which cause widespread morbidity and mortality (Almeida et al., 2020).

In poor nations where epidemics of vector-borne diseases are occurring, mosquito management is a major problem. Chemical insecticides, or synthetic pesticides, are often used to control mosquitoes in their adult and immature stages (egg, larva, and pupa). Side effects on non-target populations (particularly people), negative environmental consequences contaminating water, soil, and air have been observed by the use of these insecticides. The emergence of resistance significantly increased in recent years (Esmaili et al., 2021).

In developing nations, the *organophosphate temephos* is still commonly employed however in Europe and the USA; microbial insecticides are used to control larvae. The European Community has been strictly reviewing all chemical larvicides due to their harmful effects on *aquatic biocoenosis*. This has resulted in the withdrawal of *temephos* in Europe. Essential oils (EOs) are becoming more popular as low-risk pesticides in the past few decades. In addition to effectiveness, the majority of research reported that EOs had no negative effects on the environment or on human health (Masetti, 2016a, 2016b).

One method of controlling the adult insects from emerging and becoming the pathogen's active "transporter" or vector—which can be harmful—is to target the insect vector during its formative stages. This strategy has been proposed as critical for controlling dengue vectors and halting the spread of disease viruses. In areas where it is widespread, malaria in particular still poses a serious health risk to newborns and early children. A total of 90% of malaria-related mortality occurs in newborns and young children, with the majority occurring in sub-Saharan Africa. Every year, there are 350–500 million cases of malaria worldwide, and at least one million people die from the disease (WHO, 2009).

Dengue fever is also one of the most significant viral infections spread by mosquitoes worldwide. The incidence has tripled in the past 50 years. Over 100 endemic nations and regions where dengue viruses can spread to around 2.5 billion individuals. Every year, there are up to 500,000 infections, 50 million episodes of hemorrhagic illness caused by dengue, and 22,000 fatalities—mostly in children—from the virus (WHO, 2012).

What are Essential Oils?

The majority of Essential oils are colorless or pale yellow, liquid, or have a lower density than water. They are hydrophobic and soluble in alcohol, non-polar or weakly polar solvents, waxes, and oils, but only slightly soluble in water. Highly concentrated substances called essential oils (EOs) are taken from barks, fruit rinds, stems, flowers, seeds, roots, and resins (Fatimah, 2016). Essential oils are complex combinations of volatile molecules that are created by living things and can only be physically extracted from a whole plant or a plant portion that has a recognized taxonomic origin (pressing and distillation) and are used as health protection against many vectors (Moghaddam and Mehdizadeh, 2017).

Because of their flavor, odor, and therapeutic qualities, EOs are frequently used in a wide range of goods, including meals, medications, and cosmetics. One of the most labor-intensive and time-consuming procedures is extracting essential oils (Hanif et al., 2019)

Numerous studies have been published that extract Essential oils (EOs) from a broad range of plant species and reported that whole extract or some of its purified constituents have insecticidal action on mosquito larvae (Almadiy, 2020). EOs are extracted from plants using techniques like distillation or other extraction processes. Generally speaking, the primary components of EOs are *terpenoids* and, to a lesser extent, *phenylpropanoids* (Hou et al., 2022).

Essential oils, also known as oily liquids, are often obtained by hydrodistillation from different portions of plants such as the stem, flower, bark, and rhizome, with an apparatus similar to the Clevenger. There are a lot of studies on using essential oils to repel insects in the literature. However, because some of their constituents are volatile, the uses of essential oils as insecticides and repellents are restricted (Khanavi et al., 2013). The biological actions they possess are diverse and include repellant, larvicidal, leishmanicidal, and antibacterial properties. Because of their high environmental degradation rate, selective action on target, and low adverse effects on non-target animals, EO-based insecticides have recently been proposed as synthetic options for controlling mosquito populations (Esmaili et al., 2021).

Essential Oils as Biocides

Plant products have been employed as insecticides since the Roman era; when species like black hellebore (*Veratrum nigrum*) and white hellebore (*Veratrum album*) were used. A variety of plant pathogenic microorganisms, including (*Fusarium oxysporum, Alternaria alternative, Penicilium italicum, Penicilium digitatum,* and *Botyritus cinerea*), were investigated for their antibacterial properties using essential oils of fennel, peppermint, caraway, eucalyptus, geranium, and lemon. Because the essential oils of fennel, peppermint, and caraway were effective at suppressing the microorganisms under test, they were chosen as the active ingredients in the biocide composition. With the use of several fixed oils (sesame, olive, cotton, and soybean oils) and emulsifiers (Emulgator B.L.M. Tween20 and Tween80), successful emulsifiable concentrates (biocides) were produced from these oils (Abo-El Seoud et al., 2005).

Larvicidal Activity

Application of essential oils (*Cedarwood, clove, peppermint, thyme*, and *Bourbon geranium*) in various combinations and concentrations (5, 10, 25, 50, 75, and 100%) on human skin proved to be repellent against *Anopheles albimanus, Wiedemann* and *Aedes aegypti*. The only thing that kept *Ae. aegypti* away were large doses of peppermint oil. With a protection duration ranging from 1½ to 3½ hours, clove oil and thyme proved to be the most efficacious insect repellents. For one to two and a half hours, *An. albimanus* biting was inhibited by combining 50% *clove oil* with 50% *geranium* oil or 50% *thyme oil*. Skin irritation is a potential side effect *of clove, thyme*, and *peppermint* oils. Many plant oils, including those from thymus, basil, cinnamon, and citronella, show promising results as larvicides for mosquitoes (Barnard, 1999).

Organophosphorus chemicals, such as *temephos, fenthion,* and *chlorpyrifos*, are the most widely used larvicides because of their high activity level against aquatic insects and mosquito larvae. Because *organophosphate* larvicide is less hazardous to mammals, humans, fish, and birds, it is advised as the best larvicide for controlling *Aedes* and *Anopheles*. Many plant oils, including those from *thymus*, *basil, cinnamon*, and *citronella*, show promise as larvicides for mosquitoes. Examining larvicides made from plant oils used to repel mosquitoes, is the main focus of a previous study (Pitasawat et al., 2007).

Essential oils are considered harmless plant materials; therefore, it seems safe to utilize them as botanical larvicides. When EOs are added to water in a controlled laboratory condition, mosquito larvae exhibit acute toxic effects. Compared to LC_{50} values for chemical or microbiological larvicides, the median lethal concentrations (LC_{50}) of essential oils are higher. Few EOs have LC_{50} values less than 1 ppm, and according to multiple published studies, more than 50 ppm were needed to kill 50% of the larvae that were evaluated Numerous writers have demonstrated how the time of year, a plant's age, its history of disease or insect infestation, its geographic location, agronomic methods, and climate stressors all affect the concentration of essential oils in plants (Dias and Moraes, 2014).

In recent scientific literature, interest has significantly increased in the insecticidal action of essential oils on mosquito larvae. The effectiveness of the EOs that have been reported thus far, however, cannot be compared to that of chemical or microbiological larvicides. Furthermore, a majority of EOs' low mammalian toxicity and absence of environmental effects have been stated. The majority of aromatic plants in developed countries, where there is an opportunity to fully utilize their potential as botanical larvicides (Masetti, 2016b). For a long time, several popular EOs and their primary ingredients have been employed as food and beverage additives, cosmetic perfumes, and pharmaceutical goods. For mammals and other animals, these EOs exhibit minimal oral toxicity. The shortest environmental half-lives of Essential oils (EOs) make them more environmentally friendly than conventional synthetic insecticides (Assadpour et al., 2023).

Essential Oil as Adulticides

The adult female mosquito, which bites and spreads fatal viruses or other infections, is the target of most control plans. Typically, adulticides are used as surface treatments that are applied as residue. Several compounds found in EOs have been shown to have adulticidal properties; these chemicals come from plants belonging to the *Lamiaceae, Miliaceae, Rutaceae*, and *Ingeberaceae* families (Chellappandian et al., 2018). The Essential oil derived from *L. camara* leaves exhibits adulticidal efficacy against various mosquito species, making it a potential ingredient for use in oil-based insecticides (Dua et al., 2010).

EOs Inhibiting the Suction Activity of Mosquitoes

Using repellents to stop insects from sucking blood is the basis of protection. Natural repellents, like aromatic oils, work by discouraging females from sucking blood and hence from spreading infections. Though popular and reasonably effective, this indirect protection technique frequently has reduced efficacy because of the requirement to reapply repellent at regular intervals of many hours. In lab testing, it was shown that applying various amounts and combinations of the following five essential oils on human skin: *clove, peppermint, thyme, cedarwood*, and *Bourbon geranium* effectively repels mosquitoes. The best oils for keeping mosquitoes away were *thyme* and *clove,* which, depending on the dosage of the oil, protect for 1½ to 3½ hours (Barnard, 1999).

Nano Formulations and Essential Oils or Control of Mosquitoes

Mosquito control using EO-based Nano formulations also has been implemented. High- and low-energy techniques are typically utilized to create Nanoemulsions. High-energy techniques include ultrasonic, high-pressure homogenizer, and microfluidizer-assisted fabrications. Temperature of phase inversion, composition of phase inversion, diffusion of solvent, and spontaneous- emulsification are examples of low-energy processes. When creating EO-based Nanoemulsions, spontaneous emulsification is favored over alternative methods. Using this method, oil, water, and surfactant optimization is used to create Nanoemulsions. Thus, physical and chemical stress like temperature and pH do not affect the generated Nanoemulsions in this way (Esmaili et al., 2021).

***Cymbopogan citratus Stapf* (*Graminae*) Essential oil's Anti-Filarial Mosquito Activities**

Herbal products are frequently utilized because of their strong antibacterial, aromatic, and therapeutic qualities. By adjusting the release rate, essential oils and scents can be applied as micro- or nano-capsules to textile substrates to extend their lifespan. The ovicidal, larvicidal and repellant properties of essential oils obtained from *Cymbopogan citratus* through steam distillation were assessed about the filarial mosquito *Culex quinquefasciatus*. A 24-hour treatment period was used to observe the larval mortality. The larval instars two, three, and four were found to have LC50 values of 144.54 ± 2.3, 165.70 ± 1.2, and 184.18 ± 0.8 ppm, respectively. At 300 ppm, there was 100 percent ovicidal activity seen .*C. citratus* doses of 1.0, 2.5, and 5.0 mg/cm2 offered 100% protection for three, four, and five hours, respectively, in a skin-repellent test. For a 12-hour period, this Essential oil's overall protection percentage was 62.19% at 2.5 mg/cm2, 74.03% at 5.0 mg/cm2, and 49.64% at 1.0 mg/cm2 (Ghayempour and Montazer, 2016).

***Citronella* Essential Oil**

Citronella oil is an extensively researched Essential oil that is mostly derived from *Cymbopogon nardus*. The effectiveness of this vital oil against mosquitoes has been demonstrated. In addition to having a mosquito-repelling effect, it is a combination of ingredients with *citronellol, citronellal*, and *geraniol* as primary elements contributing to numerous actions such as antitrypanosomal, anthelmintic, antimicrobial, antioxidant, anticonvulsant, and wound healing. Because of its great performance, low toxicity, and satisfied customers, *Citronella* Essential oil is listed as a repellant for insects by the US Environmental Protection Agency (EPA). However, its practical applications are limited by its low stability in the air and high temperature. (Sharma et al., 2019).

***Hazomalania voyronii* Essential Oils as Insecticidal and Mosquito Repellent**

In Madagascar, the traditional practice of using *Hazomalania voyronii*, also referred to as Hazomalana, to ward against bug bites and repel mosquitoes is passed down through the generations. We examined the cytotoxicity of three important insect species for agriculture and public health ,*Musca domestica, Culex quinquefasciatus* and *Spodoptera littoralis* and also the effectiveness of the Essential oils (EOs) derived from the wood, fresh or dry bark ,stem of *H. voyronii* to keep away major mosquito vectors, *Aedes aegypti* and *Culex quinquefasciatus* (Benelli et al., 2017).

Clove Oil and Cinnamon Oil

The long-lasting protection ticks and mosquito bites were offered by lotion emulsions containing 10% v/v clove or cinnamon oil. We conclude that combining active chemicals from the EPA Minimum Risk Pesticides list into a 10% v/v emulsion can provide complete protection against tick crossings and mosquito bites for almost an hour (Luker et al., 2023).

Repellency Effect against Ades albopictus

There was need to develop environment-friendly and novel mosquito larvicides. Six Essential oils—*Asteraceae, Rutaceae, Mentha piperta, Carvacryl, Citronella*, and *Eucalyptus*—were evaluated in a lab setting to determine how effective they were at repelling *Aedes albopictus* mosquitoes. Human subjects were only used in the testing of Citronella and Eucalyptus oils. Mice were 100% protected after 7 hours with 7% *carvacryl* oil. Humans were protected with 15% *Eucalyptus* oil for at least three hours; five hours of protection was achieved by adding 5% vanillin.

***Thymus vulgaris* Essential oil Nano Emulsion**

After 24 hours of exposure, the thyme oil Nano emulsion's maximum activity against *C. tritaeniorhynchus* was detected, and after 24 hours of exposure, its chitosan encapsulation was most efficient against *A. stephensi*. It was possible to see consistent morphological changes in the larvae of many mosquito species. Therefore, additional research on these Nano emulsions and encapsulations for use against other insect pests in agriculture may be necessary.

Conclusion

Natural compounds made from vegetable matrices, such as Essential oils (EOs), have a large range of secondary metabolites that can act against multiple biological systems, making them potentially considered environmentally acceptable pesticides. The application of some EOs to establish green methods for cultural heritage protection has been assessed by conservation scientists in light of these features. To control dengue mosquito vectors, local, regional, and rural communities with few alternatives continue to be interested in using plant extracts, chemicals, or their derivatives as inexpensive, safe phytochemical insecticides. Since plant-based medications are widely accessible, inexpensive, and seldom cause negative effects, their application in the preservation of cultural assets can undoubtedly improve both environmental and human health when used in accordance with contemporary restoration protocols.

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Chapter 16

Harnessing Essential Oils in Veterinary Medicine: A Therapeutic Approach against Antimicrobial Agents

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ABSTRACT

Essential oils (EOs) are volatile mixtures of nonpolar molecules that are extracted from aromatic plant components. They are highly concentratedhave a range of biological and pharmacological characteristics consist of terpenes, terpenoids, and phenylpropanoids. The Veterinary field, which is growing, is interested in EOs as a potential solution for common health issues in domestic animals, especially when it comes to addressing antibiotic resistance. The possibility of essential oils for alternative treatments against microbial infections in animals is examined in this chapter. Essential oils are plant-based volatile chemicals that provide a sustainable and natural way to fight infectious diseases without using conventional antibacterial drugs. Important essential oils with broad-spectrum antimicrobial properties against viruses, fungi, and bacteria include thyme, tea tree, and oregano oils. As a result, these are effective measures in veterinary therapy. To protect the welfare of animals, safety factors such as appropriate dilution, dosage, and possible toxicity must be carefully considered. Exciting developments in EO applications for veterinary care are anticipated in the near future. To clarify the best use practices and possible synergy impacts of essential oils when used in veterinary medicine, more investigation is necessary. Veterinarians can progress the sector towards healthier and more effective antimicrobial techniques for animal health care by utilizing the medicinal benefits of essential oils.

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INTRODUCTION

The medicine *Quinta essentia,* which was named by Swiss physician Paracelsus von Hohenheim, is the origin of the word "essential oil". The term "essences" refers to the flammability of essential oils. Essential oils (EOs) are plant secondary metabolites that are derived through mechanical procedures or distillation. They have been utilized in perfumery and traditional medicine since ancient times. The content of these differs depending on various factors such as the botanical species involved, the type of plant employed (leaves, root systems, timber, bark, fruits), the time of year they are harvested, the temperature, humidity, sun irradiance, ground quality, and the extraction methods used. Essential oils are shown varying degrees of antibacterial properties against both the pathogen and the oils. Notable differences have been observed between different species of bacteria as well as between strains within a single species (Ebani and Mancianti, 2020).

Essential oils are insoluble in water but soluble in ether, alcohol, and fixed oils. At room temperature, these volatile substances are typically liquid and colorless. Except in a few instances (cinnamon, sassafras, and vetiver), they have a distinctive smell, are often liquid at room temperature, and have a density less than unity. They have a very strong optical activity along with a refractive index. The various scents that plants release is caused by these volatile oils found in herbs (Dhifi et al., 2016).

With its antibacterial, antifungal, antiviral and anti-inflammatory qualities, they can function alone or in concert. For instance, phenolic and volatile chemicals in cinnamon determine its biological activities, which include its anti-inflammatory properties. In recent years, studies have focused primarily on the biological properties of cinnamon. The vital oils of cinnamon have been proven in both in vitro and in vivo studies to possess antimicrobial capabilities against pathogenic isolates that cause bovine mastitis. This is achieved by undermining the functioning of bacterial membranes, which can act as a substitute organic antibacterial to ensure the safety of milk. Moreover, cinnamon may lessen the inflammation and mammary tissue damage linked to cattle mastitis illness (Neculai-Valeanu et al., 2021).

Antimicrobial metabolites in milk have the potential to promote hypersensitivity and resistant microorganisms in humans, as well as to impede the production of dairy products. Moreover, the milk businesses are being pressured to use fewer antimicrobial medications due to growing concerns about resistance to antibiotics in public health issues. Over the course of five years, around 90% of the residues detected in milk were linked to antibiotic treatment for mastitis (Brown et al., 2020).

As a result, the necessity for developing novel, alternative medicines are increasing, particularly for those made from natural sources like plants. This is one of the reasons why, as a substitution to antimicrobial medicines, phytotherapy is becoming increasingly popular these days. The study and application of essential oils (EOs) have expanded acceptance in recent decades owing to their many benefits over antibiotics, including non-toxicity, biodegradability, and decreased likelihood of resistance *(*Kovačević et al., 2022).

Essential Oils: Composition and Properties

Numerous essential oils are utilized in the field of veterinary medicine for a variety of reasons, such as aromatherapy, treating wounds, treating skin disorders, and relieving animal tension. Animals can react to essential oils differently than people do, so it's important to utilize them carefully and with veterinarian guidelines. Among the essential oils that are frequently utilized in veterinary medicine are:

Chamomile (German or Roman)

This essential oil belongs to specific variety *Matricaria chamomilla/ Chamaemelum nobile.* The primary sources of chamomile's biological activity are flavonoids including apigenin, luteolin, quercetin, and patulin, as well as components of essential oils such α-bisabol and their oxides and azulenes (Sahel et al., 2019).

It calms an uneasy stomach, reduces emotional and mental suffering soothes the physical being and mind when one is anxious, afraid, restless, excited, or hyperactive. It promotes the health of the skin, uplifts the soul while feeling bashful, afraid, agitated, angry, or experiencing other negative emotions. Herbal supplements containing chamomile (*Matricaria recutita*) are used as a sedative, a pain reliever, and a muscle relaxant, mostly for dogs but infrequently for cats. It has been applied locally to inflammation of the skin and taken internally to inflammation of the gastrointestinal tract, including inflammatory bowel disease and stomach ulcers (Songham et al., 2021).

Cinnamon

This essential oil belongs to *Cinnamomum zeylanicum*. Many plant extracts, such as cinnamon essential oils (CEOs) and their constituent's eugenol and cinnamaldehyde, which have antibacterial properties against *Salmonella spp., S. aureus, Parahaemolyticus, E. faecalis, P. aeruginosa, and E. coli*, are used as feed supplements in the poultry industry. Cinnamon oil also has potent analgesic, antioxidant, hypocholesterolemia, antiulcer, and anticandidal qualities. Plant and herb extracts prevent the growth of numerous harmful bacteria and encourage the creation of good bacteria in the gastrointestinal tracts of hens (Abd El-Hack et al., 2020).

Lemon Verbena

Aloysia citrodora Paláu, the scientific name for lemon verbena, is a renowned medicinal herb with a wide range of therapeutic applications. This essential oil extracted from *A. citrodora* leaves exhibited antibacterial activity against *P. aeruginosa*, *S. aureus*, and *E. coli*, with MICs ranging from 2.84 to 8.37 mg/ml. Strong antibacterial activity of the essential oil also increased silver catfish survival against *Aeromonas hydrophilia* infection. *A. citrodora* has been utilized in Ecuador to treat nervous incidents, spasms, fever, and gastrointestinal issues. Boiled and warm leaves wrapped in a cloth and applied to the affected area will help to reduce inflammation and soothe rheumatism (Bahramsoltani et al., 2018).

Bitter Orange

This essential oil belongs to specific variety *Citrus aurantium*. Neroli oil (NO) is the fundamental oil extracted from the bloom of the bitter orange tree. Due to its harmless plant-based extract and calming properties, the oil is utilized in conventional medicinal practices across the globe. Because essential NO is nontoxic, the U.S. Food and Drug Administration (FDA) contemplates it to be normally recognized to be secure (GRAS) for internal use. Numerous compounds, most notably limonene, are included in the volatile component characteristic of NO. It has been established that NO, because of its bioactive components, has a number of advantageous benefits, particularly in lab animals. By controlling serotonin receptors, NO has been demonstrated to have antidepressant and antianxiety effects in mice and rats. It has also been shown that NO possesses tranquillizer, antianxiety, and antidepressant properties in rats. Though the exact metabolism underlying the sedative effect shown in mice remains unclear, the main contributor to the sedative effect of NO is believed to be linalool (Acar et al., 2021).

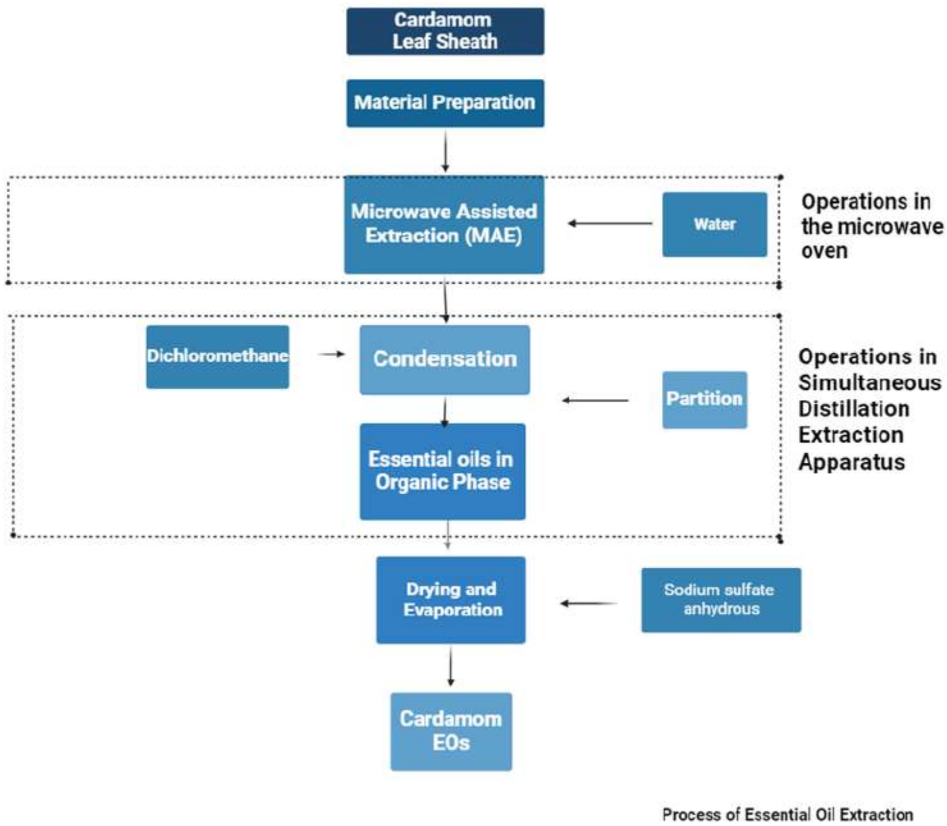

Fig. 1: Process of Essential Oil Extraction from Cardamom Leaf Sheath

Lavender

One essential oil that needs more attention is lavender *(Lavandula angustifolia*, or LEO). It functions as an antioxidant, antifungal, antibacterial, and immunostimulant. Linalool, linalool acetate, Lavandula, and γ-terpinol are the primary constituents of LEO, and they display an extensive variety of biological and pharmacological properties. Conventional broiler chickens have a progressively faster growth rate, but they are also more prone to many illnesses and ailments, such as gastrointestinal tract infections as colibacillosis. Because they contain valuable biologically active chemicals like essential oils (EOs), herbs are becoming more common in feed mixtures and supplemental solutions (Ahmadi et al., 2018). When lavender oil and enrofloxacin are combined, they exhibit a synergistic response in vitro towards resistant cultivars of *E. coli*. Active herb compounds improved the performance of grilled chickens by stimulating their digestive systems, enhancing their absorption of nutrients, and modifying their immune systems. The factors found in blood are thought to serve as indicators of the body's overall health. They aid in the diagnosis of poultry illnesses, offer crucial information about immunological testing, and assess the effectiveness of the prescribed course of action. EOs may act as organic immunostimulants. Herbal extracts and essential oils can strengthen the cellular and humoral immune systems of broiler chickens and lessen their vulnerability to infectious illnesses. The health benefits of EOs with a hypercholesterolemic impact are well-established. Additionally, some of them may lower blood levels of endogenous cholesterol and decrease the action of the liver-colored enzyme HMG-CoA reductase by controlling the amount of cholesterol that is produced naturally (Adaszyńska-Skwirzyńska et al., 2021).

Chemical Constituents of Essential Oils

Essential oils (EOs) are highly concentrated fragrant constituents derived from a variety of plants, and are well-known for their aromatic and therapeutic qualities. It is essential to comprehend the chemical constituents of EOs in order to comprehend their potential effects on biological systems. Researchers have recently developed an interest in studying the components of EOs due to the increasing need for EOs in the worldwide marketplace. Eucalyptus oil (EO) is unique in that it has a significant amount of 1,8-cineole, which makes up roughly 63.1% of its makeup. Moreover, it encompasses a range of monoterpene hydrocarbons, such as p-cymene, α-pinene, α-limonene, γ-terpinene, β-pinene, and β-myrcene. Major ingredients in peppermint extract (EO) include menthone, camphor, 1,8-cineole, Menth furan, and isopentyl acetate, which together account for a sizable percentage (72.4% of the total EO) (Brah et al., 2023).

Cymbopogon spp. EO has elemol (ranging from 29.5%to53.1%), geraniol (37.1%), and citral (90.4%) in different parts such as roots, root hair with stalk, and leaves. *Cymbopogon martinii* EO *(C. martinii)* varies in composition between leaves and roots (Čmiková et al., 2023). Because of its antibacterial qualities, *C. martinii*, also referred as palmarosa, has historically been utilized in aromatherapy as an antibacterial. It has also been used to treat skin issues and nerve pain in Ayurvedic medicine (Murbach Teles Andrade et al., 2014).

Fig. 1 : Benefits and Uses of Lavender Essential oils in animals

The plant's essential oil, referred as tea tree essential oil (TTO), has a lengthy history of usage in medicine. More than 100 substances make up TTO, including different monoterpenes, sesquiterpenes, or aromatic compounds. The monoterpenes limonene, sabinene, 1,8-cineole, p-cymene, α-terpinene, α-terpineol, terpinolene, and terpinen-4-ol together account for 80–90% of the oil (Fig. 4). The most prevalent thirty percent of these is terpinen-4, which is crucial to the oil's antibacterial properties. Depending on the climate, the chemotype and population of Melaleuca employed, the age and preparation of the foliage, and the length of the distillation process, the amount for each terpenoid in TTO might vary significantly (Sharifi-Rad et al., 2017).

Therapeutic Properties and Mechanisms of Action

Essential Oils Innovative Bovine Mastitis Treatments

Mastitis is an inflammatory disorder of the mammary gland. This is one of a significant serious illnesses affecting lactating animals that causes enormous financial losses. Infectious pathogens can cause both subclinical and symptomatic cases of mastitis. Antibiotics are always used to treat infections, and the growing issue of resistance to antibiotics has raised the chance of recurrence, particularly in cases where a bacteriological treatment is not obtained. Bovine mastitis is a frequently occurring and deadly disease that causes the dairy industry to suffer significant financial losses. The prevalence of mastitis in cattle herds remains high despite notable advancements in its treatment and control. This has a detrimental impact on productivity metrics and indirectly on financial indices in dairy farms. The disease causes dairy industries to suffer massive financial losses because it reduces milk output and quality, milk is deemed to have antibiotic residues, chronically infected cows must be culled, and related therapy costs increase (Li et al., 2014).

Because zoonotic diseases spread germs and poisons through milk, mastitis can become a severe health concern. The primary pathogens responsible for mastitis are environmental microorganisms like *E. coli*, *S. uberis,* and other coliforms, in addition to contagious microbes that thrive on skin and breast lesions, like *S. agalactiae* and *S. aureus* (Gomes et al., 2016).

By undermining the strength of bacterial membranes, research conducted both in vitro and in vivo has shown that the pure essential oil of cinnamon possesses antimicrobial activity against pathogenic isolates that cause bovine mastitis. This means that it can be used as a substitute organic antibacterial to ensure the safety of milk. Moreover, cinnamon has the potential to lessen the inflammation and mammary tissue damage linked to cattle mastitis. Many terpenes, phenols, phenolic acids, and flavonoids make up Origanum essential oil (EO), with carvacrol and thymol having the highest concentrations (together with minor quantities of p-cymene and terpinene) and terpinen-4, linalool, and sabinene hydrate (Ksouri et al., 2017).

Carvacrol is often the primary component of EO, which is responsible for a variety of pharmacological actions, including antibacterial activity. Nonetheless, thymol is thought to be one of the primary phytoconstituents in certain *origanum* species that contribute to the biological activity. For instance, the essential oil of *Origanum floribundum Munby* exhibits a high thymol concentration of 50.47 percent (Sharifi-Rad et al., 2021).

A total of thirty various kinds of essential oils were tested for their antialgal efficacy in combating *Prototheca zopfii* and *Prototheca blaschkeae*, two infections that cause protothecal mastitis, a newly growing animal health concern in dairy cows (Grzesiak et al., 2018).

Essential Oils for Otitis Externa in Dogs and Cats

Otitis externa is the term for an enlargement of the ear's outer canal. In dogs and cats, some contributory factors include trauma, immunologic and endocrinopathy diseases, foreign material, anatomic breed structure, and therapies.

Numerous bacteria can colonize the outer portion of the ear canal, and they can grow when there is damage or inflammation for a number of reasons (Greene, 2006).

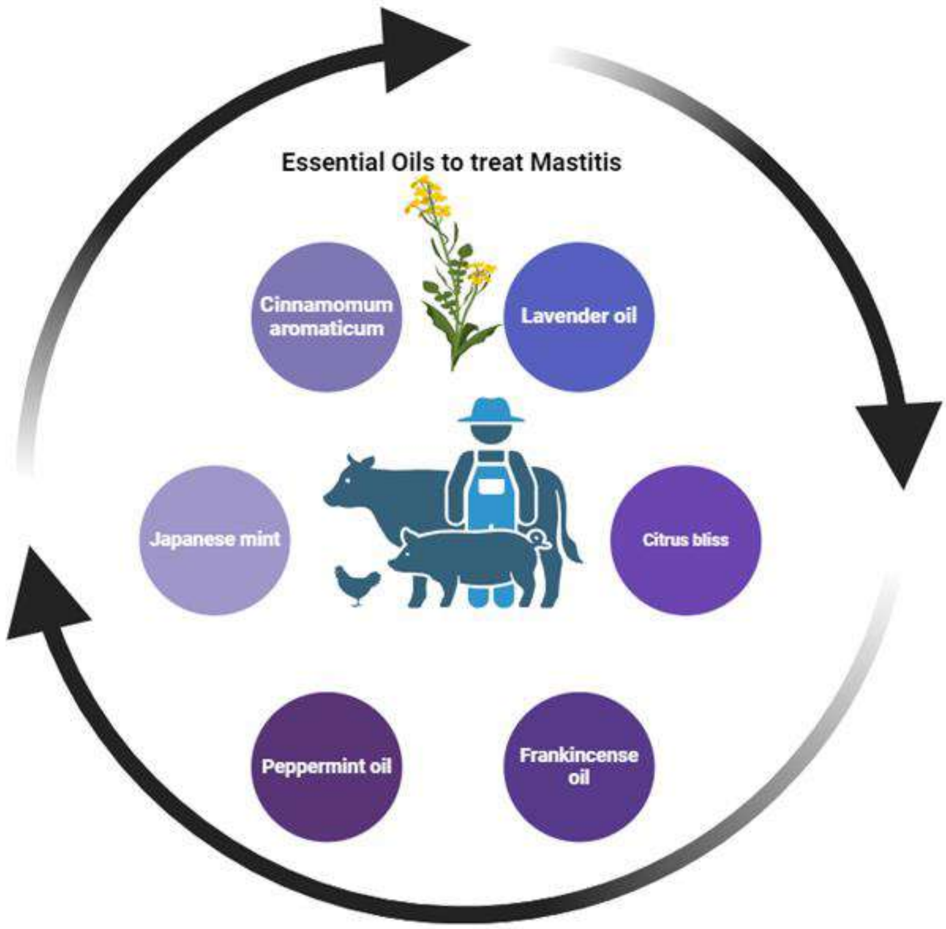

Fig. 2: Different Essential oils used to treat Mastitis in Cow

Yeasts, parasitic organisms, and bacteria are the most common causes of otitis externa. *Staphylococci,* primarily *S. pseudointermedius* (formerly *S. intermedius and S. aureus*), and Pseudomonas species are commonly isolated from the ears of pets such as cats and dogs with either acute or persistent otitis externa (Devriese et al., 2009).

Nine essential oils are used to treat otitis externa, including Roman chamomile *(Anthemis nobilis L.),* anise seeds star *(Illicium verum),* fragrant lavender (*Lavandula hybrida),* litsea *(Litsea cubeba)*, rosemary *(Ocimum basilicum L.),* oregano (the plant Origanum vulgare L. subsp. hirticum), rosemary leaves *(Rosmarinus officinalis L.)*, clary sage (Salvia, also known *sclarea L.),* bay *(Thymus vulgaris L.),* and thyme supplements *(Lymus vulgaris L.)*. Some malignancies may be aided in their fight by frankincense. Furthermore, frankincense oil might be able to identify malignant cells from normal ones and kill just the latter, according to some laboratory research (Ebani et al., 2017).

With the exception of *A. nobilis*, which had the highest proportion of non-terpenic esters such isoamyl angelate (18.7%) and isobutyl angelate (34.5%), all of these oils were high in monoterpenes. Carvacrol (65.9%) and thymol (52.6%) were the two main terpenes that are present in O. vulgare and the leaves of T. vulgaris extracts, respectively. P-cymene was only identified in T. vulgaris (15.3%). Linalyl acetate was shown to be the main component (54.7%) of *S. sclarea*. Linalool was the main component of the basil (*O. basilicum*) and *L. hybrida* extracts (46.0% and 31.5%, respectively). The significant frequency of the linalyl acetate compound (29.8 %) with *L. hybrida* and eugenol (11.5 %) in *O. basilicum* must be highlighted (Ebani et al., 2017).

Essential oils against bacterial Infection

E. coli spp.

Avian pathogenic (APEC) strains of *Escherichia coli* cause avian colibacillosis, a systemic disease that affects hens. This bacterium is enteric, and although it typically affects birds by dust inhalation, it also infects animals through an feco-oral cycle (Beernaert et al., 2010).

Usually, the first indication of the infection is septicemia, which is followed by sudden mortality or localized inflammation in many organs. Although there are other lesions linked to colibacillosis, polyserositis and airsacculitis are the most prevalent ones. Moreover, if the egg yolks are tainted with excrement, *E. coli* may break through the shell. This could lead to bacterial infection of the yolk sac and significant hatching mortality rates when the infection spreads to other hens. Economic losses resulting from necrotic cellulitis-related slaughter waste may also exist (Işcan et al., 2002).

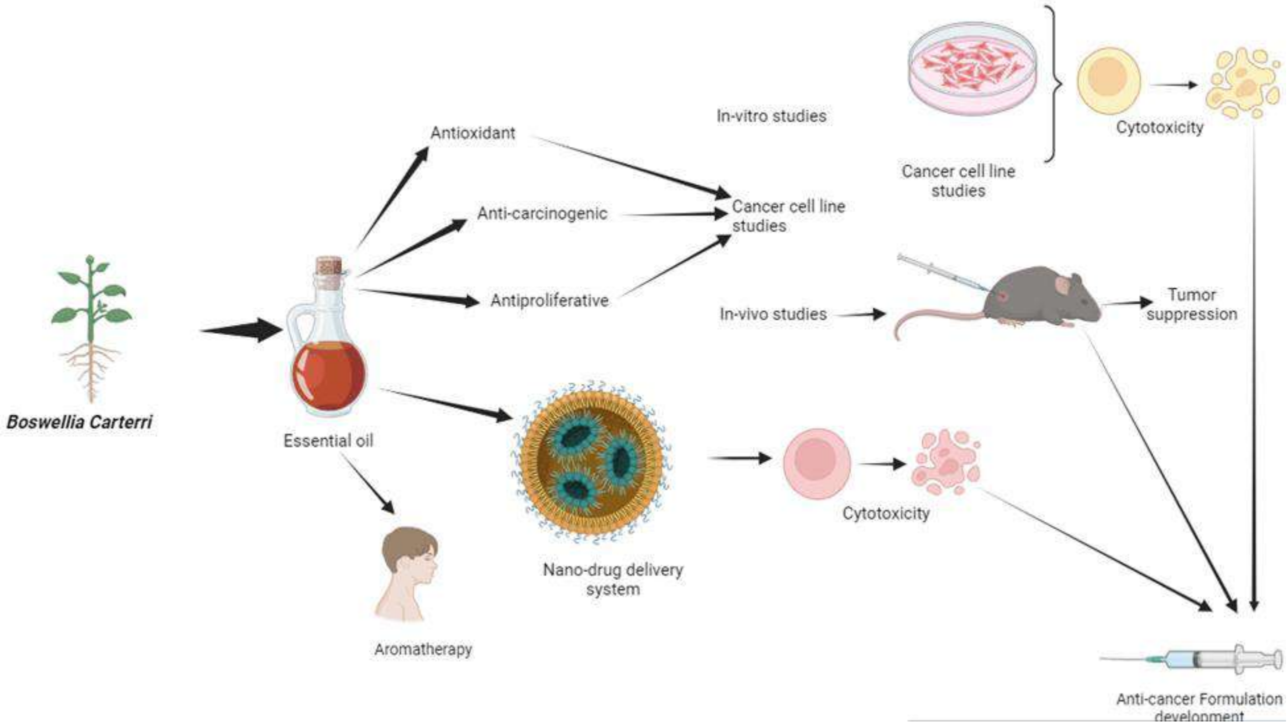

Fig. 3: Essential Oil Extraction and its medical use in animals

To treat this disease a high percentage of aromatic compounds as geranial (36.4%) of the and neral (32%) is primarily responsible for the holes and gaps in the outer membrane as well as the inner membrane of *E. coli* cells when preserved with *L. cubeba* EO, which exhibits significant anti-*E. coli* activity (Císarová et al., 2016). *M. piperita* EO exhibited strong anti-*E. Coli* action. *M. piperita* EO demonstrated the strongest antibacterial efficacy against *E. coli* and against a few other Gram-positive and Gram-negative bacteria. The antibacterial qualities of peppermint essential oil, attributing its effectiveness to menthol and its oxidative component as its main constituents (Ebani et al., 2018)

Strong antibacterial effect against *E. coli* strains recovered from chickens that had colibacillosis was demonstrated by the essential oils of clove *(Syzygium aromaticum)* and cinnamon *(Cinnamomum zeylanicum)*, when administered separately or in combination (Ebani et al., 2018).

Salmonella spp.

This genus's isolates make agricultural animals and pets sick, which costs money and raises the risk of the infection spreading to people. A total of fifteen distinct types of enteric *salmonella* serovar Heidelberg were tested against the constituents of R (+)-a chemical called limonene, orange aromatic compounds, the compound trans-c, carvacrol, and cold squeezed orange oil. The strains were retrieved from a range of sources like hogs, cattle, animals such as turkeys' poultry, and chickens. Carvacrol and trans-cinnamaldehyde completely stopped the development of all *S. Heidelberg* isolates; only two isolates were stopped from growing by cold squeezed oil of orange, R (+)-a chemical called limonene, and orange terpene against the same strains (Himanshi et al., 2015). EOs from *Crataegus zeylanicum, Crataegus cubeba, L. cubeba, M. piperita, and S. aromaticum* were evaluated against isolates of *S. enterica* serovar *Typhimurium* and *S. enterica* serovar Enteritidis that were separate from chicken. These serovars are important zoonotic infections that have been connected to grave ailments in animals, birds, and humans. *C. zeylanicum* had the strongest anti-Salmonella action, followed by *S. aromaticum* EO. It has been suggested that incorporating such EOs into poultry diets in conjunction with the delivery of *Saccharomyces cerevisiae* yeast is an integrated approach to prevent Salmonella from colonizing the intestinal tract. Furthermore, EOs from *C. zeylanicum* and *S. aromaticum* could be utilized alone or in addition to disinfect a farm (Ebani et al., 2019).

Pseudomonas spp.

Infections with *Pseudomonas aeruginosa* can occur often in hospitalized patients, animals, and people. In addition to bacteremia and pneumonia, it can result in skin, vaginal, and urinary tract infections. Other *Pseudomonas* species have the ability to infect different bodily parts, albeit this is less common. Important elements from the outer bark layers of cinnamon tree spp. shrubs have been shown to have antibacterial activity against a range of microbes, including *P. aeruginosa* (Bouhdid et al., 2010).

Certain EOs, like cinnamon, have the ability to stop this disease from proliferating and from developing a biofilm. The essential oils of cassia seeds *(Cinnamomum aromaticum)*, cloves *(S. aromaticum)*, Peru balsamic (*Myroxylon balsamum)*, red rosemary (*T. vulgaris*), and the leaves of tea trees (*Melaleuca alternifolia*) efficiently killed *P. aeruginosa* in vitro.

Furthermore, the EOs of Peru balsam, red thyme, and cassia were successful in preventing the development of biofilms (Kavanaugh and Ribbeck, 2012).

Campylobacter spp.

The genus Campylobacter contains pathogens that infect humans and many other animal species. The exceedingly high incidence of *Campylobacter* in grill and layer flocks has been shown in many recent studies. The source of infection of outbreaks associated with poultry products is Campylobacter, which can cause foodborne illness by infecting the poultry carcass (Micciche et al., 2019).

Caprylic acid, a component of coconut oil and palm kernel oil, significantly reduced the levels of Campylobacter cecal in feeds at concentrations under 1%. The oils that exhibited the greatest activity against *C. jejuni* were those from the marigold plant, ginger root, floral notes, patchouli scent, gardenia, california wood from cedar, the carrot genre seed, coriander seed, mugwort, however, spikenard, and orange bitter. Geranyl acetate, both cardamom aldehyde, estragole, carvacrol, a chemical called citral, a compound called thymol a chemical known as perillaldehyde, and a carvone R were found to be the most potent compounds against C. jejuni. It's thought that essential oils that have been shown to work against strains of Campylobacter that have different origins may have an impact on isolates from dogs and cats. (Friedman et al., 2002).

***Staphylococcus* spp.**

Although species of *staphylococcus* are well known for their ability to cause opportunistic infections, they also represent a significant risk to veterinary care. In actuality, they infect birds, mammals, and cold-blooded species in many anatomical regions. The anti-staphylococcal effectiveness of *O. vulgare* and *T. vulgaris* essential oils, mostly because of their main ingredients, thymol and carvacrol. (Utchariyakiat et al., 2016).

The anti-staphylococcal effect of *Satureja montana* EO is good. Previous findings have connected carvacrol to the antibacterial activity of *S. montana* EO against a range of bacterial species, including Gram-positive and Gram-negative species (Vitanza et al., 2019).

Safety Guidelines and Potential Side Effects

Even though EOs are becoming more and more popular, there aren't enough research on their toxicity, which is a vast concern. Usually, experimental creatures like rodents are used to evaluate the potentially hazardous impacts of essential oils and their constituents. Most EOs have mild toxic effects, having an LD50 ranges from 1–20 g/kg, according to preliminary rat testing. Initial studies on the toxicity of peppermint in sheep, EO *(M. piperita)* had no negative impact on blood parameters, behavior, or the functions of the liver and kidneys. It shows that the formulation is safe to use on sheep, particularly when used temporarily. Comparable outcomes were noted for the encapsulated mixture of anethole and carvone given to lambs at doses of 20 and 50 mg/kg orally, and for the essential oil of lemongrass Cymbopogon schoenanthus L. *(C. schoenanthus)* administered to sheep at 180 and 360 mg/kg orally. Both instances demonstrated the safety of the animals by showing no harmful impacts on liver or kidney functioning or animal behavior (Čmiková et al., 2023)

Research indicates that pesticides categorized as low-risk and not registered with the Environmental Protection Agency (EPA) may have significant negative impacts on cats and dogs. Following the use of naturally produced plant flea products, the majority of the exposed animals (92%) displayed symptoms. It's important to remember that these low-risk pesticides can still harm animals even if they are labelled as "natural" and used as directed. Furthermore, each species has unique host features, different animals may exhibit various degrees of susceptibility to EOs (Dangol et al., 2023).

Better results can also be obtained by increasing the dosage or giving several doses over the course of several days as opposed to just one application. But it's crucial to evaluate the possible toxicity before using larger doses or administering a medication more than once. Additionally, efficiency can be improved and controlled release made possible by alternate administration techniques, such as plant-based compound-containing lick blocks, enabling its extended use (Bin-Jumah et al., 2021)

Limitations in the use of EOs

- There is few research on the harmful effects of essential oils (EOs), especially when it comes to pets and animals. As a result, there is insufficient information to support both the possible risks and advantages of EOs (Mazraedoost, 2021).
- The effects of essential oils (EOs) might range greatly amongst animal species. This heterogeneity makes it more difficult to set safety recommendations and standardized dosages that work for a variety of animal species (Dangol, 2019).
- Because of things like body mass index, metabolism, and individual sensitivities, it can be difficult to determine the right dosage and application techniques for essential oils (EOs) in animals (Mazraedoost, 2021).
- The source of the plant, the extraction process, and the storage environment can all affect an EO's chemical makeup. Because of this lack of standardization, it is difficult to predict the precise effects of these oils on animals and each oil's unique qualities must be carefully considered (Adokoh, 2022).
- Certain essential oils, even those sourced from plants, may present hazards to animals. For example, consumption of tea tree oil has resulted in intoxication in both people and animals, highlighting the significance of responsible use (Dangol, 2019).

Future Perspectives

Exciting developments in EO applications for veterinary care are anticipated in the near future. We expect a revolutionary strategy to employing essential oils for animal health through state-of-the-art research and customized coaching. The efficiency and security of these procedures will be improved by technological advancements and carefully monitored clinical studies. Further comprehension of the gut microbiome and regulatory improvements will also result in a more sophisticated and comprehensive method of using essential oils in animal healthcare. These advances reflect not only the advancement of veterinary care but also our unwavering dedication to the welfare of animals (Chen, 2019).

Conclusion

The usage of essential oils in aromatherapy, and medications, has grown in popularity in recent years. Despite being widely accepted as "natural and safe," certain essential oils have the potential to have serious side effects, such as brain toxicity, endocrine dysregulations, skin sensitivity, and contact dermatitis. To guarantee safe and efficient application, care must be taken. When assessing EOs' possible effects on biological systems, it is essential to comprehend their chemical makeup, and early toxicity research offers valuable information on their safety. Thymol and thyme essential oils (EOs) have remarkable insecticidal action *against C. hominivorax* larvae, indicating possible uses in the management of myiasis. Even though EOs show promise as therapeutic agents, research is still being done to determine how they work and whether they carry any hazards. It is essential to carry out thorough safety evaluations and comprehend the mechanics behind their impacts as part of ongoing research in this field. Refinements to regulatory frameworks are necessary for customized veterinary guidelines. Customized regimens and unique formulas have the potential to completely transform animal healthcare as research progresses. EOs constitute a valuable field of investigation in veterinary medicine, especially as interest in organic and holistic methods to pet care grows. After thorough analysis and more research, essential oils (EOs) might prove to be useful instruments for improving the health of companion animals.

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Chapter 17

Larvicidal and Insecticidal Activity of *Essential Oils* of Lemon Balm against *Aedes aegypti*

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ABSTRACT

As the most significant category of insects for public health, mosquitoes are capable of spreading zoonosis as well as serious human illnesses as Japanese encephalitis, Dengue fever, Malaria, Filariasis, and Yellow fever. Millions of people have died and become ill as a result of the diseases that these insects spread. There are not any commercially available drugs or vaccines for treating dengue fever at the moment. The single strategy implemented to lower the frequency of dengue is to manage *Aedes aegypti*, the vector that also serves as the main source of Zika, Yellow fever, and Chikungunya viruses. Nonetheless, synthetic substances that mostly comprise DEET (N, N-diethyl-3-methylbenzamide) in their formulations are the most widely used repellents. DEET has certain drawbacks even if it works well as an insect repellent for a range of insects. The main one is that it can act as a solvent for paints, varnishes, and some synthetic and plastic materials. Because of their potential insecticidal efficacy, rapid disintegration, affordability, and lack of persistence and bioaccumulation in the environment, natural product components such as lemon balm essential oil are suggested as synthetic insecticide substitutes when it comes to mosquito control. Lemon balm essential oil is derived from the leaves of the *Melissa officinalis* plant and is highly prized for its lovely citrus aroma as well as a number of potential health benefits. As this chapter has shown, one of its supposed applications is as a natural insect repellent, especially against mosquitoes.

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INTRODUCTION

Ae. aegypti is indigenous to Africa, where ancestral populations are still present, reproducing in forests and ecotones, where adults prefer wild animals for blood feasts and larvae hide in tree holes (Lounibos, 1981; McBride et al., 2014). African villages and cities were popular mosquito breeding sites during extended dry seasons because people there started keeping water in containers when they first settled there. The African Aedes mosquito that took advantage of this new niche was *Ae. aegypti*. As females fled from huts in villages, they developed a taste for blood feasts from the most accessible source: people. Currently found in tropical and subtropical human settings across six continents, *Ae. aegypti* is known for having been "domesticated" (Powell and Tabachnick, 2013; Gloria-Soria et al., 2016)

The Reason Mosquitoes Find You Appealing

One of the most vital senses of mosquitoes is their ability to smell, or olfaction (Potter, 2014) that they depend on to keep their lives going. For instance, they locate oviposition sites for egg laying, nectar sources for feeding, and human hosts using their smell cues (Carey and Carlson, 2011). It has been established that a variety of human secretions (Figure 1), such as carbon dioxide from breath, lactic acid from skin and exhaled air, and 1-octen-3-ol from perspiration and breath, are mosquito attractants (Dekker et al., 2005).

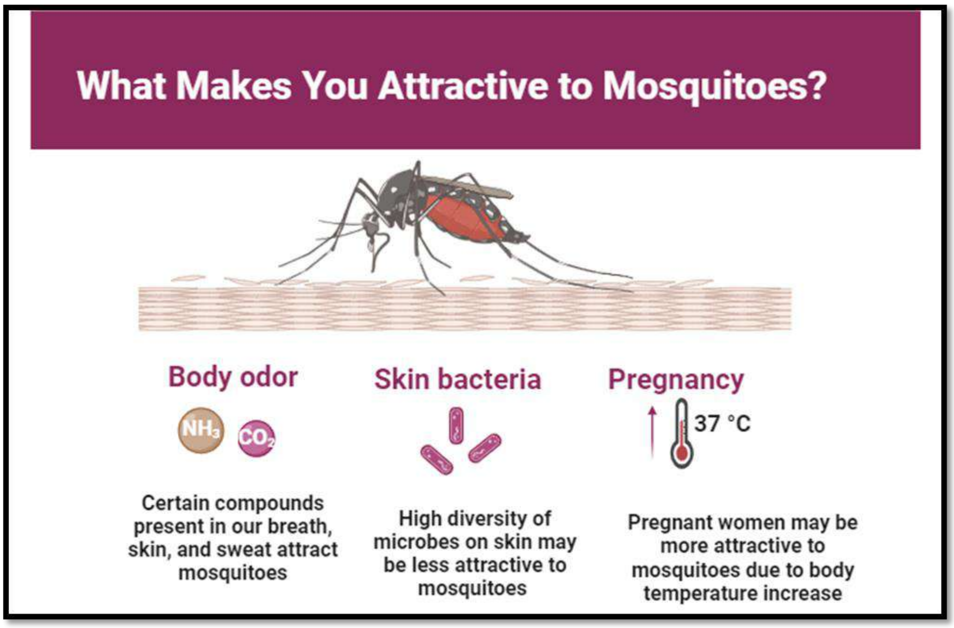

Fig. 1: Why mosquitoes are attracted to you?

Linnaeus species *Ae. aegypti* is known to carry important and dangerous illnesses, including Dengue, Chikungunya, Yellow Fever, and Zika Fever. This mosquito is native to Africa, although it is also found in tropical and subtropical areas, as well as tranquil places across the world (Benelli and Duggan, 2018). A little bit detail of these *Aedes* borne infections is given here.

Dengue Infection

Currently, dengue is one of the most significant tropical diseases that go unreported in the globe (Guzman and Harris, 2015) and in the past few decades, its occurrence has more than tripled along with the spread of dengue viruses and *Ae. aegypti* mosquitoes across new geographic areas (DENVs) (Organization et al., 2009). Dengue fever is considered the most dangerous illness in terms of epidemiology because to its high rates of morbidity and fatality. It is believed that the virus affects 60 million individuals worldwide each year, killing roughly 10,000 of them (Bhatt et al., 2013; Stanaway et al., 2016).

Dengue Virus Life Cycle

Mature viral particles bind to their hosts' cells and enter by endocytosis. When the viral and endosomal membranes merge within the cell, the viral genome is liberated (Figure 2). Viral RNA is translated into proteins, which initiates replication. Proteins from the Dengue Virus (DENV) can attach to lipids in cells and be released. After reaching maturity in the endoplasmic reticulum (ER), the virus leaves the host. Certain discharged particulates are still immature and not contagious (Guzman and Harris, 2015).

Transmission of Dengue Virus

If *Ae. aegypti* mosquito feeds on an infected person during the viremic phase of the illness, the mosquito can then carry the virus. Dengue viruses enter mosquito midgut cells and other tissues during the extrinsic phase of the cycle, then proceed to the salivary glands. A mosquito carrying the dengue virus can infect multiple individuals once it feeds or tries to feed (Figure 3). Dengue fever symptoms typically take four to six days to manifest, and an infected person can spread the virus to a new mosquito during this time. People who are symptomatic or not can infect mosquitoes with the dengue virus (Guzman et al., 2016).

Clinical Symptoms

The acute febrile stage is when fever happens. Diarrhea and mild stomach discomfort are possible. Adults typically exhibit a "flu-like syndrome" that includes body aches, headaches, and malaise, with digestive symptoms predominating over respiratory symptoms (Guzman et al., 2016).

Chikungunya Virus (CHIKV) Infection

Aedes mosquitoes carry the Chikungunya virus (CHIKV), an arthropod-borne virus that mostly causes acute and persistent articular symptoms (Simon et al., 2008). It was first discovered in Asia in 1954 after being first reported in Africa (Tanzania) in 1954. It produced widespread epidemics on both continents from the 1960s to the 1980s, and then there was a relatively peaceful period for the next 20 years (Pastorino et al., 2004). Recently, CHIKV has resurfaced, infecting millions of people in nations surrounding the Indian Ocean that have climates conducive to high vector densities (Caglioti et al., 2013).

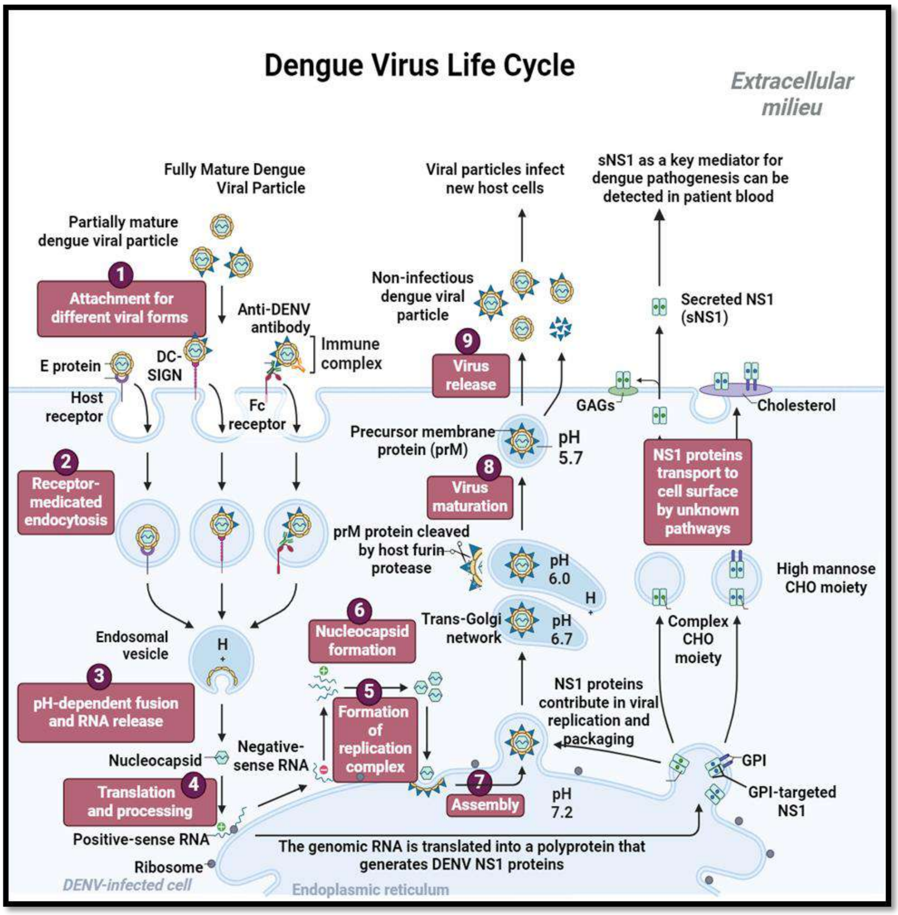

Fig. 2: Life-Cycle of Dengue Virus.

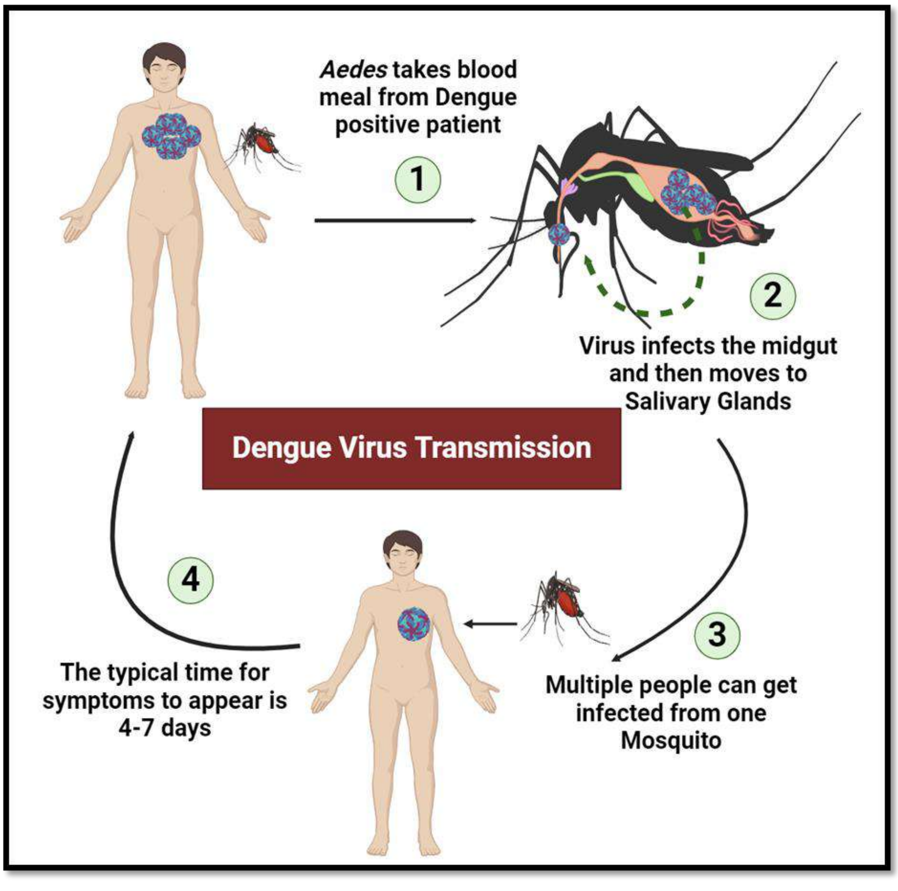

Fig. 3: Transmission of Dengue Virus.

Life Cycle of Chikungunya Virus

Replication cycle of Chikungunya virus (alphavirus) in susceptible cells (Figure 4) occurs in following steps:

1) Envelope protein-2 (E2) attaches itself to the surface of cells through an unidentified receptor and maybe glycosaminoglycans acting as attachment factors.

2) By means of clathrin-mediated endocytosis, CHIKV gains entry into the cell. The fusion peptide in Envelope protein-1 (E1) is inserted into the endosomal membrane as a result of endosome acidification.

3) The nucleocapsid is released into the cytoplasm upon the fusion of the viral envelope and endosomal membrane.

4) Positive-sense genomic RNA is released during nucleocapsid disintegration, and nonstructural protein (nsP) translation takes place.

5) The plasma membrane (PM) is modified by the assembly of four nsPs, genomic RNA, and maybe host proteins to create viral replication compartments (spherules) that hold viral dsRNA. To produce genomic, antigenomic, and subgenomic vRNAs, nsP1-4 localizes to the spherule neck and perform the role of a replicase.

6) Multiple spherules are housed in enormous cytopathic vacuoles (CPV-1) that are formed during spherule internalization. The spherules in CPV-I or at the PM are operational.

7) Following translation of subgenomic RNA into a structural polyprotein, capsid autoproteolysis releases the free capsid into the cytoplasm. After posttranslational modification, E2/E1 travel via the secretory route and arrive at the PM.

8) Capsid-genomic RNA interaction results in the formation of isosahedral nucleocapsids.

9) At the PM, nucleocapsids assemble with E2/E1, causing mature progeny virions to emerge.

10) Nucleocapsids are studded within the hexagonal E2/E1 lattices of CPV-IIs, which develop later in infection.

11) Most likely, CPV-IIs are used as transport vehicles.

12) Structural protein assembly locations.

13) permitting the development of mature virions.

14) Egress (Kujala et al., 2001; Frolova et al., 2010; Spuul et al., 2010).

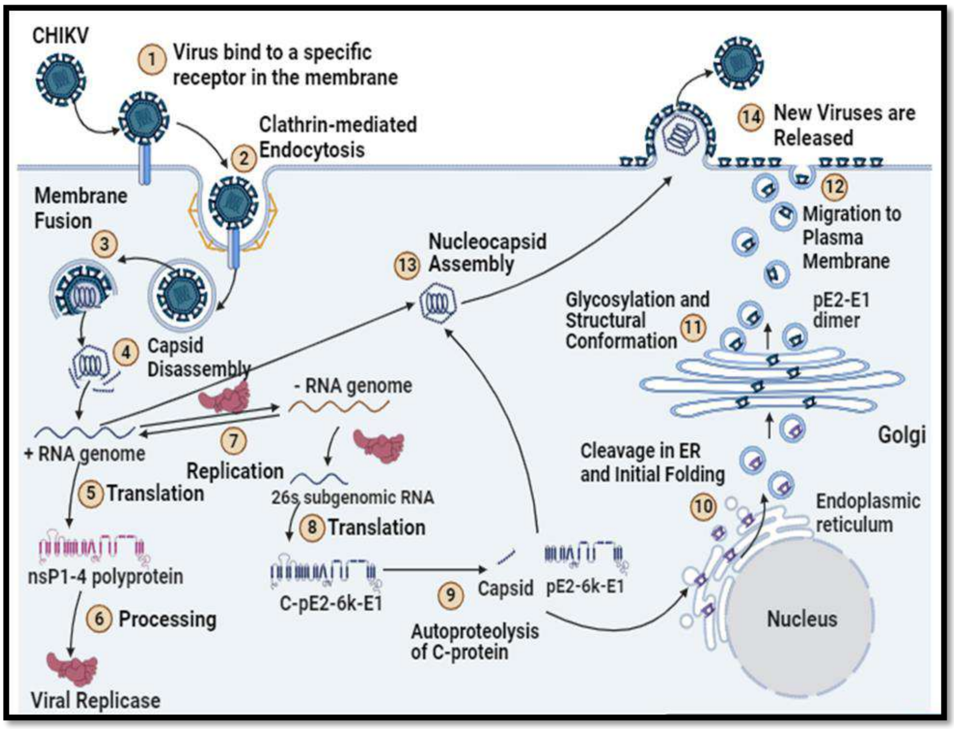

Fig. 4: Replication cycle of Chikungunya virus (alphavirus) in susceptible cells

Two Stages to the Chikungunya Infection

Acute Stage

Most people infected with CHIKV show acute symptoms two to six days after being bitten by the infectious mosquito (Josseran et al., 2006). The initial symptoms appear suddenly and persist for almost a week before clearing up on their own (Figure 5). The ten days following the commencement of the sickness are referred to as the acute stage (Simon et al., 2007). The most common symptoms include headache, arthralgias, back discomfort, and high temperature (Organization, 2008). Intense exhaustion, anorexia, myalgias, nausea, vomiting, and even momentary forgetfulness in older individuals are all linked to illness (Simon et al., 2011).

Chronic Stage

A newly infected patient may experience early aggravation, inflammatory relapses, chronic rheumatism, and a significant decline in quality of life following the brief recovery following the acute stage of the virus (Simon et al., 2007). This decline is more common in those over 40 and/or those with underlying medical disorders, especially rheumatic or traumatic diseases (Sissoko et al., 2009). The persistence of symptoms during the acute phase (Figure 5) is also linked to high CHIKV virus loads (Hoarau et al., 2010). A few weeks after the condition starts, further ocular abnormalities such as optic neuritis, retinitis, anterior uveitis, and episcleritis may appear and might occasionally result in blindness (Mahendradas et al., 2008).

After CHIKV infection, the most typical symptom is polyarthritis similar to Rheumatoid Arthritis (RA). The 1987 American College of Rheumatology criteria state that RA is characterized as follows: anti-CHIKV IgM and IgG antibodies are present; persistent arthritic symptoms from the start of CHIKV infection until the diagnosis of RA is made; and there is no other definitive diagnosis of arthritis (Bouquillard and Combe, 2009).

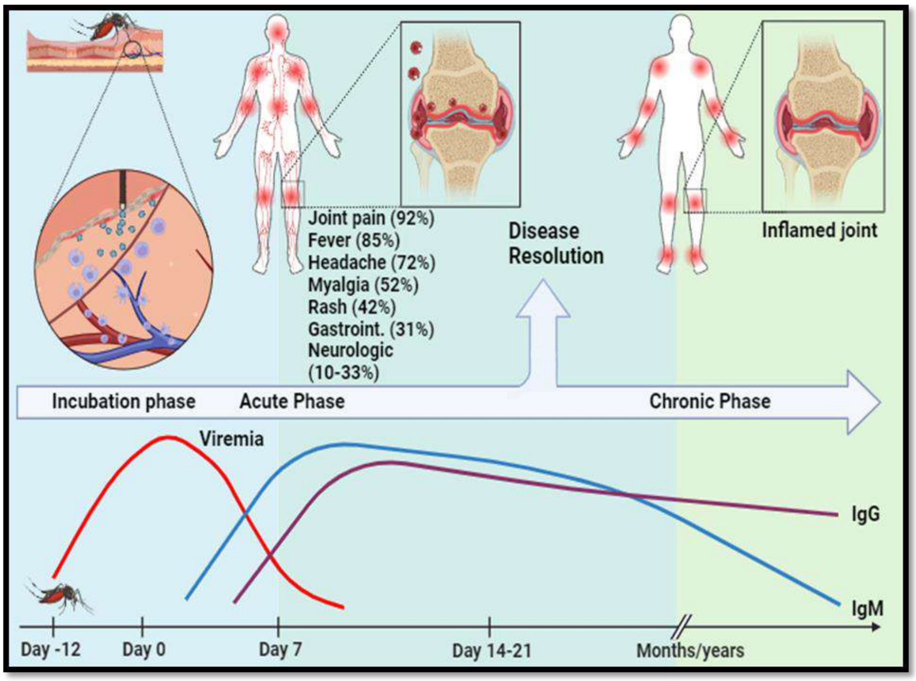

Fig. 5: Chikungunya disease progression with typical viremia and antibody immune response.

Zika Virus (ZIKV) Infection

In 1947, the Zika virus was discovered by a monitoring monkey in Uganda's Zika woodland. It is a member of the Flavivirus genus and family Flaviviridae. Subsequent epidemiological studies revealed that the Zika virus had extensively dispersed across Southeast Asia and sub-Saharan Africa. In Nigeria in 1954, there was the first recorded case of human infection; however, the virus's identity was later called into doubt, and Spondweni was assumed to be the culprit. In Uganda, reports of the earliest known human infection date back to 1962–1963 (Wikan and Smith, 2016).

Life Cycle of ZIKV

ZIKV adheres to a host cell's surface before entering through a procedure known as endocytosis (Figure 6). The virus enters the cytoplasm after combining with the endosomal membrane deep within the cell. The virus's genome is released by the viral particle. Translating a single polypeptide from viral RNA into 10 different proteins, the virus duplicates its genome. On the surface of the endoplasmic reticulum, viruses clump together. The trans-Golgi network carries the immature virus particles until they reach adulthood and are infectious. Once they leave the cell, the evolved viruses may infect other cells (Acosta-Ampudia et al., 2018).

Clinical Manifestations of ZIKV Infection

In most cases, a ZIKV infection is asymptomatic. When it manifests, symptoms include conjunctivitis, a wide pruritic maculopapular rash, arthralgia, and myalgia. The illness normally goes away after 3 to 12 days of incubation (Figure 7). Many injuries to the central and peripheral nervous systems, including meningoencephalitis, GBS, TM, ophthalmological symptoms, and other neurological problems, have been connected to ZIKV (Acosta-Ampudia et al., 2018).

Yellow Fever Infection

Mosquitoes carry the flavivirus that causes yellow fever, which is common in tropical parts of Africa and South America. Travelers and inhabitants of endemic places are still at danger for this disease, despite the fact that there has been a trustworthy vaccination for roughly 70 years. The disease has historic significance (Monath and Vasconcelos, 2015).

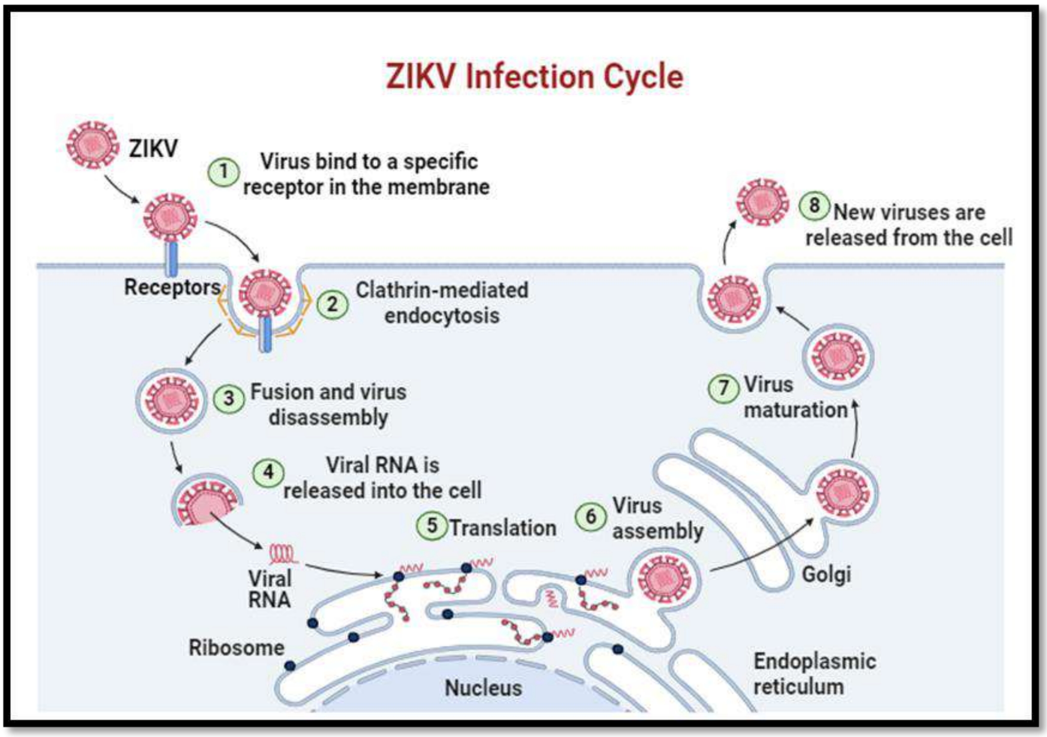

Fig. 6: Infection Cycle of ZIKV

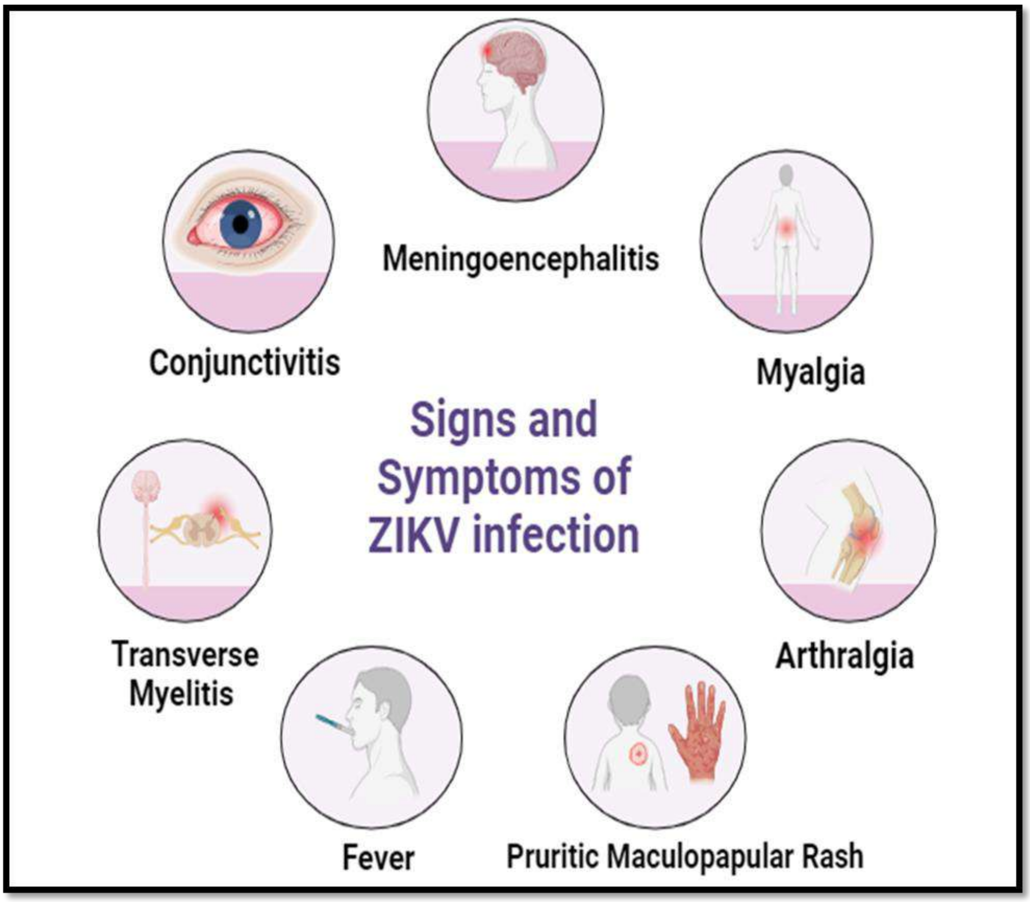

Fig. 7: Signs and Symptoms of ZIKV infection.

Replication Cycle of Yellow Fever Infection

The yellow fever virus (YFV) binds to host cell receptors and then enters the host through receptor-mediated endocytosis to start its reproduction cycle. In order to promote translation and replication in the cytoplasm of the host cell, the released viral RNA genome is used by the RNA-dependent RNA polymerase (RdRp) (Figure 8). RNA genomes and freshly produced viral proteins then come together to form new virus particles, which develop by taking on an envelope made of host cell membranes. Ultimately, the replication cycle is continued by the release of mature virus particles through budding, which infect nearby cells (Gubler, 2007).

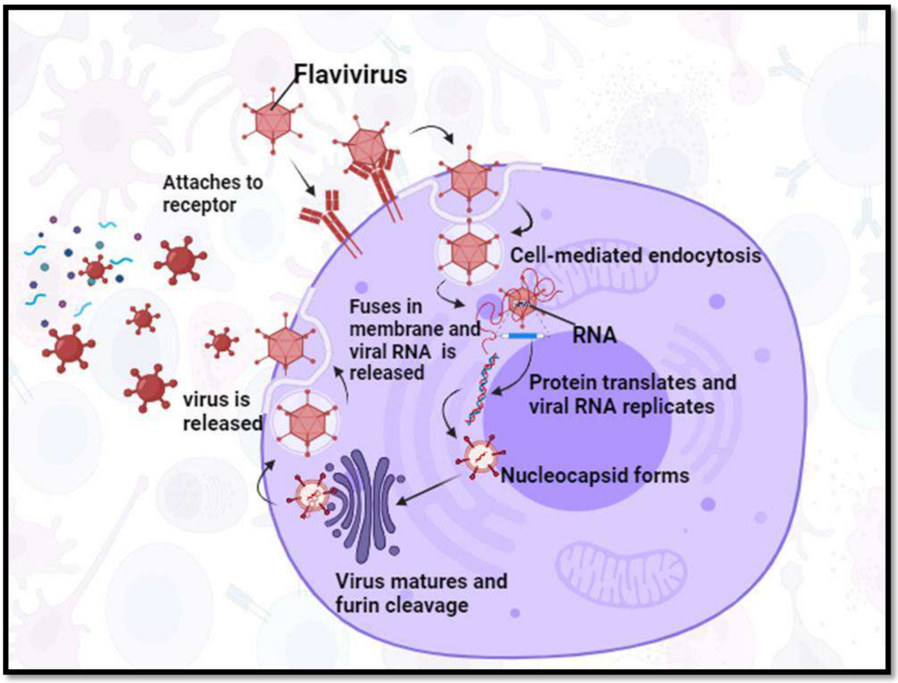

Fig. 8: Replication Cycle of Yellow Fever Infection.

Transmission of Yellow Fever Virus

The virus can only infect a comparatively small number of hosts before becoming productively infected. The primary vectors of transmission in the wild are blood-feeding mosquitoes, primarily from the genera *Haemagogus* and *Aedes* in South America and Africa, respectively, as well as transovarial transmission via these vectors. The disease known as "Jungle Yellow Fever" is occasionally transmitted to humans by sylvatic mosquitoes that bite them after feeding on a viremic monkey. But *Aedes aegypti*, a species that breeds in water-filled receptacles inside or close to houses, can also serve as the viremic host for the spread of the disease between humans (Monath and Vasconcelos, 2015).

Vector control: A strategy to prevent Human Life-Threatening Diseases

As was previously said, one mosquito serves as the main vector for a number of serious human diseases. As such, controlling the one mosquito species is more effective than combating each disease as it emerges.

In order to protect humans against vector mosquitoes, chemicals can irritate, repel, or kill them (Grieco et al., 2007). Several research work has focused on artificial substances (Pothikasikorn et al., 2007; Polsomboon et al., 2014) designed to lessen disease transmission and mosquito populations (Noosidum et al., 2008). However, due to the issue of toxicity, non-biodegradable material effects, vector resistance to synthetic insecticides, and detrimental effects on non-target organisms, new strategies utilizing natural products are required to control harmful insects and disease vectors (Jantan et al., 2005).

Research has indicated that insect repellents function in a comparable way. Each repellent exerts its deterrent effects by binding to and interacting with particular insect gustatory and odorant receptors, which changes their activity (Xu et al., 2014). With 200 million users globally, N,N-Diethyl-meta-Toluamide (DEET) is the repellant that has been most frequently used for nearly 50 years (Syed and Leal, 2008) because of how well it protects troops (Das et al., 1999). However, research has demonstrated that using DEET can have a number of dangerous negative effects, such as skin irritation and dermal infection (Das et al., 1999; Patel et al., 2012). Therefore, research is being done to determine whether botanicals may effectively repel mosquito vectors and serve as a viable substitute for industrial insecticides (Warikoo and Kumar, 2015). Mosquito breeding places have increased as a result of insufficient waste management systems and water supplies. Due to them, the number of mosquito-borne illnesses that now affect over 700,000,000 people worldwide has increased dramatically (Jantan et al., 2005). Because natural product components break down quickly, are inexpensive, do not persist in the environment, and do not bio-accumulate, it has been suggested that they could take the role of synthetic pesticides in the control of mosquitoes (Ajaegbu et al., 2022).

Melissa officinalis:* A Medicinal Herb to Control *Ae. aegypti

M. officinalis, or lemon balm, is one of the most significant herbs among the autochthonous therapeutic plants of the genus *Melissa*. In Central and Southern Europe as well as Asia, *M.officinalis* is a common plant. In sandy and shady places, lemon balm grows spontaneously (Schnitzler et al., 2008) although it has also been observed to grow at altitudes from sea level to the mountains on moist wasteland. This plant is classified according to the following taxonomy; Plantae is the kingdom; Tracheophyta is the division; Speramtophyta is the subdivision; Magnoliopsida is the class; Asteranae is the superorder; Lamiales is the order; *Melissa* is the genus; *officinalis* is the species (Miraj et al., 2017).

The insecticidal characteristics of *M. officinalis* essential oil are covered in this chapter, along with how it works as a repellent and larvicidal against *Ae. aegypti*, the critically ill species that causes dengue fever.

Chemical Constituents in Essential Oil (EO) of *M. officinalis*

It has been shown that the EO sample of *M. officinalis* has around 24 components, the bulk of which are citronellal (22%), β-citronellol (14%), geraniol (17%), geranial (11%), and geranyl acetate (12%) (Baranitharan et al., 2016). Studies conducted on *M. officinalis* reveal that citral, a combination of geranial (α-citral) and neral (β-citral) isomers, is the main volatile constituent (Pinto et al., 2015). The study conducted by (Luz et al., 2014) shows variations in the chemical composition of the essential oil (EO) extracted from *M. officinalis* leaves collected in the summer and winter, both in terms of quantity and quality, indicating the influence of the seasons. As per the quantification by external pattern, the concentration of geranial and neral was higher in the summer season (47% geranial and 31% neral) compared to the winter period (16% geranial and 9% neral). From a phytochemical perspective, EOs and other natural plant extracts have been viewed as significant substitutes, especially given their wide range of chemical composition (Martins et al., 2021). Geographical and agronomic circumstances, including soil, plant genotypes, phytogeographic factors, microclimatic conditions, and plant genotypes can all influence the amount and range of EO present in plants of the same species grown in various places. But generally speaking, the essential elements stay the same; their levels of concentration simply change (Kumar et al., 2011).

Larvicidal activity of *M. officinalis* against *Ae. aegypti*

Larivicidal potential is categorized using Lethal Concentration (LC). When an EO's LC_{50} > 100 mg/L, it is deemed inactive; when it is less than 100 mg/L, it is considered active; and when it is less than 50 mg/L, it is considered highly active (Dias and Moraes, 2014). According to (Martins et al., 2021)the EO of *M. officinalis* showed highly effective larvicidal action by maintaining LC_{50} < 50 mg/L as LC_{50} is 40 mg/L. At different concentrations (125, 250, 500, and 1000 ppm), the larval mortality of *M. officinalis*' EO against *Ae. aegypti* is 0, 12, 12, and 20%, respectively (Onah et al., 2022). When *M. officinalis* is used as an EO against *Ae. aegypti*, the larval death rate is 72.5% (Sheng et al., 2020). The LC50 and LC90 values for essential oil's capacity to inhibit *Ae. aegypti* larvae are 61 and 88 mg/L respectively (Koliopoulos et al., 2010).

Table 1: The LC_{50} and LC_{90} Values of five compounds (Citronellal, β-Citronellol, Geraniol, Geranial and Geranyl acetate) of essential oil of *M. officinalis*

Major Compounds	LC50 (ppm)	95% CL (LCL–UCL)	LC90 (ppm)	95% CL (LCL-UCL)
Citronellal	85	(62–102)	159	(138–192)
β-Citronellol	109	(88–134)	185	(162–257)
Geraniol	98	(79–125)	172	(145–238)
Geranial	145	(129–169)	248	(228–287)
Geranyl acetate	126	(105–142)	213	(195–253)

The values are given as the average of five replications. LCL: Lower confidence limit; UCL: Upper confidence limit; LC50: Lethal concentration 50; LC90: Lethal concentration 90; CL: Confidence Limit (Baranitharan et al., 2016). In the literature, other compounds of EO of *M. officinalis* (citral, carvona and limonene) chemotypes showed effective larvicidal activity with LC50 = 7 mg/mL, LC50=29 mg/mL and LC50 = 31 mg/mL, respectively (Silva, 2019).

Repellent activity of *M. officinalis* against *Ae. aegypti*

Relative repellent effectiveness of 1% essential oil of Melissa against laboratory mosquitoes of *Ae. aegypti* on guinea-pigs and human hand skin is 92 and 60% respectively (Oshaghi et al., 2003). *M. officinalis* essential oil has notable mosquitocidal property. Repellent activity of different compounds of *M. officinalis* is up to 120 minutes against *Aedes* mosquitoes (Baranitharan et al., 2016). Essential oils of *M. officinalis* have a repellent effect on adult *Ae. aegypti* at "high" doses of 0.2 mg/ cm^2, "moderate" doses of 0.08 mg/ cm^2, and "low" doses of 0.04 mg/ cm^2, with an average of 0 and 5 landings. At both high and moderate dosages, this essential oil provides complete protection against mosquitoes (Giatropoulos et al., 2018).

Conclusion

The international concerns are human infections spread by insects, especially those carried by mosquitoes, such as viruses like Dengue, Zika, and Chikungunya that are carried by *Aedes* mosquitoes. In the last fifteen years, insecticide-based methods have been used to reduce mosquito vectors in order to contain viral epidemics. Alarming rates of pesticide resistance in insect populations, however, are already posing a danger to disease control and necessitating the development of new, targeted tactics that can lower vector-mediated transmission. An alternative and successful method of eliminating annoying insects has been shown by numerous studies to be the use of essential oil components and their derivatives. Because most essential oil ingredients are determined to be harmless to mammals, birds, and the aquatic ecology, essential oils are justified as green insecticides. *M. officinalis* is one of the crucial herbs having the insecticidal effects. Without endangering people or the environment, its essential oils can be utilized to create mosquito-repellent personal protection compositions that are both affordable and effective.

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Chapter 18

Larvicidal, Insecticidal and Mosquito repellent activity of Scented Geranium (*Pelargonium species*) essential oil against Malarial Vector; *Anopheles stephensi*

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ABSTRACT

The primary malaria vector in Asia is *Anopheles stephensi*, which comes in three distinct biotypes. It has terrible effects on newborns and early children in endemic areas and breeds in different habitats. Typically, microbiological agents, insect growth regulators, and pesticides are used to target mosquitoes. Insecticide-treated bed netting and indoor residual spraying have both been used. On the other hand, these tactics cause resistance in certain species and have detrimental impacts on the environment and human health. Plant-based pesticides are among the environmentally benign methods that have been used recently to combat mosquito vectors. Essential oils (EOs) are highly scented aromatic oils that are produced by plants as secondary metabolites. These oils have a variety of biological characteristics, such as repellant and larvicidal effects. For a very long time, people have employed Scented geranium (*Pelargonium graveolens*) essential oils or their extractions as insect or mosquito repellents. Research has shown that the EO increases the % repellency against Anopheles species and has insecticidal action. Because they are widely accessible, reasonably priced, and safe, plant oils could eventually replace synthetic repellents in many areas of the world.

KEYWORDS		
Malaria, *Anopheles stephensi*, Essential oils, *Pelargonium graveolens*, Larvicidal, Repellency	Received: 02-May-2024 Revised: 01-July-2024 Accepted: 08-Aug-2024	A Publication of Unique Scientific Publishers

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INTRODUCTION

The world's deadliest creatures are thought to be mosquitoes (Diptera: Culicidae), as they transmit and carry several diseases that kill millions of people every year, including Lymphatic filariasis, Zika, Chikungunya, Malaria, Dengue, Encephalitis, Yellow fever, and Rift valley fever (Lee et al., 2018). In endemic areas, malaria, in particular, still has a terrible effect on newborns and early children. Malaria claimed the lives of 405,000 individuals worldwide in 2018, down from an estimated 416,000 in 2017 and 585,000 in 2010 (Al-Awadhi et al., 2021; Patel et al., 2024). A substantial risk to human life, malaria has been reported to have caused 247 million cases and 619,000 deaths in 2021 (WHO, 2022). The primary method of transmission is by the bites of female Anopheles Meigen mosquitoes carrying the parasite, which act as vectors for the infection (Lefevre et al., 2018). Preventing mosquito bites is one of the best strategies to reduce the incidence of malaria. A complete strategy for managing diseases spread by insects must include the use of repellents to protect people from mosquito bites (Aregawi et al., 2009; Patel et al., 2024). Chemicals including dimethyl phthalate, allethrin, N, N-diethyl mendelic acid amide, and N, N-diethyl-metatoluamide (DEET) are used in the production of most commercial repellents (Patel et al., 2012). It has allegedly been demonstrated that these chemical repellents are unhealthy for the general public and ought to be applied sparingly. The reason for this is their harmful effects on plastic and synthetic fabrics, in addition to their toxic responses that can cause dermatitis, allergies, and adverse effects on the nervous system and cardiovascular system (Patel et al., 2012). The extended and regular application of artificial repellents to manage mosquito populations has led to pesticide resistance, resurgence in mosquito populations, and detrimental effects on non-target creatures (Hemingway et al., 2002; Weill et al., 2003; Liu et al., 2006; Liu, 2015). By substituting natural insect repellent products, it would be able to make new eco-friendly repellents that counterbalance the harmful effects on the environment and human health. The availability of safe, bioactive phytochemicals found in plants that can be examined for their insecticidal and mosquito-repelling qualities has made using them popular once more in recent times. These phytochemicals also biodegrade into harmless byproducts (Nerio et al., 2010; Benelli et al., 2014; Palanisami et al., 2014; Pavela, 2015). Numerous research has demonstrated the global malaria vector-repelling abilities of plant extracts or essential oils. Rose-scented geranium, a member of the *Geraniaceae* family, is one of them (*Pelargonium* species). The insecticidal properties of geranium oil and its constituents, primarily citronellol and geraniol, are widely recognized (Dale and Saradamma, 1981) and these effects are discussed in this chapter.

Malaria: A Deadly Threat to Humanity

A female *Anopheles* mosquito carrying the *Plasmodium* parasite causes malaria, a deadly disease that infects humans when it bites. Malaria is the leading cause of mortality globally, but unfavourable outcomes can be prevented with early identification and timely intervention. In Africa and several Asian countries, malaria is the most prevalent disease; in the industrialized world, malaria is imported from endemic regions. As far back as the second century BC, Chinese medicine employed the sweet sagewort plant to treat malaria. Quinine became known for its antimalarial properties much later. In 1955, the global campaign to eradicate malaria began, and in 1964, Croatia proclaimed it to be eradicated forever (Talapko et al., 2019).

Malaria is caused by a small protozoon with several subspecies that belongs to the *Plasmodium* species group. Certain *Plasmodium* species cause illnesses in humans (Walker et al., 2014; White et al., 2014). Malaria pigment is an insoluble metabolite of hemoglobin that is acquired by amoeboid intracellular parasites belonging to the genus *Plasmodium*. There are several different vertebrates that these parasites infect, and some of them are present in tissue and red blood cells. There are known to be five human-infecting *Plasmodium* species out of 172. These are *P. malariae*, *P. falciparum*, *P. vivax*, *P. ovale*, and *P. knowlesi*. South-East Asia is home to *P. knowlesi*, a zoonotic malaria parasite. Infections of humans by other species are rare (Antinori et al., 2012; Singh and Daneshvar, 2013; Walker et al., 2014; Ashley, 2018). One of the most common diseases produced by any of the aforementioned *Plasmodium* species is malaria (Latin *Malus aer*, meaning "Filthy-air"). All species share comparable morphologies and biological characteristics (Vuk et al., 2008).

Revealing *Anopheles Stephensi*: An Up-Close Look at the Vector of Malaria

Approximately forty species of Anopheles are known to be the primary malaria vectors (Hay et al., 2010). *An. stephensi*, the Asian malaria mosquito, is one of these species and is found over much of Asia, ranging from the Middle East to the Indian subcontinent and Southeast Asia (Krishnan, 1961; Manouchehri et al., 1976; Vatandoost et al., 2006; Karimian et al., 2014; Hoosh-Deghati et al., 2017). Three biological forms (BFs) of *An. stephensi* have been identified based on egg phenotypes. The "Type" form of malaria is supposed to be more adept at spreading the disease throughout urban areas and to be anthropophilic, whereas the "Mysorensis" and "Intermediate" forms are thought to be more zoophilic and less successful in spreading the disease throughout rural areas. *An. stephensi* is known to be an effective vector for the malaria parasites *Plasmodium falciparum* and *Plasmodium vivax*, which cause clinically severe malaria (Sinka et al., 2011), additionally for *Plasmodium* species, the organisms that cause malaria in rodents (Matsuoka et al., 2002). A wide variety of fresh and brackish waters in rural, coastal, and urban environments are home to *A. stephensi* larvae throughout their breeding season. In rural areas, the larvae feed on surrounding water storage containers, wells, catch basins, seepage canals, freshwater pools, and stream walls and bottoms. They readily proliferate in urban settings in a range of man-made containers found in houses and businesses, both inside and outside of them (Zaini et al., 1975; Sinka et al., 2011; Hanafi-Bojd et al., 2012).

Bioluminescent Revelations: Shedding Light on Plasmodium's Life Cycle

Plasmodium Mosquito Stages

The term "sporogonic cycle" describes the parasites' capacity to proliferate inside of mosquitoes (Figure 1). The microgametes in the mosquito's stomach pierce the macrogametes, creating zygotes. The ookinetes are elongated, motile zygotes that enter the mosquito's midgut wall and develop into oocysts. As the oocysts mature and rupture, sporozoites are released and make their way to the mosquito's salivary glands. The malaria life cycle is maintained by injecting the sporozoites into a new human host (Tuteja, 2007).

Plasmodium Human Stages

During a blood meal, sporozoites from a female Anopheles mosquito carrying the malaria virus are injected into the human host. Sporozites grow into schizonts, which rupture and release merozoites, once they infect liver cells. After first replicating in the liver (exo-erythrocytic schizogony), the parasites then reproduce asexually in the erythrocytes (erythrocytic schizogony). Merozoites cause infections in blood cells. During the ring stage, trophozoites transform into schizonts, which then rupture to release merozoites. Blood-stage parasites are responsible for the disease's clinical manifestations. The gametocytes are consumed by Anopheles mosquitoes (Figure 2) during a blood meal. The gametocytes are classified as male (microgametocytes) and female (macrogametocytes). Injecting sporozoites into a newly recruited human host initiates the malarial life cycle (Meibalan and Marti, 2017).

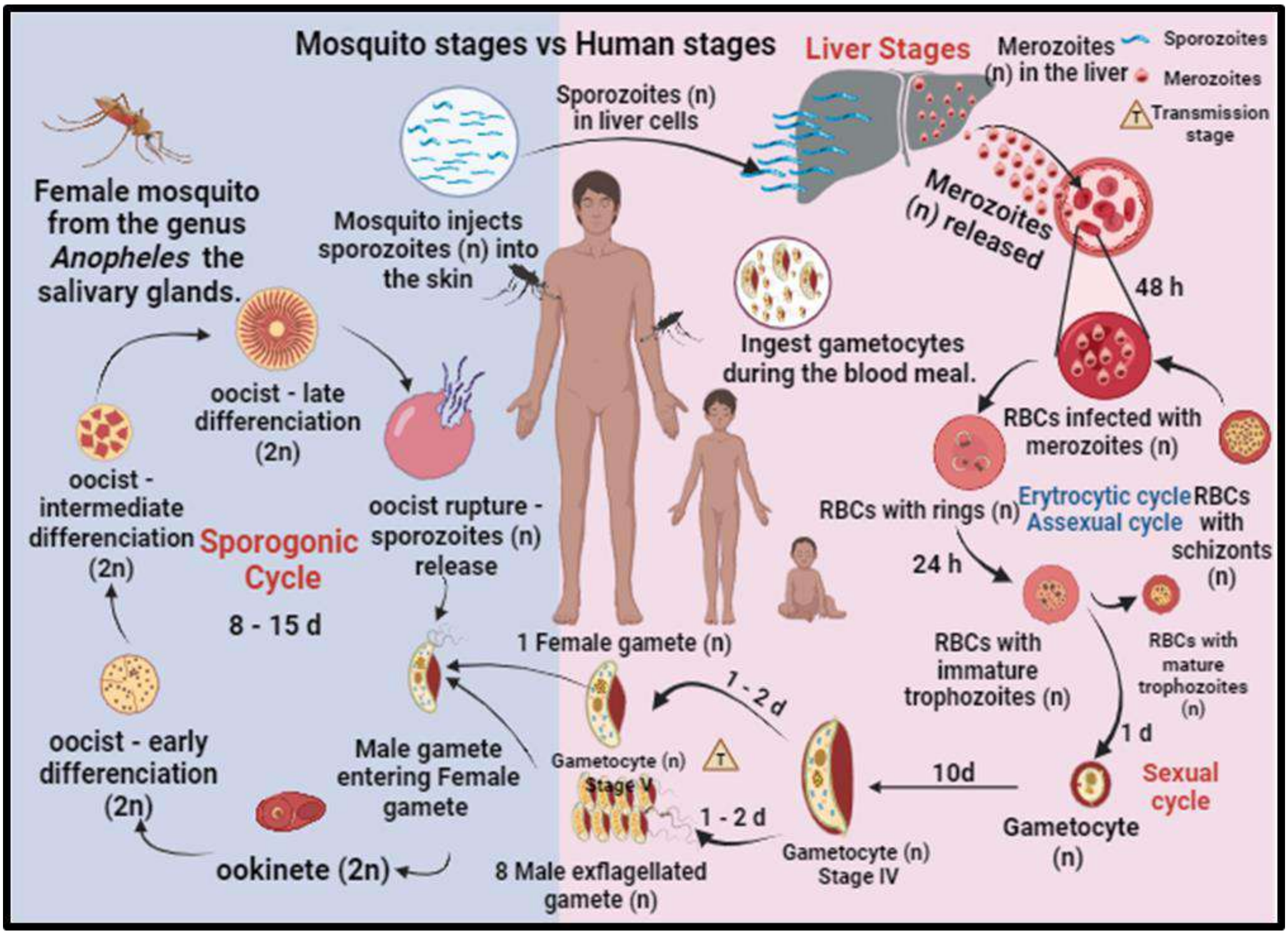

Fig. 1: Life cycle of Malaria

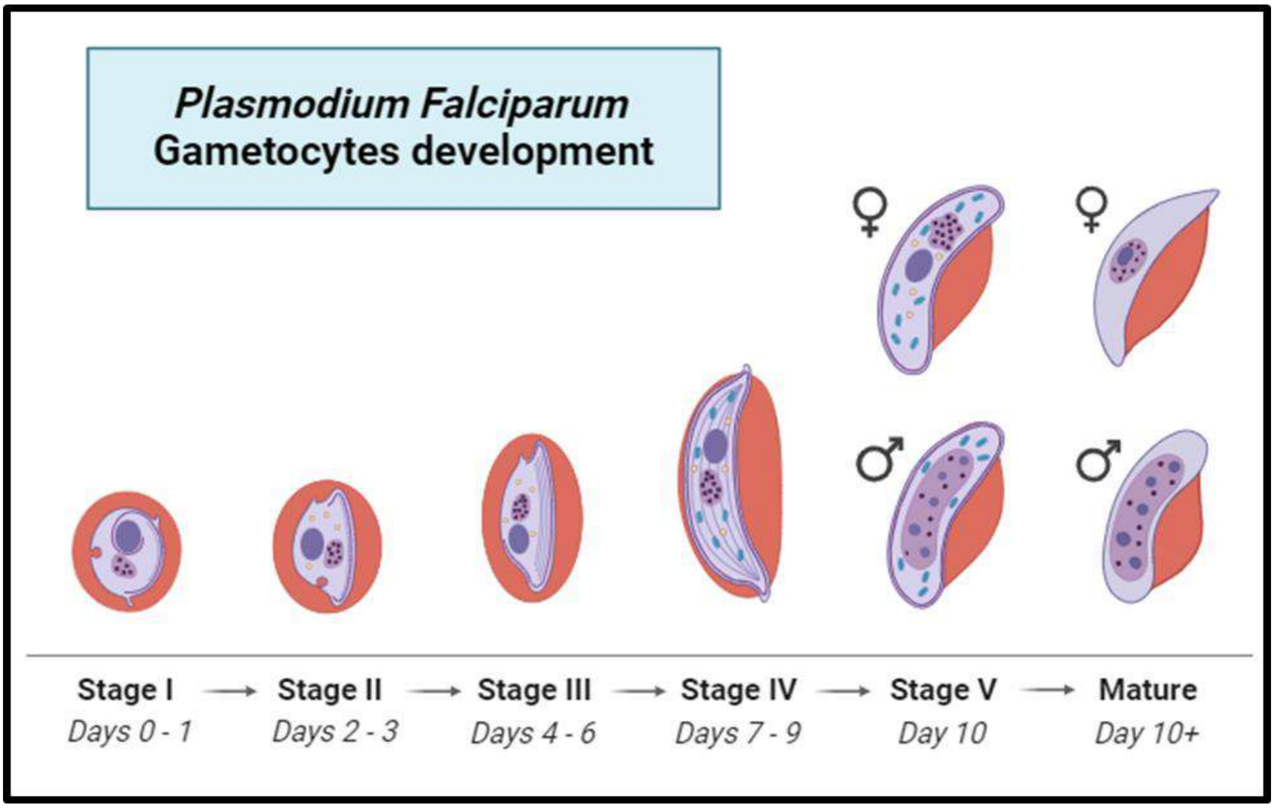

Fig. 2: Plasmodium Gametocytes Development from Dormancy to Fertility in erythrocytes

Mapping Malaria's Asexual Reproduction

When sporozoites from infected mosquitoes enter the human bloodstream and infiltrate hepatocytes, the asexual phase of the Plasmodium life cycle begins (Figure 3). Sporozoites mature into schizonts within hepatocytes, and those schizonts go through several rounds of replication via schizogony. Merozoites are created as a result, and when a hepatocyte ruptures, they are released into the bloodstream. After that, erythrocytes are invaded by merozoites, starting the erythrocytic cycle of infection. Erythrocytic schizonts are formed when merozoites proliferate asexually inside erythrocytes during the erythrocytic cycle. These schizonts divide into several daughter merozoites during schizogony. After erythrocyte lysis and merozoite release from infected erythrocytes, merozoites are released into the bloodstream. The typical symptoms of malaria are partly caused by this cycle of invasion, replication, and erythrocyte rupture (Cowman et al., 2016).

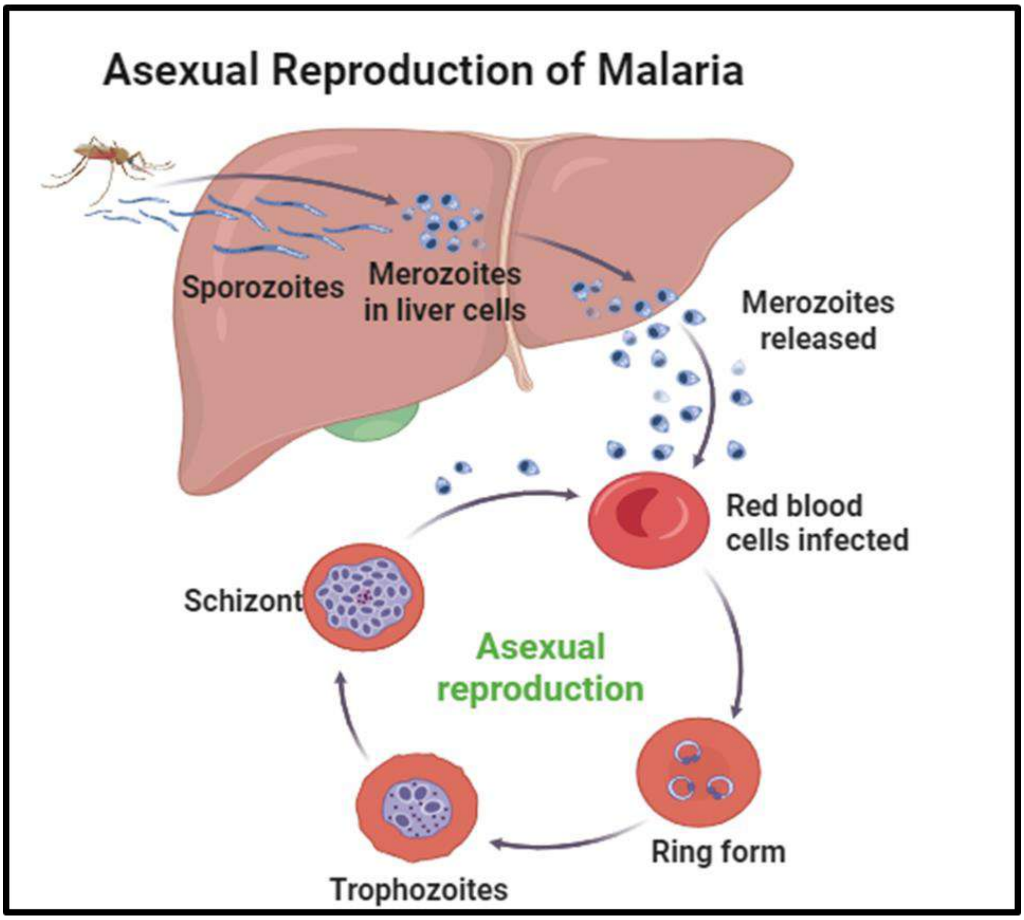

Fig. 3: Malarial Asexual Reproduction in Host

Spotting Malaria: Recognizing the Signs and Symptoms

The breakdown of erythrocytes and schizont rupture are the main causes of malaria's clinical symptoms. Malaria can present with vague symptoms and either a slow or rapid progression. Malaria frequently presents like other common viral diseases, which might cause a delay in diagnosis (Murphy and Oldfield, 1996). Fever (>92% of instances), chills (79%), headaches (70%), and diaphoresis (64%) are experienced by most patients (Genton and D'Acremont, 2001). Additional typical symptoms include dry cough, moderate diarrhoea, nausea, vomiting, myalgia, dizziness, and malaise (Figure 4). Among the physical signs are hepatomegaly, splenomegaly, tachycardia, pallor, jaundice, and temperature. Even in the absence of a fever, a non-immune person's clinical evaluation may be entirely ordinary (Trampuz et al., 2003).

Malaria and Pregnancy

According to (Chua et al., 2021) pregnancy-related malaria can cause a disease called placental malaria. Erythrocytes contaminated with *P. falciparum* adhere to placental receptors, inflaming the placenta and resulting in harm to both the mother and her fetus. Histopathological examinations of placentas infected with *P. falciparum* revealed a range of anomalies pertaining to the placenta, such as increased syncytial knotting, thickening of the trophoblast basal lamina, disruption of syncytiotrophoblast integrity, and accumulation of mononuclear immune cells within intervillous spaces (Figure 5). As a result, these events may impair the placenta's ability to grow and function, which could result in low birth weight, preterm delivery, intrauterine growth restriction, and placental weakness. Infected cells adhere to chondroitin sulfate A in syncytiotrophoblasts via VAR2CSA. The immune system reacts to a parasite's replication by releasing cytokines and activating complement, which compromises the placenta's ability to exchange nutrients and gases and modifies its structure.

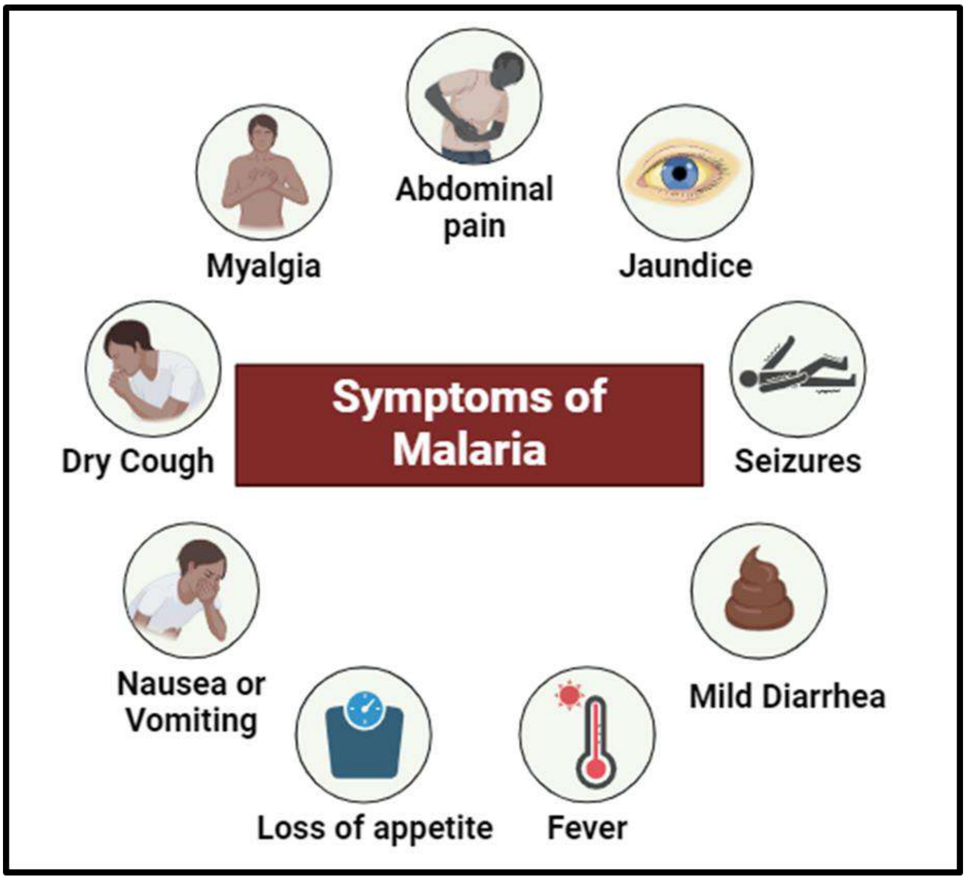

Fig. 4: Symptoms of Malaria

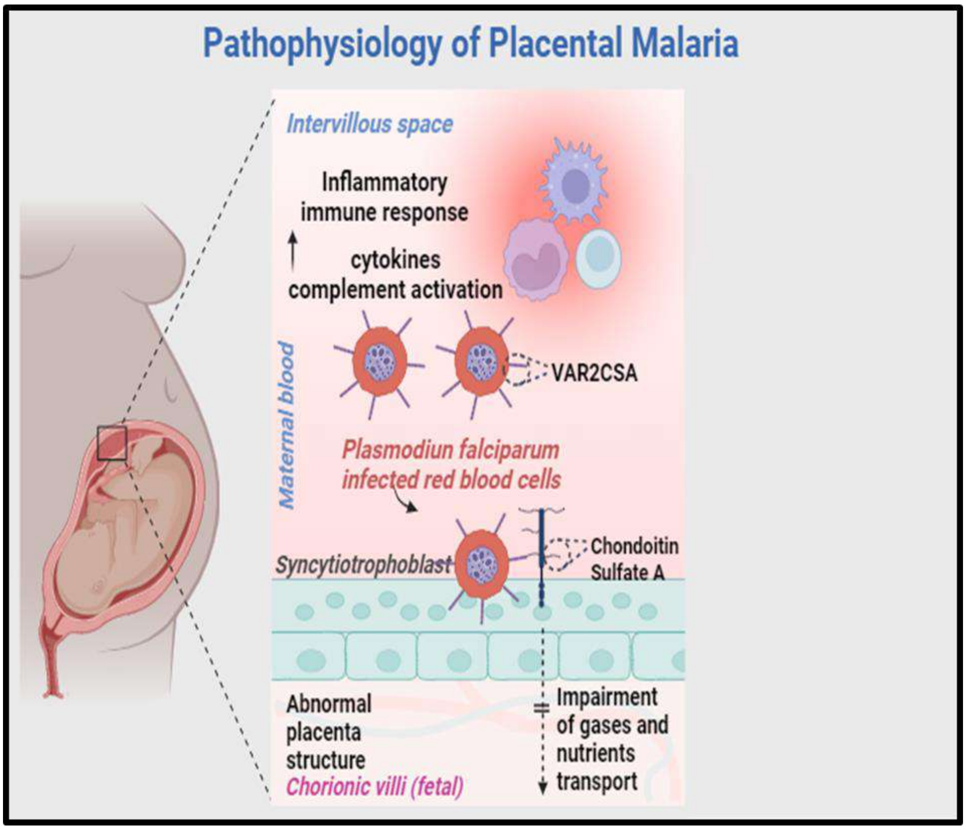

Fig. 5: An illustration of the pathophysiology of placental malaria that shows how red blood cells infected with *P. falciparum* sequester in the placental intervillous region.

Green Vector Control: Exploring the Efficacy of Plant Essential Oils against Malaria

A fundamental control strategy against major diseases carried by mosquitoes has traditionally been to target mosquito vectors to disrupt the circulation of infections (Niang et al., 2018). The mainstay of early mosquito control strategies was the management of the larval supply, which included environmental changes, larviciding, and biological control agents (Mulla, 1994; Tusting et al., 2013). The early 1940s saw the advent of the chemical age in vector control with the adoption of organochlorine DDT as a larvicidal and adulticide (WHO, 2012). Organochlorines gradually supplanted two classes of powerful cholinesterase inhibitors, carbamates and organophosphates (Bird et al., 2014; Srivastava and Kesavachandran, 2014). Insecticides used for public health were expanded to include synthetic pyrethroid chemicals in the 1980s (Sougoufara et al., 2017). These substances are widely advised as contemporary pesticides for treating mosquito nets and other fabrics, as well as for controlling insects within the home (Zaim et al., 2000; Chrustek et al., 2018). Even while chemical pesticides are effective in controlling vectors, there are still problems that threaten the progress made in getting rid of or controlling serious diseases spread by mosquitoes. When people are exposed to chemicals, their health may suffer both immediate and long-term repercussions (Collotta et al., 2013). Furthermore, constant pesticide usage pollutes the environment and interferes with biological and natural control systems (Aktar et al., 2009; Roubos et al., 2014; Özkara et al., 2016). The development and dissemination of pesticide resistance are extremely concerning problems that have led to higher pesticide dosages and a search for more potent and secure substitutes (Karunamoorthi and Sabesan, 2013). The majority of methods that could lessen dependency on artificial pesticides are in the field of biological control (Benelli et al., 2016), both paratransgenic and transgenic techniques (Coutinho-Abreu et al., 2010; Maleki-Ravasan et al., 2015; Dehghan et al., 2017; Stigum et al., 2019) as well as plant-based essential oils (EOs), which have the potential to function as environmentally friendly insecticides (Mossa, 2016; Nollet and Rathore, 2017; Tahghighi et al., 2019). Pelargonium graveolens is one of these; studies have shown that its essential oil (EO) has some anti-mosquito efficacy against laboratory strains of malaria vectors (Tabari et al., 2017).

Pelargonium graveolens

The genus *Pelargonium* (*Geraniaceae*) comprises over 280 species of evergreen perennial flowering plants. They are generally referred to as geraniums, pelargoniums, or storksbills (Albers and Van der Walt, 2007; Wagh et al., 2015). They can withstand heat and drought and are found throughout the world in temperate, tropical, and subtropical regions (Blerot et al., 2016). One variety of Pelargonium that is grown for both its fragrance and beauty as an ornamental plant is *Pelargonium roseum* (PRO), which is used as a key component in the food, beverage, and perfume industries (Szutt et al., 2020). Research has shown that essential oils and the main parts of geraniums can have some anti-mosquito effect on laboratory strains of malaria vectors (Gnankiné and Bassolé, 2017; Tabari et al., 2017; Tahghighi et al., 2019; Dehghankar et al., 2021).

Larvicidal Activity of *Pelargonium graveolens* EO and its Main Constituents

A larvicidal activity analysis reveals that the four main constituents are citronellol (21.34%), L-menthone (6.41%), linalool (4.214%), and geraniol (2.19%). Many plants use geraniol, an acyclic monoterpene alcohol, as the primary component in the synthesis of citronellol. A microbiological reduction process that creates citronellol or an ionization-dependent reaction can both make this chemical. Linalool is among geraniol's structural isomers. A minty-flavored monoterpene called L-menthone is found naturally in several essential oils (Chen and Viljoen, 2010). For *An. stephensi* intermediate, the LC50 and LC90 values are 12.55 and 47.69 ppm, respectively, but the values for *An. stephensi* mysorensis larvae are 11.44 and 42.42 ppm. Citronellol and linalool, in particular, are linked to the strongest and lowest larvicidal activity in both types of *An. stephensi*, respectively (Dehghankar et al., 2021). According to (Yohana et al., 2022) EO exhibits more larvicidal efficacy in the lab than in semi-field studies. *P. graveolens* has LC50 values of 7.13–0.9 ppm and 13.63–8.98 ppm in semi-field and laboratory settings, respectively, for exposure times of 24–72 hours.

Mosquito-repellent Activity of *Pelargonium graveolens* essential oil

According to (Moore et al., 2002) the EO of *P. graveolens* exhibits 96.88% mosquito protection for four hours. Geranium has the same repellent effectiveness as DEET, providing 140 ± 6 minutes of total protection (Sanei-Dehkordi et al., 2023). *An. stephensi* is repelled by *P. graveolens* 20% oil solution for eight hours with 61.9% efficacy (Asadollahi et al., 2019). The wild populations and laboratory strains of *An. stephensi* show mean percentage mortality rates of 98.13% and 87.5%, respectively, at 50 ppm concentration after being exposed to *P. graveolens* EO-treated papers (Yohana et al., 2022). At different *P. roseum* concentrations, the average survival rate is roughly 35%. When exposed to a 25% concentration, female mosquitoes have a mean survival rate that is twice as high as 100%. The statistical significance of this difference is $p<0.001$ (Alipour et al., 2015).

Conclusion

Pervasive illness and pest management are severely hampered by vector resistance to chemical control methods. It is critical to establish practical solutions to solve this issue. With the growing need for eco-friendly, safe, and enjoyable insect repellents, the field of herbal remedies is developing quickly. The use of local flora as repellents offers an appealing alternative because the high expense of manufacturing repellents could impede the creation and successful implementation of pest and vector control programs. Essential oils and plant extracts are becoming more and more popular as prospective treatments for controlling *Anopheles* spp. due to their risk-free, inexpensive, and simple-to-use qualities. Plant essential oils, including geranium, have demonstrated good repellency against various *Anopheles* species for up to eight hours.

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Chapter 19

Anti-Inflammatory Effect of Essential Oils

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ABSTRACT

Essential oils (EOs) are complex combinations of aromatic compounds found in various plant species, renowned for their therapeutic properties and potential as agents for inflammation reduction. Originating from the plant's secretory organs, EOs are extracted through pressing or distillation methods, offering unique energetic and therapeutic benefits. The chemical composition of EOs, comprising terpenes, phenylpropanoids, and other volatile compounds, contributes to their diverse medicinal properties. Inflammation, the body's response to tissue damage or infection, is a complex biological method regulated by intricate indicating pathways and inflammatory mediators. Essential oils have shown promise in modulating inflammatory pathways, including NF-κB, MAPK, and JAK-STAT, thereby mitigating the release of pro-inflammatory cytokines and reducing tissue damage. Topical use of certain essential oils, such as chamomile, lavender, and eucalyptus oils, has demonstrated anti-inflammatory effects in preclinical studies, offering potential therapeutic benefits for conditions like rheumatism, arthritis, dermatitis, and eczema. Experimental models, both in vivo and in vitro, have provided insights into the mechanisms underlying the anti-inflammatory properties of essential oils, highlighting their potential as novel therapeutic agents. However, while preclinical evidence is promising, further clinical trials are warranted to assess the efficacy and safety of essential oils in human therapy. Clinical studies have shown promising results in conditions such as chronic periodontitis and dental plaque accumulation, but more research is needed to explain the precise tools of action and determine optimal dosage regimens. In conclusion, essential oils hold significant potential as natural remedies for inflammation-related disorders, but their therapeutic utility requires further exploration through rigorous clinical investigation.

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INTRODUCTION

Essential oils are important part of the plant's defense mechanism; they are aromatic compounds that are present in certain plants' specialized cells or glands and that the plant uses to attract pollinators and protect it from pests and predators. The eminent Swiss physician, physicist, astrologer, theologian, and alchemist Paracelsus is credited with naming essential oils by coining the term "quinta essentia," which refers to the plant's essence (Jahan et al., 2015). Essential oils are volatile, very concentrated substances that are taken out from different parts of specific plant species. Each essential oil has unique energetic and therapeutic properties. These volatile liquids are incredibly complex molecules with incredibly strong and targeted actions. Since essential oil doesn't contain any fat, it isn't considered oil. It comes from the essence that the cells of specific plant parts secrete, which is rich in naturally occurring flavors, and active ingredients. Precious liquids can be attained by pressing or distilling the secretory organs. e.g. citrus skin is distilled, and the remaining plant components stem and leaves are flowers, root, and wood are cold pressed (Moghadam et al., 2018). These procedures produce an authentic source of active ingredients as well as an aromatic concentrate. Volatile oil and ethereal oil are other names for essential oils (Branch, 2016). Because a lot of raw materials are needed to extract just a few milliliters of oil, the process can be costly. This explains why authentic essential oils are so expensive. For instance, about 60 roses are needed to produce one drop of essential rose oil (Interfaces et al., 2018). But because there are a lot of low-cost resources and great productivity, there are also less expensive oils. These oils include tea tree oil, lemongrass oil, orange, bergamot, lime, and lemon. As such, EO is very valuable, but a drop is required for valuable effects, and a dose exceeding 2% is hazardous and has unfavorable things (Righi et al., 2017).

Essential Oil Biosynthesis

Majority of offensive compounds are biosynthesized in the leaves, where they stay until flowering. Some of the essential oils that are consumed during fertilization migrate into the flowers during flowering. After fertilization, it either gathers in fruits and seeds or migrates to leaves, bark, and roots (Nikolova and Georgieva, 2022).As plants get older, their essential oil composition changes. These oils are mainly made up of simpler molecules and terpenic hydrocarbons in young plants, while the reproductive structures of plants hold etheric oils, which are higher in oxygenated mixtures. Though their precise role within the plant is unknown, the ethereal oils have a multitude of uses. Out of the over 3,000 essential oils that have undergone chemical and physical characterization, around 150 are produced on an industrialized basis (Rezzoug et al., 2019).

The Chemical Make-Up of Essential Oil

Essential oils are complex combinations made up of 5000–7000 different chemical constituents. The majority of these constituents are mono- and sesquiterpenes, but they also contain aromatic compounds, which are sometimes diterpenes and frequently derivatives of phenyl propane. Terpenic compounds include hydrocarbons, oxygenated products (alcohols, alcohols, aldehydes, ketones, acids), and their reaction yields (ethers, esters). Plant-based mixtures known as terpenic compounds naturally combine with other molecules to form molecular mixtures that eventually form volatile (etheric, essential) oils. Essential oils and aromatic waters can only be obtained with the right raw materials, plant products, and quality. To ensure that the plant material is not contaminated with other plant species, it is important to harvest it carefully (Butnariu and Sarac, 2018). The primary constituents of essential oils can belong to the aliphatic, aromatic, or terpenic series, although their chemical makeup is extremely diverse. Volatile products contain terpenes aromatics, aldehydes, ketones, phenols, unstable acids, esters, and more. The plant's substantial focus to hydrodynamics is not always pick up after harvesting. Typically, plant which is fresh produce more pleasing scents and have a stronger healing effect; the exceptions are dried lavender, lime, and cinnamon flowers. When it comes to dry plants, morphological and chemical changes brought on by air pressure, heating, gramme accumulation, and possibly modification can occasionally result in lower volatile urine levels (Zerkaoui et al., 2018).

Inflammation

The body's natural reaction to tissue impairment caused by a range of possibly hazardous incentives that are brought by biological, chemical, and physical aspects is known as inflammation (Kolaczkowska and Kubes, 2013). If the stimulus is not removed or treated sufficiently, chronic inflammation develops, which puts the host at risk for a variety of illnesses, such as cancer and neurological disorders. Researchers have been motivated to study and create new medications in recent years due to the need for more potent medications that have fewer adverse effects when treating inflammation. The quest for naturally occurring plant-based products is a likely endeavor, and among the compounds with a pharmacological perspective are essential oils. This review aims to discuss the application of essential oils in management of inflammation (Zuo et al., 2020).

Mechanism of Inflammation

The term "inflammatory response" refers to the harmonized initiation of indicating paths that set the amounts of the inflammatory mediators in neighborhood cells of tissue as well as inflammatory cells isolated from blood (Lawrence, 2009). An inflammatory etiology is shared by a number of chronic illnesses, with diabetes, cancer, bowel and cardiovascular diseases, and arthritis (Libby, 2007). The nature of the inflammation response's procedures depends on the details of the early stimulus and where it is located in the body, but share a parallel mechanism expressed as follows: 1) Triggering of inflammatory pathways 2) Release of inflammatory markers 3) Recruitment of inflammatory cells and 4) Identification of pathogenic stimuli by the cell surface sequence receptors.

Inflammatory Pathway Activation

Inflammatory pathways affect many prolonged diseases and involve common inflammatory guiding pathways. Inflammatory stimuli begin intracellular indicating pathways, which in order cause the synthesis of inflammatory. Significant intracellular signaling networks including the Janus kinase (JAK)-signal transducer and activator of transcription (STAT) pathway, nuclear factor kappa-B (NF κB), and mitogen-activated protein kinase (MAPK) pathways, are triggered by receptor activation. Main inflammatory stimuli, which include products of microbe and cytokines like TNF-α (TNFR), IL-1 receptor (IL-1R), IL-6 receptor (IL-6R), and interleukin-1β (IL-1β), interleukin-6 (IL-6), and tumor necrosis factor-α (TNF-α), interact with TLRs to mediate inflammation (E. K. Kim and Choi, 2010).

The NF-κB Pathway

The record aspect NF-κB is intricate in response to immune, survival, inflammation, and apoptosis, among other important procedures. NF-κB activity can be triggered by a variety of chemicals, such as those that come from infectious agents, intercellular inflammatory cytokines, and multiple enzymes. In physiological situations, cytoplasmic IκB proteins inhibit NF-κB. PRRs activate IκB kinase (IKK) via analogous sign transduction pathways. IKK is composed of one regulatory subunit, IKKγ, and two subunits of kinase, IKKα and IKKβ. IKK phosphorylates IκB to regulate the NF-κB pathway's stimulation. The proteasome degrades phosphorylated IκB, freeing NF-κB, which subsequently triggers nuclear translocation and gene transcription. The inflammatory cells recruitment and the generation of pro-inflammatory cytokines, which together augment the inflammatory response, are governed by this pathway (L. Chen et al., 2018).

MAPK Pathway

The response of cells to various stimuli, including thermal shock, mitogens, osmotic stress (OS), and cytokines associated with inflammatory processes like IL-1, TNF-α, and IL-6, which impact the survival of cells, their proliferation, differentiation, and apoptosis, is regulated by a family of serine/threonine protein kinases called MAPKs. The mammalian MAPKs are c-Jun N-terminal kinases (JNK), p38 MAP kinase, and extracellular signal-regulated kinase (ERK1/2) (E. K. Kim and Choi, 2010). The three components of any MAPK signaling pathway are, at minimum, MAPK, MAPK kinase (MAPKK), and MAPK kinase (MAPKKK). Through MAPKKKs, phosphorylating and activating MAPKKs phosphorylates and activates MAPKs. ERKs are usually activated by mitogens and signals of differentiation. However, JNK and p38 are started in response to stress and inflammatory factors. MKK4 and MKK7 activate ERK1/2, MKK1 and MKK2 initiate JNK and MKK3 and MKK6 initiate p38. Phosphorylation and the beginning of MAPKs, for example, Erk1/2 and JNK, present in cytoplasm or nucleus, initiates the response inflammation and activates p38 transcription elements (Raingeaud et al., 1996).

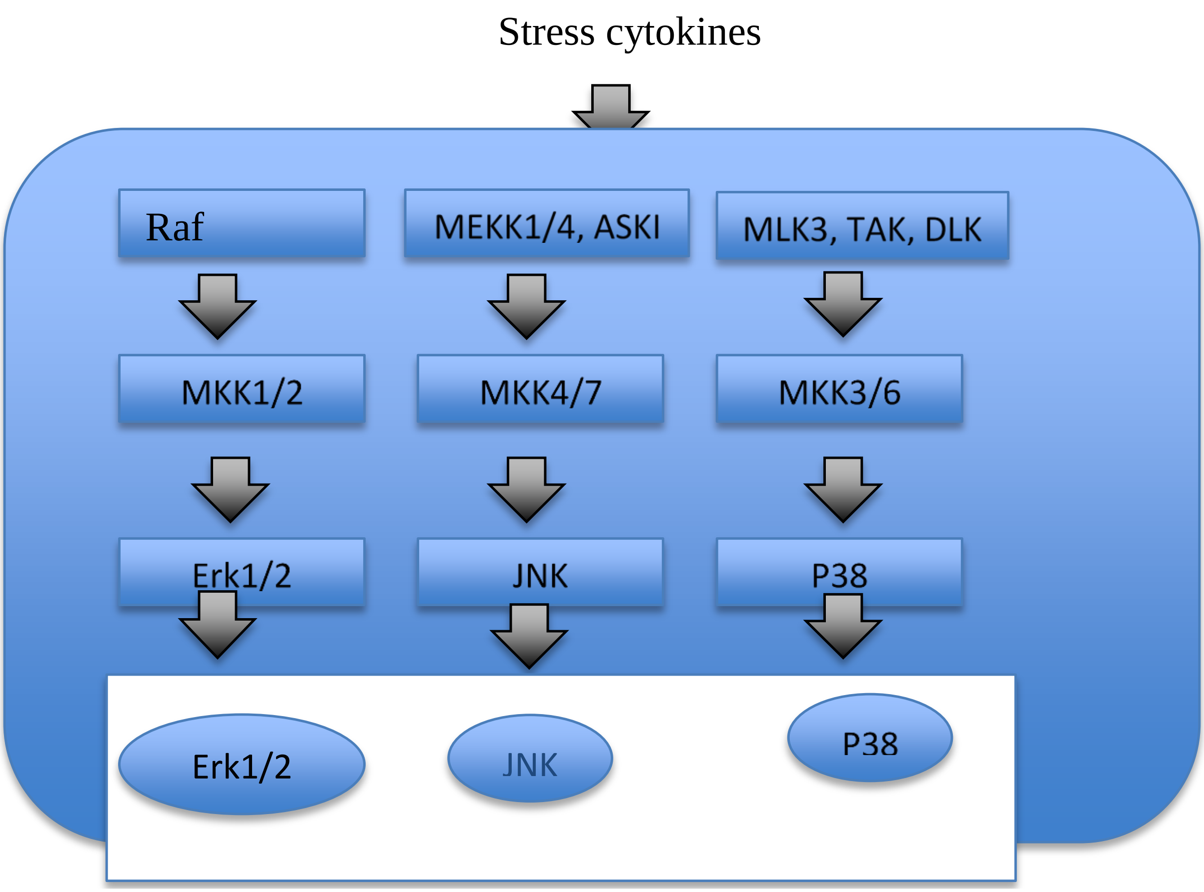

Fig. 1: MAPK PATHWAY

The JAK-STAT Pathway

The greatly evolved JAK-STAT pathway, an indicating process that includes a range of factors of growth, cytokines, interferon’s associated molecules like growing hormone and leptin, allows extracellular factors to regulate gene expression (Pengse et al., 2017). Latent cytoplasmic transcription factors known as STATs have docking sites created by receptor-linked JAKs that are stimulated by ligands and phosphorylate one another. When cytoplasmic STATs are attracted to these locations, they undergo dimerization and phosphorylation before moving into the nucleus (Walker and Smith, 2005). Tyrosine phosphorylation is required for DNA binding and STAT dimerization (Ivashkiv and Hu, 2003). Thus, JAK/STAT signaling enables the direct translation of an outside of cell signal into a transcriptional response. For example, JAK-STAT proteins are triggered when IL-6 family members attach to plasma membrane receptors. Target gene promoter regions are bound by translocating STAT proteins into the nucleus to regulate the transcription of inflammatory genes. Inflammatory diseases, cancer, autoimmune, and digestive disorders are all associated with irregularities of JAK-STAT, MAPK, or NF-κB activity Signaling through transcription factors causes the release of cytokines. Numerous transcription factors regulate an abundance of inflammatory genes, such as IL-1, TNF-α, IL-6, interferon’s growth factors such as transforming growth factor (TGF), colony stimulating factor (CSF), and chemokine’s (Oeckinghaus et al., 2011).

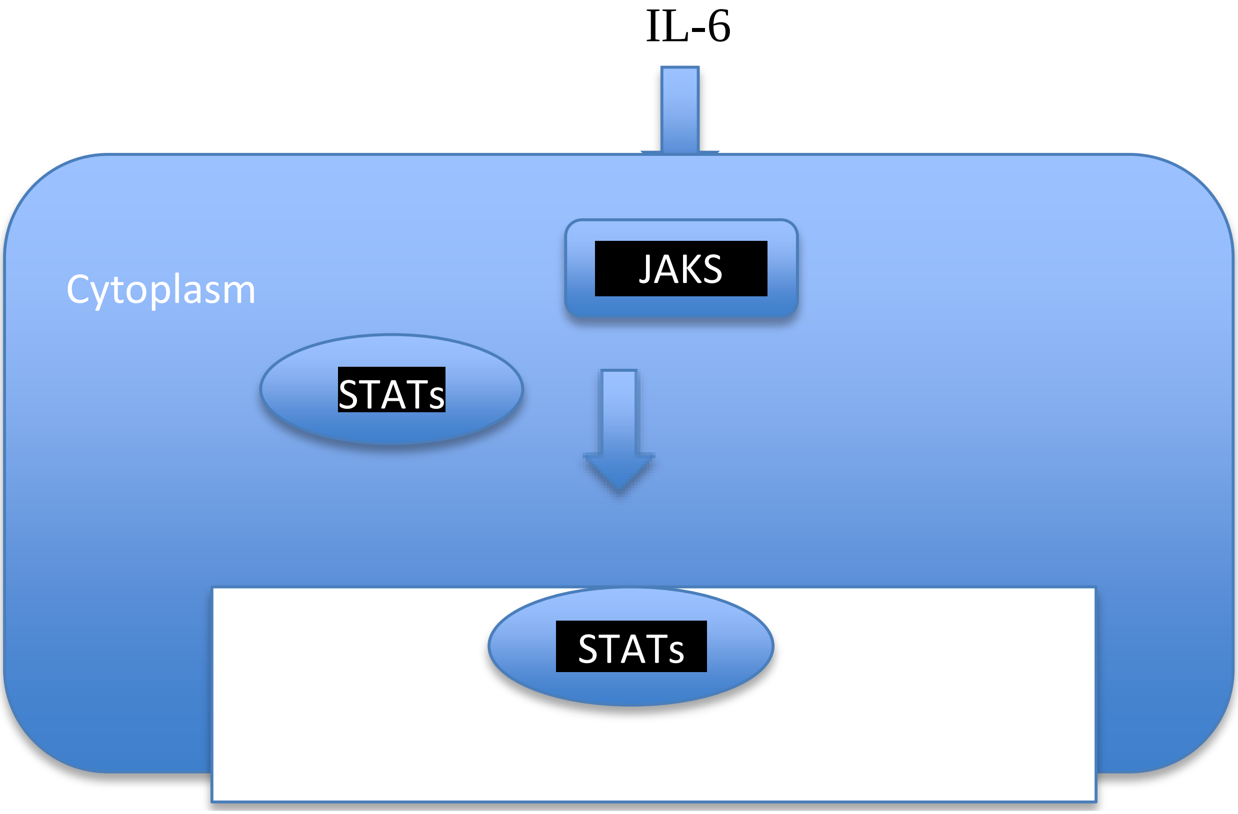

Fig. 2: The JAK-STAT Pathway

Markers of Inflammation

Markers are employed in clinical settings to assess the effectiveness of healing interventions and to distinguish between biological processes that are healthy and unhealthy. Inflammatory markers have been discovered to be associated with the reasons and concerns of a range of inflammatory diseases (Ivashkiv and Hu, 2003) like infections, endothelial disorders, and heart conditions, and to be predicting of inflammatory diseases (Carrero et al., 2008). Stimuli not only trigger the production of inflammatory proteins and enzymes but also cause the release of inflammatory cytokines such as TNF-α, IL-1β, and IL-6, as well as the activation of inflammatory cells such as macrophages and adipocytes. These substances could serve as biomarkers for the diagnosis, prognosis, and choice of suitable therapies(Goldstein et al., 2009).

Proliferating Cytokines

Cytokines are released by most immune cells, including lymphocytes, macrophages, and monocytes. Pro-inflammatory cytokines support inflammation while anti-inflammatory cytokines stop it. Leukocyte assembly at the site of damage or infection is the principal role of cytokines that are inflammatory (Turner et al., 2014), which include ILs, colony-stimulating factors (CSF), IFNs, TNFs, TGFs, and chemokines. Cytokines regulate inflammatory processes and the response of immune system's to inflammation or infection via an intricate network of interactions. Conversely, excess production of inflammatory inflammatory mediators can cause tissue damage, changes in hemodynamics, failure of organs, and eventually death. A deeper knowledge of cytokine pathway regulation would enable treatment of inflammatory conditions and accurate determination of agent-mediated inflammation (Czaja, 2014).

Additional Inflammatory Indicators

Defense mechanisms of antioxidants, such as antioxidant enzymes, have an impact on oxidative stress. Reactive oxygen species (ROS), AP-1, isoprostanes, and other chemicals can be produced as a result of increased oxidative stress (Lopresti et al., 2014) (Huang et al., 2010). A range of factors transcription, including NF-κB, AP-1, p53, and STAT, can be activated by these substances. Consequently, this cascade could up-regulate the gene expression encoding factors growth, inflammatory cytokines, and chemokines (Park et al., 2015). Oxidative stress is linked with amount of diseases, for example, aging, cancer, heart disease, hypertension, diabetes, and atherosclerosis. As a result, oxidative stress-connected products could be markers of the reaction that is inflammatory.

Essential Oils as Agents of Inflammation Reduction

Inflammation is the natural defensive response of the body to injury or infection; it rids the body of dead or damaged host cells and combats foreign invaders. The inflammatory response results in elevated endothelial lining permeability of cells, blood leukocytes, influxes into the interstitium, an oxidative burst, and the release of cytokines. Furthermore, it raises the activity of several enzymes and the metabolism of arachidonic acid. In clinical settings, aromatic oils have recently been used for treating inflammatory diseases like rheumatism and arthritis (Zaman et al., 2020).

Evidence suggests that some essential oils can scavenge free radicals while also having anti-inflammatory qualities. For example, essential chamomile oil has been used for several centuries to treat severe irritations such as dermatitis and eczema by reducing inflammation (Kamatou and Viljoen, 2010). In blended formulations, essential oils such as eucalyptus, rosemary, lavender, and mille folia, as well as other plants like pine, clove, and myrrh, have also been used as anti-inflammatory agents (Darshan and Doreswamy, 2004).

Potential Health Benefits of Applying Essential Oils Topically to the Skin

Olive Oil

The fruits of the *Olea europaea* tree are used to make olive oil. It is mostly made up of the oleic acid, with trace amounts of further fatty acids like palmitic and linoleic acid. Olive oil contains over 200 different chemical compounds, such as phenolic compounds, triterpenic alcohols, carotenoids, and sterols (Nasopoulou et al., 2014).

Oil of Eucalyptus

Compounds found in eucalyptus include cineole (70–85%), limonene, terpinene, cymene, phellandrene, and pinene. Its antibacterial, anti-inflammatory, anti-proliferative, and antioxidant properties have been demonstrated by eucalyptus oil, and studies have conclusively shown that it is extremely effective in treating a wide range of infectious and metabolic disorders. The essential oils of this plant have a well-established history of treating rheumatoid arthritis as well as aches and pains in the muscles and joints (Mulyaningsih et al., 2011).

Eucalyptus oil's Medicinal Benefits and its Anti-inflammatory Qualities

The anti-inflammatory effect of the eucalyptus species is demonstrated by the edema caused in rats by the combination of dextran and carrageenan; neutrophil migration into the peritoneal cavity causes the combination of histamine and carrageenan to induce vascular permeability. The outcome does not follow the same pattern that we saw in the parameters that should be assessed; these will be assessed in terms of activities and dependent on dose relationships. For the study, the assay condition and oil were used. The information utilized for the oil extracts of EG, EC, and ET, which have both independent and dependent anti-inflammatory properties and central and peripheral effects of anti-inflammatory goods due to their phenolic content.

Lavender Oil

The essential oil of *Lavender augustifolia* and its principal components, linalyl acetate and linalool, showed in rats the anti-inflammatory propertie. Many investigated studies have the anti-inflammatory properties of compounds present in lavender oil. These studies investigated the special properties of unlike constituents found in EO, such as α pipine, α-terpinene, terpin-4-ol, α-terpineol, linalyl acetate, and linalool. According to the results of these studies, the compounds present in lavender oil may possess anti-inflammatory or ant nociceptive properties (H.-M. Kim and Cho, 2010).

Clove Oil

The essential oil known as clove oil is derived from *Syzygium aromaticum*. Because eugenol has analgesic, anti-inflammatory, and antiseptic qualities, it is an oil that is frequently used in dental products. The most significant components of cloves are eugenol, sesquiterpenes, and gallotannic acid. Other significant ingredients include vanillin, crategolic acid, betacaryophyllene, eugenin, kaempferol, and rhamnetin (Schmuth et al., 2015).

Clove oil's Medicinal Ability to Treat

- acne
- They eliminate parasites.
- To Increase Circulation of Blood
- In order to lessen gum disease
- To Increase Vitality
- They have natural anti-inflammatory properties.
- They eradicate fungi and mould

Turpentine in Oil

The resin of some pine trees is used to make turpentine oil. Turpentine oil is topically applied to relieve joint pain, toothaches, muscle soreness, and the nerve pain (Aswandi and Kholibrina, 2021).

Camphor

Camphor is a white, clear solid with a waxy consistency and a potent scent. With the chemical formula $C_{10}H_{16}O$, it is a terpenoid. Rosemary leaves from the *Rosemary officinalis* family contain camphor. Rosemary has a melting point of 175–177˚C and contains 10–20% camphor.

The Medical Advantages of Camphor

Camphor easily absorbed through the skin and give off a feeling of warmth or coolness. Serve as a mild local anaesthetic and antibacterial agent.

Experimental Models with Anti-inflammatory Properties

In Vivo

Mice are inoculated with different chemical agents to induce inflammation, which is one of the main in vivo models used to assess the anti-inflammatory capabilities of PEOs. Notably, the model contains common disease like animal models with allergic rhinitis, colitis, wound infection, tissue edema, skin inflammation, and anxiety. The anti-inflammatory qualities of PEOs have been assessed in a range of stimuli-induced inflammation models. Mice with colitis caused by dextran sodium sulphate were helped by cinnamon (Cinnamomum verum J.Presl) EO by correcting the imbalance in intestinal flora (Z. Chen et al., 2020). Tea tree (*Melaleuca alternifolia* (Maiden and Betche) EO decreases cell apoptosis, TNF-α expression, and IL-6 in the Lipopolysaccharides (LPS)-induced mastitis model, thereby reducing the damage brought on by inflammation. Oral PEO administration in vivo models is not feasible due to its inherent volatility and instability. Orally administering PEOs to animals also induces anxiety and discomfort. This results in abnormal behaviors like smearing and grabbing, which negatively impact the outcomes (Yuan et al., 2021). On day 7 of the pathogen-infected mice model of wounds, Mentha piperita L. EO treatment bigger IL-1β levels in the diseased wound tissue while lowering the levels of fibroblast growth factor-2 (FGF2) and vascular endothelial growth factor (VEGF). The exact mechanism of action of this effect is yet unknown; however, it contradicts the anti-inflammatory response that PEOs mediate (Modarresi et al., 2019).

In vitro

The structure and biological function of the cells can be evaluated in in-vitro experiments. Human keratinocytes, BV-2 microglia, HaCaT cells, THP-1 macrophages, and RAW264.7 cells triggered with LPS or other reagents are a few of the frequently used invitro inflammatory models. To lessen harmfulness and irritability, PEOs are usually used at lower focuses for in vitro research than for in vivo studies. The recommended PEO application range for in vitro studies is 1–100 µg/kg. On the other hand, 100 mg/kg is the recommended PEO dose for in vivo research. Leukocyte chemotaxis in the white blood cells chemotaxis model is markedly suppressed when 1–60 µg/mL PEOs are administered (dos Santos et al., 2021). For skin inflammation, ginger-grass extract has been shown to have therapeutic benefits. PEO concentrations of 0.001–0.1% and 0.1–0.3%, respectively, were utilized for topical application and incubation. PEOs are unstable at 37 ◦C, and the in vitro research the lines of the cell are protected at this temperature. As such, it is challenging to determine a relationship between both in vitro and in vivo models' bio-accessibility and bioavailability (Singh et al., 2022).

Clinical Trials

Although PEOs' have been shown anti-inflammatory effects in models in vitro and in vivo, more investigation in the form of epidemiological and also clinical studies is compulsory to evaluate the anti-inflammatory PEOs' potential applications in therapy and prevention. Studies show that PEOs are used to treat inflammatory conditions such as rheumatoid arthritis, migraines, and anxiety (Bahr et al., 2018). When PEOs are applied topically or inhaled, patients report reduced pain and tension; however, more research is required to decide the precise mechanism responsible for PEOs' anti-inflammatory effects. Clinical studies have shown that breath fresheners with PEOs can effectively minimize the incidence of chronic periodontitis and stop dental plaque from accumulating (Anusha et al., 2019). It is first essential to determine whether PEOs are effective in treating humans, either only or in combination (with natural or artificial drugs). Clinical trials evaluate PEOs' anti-inflammatory properties mainly in the context of aromatherapy and stomatitis treatment; comparatively few studies focus on PEOs' absorption and digestion. Patients with type II diabetes experience fewer complications and reduced levels of TNF-α and CRP when they take 100 mg of Cuminum cyminum L. EO pills. Although inflammation-linked signs were not the focus of this study, more inflammatory models will therefore be required in the upcoming to provision the clinical use of PEO (Jünger et al., 2020).

Conclusion

Essential oils have gained attention for their potential anti-inflammatory properties, notably chamomile, lavender, clove, and eucalyptus oils. Experimental studies reveal their modulation of inflammatory pathways, enzyme inhibition, and cytokine regulation. Clinical trials show promise in managing inflammatory conditions like rheumatoid arthritis. However, further research, especially in human trials, is necessary to understand their efficacy, safety, and interactions with medications. Overall, while essential oils offer potential as natural anti-inflammatory remedies, ongoing scientific exploration is crucial to confirm their benefits and refine their application

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Chapter 20

Effect of Essential Oils as Natural Alternatives and Antioxidants for the Growth of Poultry Broilers

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ABSTRACT

Poultry farming is important in today's food security issues and is crucial for economic development. Intensive production methods in the poultry industry necessitate the use of antibiotics, raising concerns about animal welfare. In this study, we investigate the potential of essential oils (EOs) as natural substitutes for antibiotic growth promoters (AGPs) in broiler production. This exploration aims to harness the power of EOs as a potentially transformative solution, moving beyond antibiotics towards a more sustainable and ethical approach to broiler growth. We also read about the essential oil extraction techniques and their different disadvantages. We explore the various applications of EOs, such as their antifungal, antiviral, antioxidant, and antibacterial activities. We discuss how these characteristics help broilers' immune systems, intestinal health, and disease resistance. Furthermore, we examine the impact of EOs on growth performance parameters like feed conversion ratio, body weight, and meat quality. Finally, we'll see about the urgent research needed to refine the use of EOs in poultry diets. This will optimize their effectiveness and ensure the safety of this promising alternative to antibiotics.

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INTRODUCTION

Poultry farming is a critical driver of livestock worldwide, enhancing the GDP of developing countries like Pakistan. It also leads to the fulfillment of nutrition and economic growth of a country (Gulilat et al., 2021). Poultry farming, as a cornerstone of animal husbandry, is necessary for economic development. It is a source of increased income for farmers in the agriculture sector (Wu et al., 2022). Poultry products are nutritious and appetizing at the same time (Tajima et al., 2023). The poultry industry has grown tremendously because of increased prepared chicken products catering to the demand of working individuals (Barbut et al., 2022). A huge number of birds are killed and consumed annually to meet their high demands of consumption (Ayalew et al., 2022). Poultry meat is also the cheapest halal protein source preferred by people (Paputunganet al., 2020). Broiler farming delivers chicken meat production requirements to large consumer populations Wilcox et al., 2023). Broiler meat is the most favored white meat, liked by every culture and religion, is low in fat, and is an economical source of protein (Ramukhithi et al, 2023). The quality of the broiler meat is judged based on its parts, such as breasts, thighs, and drumsticks (Kuźniacka et al., 2014).

Being one of the largest industries in the world, in itself comes with a lot of challenges. The most significant challenges facing poultry are health and environmental hazards in large intensive production systems (DR Korver, 2023). The root of the problem lies in the high bird density and intensive nature of production (Gržnić et al., 2023). The unique gut system of chickens and their microbes demand close attention to gut health for maximum and optimal nutrient absorption (Wickramasuriya et al., 2022). Many chemicals are used to improve gut health, increase the growth rates in poultry, and prevent infections. Antibiotics are the most used worldwide to improve feed conversion efficiency (Samad, 2022).

Antibiotic Growth Promoters (AGPs)

Antibiotic growth promoters have been tremendously used in the poultry industry generating a wealth of associated literature. Its use has mounted public concern (Cardinal et al., 2020). AGPs used at the sub-therapeutic level are used for bird productivity rather than for treating some diseases (Abd El-Hack et al., 2022). Feed and meat residues of AGP are the greatest threat to humans (Sapsuha et al., 2021) but AGPs have also helped in the growth of animals by 4 mechanisms: (1) decline sub-clinical infections (2) enhanced nutrient availability (3) improved nutrient uptake (4) improvement in the intestinal environment (Rahman et al., 2022) but antibiotic resistance has been a significant issue regarding AGP use.

AGP Alternatives Used in Poultry

There has been a growing application of AGP alternatives such as pre-biotics, pro-biotics plant extracts, and organic acids as part of the trend towards natural solutions (Oluwafemi et al., 2020). The demand for poultry products raised without antibiotics is increasing. Producers have to follow the demand and ensure that they address animal welfare concerns by using AGP alternatives (Rahman et al., 2022).

Organic acids have no residue problems and improve the digestibility of nutrients and minerals in poultry. Examples include short and medium-chain fatty acids (Aljumaah et al., 2020). OAs decrease the pathogen population by reducing the pH of the gut (Scicutella et al., 2021). OAs also require a lot of research in application in poultry as different conditions need to be assessed for their application (Melaku et al., 2021).

The use of probiotics in poultry production, for example, involves mechanisms of very complicated reactions (Hassan et al., 2018). Probiotics are the normal intestinal micro-flora given in proper concentrations exogenously. It doesn't have as much negative impact as antibiotics (Krysiak et al., 2021). Several studies reveal that probiotics are thought to increase body weight by reducing FCR, and can ward off necrotic enteritis. Peng et al. (2016) claimed that *L. plantarum* supplementation improved the growth of broiler chickens previously colonized with *E. coli* in the cecum. Therefore, *L. plantarum* supplementation increased populations of lactic acid bacteria in the cecum (Sapsuha et al., 2021). Another experiment carried out by Ferdous et al. in 2021 shows that probiotics increase body weight by stimulating gut bacteria, better digestibility, and feed intake. They improve the production rates and health of broilers, *B. subtilis* is a great example as it is resistant to temperature change (Rivera-Pérez et al., 2021). Probiotics don't play a larger or clearer role in growth performance but do reduce the chances of infections (Yaqoob et al., 2022).

Prebiotics are indigestible food ingredients that enhance the growth of one or more beneficial bacteria (Ricke, 2021). Most of them consist of carbohydrates and associated products that the healthy gut microbiota can digest. Bacteria ingest the goods to enhance gut health and counteract the activities induced by harmful bacteria (Abd El-Hack et al., 2022). By improving intestinal characteristics (longer villi, more goblet cells) that promote beneficial bacteria like *lactobacilli* and *bifidobacteria*, prebiotics increase the feed conversion ratio in broilers (Thora et al., 2015). In an experiment done by Murshed and Abudabos, (2015) prebiotics (mannan oligosaccharides) are known to be an alternative to antibiotics and improve the FCR and broiler performance. In another experiment carried out by Rehman at al., 2020 importance of mannan oligosaccharide was highlighted that it causes the growth of beneficial bacteria (*Lactobacilli* and *Bifidobacteria*) and reduces pathogenic bacteria (*E. coli* and *Salmonella*). Prebiotics are used in combination with probiotics to have better efficacy but a great deal of research is necessary to prove the effective growth effects on poultry (Khomayezi and Adewole, 2022). A rise in the immune system, performance, and meat quality of the broiler chicken was seen when prebiotics were used in an experiment conducted by Al-Khalifa et al., 2019. In an examination prebiotics like oligofructose were known to improve the weight gain, breast weight, and percentage of the carcass (Al-Khalaifah, 2018).

Plant extracts are very beneficial in promoting poultry health. They may improve feed intake, increase body weight, and improve the feed conversion rate (Oluwafemi et al., 2020). For instance, whereas it is indicated that the Moringa plant, due to its high nutritional value, happens to be one among these herbal plants that have the potential to work as a supplement in chicken feed, there is still a controversy surrounding the best dosage and its resultant effect on performance (Mahfuz and Piao, 2019). As far as environmentally friendly and improvement of performance are concerned, the application of phytogenic derivatives has been on the rise in animal feeds (da Silveira Deminicis et al., 2021). Phytogenic feed additives (PFAs) are now being used as replacements in poultry feed due to their different complex activities that lead to disease prevention and increase in production (Stevanović et al., 2018). The use of Essential Oils as PFAs in monogastric like poultry as an alternative to AGPs is an emerging topic (Mucha and Witkowska, 2021). The addition of phytobiotic additives can enhance the appetite, boost the production of digestive enzymes, strengthen the immune system, and also amplify the quality of animal products (Krauze et al., 2021).

Essential Oils are secondary metabolites produced by different plant parts and oil glands, extracted by different techniques (Herman et al., 2019). They are hydrophobic and volatile chemical compounds. They have been used for clinical and medicinal uses along with their aromatic properties in food (Wińska et al., 2019).

Essential Oils: Potential Natural Alternatives for AGPs

Essential oils are safe to use but toxicities can result in some cases (De Groot and Schmidt, 2016). EOs consist of many components in different ratios but only two to three components constitute 20-70% of the total concentration. These major components are responsible for the biological properties of the EO (de Sousa et al., 2023). EOs are also bio-active substitutes for different antimicrobial, antiviral, nematicidal, antifungal, and antioxidant drugs and compounds (Turek and Stintzing, 2013). Essential Oils are also used to improve drug penetration through the skin (Adorjan and Buchbauer, 2010) and also for nematicidal and larvicidal activities in some parts of the world (Lahlou, 2004). EOs are also used as repellents against arthropod species, for example, *Cymbopogon* species are used to repel mosquitoes in Amazon areas (Nerio et al., 2010).

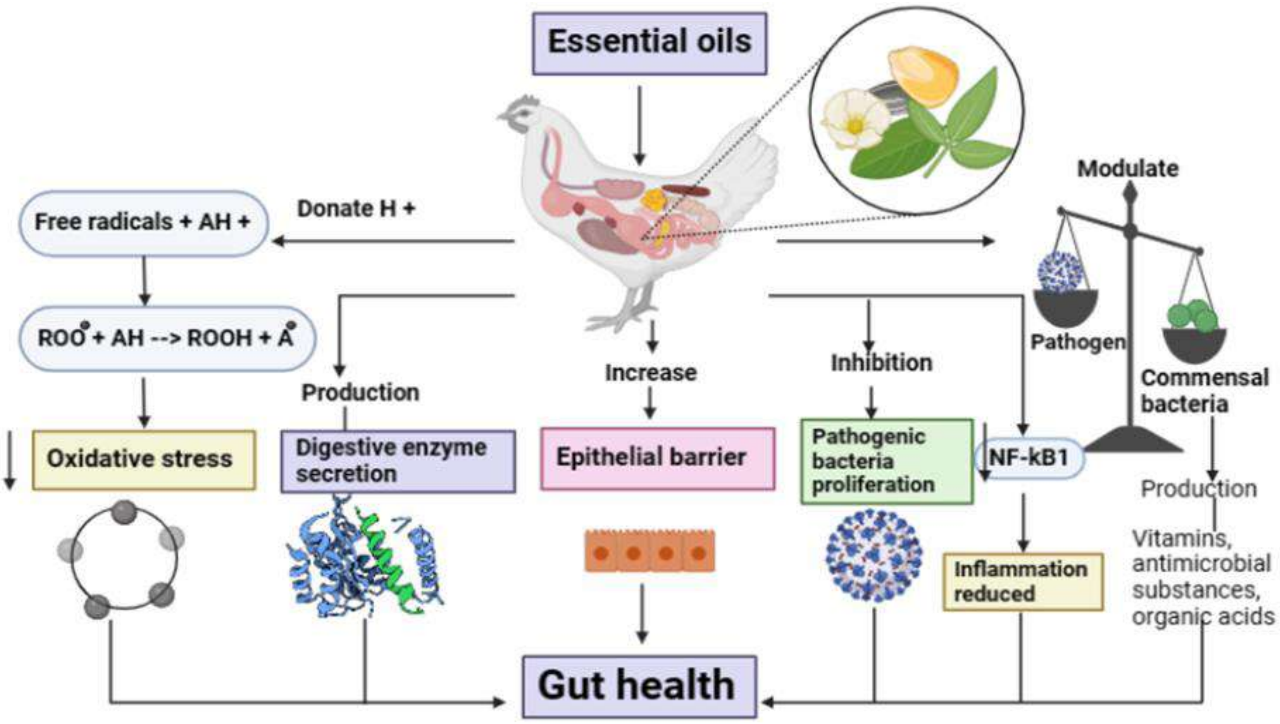

Fig. 1: Essential oils and their effects on broiler chicken

Extraction of Essential Oils

Extraction of EOs can be carried out by several techniques but the most common ones are Hydro-distillation (HD), steam distillation, cold pressing (CP), solvent extraction (Reyes-Jurado et al., 2015), and Enzyme assisted extraction (Ferrentino et al., 2020). These conventional methods are simple but take time and produce low amounts of EOs. Ultrasound and microwaves are new approaches that offer faster extraction and higher yields. Less energy is consumed and a higher quality product is obtained (Lainez-Cerón et al., 2022).

Conventional Methods of Extraction

Hydro-distillation

Distillation extracts the plant essential oils through differential pressure aimed at evaporation and condensation of the mixture components. Hydro-distillation method, which is widely applied for extracting essential oils, is easy and cheap (Drinic et al., 2021). It involves immersion of the plant matter in water, after which the mixture is boiled and then the vapor is condensed, separating the oil from the water. However, heat and water may destroy sensitive compounds while preventing the recovery of water-soluble oils (Ghasemy-Piranloo et al., 2022).

Steam Distillation

The steam is above boiling water and the plant material is not submerged in this boiling water. In this process, the plant material comes into contact only with the steam of the boiling water, not with the water itself (Oktavianawati, 2020). This method requires simple instruments and hence is simple without complexities, therefore having many advantages as indicated by Saldaña-Mendoza et al. 2022. Water- Steam distillation which as explained earlier involves placing plant material above boiling water while Steam distillation involves the use of external sources of steam (Ghasemy-Piranloo et al., 2022).

Cold Pressing

Due to the absence of a chemical refining stage, cold-pressed oils (CPOs) provide pure mechanically derived oils hence securing naturally occurring beneficial nutrients, including vitamins, minerals, and antioxidants, from the product (Rabiej-Kozioł et al., 2023). It is more economical and safer both for the consumer and their environment because it doesn't require chemicals (Kabutey et al., 2023). The method ensures that antioxidants are present in the oil, making it stable throughout a long shelf life (Prescha et al., 2014).

Table 1: Constituents and roles of important essential oils used in the poultry industry

Essential Oil Name	Common Name	Family Name	Major Compounds	Amount Used	Growth Promoters	References
Oregano Essential Oil (OEO) from *Origanum* genus	Oregano essential oil	*Labiatae*	carvacrol and thymol	01%, 1% w/w	Have antioxidant effect, inhibiting hydroperoxide and phenols, influence gene expression	[Peng et al., 2016] [Pontes-Quero et al., 2021] [Puvača et al., 2022] [Pateiro et al., 2018]
Basil leaves from *Ocimum basilicum*	Basil	*Lamiaceae*	Estragole, limonene and p-cymene	0.062, 0.125 and 0.25%	Have antioxidant effects, improve growth, feed conversion, immune response and general health. Also reduce harmful bacterial counts and influence beneficial bacteria.	[VLAICU et al., 2022] [Mkaddem Mounira et al., 2022] [Oliveira et al., 2024] [Pateiro et al., 2018]
Thymus vulgaris	Thyme	*Lamiaceae*	O-Thymol, Tetra hydro-3-methylfuran, thymol	0.5%	Play important antioxidant, antigenotoxic and antimicrobial effects, improve immune response, kidney and liver function. Also improves nutrient digestibility.	[HOSSAİN et al., 2022] [Chbel et al., 2022] [Fawaz et al., 2021] [Pateiro et al., 2018]
Cinnamon (species Cinnamomum)	Cinnamon	*Lauraceae*	*Trans-cinnamaldehyde*, δ-cadinene and β-cubebene	200 mg/kg	Has antiinflammatory, antimicrobial and antioxidant properties improving health, immunity metabolism, carcass traits, and meat quality.	[Dahmani et al., 2021] (Alizadeh Behbahani et al., 2020) [Ali et al., 2021] [Hippenstiel et al., 2011]
Garlic (Allium sativum)	Garlic	*Amaryllidaceae*	Diallyl disulfide, Diallyl trisulfide	300 mg/kg	Act as antioxidants, boost immunity and gut health of poultry and maintain blood parameters.	[Ezeorba et al., 2022] [El-Saber Batiha et al., 2020] [Abd El-Ghany, 2024] [[Hippenstiel et al., 2011]
Black cumin seed oil (*Nigella sativa L.*)	Black cumin seed / black seed	*Ranunculaceae*	thymoquinone, thymohydroquinone, dithymoquinone, thymol and nigellone	2-3%	It has a good antioxidant effect, improves growth and egg production, and also reduces harmful bacteria in the gut.	[Elnour and Abdelsalam, 2018] [Hannan et al., 2021] [Seidavi et al., 2020]
Ginger (*Zingiber officinale)*	Ginger	Zingiberaceae	zingiberene, camphene, Curcumene and β-phellandrene	0.2%	Promote the functioning of antioxidant defense systems, improve reproductive performance, and prevent harmful bacterial colonization by acting as an antimicrobial.	(Mao et al., 2019) [Abd El-Hack et al., 2020] [Pateiro et al., 2018]
Rosmarinus officinalis	Rosemary Essential Oil	*Lamiaceae*	α-Pinene, Bornyl acetate, Camphor, 1,8-Cineole	0.15, 0.3 g/kg	Regulates host immunity, and intestinal microflora and also has a beneficial antioxidant role. Has potential anticoccidial activity.	[Lahlou et al., 2021] [Hippenstiel et al., 2011]

Solvent Extraction

Another alternative process to achieve the extraction of essential oils from plants is solvent extraction. The technique aims to dissolve the oils from the plant components using different kinds of solvents, including ethanol, diethyl ether, and n-hexane (Ezeorba et al., 2022). Several factors affect the recovery by this method, such as the type of solvent, temperature, and particle size. The process is dependent on diffusion and concentration gradients which assist in the flow of oil from plant material to the solvent, which at the end should be easily separable from the oil, according to Ntalikwa, 2021. Solvent extraction is an extensive and widely employed oil extraction technique although it has drawbacks like undesirable residues and flavor changes (Khalil et al., 2017).

Modern Techniques of Essential Oil Extraction

Microwave-assisted Water Distillation

The process called microwave-assisted water distillation has huge potential for the extraction of essential oils. There are many advantages MAWD has over conventional techniques such as water distillation (Drinic et al., 2021). First, it reduces extraction time considerably; 30 minutes instead of the 4.5 hours it takes with conventional procedures for similar yields and quality (Guha and Zari, 2017). Second, the increased heating speed reduces thermal deterioration and may preserve the sensitive volatile substances. However, optimization of microwave power is needed for effective and superior extraction. Further investigation is required for MAWD to be applied to a more diversified range of plants, like thyme, to fulfill its potential (Akdağ and Öztürk, 2019).

Enzyme-Assisted Extraction (EAE)

These modern, green techniques involve the use of specialized enzymes to break down the components of the cell wall: lignin and cellulose (Lubek-Nguyen et al., 2022). EAE applies specific enzymes degrading those two elements of the cell wall, releasing the bound metabolites. The enzymes play their role naturally, just like keys. Enzymatic treatment facilitates the transfer of essential oils during extraction (Amudan et al., 2011; Hosni et al., 2013).

Ultrasound-Assisted Extraction (UAE)

UAE is a low-frequency sound wave technique below 16 kHz, improving oleoresins' plant extraction (Nora and Borges, 217). It creates acoustic cavitation in the cell walls of the plant material and eventually makes them release the essential oils (Mushtaq et al., 2020). Compared with other extraction procedures, some of the biggest edges associated with UAE include higher extraction rates, lower energy consumption, and a lower temperature at the time of extraction (Shen et al., 2023).

How do EOs act in poultry growth improvement?

Essential oils added as flavorings in poultry have been shown to have a range of physiological effects. These effects can be categorized into several groups, and there may still be more potential benefits waiting to be discovered

Role of Essential Oils as Antioxidants

The most widely studied physiological effects are the antioxidant activity of the EOs (Mutlu-Ingok et al., 2020). EOs directly neutralize free radicals in the gut and, up-regulate the expression of antioxidant enzymes in the gut and liver. They may down-regulate enzymes that produce reactive oxygen species (ROS), such as MPO, COX-2, and iNOS. MPO down-regulation diminishes oxidative stress and thus tissue damage. Down-regulation of COX-2 and iNOS can result in anti-inflammatory activities (Ezzat Abd El-Hack et al., 2016). They also scavenge free radicals like DPPH, ABTS, and also lipid peroxides. EOs protect from DNA oxidative damage, and they maintain β-carotene molecules without oxidation. Their activity depends upon the source of plant material, extraction method, and type of compound present, according to Valdivieso-Ugarte et al., (2019). The antioxidant activity of essential oils reduces lipid peroxidation in meat chicken muscles. This is highly useful for thigh muscles, which are more easily oxidized because of their higher content of polyunsaturated unsaturated fatty acids. The addition of essential oils to animal feed further aids in reducing rancidity in meat. Antioxidants play an important role in reducing lipid oxidation improving oxidative stability and removing stressors to chicken health (Adaszyńska-Skwirzyńska and Szczerbińska, 2017).

For example, the antioxidant activity of thymol in various essential oils involves the scavenging of free radicals such as super-oxide and hydroxyl and the enhancement of endogenous antioxidant enzymes such as glutathione peroxidase and superoxide dismutase. Thymol chelates iron and copper, making them unavailable to catalyze free radical generation (Gholami-Ahangaran et al., 2022). Thymol is also transferred to the yolk via chicken tissues. This also protects the yolk along with the meat in poultry (Ezzat Abd El-Hack et al., 2016).

The Rosemary Essential Oil components, which are mainly composed of phenolic diterpenes, show antioxidant activity by scavenging free radicals by acting as electron donors and stabilizing them (Candan and Bağdatlı, 2017).

Tea tree oil is used in conjunction with other EOs for an enhanced antioxidant effect ((Puvača et al., 2022). Components of oregano (*Origanum vulgare*) EO have free radical neutralizing properties, although not as much as vitamin C, still acting in the vicinity of Vitamin E and BHT. Hens fed with a thymus-enriched diet produced eggs with longer refrigerator life because of the decreased level of oxidation in yolks (Nehme et al., 2021).

The antioxidant role of essential oils of plants is dependent upon the different activities of the constituent compounds (Mnisi et al., 2022). Although Oregano EO supplementation in broiler did reduce the malondialdehyde (MDA) serum levels, the result was even better when it was used in synergism with vitamin C supplementation. Total antioxidative capacity, TAC increased when oregano oil was given with vitamin C (Ghazi et al., 2015). Organosulfur bioactive compounds present in garlic essential oil exhibited good antioxidant activity against 2,2-diphenyl-1-picrylhydrazyl (DPPH). It decreases thiobarbituric acid reactive substances (TBARS), which is an indication of lipid oxidation in broiler meat (Rafeeq et al., 2022).

Essential oils can still, have toxic effects when taken in excess. These include problems in the respiratory tract, skin, and reproductive system, depending on the dose, time of exposure, and components of the oil, among other factors (Horky et al., 2019). Essential oils, when used alone, undergo oxidation. Terpenes oxidation also forms radicals, so microencapsulation of essential oils can help to provide safe antioxidant operation without the radicals oxidizing the terpenes since the terpenes are prone to oxidation due to the presence of unsaturated carbon bonds (Nehme et al., 2021).

Table 2: Some common essential oils and their antioxidant potential

Plant name	Utilized part	Major component	Performance effect on poultry	Antioxidant role	References
Thymus vulgaris	Whole plant	Thymol	Growth performance was enhanced	Remarkable antioxidant property	Oluwafemi et al., 2020 Kosakowska et al., 2021
Cinnamon (species Cinnamomum)	Leaf	Cinnamaldehyde	Improved the growth performance	Remarkable antioxidant activity	Oluwafemi et al., 2020 Alizadeh Behbahani et al., 2020
Garlic *(Allium sativum*)	Bulb	Allicin	Body weight and feed efficiency were improved	Good antioxidant role	Oluwafemi et al., 2020 Abd El-Ghany, 2023
Black cumin seed oil (*Nigella sativa L.*)	Seed	Cuminaldehyde	Body weight improved, feed efficiency was also enhanced	Has a great antioxidant capacity	Oluwafemi et al., 2020 Aydogan et al., 2020
Ginger (*Zingiber officinale*)	Rhizome	Zingerone	Improved carcass quality	Improved antioxidant effect	Oluwafemi et al., 2020 Abd El-Ghany, 2023 Gholami-Ahangaran et al., 2021
Rosemary *(Rosmarinus officinalis L.)*	Leaf	Cinneol	Increased average daily gain and feed conversion	Has a strong antioxidant activity	Oluwafemi et al., 2020 Petricevic et al., 2018 Hcini et al., 2023
Basil leaves from *Ocimum basilicum*	Leaves, stems	Methyl chavicol	Significantly improve body weight and feed conversion ratio.	Potentially beneficial antioxidant agent	Herman et al., 2019 Zweil et al., 2019

Essential Oils as Growth Promoters

Essential oils are also termed as very effective growth promoters. Growth performance improves due to the synergistic actions of the EO components used in the forms of blends or alone. When EO blends of thymol and cinnamaldehyde or carvacrol, cinnamaldehyde, and capsicum oleoresin were used, all caused an increased appetite, FCR (feed Conversion Ratio), and muscle mass, which meant an overall improved broiler performance (El-Ghany, 2020). They are involved in maintaining the growth rate and utilization of nutrients (Zhai et al., 2018). EOs are known to have a positive effect on the feed conversion ratio, body weight, feed intake, etc if used in an optimum amount. Mixtures of essential oils can also positively impact the growth rate of broilers (Adaszyńska-Skwirzyńska and Szczerbińska et al., 2017). Mixtures of essential oils can also positively affect the growth rate in broilers. Essential oils also increase the dry matter, crude protein, and ether extracts when raising an EO level from 0 to 400 mg/kg (Su et al., 2021). Apart from their role in increasing body weight gain and improving feed conversion ratio, EOs increase beneficial gut bacteria and reduce harmful ones. This shows their potential use as natural growth promoters with added health benefits (Irawan et al., 2021). Studies conducted on commercial blends such as CRINA (comprised of thymol, eugenol, and piperine) indicate that these blends enhance the activity of enzymes within the pancreas and gut lining in broilers. Birds supplemented with these blends have potentially better digestion of ingested feed. EOs like Heryumix TM and thyme oil improved the FCR and body weight gain of poultry (Micciche et al., 2019).

Oregano extracts can be used as alternatives to synthetic feed additives as they're less toxic, which most likely have potential benefits like improved growth, feed efficiency, gut health, disease resistance, and even immune responses. Positive effects were recorded at certain moderate inclusion levels; for example, 240 mg/kg for the protection against *C. perfringens* in poultry (Alagawany et al., 2018).

Supplementation of the fowl with thymol essential oil increased body weight, carcass breast weight, reduced count of total cholesterol and the population of harmful gut bacteria, and improved growth and function with better FCR. However, it decreased wing and thigh weight (Seidavi et al., 2021). Less prominent effects resulting in broilers' performance were seen when the feeds were supplemented with oregano, cinnamon, and pepper EOs (Oluwafemi et al., 2020).

Popović et al. (2019), evaluated that poultry raised on a mixture of thyme, oregano, and rosemary oil are nutritionally more valuable and low in fat/calories. According to an experiment stated by Barbarestani et al., 2020, antibiotics or feed alone were not able to result in an efficient increase in body weight gain as was seen when lavender essential oil was added in poultry ration. The feed conversion ratio was also reduced. In the study conducted by Thuekeaw et al.,, 2022, the effect of avilamycin, free basil oil, and modified basil oil was evaluated on the performance of conventionally raised broiler chickens. Avilamycin increases the average daily gain and feed conversion ratio in broiler chickens. Supplementation with 500 mg/kg of cinnamon oil improved weight gain and FCR, and reduced bad cholesterol in broilers, according to Saied et al., (2022).

The addition of some spice blends orEOs in chicken, such as *Lippia origanoides* + *Rosmarinus officinalis* with beetroot or natural betaine, improved growth, feed intake, and FCR, reducing the negative effects of heat stress as compared to the chicken that did not receive EOs. Dietary supplementation of 600 mg/kg lavender essential oil in broilers improved weight gain but showed undesirable interactions with its level on the levels of ileal *Lactobacillus* spp. in the gut that constitute part of the microbiota (Pilego et al., 2022).

The application of EOs in the food industry is an evolutionary change, but their intense aroma, reactivity, and reduced solubility have practically created limitations for the use of essential oils. It all requires the administration of EOs in modified forms like nanoencapsulation (Maurya et al., 2021). Much research and collection of information is still needed to understand the proper pharmacodynamics of EOs so that they may be administered in animal production precisely according to requirements (Simitsiz, 2017).

Conclusion

Antibiotics and other Alternative growth promoters have played a vital role in the growth of the poultry industry. They are still used in the industry but due to the concerns over antibiotic resistance and drug residues, their use has reduced or they are used in conjunction with other alternatives, such as essential oils. Essential oils show great promise to be used as AGPs and are a hope for ethical poultry farming. However further research is needed to understand their exact mechanisms and effects in specific target industries, in our case the poultry industry. This review has explored the functions of essential oils, including their antibacterial, antioxidant, antiviral, and antifungal features all of which contribute to the growth and health outcomes of broiler chickens. There is a need for further research on dosage, delivery methods, and potential side effects of EOs so they can be used for sustainable poultry practices. This requires the development of ethical approaches that prioritize both animal welfare and public health.

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Chapter 21

Unveiling the Versatile Role of Essential oils in Food Industry for Enhanced Food Preservation

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ABSTRACT

The global food industry faces significant challenges stemming from the substantial loss of food materials due to spoilage and microbial contamination, exacerbating the scarcity of food per capita. Traditional preservation methods, reliant on synthetic additives, pose health risks, prompting a search for safer alternatives. Essential oils (EOs) have emerged as a beacon of hope, possessing multifaceted properties that render them invaluable in food preservation. This chapter delves into the pivotal role of EOs in combating food spoilage, elucidating their natural antimicrobial, antioxidant, and antifungal attributes with minimal health implications. Through an in-depth exploration of their application methodologies, the versatile efficacy of EOs in preserving food integrity is unveiled, underscoring their potential as avant-garde solutions in mitigating food loss and fortifying global food security.

KEYWORDS		
Encapsulation, Essential oils, Terpenoids, Antioxidants, Microencapsulation, Nano encapsulation	Received: 04-Jun-2024 Revised: 18-Jul-2024 Accepted: 07-Aug-2024	A Publication of Unique Scientific Publishers

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INTRODUCTION

Food Contamination or Spoilage

Organic substances which are mainly used to get energy or nutrition are referred to as food. Food can either be a plant or an animal origin. Foods are the source of micronutrients which are essential for the growth and development. Mostly food get spoiled which may cause change in the nutritional value of the food (Alonso et al., 2018). When the food does not affect the consumer's health and wellbeing it is considered as safe or secure. So food safety is referred as all the activities that guaranteed the food will not cause any health risk to the consumers (Kamala and Kumar, 2018). As human population has increased globally one of the major challenge is food insecurity or spoilage. A large portion of food get spoiled due to certain factors which is increasing the global hunger index. It has become difficult to fulfil the second sustainable development goal that is zero hunger due to unprecedented food spoilage. According to FAO almost one third of the food which can be used for human consumption get spoiled (Garvey, 2019). The primary stage of contamination started with changing the shape, color, texture and odor of food.

Causes of Food Contamination

Food contamination can be caused due to three main process that are microbial contamination, physical contamination and chemical contamination (Amit et al., 2017).

The food contamination through microorganisms is more common which enter in the food chain through several ways. Pesticides and inorganic fertilizers cause chemical contamination in food (Pina-Perez et al., 2017).

The microorganisms enter the food and start to multiply which causes a high level of food spoilage. They not only cause spoilage of food but also produce toxic materials in food which are usually referred as mycotoxins (Batiha et al., 2021). These microbes enter in food chain at any level during pre or post harvesting. These mycotoxins are contributors to food borne diseases which pose a great threat to public health and food security or sustainability (Alonso et al., 2018). Food spoilage due to microorganisms occurs in many ways as they alter the texture of food they cause a bad odor. As these microbes break down the proteins or fats in food it results in formation of grains or fungus over the food. Which identifies that the food gets spoiled (Hamad, 2012).

Traditional Food Preservation Methods

Food preservation encompasses methods and techniques employed to prevent the spoilage and degradation of food. Across ages, a plethora of traditional methods have been embraced to ensure the safety and security of food (Joshua Ajibola, 2020). A spectrum of preservation techniques is employed, spanning physical, biological, and chemical methodologies. Physical processing encompasses drying, chilling, pickling, irradiation, and freezing (Afsah-Hejri et al., 2020). Biological techniques for food preservation encompass fermentation processes, such as lactic acid fermentation for dairy goods or vinegar fermentation. Fermentation occurs spontaneously in certain foods, while in others, it may require initiation. Biological methods rely on microorganisms for food processing (Soomro et al., 2002).

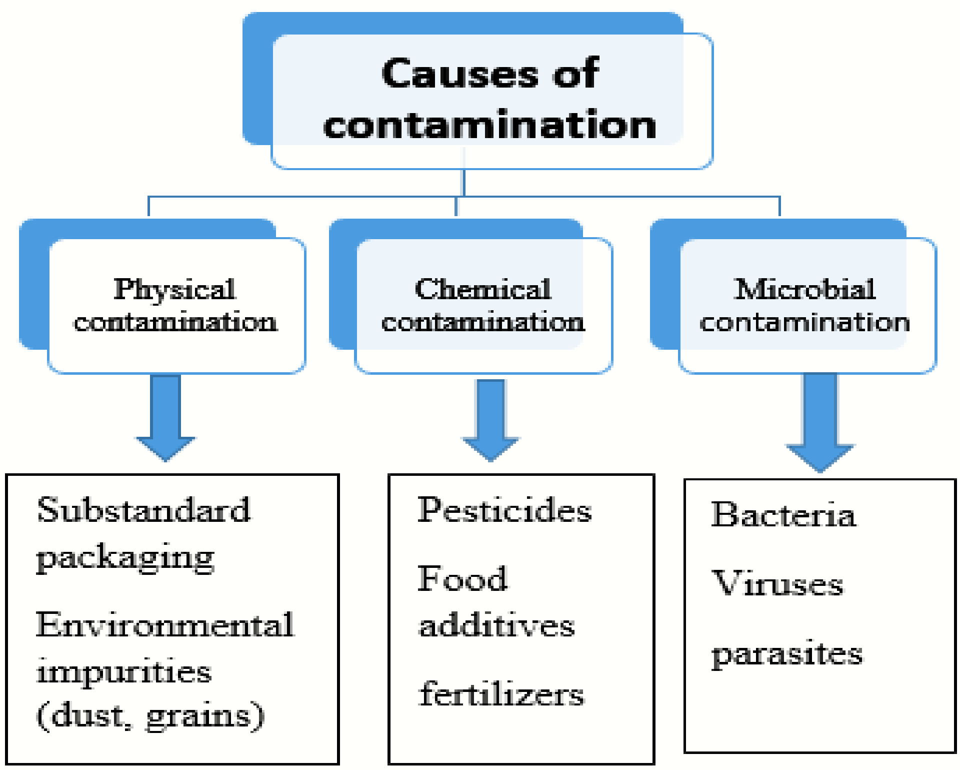

Fig. 1: Causes of food spoilage

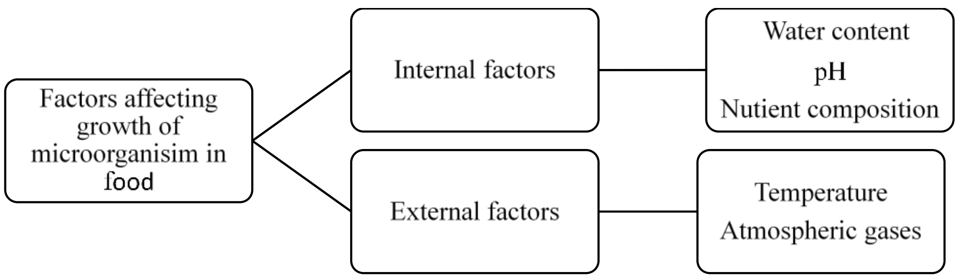

Fig. 2: Factors causing food deterioration by microbes

Chemical preservatives involve the incorporation of additives into food, encompassing both naturally occurring and synthetic food enhancements (Syamaladevi et al., 2016). Food additives are chemical compounds utilized to deter spoilage, enrich nutritional value, and augment flavor profiles in food products. Nonetheless, these additives have been linked to deleterious health ramifications (Mowafy et al., 2001). In our current era, artificial additives are extensively utilized in food production despite their recognized health hazards. These additives pose significant risks, especially for vulnerable populations such as patients, infants, the elderly, and expectant mothers, potentially precipitating various health conditions (Singh and Shalini, 2016). Therefore, there is an imperative need for additives or enhancements that carry no adverse health effects and instead offer favorable attributes for food preservation (Dwivedi et al., 2017).

The conventional approaches to food preservation have become obsolete in the face of modern advancements and preservative innovations. Essential oils have emerged as a cutting-edge alternative for safeguarding food, boasting a diverse set of properties that work wonders in ensuring food safety and stability, all without posing any harmful effects (Tiwari et al., 2009).

Introduction to Essential Oils

Essential oils represent the aromatic essence distilled or extracted from various botanical sources such as bark, herbs, woods, roots, and fruits (Turek and Stintzing, 2013). Commonly known as "volatile oils," they typically possess a colorless appearance alongside distinctive fragrances. Widely embraced across pharmaceuticals, cosmetics, and the culinary world, these oils are renowned for their potent aromas (Bakkali et al., 2008; Raut and Karuppayil, 2014), often utilized in perfumery and ambiance creation. Referred to as ethereal oils, they exhibit hydrophobic properties and are harbored within the oil glands of plant parts, particularly fruit peels. Diverse extraction methodologies are employed to harness these precious oils (Aziz et al., 2018).

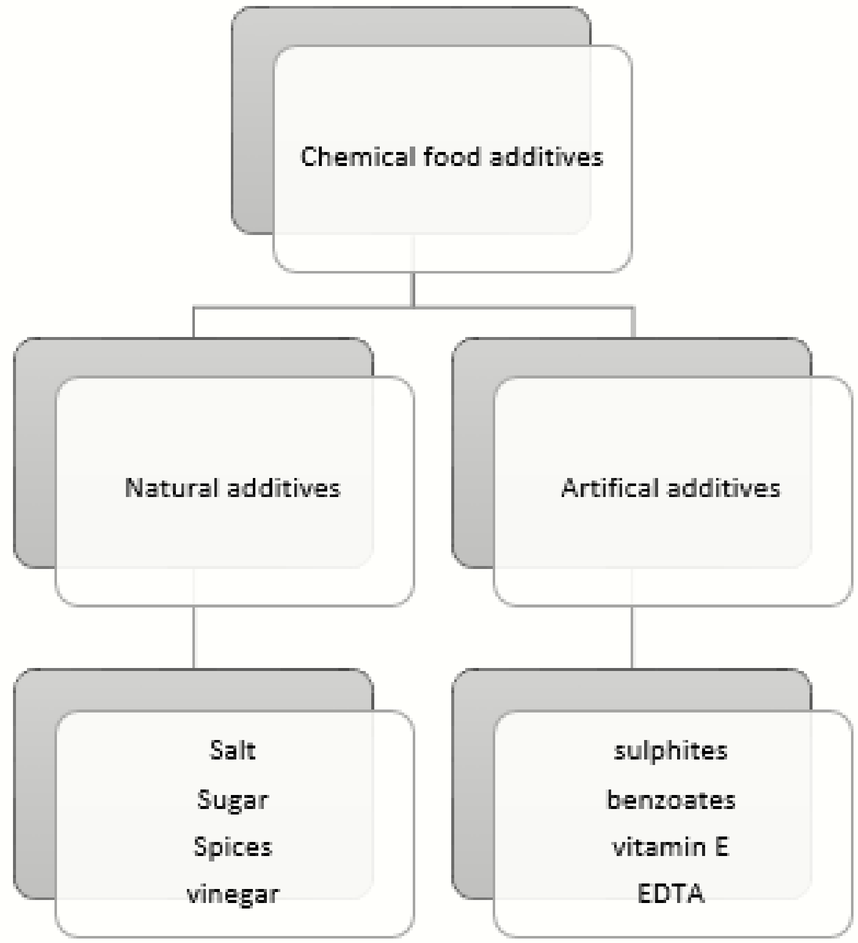

Fig. 3: Type of additives used in food

While essential oils have a historical presence, their resurgence in contemporary research and experimentation is fueled by their concentrated manifestation of nature's botanical treasures. Essential oils, derived from natural plant sources, are recognized for their innate antiviral, antifungal, and antimicrobial attributes (Langeveld et al., 2014). Classified as phytochemicals, they offer anti-inflammatory, analgesic, and fungicidal properties, along with acting as herbicidal agents. Additionally, they possess the capability to attract insects (Martins et al., 2017).

Components of Essential Oils

Essential oils represent a fascinating amalgamation of diverse chemical compounds, spanning both polar and nonpolar realms. Their intricate composition is a result of a multitude of factors, including the intricate interplay of the extraction methodology, botanical origin, and geographical specificity (Majeed et al., 2015). Primarily, essential oils are delineated into two fundamental groups: aromatic compounds and terpenoids (Vokou, 2007), each contributing distinct characteristics to the overall profile. Aromatic compounds, often referred to as phenylpropanoids, boast aromatic rings in their molecular architecture (Kar et al., 2018). These compounds are frequently imbued with benzene derivatives (Garay et al., 2020), showcasing an array of functional groups such as alcohols, aldehydes, ketones, and esters. Their aromatic nature not only confers pleasing scents but also imparts various therapeutic properties, ranging from antimicrobial to analgesic effect (Tongnuanchan and Benjakul, 2014).

Conversely, terpenoids exhibit a more nuanced complexity, stemming from their isoprene-based structures (Rao et al., 2019). These hydrocarbon-based molecules are assembled from isoprene units and subunits, manifesting a rich diversity of chemical functionalities. Monoterpenes, comprising a single isoprene unit, and sesquiterpenes, consisting of three isoprene units, dominate this category (Dehsheikh et al., 2020). Their intricate molecular frameworks endow essential oils with a plethora of biological activities, including anti-inflammatory, antioxidant, and neuroprotective properties (Nazzaro et al., 2013).

Moreover, the specific composition of essential oils is further shaped by ancillary factors such as environmental conditions, seasonal variations, and genetic predispositions of the botanical source. Consequently, essential oils serve as veritable reservoirs of chemical complexity (Crepet et al., 2007), offering not only olfactory delights but also a myriad of therapeutic potentials that continue to captivate scientific inquiry and application in diverse domains, from aromatherapy to pharmaceuticals (Mahmoudi et al., 2017).

In addition to terpenes, aromatic compounds constitute a significant portion of essential oils. These aromatic compounds typically contain benzene rings, albeit in relatively small proportions within the oil's overall composition (Mahato et al., 2019). They may exhibit a variety of functional groups such as hydroxyl, methoxy, and carboxylic groups, contributing to the complexity of the oil's chemical profile (Saad et al., 2013). Moreover, essential oils are known to contain a diverse array of chemical constituents beyond aromatic compounds and terpenes (Lee and Ding, 2016). These may include straight-chain molecules as well as other functional groups such as sulfur and nitrogen, further enriching the oil's composition and properties (Moleyar and Narasimham, 1992).

Properties of Essential Oils

The food industry extensively employs essential oils owing to their remarkable attributes and advantages, rendering them valuable for food preservation and storage purposes. These oils possess exceptional properties that contribute to their efficacy in maintaining the quality and safety of food products over time (Raut and Karuppayil, 2014).

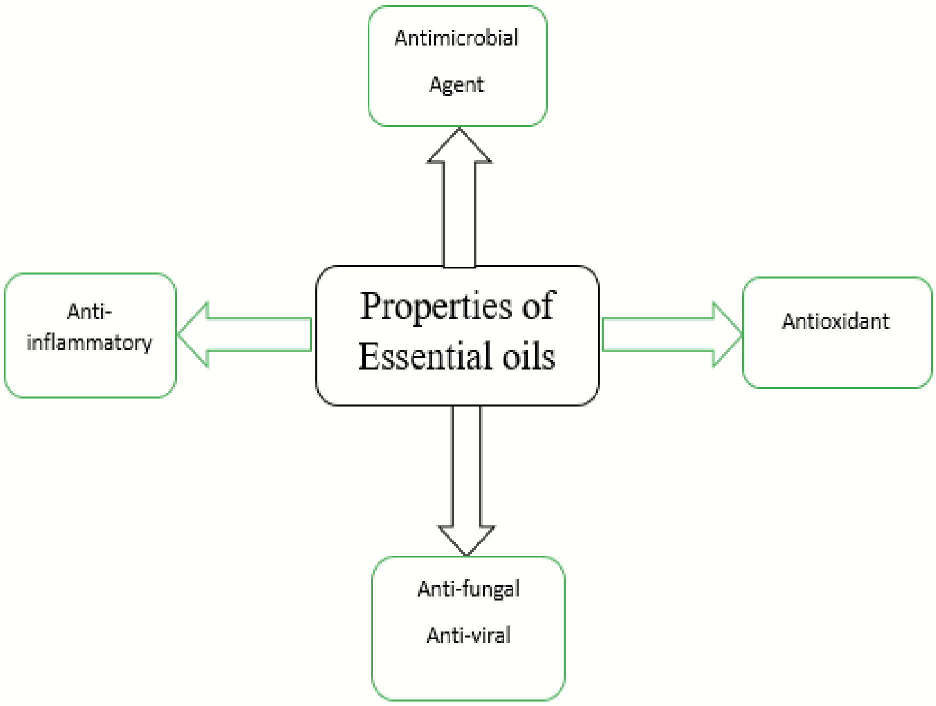

Fig. 4: Properties of essential oils

Elevating Antimicrobial Efficacy: The Prime Potential of Essential Oils

Antimicrobial agents represent a diverse array of compounds adept at impeding microbial growth or inducing their demise. Essential oils have emerged as particularly potent among these agents. Their hydrophobic nature facilitates penetration deep into microbial cell membranes, where they wreak havoc by disrupting the delicate balance of ion transport, ultimately leading to the demise of the microorganisms (Chouhan et al., 2017).

Recent findings suggest that aromatic essential oils (EOs) outperform their terpene-containing counterparts in terms of antimicrobial potency. In modern perspectives, EOs have garnered significant attention as potent antimicrobial agents owing to their health-preserving attributes and organic provenance, thus circumventing the apprehensions linked with harmful additives that pose substantial health risks (Dorman and Deans, 2000).

Essential oils featuring aldehydes, ketone, and ester moieties demonstrate heightened antibacterial effectiveness in contrast to those lacking such chemical constituents (Gyorgy, 2010).Essential oils possess the capability to induce cell wall damage, impede ATP synthesis crucial for bacterial energy metabolism, and heighten membrane permeability. This multifaceted action culminates in the degradation of microbial cell walls and subsequent leakage of intracellular contents. The antimicrobial prowess stems from the synergistic interplay of essential oils (EOs) sourced from varied botanical origins. Synergism, characterized by an amplification of effect when two compounds are conjoined, encapsulates this attribute. Despite the potential for antagonistic interactions, EOs exhibit synergistic effects (Ju et al., 2022; Probst et al., 2011).

When two distinct essential oils are amalgamated, their antimicrobial efficacy surpasses that of individual components, showcasing a heightened potency in tandem (Hammer et al., 1999).A catalog of plant sources yielding essential oils underscores their utility as antimicrobial agents, presenting intriguing prospects for future research. Notably, lemongrass oil, derived from Cymbopogon citratus (Mukarram et al., 2021), commonly known as lemongrass, emerges as a particularly noteworthy candidate. Exhibiting considerable antibacterial activity against a spectrum of pathogens, including both gram-positive and gram-negative bacteria such as Escherichia coli (Moore-Neibel et al., 2012), it showcases remarkable efficacy against disease-causing microorganisms. The aldehydes constituents found within lemongrass are credited for augmenting its antimicrobial potency (Premathilake et al., 2018), signaling promising avenues for further investigation.

Bustos C et al. (2016) was involved in pioneering research centered around the utilization of Lemon Grass Oil (LMO) as a protective film to impede the proliferation of E. coli bacteria. This innovative approach was tailored towards extending the shelf life of food commodities primarily sourced from fatty fruits. To accomplish this microcapsule for encapsulating lemongrass oil were developed, representing a cutting-edge strategy for enhancing food preservation and safety.

Boukhatem et al., (2014) research focused on unlocking the antimicrobial potential of lemongrass oil against both bacterial and yeast pathogens. By meticulously dissecting its chemical composition, we pinpointed the specific agents responsible for its antimicrobial efficacy. The findings underscored the superiority of certain components, particularly the essential oils, in providing formidable defense against gram-positive bacteria and select yeast strains. Moreover, we posited a novel conjecture that the efficacy of these essential oil constituents is heightened in their gaseous state compared to their liquid form. This revelation underscores the remarkable versatility and potency of lemongrass oil as a natural antimicrobial agent, positioning it as a cornerstone in the quest for innovative antimicrobial solutions.

Table 1.1: Utilizing Plant Essential Oils as Antimicrobial Agents for Optimal Food Preservation

Sources of EOs	Antimicrobial activity	Effect in food preservation	References
Lemongrass oil	Combating against bacterial and fungicidal microbes	Assist in the creation of coatings that prolong the shelf life.	(Bustos et al., 2016)
Clove oil	Enhanced antimicrobial potency against pathogenic bacteria such as *S. aureus, E. coli,* and *L. monocytogenes*.	Utilizing clove essential oil encapsulated within a polysaccharide matrix serves to inhibit bacterial proliferation, thus enhancing the preservation of meat products. Additionally, its robust scavenging capabilities play a pivotal role in extending the shelf life of cheese.	(Menon and Garg, 2001; Radunz et al., 2019)
Tea tree oil	Enhanced activity against *L. monocytogenes* and *E. coli*	Tea tree oil disrupts the cellular membranes of bacterial pathogens, leading to their demise, thereby aiding in the preservation of freshly squeezed fruit juices, particularly cucumber juice.	(Shi et al., 2018)
Limonene oil	Best antimicrobial agents against *Salmonella enterica and Listeria monocytogenes.*	The application of a d-limonene nanoeulsion coating on fresh bananas exhibited a notable extension in their shelf life and a marked reduction in microbial proliferation, promising enhanced preservation.	(Hou et al., 2022)
Lavender oil	Suppress bacterial and fungal growth	Demonstrated to be a cost-effective preservation additive, aiding in the preservation of ready-to-use mushrooms. This is achieved through the utilization of lavender oil encapsulated within chitosan, complemented by cinnamon oil serving as a natural preservative. The chitosan-encapsulated lavender oil also contributes to the preservation of food items.	(Farokhian et al., 2017; Liu et al., 2022)
Eucalyptus oil	Antifungal agents against fungus species (P. expansum)	A blend of eucalyptus essential oil and rosemary oil was employed to protect pears and apples, resulting in diminished fungal growth and prolonged fruit shelf life. This underscores its potential as a natural fungicidal preservative for food products.	(Xylia et al., 2021)
Thyme essential oil	Against bacteria, viruses and fungal species	Nanoemulsions of thyme essential oils were used for the preservation of meat and increasing the storage period.	(Snoussi et al., 2022)

Essential Oils: Superlative Antioxidants for Food Preservation

The inclusion of phenolic components endows essential oils with exceptional antioxidant properties, sourced from a diverse array of botanicals and herbs. These compounds, known as polyphenols, are present in minute proportions relative to oxidants but exert significant influence by impeding oxidation processes. Consequently, essential oils emerge as invaluable food supplements, instrumental in mitigating health risks and fortifying cardiovascular health (Baratta et al., 1998).

The innate redox characteristics of essential oils underscore their unparalleled efficacy as reducing agents. Employing diverse methodologies like the DPPH or FRAP assays enables the quantification of phenolic content (Teixeira et al., 2013), illuminating their radical scavenging prowess. Within essential oils, aromatic compounds serve as primary sources of polyphenols (Jirovetz et al., 2006), thus augmenting their anti-oxidative capacity. Certain botanical species, such as cloves, exhibit notably elevated levels of phenolic compounds in their essential oils, endowing them with exceptional antioxidant properties, often surpassing synthetic counterparts.

This heightened efficacy is primarily attributed to the presence of eugenol (Misharina and Samusenko, 2008). Similarly, carvacrol, a constituent found in oregano, imparts potent antioxidant attributes to its essential oil (Olmedo et al., 2014). The complex interplay between essential oil constituents and radicals serves as the cornerstone of their antioxidant functionality. Furthermore, the synergistic amalgamation of these bioactive components within essential oils further enhances their antioxidant potency, making them formidable allies in combatting oxidative stress and preserving health. In the endeavor to thwart oxidation, essential oils (EOs) deploy multifaceted strategies (Misharina and Polshkov, 2005).

Through the donation of hydrogen ions, EOs intricately disrupt the oxidative cascade, facilitating the conversion of free radicals into stabilized molecules. This pivotal role defines them as primary antioxidants (Damien Dorman et al., 1995). Concurrently, secondary antioxidants operate by engaging chelating agents, orchestrating the neutralization of free radicals, and orchestrating their transformation into inert components (Yang et al., 2010).

The rich array of antioxidants inherent in natural food matrices serves as a bulwark against diseases stemming from the menacing presence of nitrogen and oxygen species. Harnessing essential oils to stave off lipid oxidation heralds an innovation in the preservation of vegetable oils harboring both saturated and unsaturated lipids (Perumal et al., 2022), thereby significantly extending their shelf life. Descriptive accounts delineate how particular essential oils operate and their efficacy as natural antioxidants in ensuring food preservation and safety, elucidated as follows:

Rodriguez-Garcia et al. (2016) delved into the utilization of oregano essential oils' antioxidant prowess. Their investigation revealed a significant contribution in inhibiting lipid peroxidation, thus bolstering the longevity of dairy products, oils, and various lipid-rich food substrates.

Yang et al. (2010) undertook a comprehensive analysis to discern the antioxidant efficacy among six distinct essential oils. Notably, lavender oil emerged as a standout, boasting elevated phenolic content and robust lipid peroxidation inhibition. Their findings underscored the profound potential of these botanical extracts in quelling free radicals, thereby combatting food spoilage. Thus, the discerning use of essential oils as natural antioxidants holds promise for bolstering preservation strategies within real-world food systems.

Unveiling Essential Oils: Antifungal and Anti-inflammatory Potency

Fungal infections, often more menacing than those caused by bacterial pathogens, pose significant risks to living organisms. With chitin comprising the structural backbone of fungal cell walls, targeting its destruction becomes imperative for inhibiting fungal growth. To safeguard food materials against fungal contamination, the use of natural antifungal additives, notably essential oils extracted from a myriad of plant sources, has emerged as a frontline defense. Renowned for their formidable fungicidal properties, these essential oils deploy diverse mechanisms of action, presenting a sophisticated arsenal against fungal proliferation in food matrices (Nazzaro et al., 2017).

When tissues succumb to infection, inflammation swiftly follows suit, serving as the body's frontline response against intruders. Across centuries, essential oils sourced from select plants have emerged as venerable allies in combating inflammation. Notably, their profound anti-inflammatory prowess intricately intertwines with their robust antioxidant potency, forming a formidable defense against tissue damage and oxidative stress (Tsai et al., 2011).

Indeed, while the anti-inflammatory properties of essential oils stand out, their efficacy is influenced by various factors beyond antioxidant activity alone. Essential oils possess a diverse composition, each with its unique blend of bioactive compounds. Additionally, multiple mechanisms come into play, impacting their anti-inflammatory potential. Consequently, the effectiveness of essential oils in mitigating inflammation can be influenced by factors such as their chemical composition, concentration, and interactions with biological systems (Miguel, 2010).

Advanced Application Methods of Essential Oils in Real Food Systems for Enhanced Preservation Efficacy

During preparation, storage and distribution many food products must be preserved from deterioration as they are naturally perishable (Teodoro, 2019). The consumer demand of food products with improved shelf life has increased because of general availability of the goods in different regions of world (Mani-Lopez et al., 2018). International trading of perishable food has become possible but refrigeration is not promising process which assure the quality of food (Sahu and Bala, 2017). However, the worth of traditional methods of food preservations have been acknowledged and concerns has been raised about their safe (Ribes et al., 2018).

In order to satisfy consumers demand for food a number of nontraditional techniques have been developed. in order to kill vegetative bacterial species foods are processed via thermal heating at higher temperature for a specific interval of time (Powell et al., 2011). A great amount of energy is transferred to food during this process. But this process results in unwanted side reactions which effects the organoleptic properties of food (Pal, 2014).

Encapsulation of essential oils

Encapsulation techniques have promising effect on food safety and preservation. Encapsulation is widely used method for engineered goods in many food industries, specifically in production, processing and development of new products (Vemmer and Patel, 2013). Encapsulation involves entrapment of functionally active core material into matrix of inert material. It requires a core material and a coating material (Comunian et al., 2021). There are many methods of encapsulation which are classified into physical and chemical methods (Zhang et al., 2021).

Microencapsulation of Essential Oils

The process through which a coating is made around small particles that may be solid, liquid and gas to form small capsules which are referred to as microcapsules. ME is basically a food packaging technology of materials in sealed and tiny capsules (Ozkan et al., 2019). It helps in protection of flavors and aroma of volatile compounds during their processing and storage. Which in turn are used in enhancement of taste of food products. Microencapsulation results in extension of shelf life of food materials by encapsulating active ingredients (Aloys et al., 2016). Which results in maintenance of quality of food products.

Emulsification Encapsulation of Essential Oils

Emulsification encapsulation is extensively used technique in food and pharmaceutical industries to encapsulate a liquid or solid particle in any of the liquid medium. Two liquids that are immiscible are used to form a stable emulsion (Kakran and Antipina, 2014).

Nano Encapsulation of Essential Oils

The use of nanotechnology in food industry results in innovation of large scale properties for food as its color, flavor, texture, taste, coloring strength and stability. Furthermore, nanotechnology can increase the water solubility, thermal stability and oral absorption of bioactive compounds (Paredes et al., 2016) It has enormous benefits as Nano encapsulation provides better stability to the active materials as EOs, vitamins, enzymes, polysaccharides and carbohydrates and results in targeted drug delivery in pharmaceutical industries as well as in food industries. It protects targeted substances from external environmental conditions (Ayala-Fuentes and Chavez-Santoscoy, 2021)

Formation of Edible Films and Coatings

Essential oils play a pivotal role in crafting edible coatings and films, instrumental in safeguarding food items. These innovative coatings, when applied to food materials, effectively extend their shelf life. The creation of these edible coatings and films involves diverse encapsulation techniques, which are subsequently utilized to enhance their effectiveness upon application to food products.

Pirozzi et al. (2020) a studied the utilization of Nano emulsions containing oregano oil demonstrated remarkable efficacy in preventing the spoilage of tomatoes during prolonged storage periods. This innovative approach showcased the extraordinary capacity of essential oils to extend the shelf life of tomatoes by up to 14 days, effectively inhibiting microbial growth and preserving their freshness.

Usage of Essential Oils as Natural Preservatives

In the realm of food preservation, the drawbacks of synthetic preservatives, including health risks and environmental harm due to their pesticidal properties and non-eco-friendly nature, spurred a quest for viable alternatives (Ballesteros et al., 2017). Essential oils emerged as a transformative solution, offering a blend of natural efficacy and sustainability in replacing artificial additives (Galvez et al., 2014).

Their innate hydrophobicity and volatility make them adept at preserving food without altering its composition or sensory attributes, thus seamlessly integrating into food systems(Tiwari et al., 2009). As a result, essential oils extracted from plant sources have become prized assets in the food industry, supplanting synthetic preservatives and championing a greener, more health-conscious approach to food preservation.

Conclusion

The aforementioned discussion indicates that essential oils extracted from different plants possess distinct effects and harbor numerous beneficial properties that can be harnessed in actual food systems to combat pathogens, effectively safeguarding food from spoilage. Moreover, these oils are considered safe for consumption, given their organic nature, and have not been associated with adverse health effects. Examples showcasing the utilization of essential oils, which exhibit potent antimicrobial properties against specific microorganisms, highlight their efficacy as unparalleled antimicrobial agents in preserving food integrity and prolonging its shelf life during storage periods.

Despite their remarkable benefits, some challenges such as strong odors can be addressed through techniques like encapsulation. Various methods have been devised to incorporate essential oils into food applications. While numerous essential oils have already found application in real food systems, there remains a necessity to explore their potential as bio preservatives further. Extensive research is warranted to unravel their full spectrum of beneficial properties. Nonetheless, the integration of essential oils into food preservation techniques represents a sophisticated approach, paving the way for enhanced bio preservation methods in the food industry.

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Chapter 22

The Potential of Essential Oils as Antiviral, Antioxidant and Immunomodulatory Agent

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ABSTRACT

The aim of this chapter is to take a view and highlight the different biological properties of essential oils. Since ancient times, essential oils (EOs) have been used for many medicinal and preservative purposes. But now, they are increasingly studying to treat various diseases. Current antibiotics and antivirals have a major issue which is resistance, which can be resolved by using natural compounds. EOs are herbal volatile oils derived from plants through various extraction methods. Pharmacologically, they are very active and exhibit wonderful characteristics like preservatives, flavoring agents, antimicrobials, antiseptics, anti-inflammatory, antioxidants, immunomodulatory, antiviral, etc. Each bioactive component in the EOs has its properties and performs various functions in the body. EOs show antiviral activity by binding to the free viruses and inhibiting their multiplication. Phenolic and oxygenated compounds of EOs are responsible for antioxidant activity because of the presence of double bonds. Immunomodulatory properties of EOs are manifested majorly by the modification in the release of cytokines. These applications highlight the scope of EOs in the modern world.

KEYWORDS
essential oil, Antiviral, Antioxidant, Immunomodulatory

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INTRODUCTION

Medicines used in humans and animals are prone to bacterial resistance and side effects like allergic reactions (Arsène et al., 2022). That's why researchers are studying natural compounds that have less toxicity and resistance issues because of broad-spectrum mechanisms of action. These compounds are obtained from plants or natural sources. Essential oils (EOs) are one of them which is our topic of discussion. EOs are highly concentrated, colorless aromatic oils derived from plants, and used for medicine in diluted form (Bakkali et al., 2008). Plants synthesize them through various extraction processes which are solvent extraction, steam vaporization, enfleurage, cold pressing, maceration, and distillation (Shikov et al., 2022). The bioactive compounds present in them enable them to show various characteristics like antimicrobial, antiseptic, insecticidal, antitumor, immunomodulatory, antioxidant, etc. (Murbach Teles Andrade et al., 2014). In this chapter, we will cover the antiviral, antioxidant, and immunomodulatory aspects of essential oils in the aforementioned sections that are very frequently used in our daily lives.

EOs

EOs are the intricate combinations of monoterpenes and sesquiterpenes (C10 and C15 respectively), phenylpropanoids, and oxygenated compounds (aldehydes, alcohols, and ketones) (Yingngam, 2022). They are hydrophobic in nature, soluble in alcohol, oils, ether, and waxes, and slightly soluble in water, as are weak polar solvents. The function of EOs depends upon the chemistry (functional groups and composition) of EOs. EOs have an intense odor. They are secondary metabolites of plants that help them in their fight against pathogens and attraction for insects that help in communication between plants through pollination, that's why explored in the field of medicine (Manion and Widder, 2017). EOs are also known as plant essences, used in aromatherapy, which means the usage of aromatic oils as therapeutic agents (A. Sharma et al., 2023). Thousands of EOs are well known and many of them are commercially available. It includes many groups like terpenes, monoterpenes, sesquiterpenes, carotenoids, aldehydes, flavonoids, phenols, oxides, hydrocarbons, volatile compounds (esters, alcohol, and alkenes) etc. Each EO consists of numerous bioactive compounds in them that produce or show their effect according to the chemical structure. Phenols consist of thymol, carvacrol, and eugenol (Chouhan et al., 2017). Various EOs along with their bioactive components are represented in the Fig. 1. These bioactive compounds constitute antimicrobial contents and flavors as they contain proteins, vitamins, and heterocyclic compounds.

Most widely customized aromatic oils are derived from oregano, peppermint, spearmint, mustard, lemon, thyme, lavender, eucalyptus, dill, cinnamon, rose, orange, clove, tea extracts, etc. (Mohammed et al., 2024). EOs can be obtained from every part of the plant, like leaves, bark, roots, shoots, twigs, wood, fruits, flowers, seeds, etc. from these parts of plants (Hanif et al., 2019). EOs can be extracted through the above-mentioned processes. Each process produces EOs of different compositions in quality and quantity. The type of method is selected on the basis of the purpose of the application. Because of its numerous properties, they are extensively used as flavoring, aroma, antimicrobial, and therapeutic agents. EOs enhance the shelf life and quality of edible products (Pérez-Santaescolástica et al., 2022). Biological properties enable them to act as antiviral, antifungal, antiparasitic, antibacterial, antidepressant, antioxidant, immunomodulatory, and insecticidal. They can be used in the form of oils, capsules, powders, lotions, ointments, creams, etc.

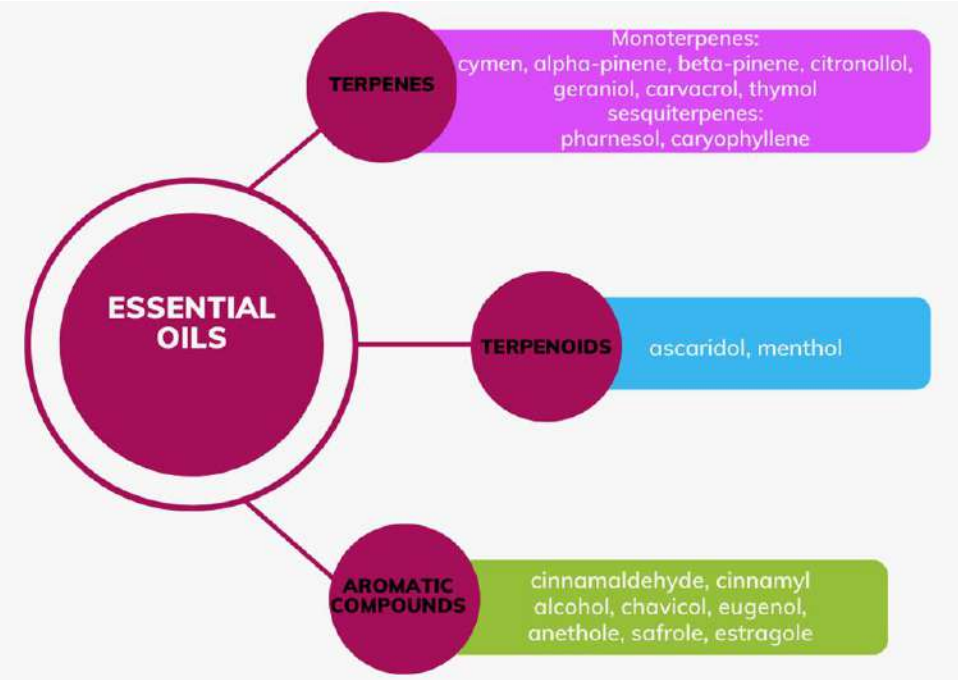

Fig. 1: EOs and its Classifications

History of essential oils

It is hard to find the exact discovery and first usage of EOs. Empirically, they are used to wipe off the foul odor and preserve or flavor the foods. These EOs have high economic and cultural importance. They have been in use since BCE, but reported medicinal use started later. In 1912, Gattefosse's hand was burned in a lab burst, he dipped his hand in lavender oil and got healing (Buckle, 2002). Paracelsus von Hohenheim coined the term EOs from a drug named Quinta Essentia (Brenner, 1993). Later on, the processes of its extraction are discussed, and they became industrially commercialized for use in cosmetics and therapeutics.

Critical Analysis

Synergism within EOs' Components

EOs are complex mixtures of different compounds and produce a combined effect (Sheng et al., 2020). The combined effect is the effect of all the major and minor components present in the EOs. These minor components possess synergistic effects, and the resultant effect is represented as the effect of the main component (Saad et al., 2013). All components together identify the cell penetration, density, fragrance, color, and texture of each EO. These minor components, in addition to synergistic effects, can also pose antagonistic or additive effects. The synergistic effect provides broad-spectrum activity and increased efficacy to EO (Ju et al., 2022). Two or more compounds synergistically are used to produce flavor and aroma without causing adverse effects.

Administration Routes

The most widely employed routes of administration include oral, inhalation, and topical. In the topical route, EOs in small quantities are mixed with some base or carrier and massaged on the skin (Guzmán and Lucia, 2021). A very small quantity is required that can produce its effect pronouncedly (Baldim et al., 2021). Very frequently used in lotions, ointments, and creams. In inhalation, there is stimulation of olfactory nerves either through sprays, inhalation through bottles, or baths (Rowland, 2024). This is used to enhance a balance of physical and mental state. It is widely reported that

EOs show maximum effects in both humans and animals.

Some oils cause toxicity, so should be administered with precautions, oral route shows maximum effect due to exposure to the lymphatic system through the gastrointestinal system (Baptista-Silva et al., 2020). It shows its mechanism in three ways viz; in biochemical mechanism, it transfers through blood in the whole body and interacts with hormones and enzymes (Cimino et al., 2021). In psychological innervation of the brain occurs through olfactory stimulation and then shows its effect on mental health by producing neurotransmitters. In physiological mechanisms, oils act on specific systems of the body and perform a therapeutic function (Sadgrove et al., 2021). Precautions should be undertaken while using these because higher doses cause adverse effects.

Essential oils as Antiviral Agents

Phenols and aldehydes have the ability to initiate immune responses. Lemon, eucalyptus, cinnamon, tea tree (TT), clove, peppermint, garlic, etc. are involved in antiviral activity. EOs act by boosting the weakened immune system (Zuo et al., 2020). The mechanism of action depends upon the interaction of EOs either outside or inside of the cell with free viruses (Ma and Yao, 2020). They act by making changes in the structure of the virus and hiding their proteins (Reichling, 2022). There are various mechanisms of action that depend on the type of EOs, for example, carvacrol acts by hiding the capsid or by binding to the virus (Javed et al., 2021). Isothymol derived from *Ammoides verticillate* inhibits the COVID-19 receptor, which is angiotensin converting enzyme 2 (Abdelli et al., 2021). EOs are effective against many viruses like respiratory syncytial, bovine viral diarrhea, yellow fever, Zika, and alpha herpes viruses, and many others (K. Sharma et al., 2023) which are as follows: Germacron EOs are involved in antiviral activity against feline caliciviruses (K. Sharma et al., 2023). EOs derived from Australian TT, Star Anise, piperitenone, *Eucalyptus caesia*, *Zingiber officinale,* oregano, and eugenol, 1,8 cineole showed antiviral activity against HSV-1 (El Gendy et al., 2022). While EOs derived from *Savia desoleana*, germacrene D, linalool, linalyl acetate, 1,8 cineole, α-terinyl acetate, and β-caryophyllene, showed antiviral activity against HSV-2 (Sharifi-Rad et al., 2017). EOs like β-santalol, clary sage, 1,8 cineole, marjoram, terpinene-4-ol, anise EOs, citrus *bergamia, Cinnamomum zeylanicum,* and *Thymus vulgaris* showed antiviral efficacy against influenza virus (Vimalanathan and Hudson, 2014). EOs from cedar leaf are very effective against the hemagglutinin protein of the influenza virus (Oriola and Oyedeji, 2022, Mustafa et al., 2023) . Oregano with its major component carvacrol, has antiviral activity against norovirus and rotavirus (Sarowska et al., 2021). Isothymol and 1,8 cineole are effective against COVID-19 (Nadjib, 2020; Soleymani et al., 2022). Oxygenated EOs have proved effective against influenza virus while non-oxygenated against HSV.

Essential oils as Immunomodulatory Agents

The process of increasing or decreasing the immune system is known as immunomodulation. EOs show an immunomodulatory effect by expressing interleukins through lymphocyte proliferation and modulating inflammation by stimulating phagocytic activity (Pelvan et al., 2022). EOs help in initiating the immune response against pathogens by activating the immune system, which consists of innate and adaptive immune systems (Grazul et al., 2023). The innate immune system consists of dendritic cells, monocytes, and macrophages, and is involved in the primary defense mechanism by initiating inflammatory immune responses (Zhao et al., 2023). Adaptive immune systems include dendritic cells, macrophages, neutrophils, natural killer cells, eosinophils, basophils, B and T cells, etc. (Akhand and Ahsan, 2023). Is stimulated by the EO activity by cytokine release and phagocytosis. Pattern recognition receptors recognize the pathogen-associated molecular patterns and induce innate immune cells to inflammation that, in turn activate the adaptive immune system (Singh et al., 2023). T cells on stimulation, differentiate into $CD4^+$ (Th1) and $CD8^+$ Th cells that produce cytokines. Th2 cells differentiate into B cells that produce antibodies to neutralize pathogens (Zuo et al., 2020). Many therapeutic EOs like lemon grass and balm, clove, black cumin, eucalyptus, marjoram, rose, fennel, lavender, thyme, sage, TT, bay laurel, peppermint, etc. are involved in immunomodulatory and anti-inflammatory effects (Tirant et al., 2024). Oropharyngeal candidiasis produces IL-8 which is inhibited by TT oil (Sosa et al., 2023). TT oil also exerts an effect on hypersensitivity and histamine-induced edema. Eugenol is involved in the inhibition of IL-1β,6,10, and lipopolysaccharide inflammatory action through the mechanism of inhibiting the nuclear factor Kappa β pathway (Saini and Dhiman, 2022). Parsley shows an effect on inflammation by inhibiting the proliferation of phytohemagglutinin-stimulated splenocytes (Yousofi et al., 2012). In a study of clove bud and cinnamon bark, EOs proved effective in combating Newcastle disease and were involved in increasing intestinal villi length (Sandner et al., 2020). Ginseng is involved in immunostimulants by the production of IFN-γ and TNF-α. TT EOs enhance intestinal immunity by releasing IL-2, IL-10, and IFN-γ and also enhance growth performance, and reduce the incidence of diarrhea in small pigs (Zhu et al., 2018). Clove EOs was studied *in vitro,* and showed cellular and humoral immunity in immunocompetent and immunosuppressed mice respectively (Peterfalvi et al., 2019). Herbal EOs have been researched in various studies and resulted in the best remedies for reducing inflammation by modifying inflammatory cytokines (de Lavor et al., 2018). Sandner et al., 2020 reviewed that EOs can be alternative to antibiotics for use in broilers.

Essential oils as Antioxidant Agents

EOs like monoterpenes, sesquiterpenes, and oxygenated derivatives have different chemical structures that enable them to act as antioxidants (Bhavaniramya et al., 2019). The EOs which have a scavenging effect on reactive oxygen species illustrate antioxidant activity (Valdivieso-Ugarte et al., 2019). Phenols contribute mainly because they have strong redox potential. These and others, like aldehydes, ketones, monoterpenes, alcohols, and ethers, cause disruption of peroxides and removal of free radicals (Amorati et al., 2013). The compounds involve menthone, isomenthone, thymus, linalool, citronellal, 1,8 cineole, carvacrol, α-terpinene, β- terpinene, α-terpinolene, cinnamon, neral, etc. show antioxidant activity**.** Double bonds present in compounds especially phenols are responsible for its mechanism of action. The process of oxidation consists of initiation, elongation, and termination steps. EOs break the chain of reaction either at the initiation or elongation stage. Both natural and synthetic EOs act as antioxidants (Salanță and Cropotova, 2022). The compounds obtained from thyme, oregano, mint, nutmeg, clove, basil, cinnamon, parsley, *etc.* are rich sources of oxygen and have great potential to act as antioxidants. Tocopherols, *Origanum compactum, Helichrysum italicum,* black cumin, sage, winter savory, wild thyme, basil, mint, clove, parsley, oregano, nutmeg, and retinol produce antioxidant effects (Jabeen et al., 2022).

Limitations to Essential Oils

Despite the huge advantages and applications of EOs, they also have some disadvantages. They can cause irritation (dermatitis), pneumonitis, photosensitivity, seizures, etc. Insufficient data is available that demonstrates the toxic risk of each EO. EOs as volatile oils, means are unstable. Being lipophilic in nature can damage cell membranes and make them more permeable (Barradas and de Holanda e Silva, 2021). Higher doses cause a reduction in the level of feed intake.

Future Prospects and Conclusion

There is a need for more studies that highlight the various mechanisms of action of EOs as antioxidant, immunomodulatory, and antiviral agents. Further studies are the need of time for the evaluation of the synergistic effects of various bioactive components of EOs, which may prove beneficial. In the future, more research may be done as there are many fields of EOs that require more advanced studies. Exploring EOs with others through conjugation may enable them to be the best preventive agents in the field of biology. EOs may be available as inflammatory drugs in the future. These EO-based drugs may be used as therapeutic drugs for treating infectious ailments. EOs, because of their enormous properties and popularity, are increasingly used in various fields to perform different functions. Multiple types of EOs due to the presence of bioactive components are explored in antiviral, immunomodulation, and antioxidant. They are industrially produced, and many are being commercialized. Phenolic EOs are very effective in producing the desired effects. They are safe to consume at recommended concentrations. Synergistic interactions can produce better results. EOs reduce the inflammation caused by disease mechanisms, boost the immune system against various viral diseases and improve health.

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Chapter 23

Essential Oil-Based Functional Feeds for Promoting Growth in Aquaculture Species

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ABSTRACT

The aquaculture industry is searching for sustainable and environmentally friendly non-synthetic growth promoters to replace the synthetic, antibiotics or hormone-based additives. Essential oils, extracted from different plant material sources have recently been recognized as effective non-conventional natural feed additives for growth promoters in aquaculture species. Abstract This book chapter provides an overarching and comprehensive view on application of essential oil based functional feeds for growth promotion in aquaculture. Essential oils are complex mixture of volatile compounds with a variety of biological properties, which include antibacterial, antioxidant, immunomodulatory and orexigenic effects. It comes from enhancing feed intake, nutrient digestion and absorption, gut microbiota and intestinal health to digestive enzyme secretion, nutrient transporters, and hormonal pathways. The examination of these topics is also performed in the light of particular aquaculture species (carp, tilapia and catfish for freshwater; shrimp, salmon and sea bass for marine) at several life stages regarding distinct production systems. The present review provides an overview of the inhibitory effect and action mechanism on L. monocytogenes by essential oils, including source, composition combined with dosage, administration method and environmental conditions that may be instrumental for efficacy effects. This part accordingly addresses practical applications and feeding strategies (including the incorporation into commercial feeds, combination with other feed additives [prebiotics/probiotics]...), in particularly considering integrating probiotics for aquatic animal use would be an environmentally sustainable approach. The chapter concludes by discussing some of the challenges and future perspectives with respect to NEMs, such as safety concerns related to potential toxicity, compositional variability regulatory status, and consumer acceptance. Lastly, potential emerging trends and/or future directions are also discussed including new essential oil sources as well as other extraction methods like microwaving, blending strategies with existing therapies to improve efficacy of treatment for species that exhibit resistance towards available treatments along with encapsulation technologies for targeted delivery. In sum, this chapter highlights that only comprehensive and interdisciplinary collaborations will reveal the entire spectrum of research opportunities detailing functional feeds based on EOs for general applicability in sustainable aquaculture practices.

KEYWORDS		
Aquaculture, Essential oils, Sustainable growth promoters, Functional	Received: 18-May-2024 Revised: 15-July-2024 Accepted: 23-Aug-2024	A Publication of Unique Scientific Publishers

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INTRODUCTION

In the last few decades, aquaculture industry has grown at an impressive rate to meet seafood demand and overfishing of wild fish stocks. Despite the potential for substantial growth in an aquaculture Industry, sustainable and efficient development of marine aquaculture poses a significant challenge. Growth promotion is very important in achieving the desired maximum productivity, profitability and making it possible to meet the ever-increasing demands for aquatic products (Naylor et al. 2021). It is essential to accelerate aquaculture species growth-ons for numerous reasons.

Principally, by decreasing the production cycle and increasing productivity and economic feasibility of horticulture (Khanjaniand Sharifinia 2020). Second, better feed conversion results in less waste and reduces environmental impacts of wasted nutrients. Plus, growth promotion may also provide a higher quality and healthier product in the end that fits within consumers demands of sustainable seafood sources (Cooney et al. 2023). Historically, antibiotics and synthetic hormones have been administered to farmed aquatic animals as growth promoters. But there are also concerns over potential development of drug resistance, build-up of unhealthy residues in aquatic products and environmental and consumer health impacts (Mog et al. 2020). Owing to these limitations, there has been an increased focus on the scrutiny and regulations of some organic compounds used, hence leading to a need for safer or more sustainable alternatives.

The use of essential oils (EOs) are one such promising natural growth promoters in aquaculture, due to their multifunctional properties and proven potential towards growth performance, feed efficiency and health stimulus to cultured species (Qiu et al. 2024). EOs are volatile, fragrant oils extracted from many types of plant material including flowers, buds seeds leaves twigs bark herbs wood and roots. They have exhibited antimicrobial, antioxidant, immunomodulatory and appetite-stimulating abilities that might make them potential candidates to be functional feed additives in aquaculture arena (Tripathi et al. 2024). The application of functional feeds made with essential oil is more a promising method to induce growth and prevent the conventional limitations or concerns on traditional growth promoters in cultured species. The unique bioactive potential of essential oils could be harnessed to increase productivity, feed efficiency and the health status at farm level in a sustainable way within aquaculture (Grover et al. 2024).

Essential Oils and Their Bioactive Compounds

Essential oils are volatile, complex mixtures of chemical compounds originating from different parts of plants such as blossoms, buds/seeds (fruit), leaves and twigs; bark herbs fall into six categories according to the Botanical system Root. Such aromatic oils are normally extracted using various techniques including steam distillation, hydrodistillation, solvent extraction or cold pressing depending upon the plant material and spectra of oil to be obtained (Olalere et al. 2024). Steam distillation and hydrodistillation are two of the most popular methods, in which plant material is subjected to steam or boiling water (respectively) will cause volatile compounds to evaporate and then condense into essential oil (Pheko-Ofitlhile and Makhzoum 2024).

Essential oils contain a variety of different [sic] chemical constituents but mainly terpenes and phenolic compounds (Bakkali et al., 2008; Tongnuanchan and Benjakul, 2014). Monoterpenoids like limonene, α-pinene and β-pinene or sesquiterpenes are commonly found in essential oils which determine the unique scent profile of these extracts together with their pharmacological effects (Siddiqui et al. 2024). Also, some essential oils contain numerous phenolic compounds (e.g., caffeic acids; rosmarinic acid) and phenoilc diterpenes (e.g., carnosol, carnislic acd) which may contribute to a relevant content of these molecules in diet (Rastegarnejad et al. 2024). The essential oil and their bioactive compounds have a wide range of biotechnical potentials which could be useful in aquaculture. Most famously, they can kill off pathogens as a result of their ability to damage cell membranes, denature proteins and interfere with bacterial energy metabolism (Dawood et al. 2022). A number of essential oils, including oregano, thyme and clove oil are effective in killing a broad spectrum of pathogenic bacteria, fungi and viruses (de Almeida et al. 2023).

In addition, the antioxidant properties of essential oils can reduce oxidative stress and contribute to a healthier condition in fish. Essential oils have many constituents, and their antioxidant activity is primarily due to the phenolic ingredients which can exhibit free radical scavenging properties as well as inhibiting lipid peroxidation (Dawood et al. 2022). Furthermore, the immunomodulatory and anti-inflammatory effects of essential oils in addition to their stimulant effect on appetite would result in improved growth performance, feed utilization efficiency, health status etc. of aquatic species as reported by many authors (Mansour et al. 2024).

Due to the varied biological effects of essential oils and their bioactive components, they can be incredibly useful for incorporation into fish feed as functional additives in aquaculture which will again lead to advantages like improved growth performance,decreased severity from infectious diseases that mostly bring high mortality rate among cultured species (Hernández-Contreras and Hernández 2020).

Effects of Essential Oils on Growth Performance

Essential oils have been documented to enhance feed intake and appetite of several aquaculture species, thus improving growth performance (Bandeira Junior et al. 2022). Dietary ginger (Zingiber officinale) essential oil (GEO) supplementation significantly increased feed intake and weight gain in hybrid grouper Epinephelus lanceolatus ♂ × E. fuscoguttatus ♀ at higher doses compared to the control group (Adeli et al. 2021). Dietary black cumin (Nigella sativa) essential oil improves growth performance in Asian sea bass (Lates calcarifer) (Abd El-Hack et al. 2021). These effects have been considered as the reasons to explain why appetite-stimulating properties of essential oils could be mediated by evasion of olfactory or gustatory responses through aromatic features that can modulate levels and activities neuropeptides involved in regulating appetite (Nguyen et al. 2023). The inclusion of essential oils has allowed an increased nutrient digestibility and absorption in aquaculture species implying better growth performance (Dawood et al. 2022). For instance, Abdel-Latif et al. (2020) reveled that the addition of oregano essential oil (OEO) to diet enhanced nutrient digestibility while synthesis, mainly for dry matter, protein and energy in common carp feed were lower where results further reflected increment levels on growth performance values and FCR. The use of essential oils for modulating the gut microbiota and promoting intestinal health could indirectly affect growth performance in aquaculture species. Antimicrobial and anti-inflammatory effects of essential oils help in maintaining gut microbiota homeostasis, promoting intestinal integrity which improves nutrient absorption leading to good growth performance (Firmino et al. 2021).

Essential oils were also shown to enhance feed intake, improve nutrient digestibility and absorption, modulate gut microbiota composition, which are the factors that primarily lead their growth-promoting effects in aquaculture species. It should be noted, however, that the species-selective effects may depend on essential oil composition and inclusion level required to study in a more detailed manner than it was done previously.

Mechanisms of Growth Promotion

Some of the best growth promoters in aquaculture species are essential oils since these have strong antimicrobial and anti-inflammatory properties. Mechanism of essential oils in their antimicrobial activity Essential oils are quickly able to disrupt cell membranes, denature proteins and interfere with important cellular processes that the microorganisms can no longer survive (Angane et al. 2020). Furthermore, the anti-inflammatory effects of essential oils can counteract inflammation-induced metabolic disorders and enhance nutrient utilization favoring growth (Pezantes-Orellana et al. 2024). These metabolites secreted by the essential oils can affect digestive enzymes and nutrient transporters, resulting in increased digestion of nutrients (Su et al. 2020). A study by Alagawany et al. (2020 Oregano essential oil (OEO) dietary supplementation enhanced the activity of digestive enzymes such as amylase, protease and lipase in gibel carp (Carassius auratus gibelio), leading to increased growth performance. The effects of various chemically defined bioactive compounds found in EOs modulate secretion of digestive enzymes, nutrient transporter activity and stimulate enzymatic function, acting on specific cellular signaling pathway mediators regulating gene expression (Patra et al. 2019). Essential oils interact with numerous hormonal and metabolic pathways which ultimately leads to growth promotion in aquaculture species (Aanyu et al. 2020). Furthermore, according to some studies reported that essential oils have potential of modulating the growth hormone such as insulin-like growth factors (IGFs) and Growth Hormone (GH) (Ahmadifar et al. 2021). Researches concerning the trials of bitter orange (citrus aurantium) essential oil on growth indicators, histology and gene expression levels in cyprinus carpioessential oils have a positive effect on the generation level to improve weight gain with two key genes that are GH and IGF-1. Moreover, essential oils may change the metabolic pathway that ensures energy production, protein synthesis and lipid metabolism for better nutrient utilization efficiency which facilitate growth (Kisová et al. 2020). The growth promoting mechanisms of essential oils in aquaculture species are diverse and include antimicrobial, anti-inflammatory Action regulation of digestive processes involving the modulation hormonal metabolic pathways. These mechanisms synergize to increase feed intake, nutrient utilization and overall growth performance as well, making essential oils an interesting candidate for a functional feeds additive in the aquaculture industry.

Essential Oils for Specific Aquaculture Species

Freshwater species (carp, tilapia, catfish, etc.)

The growth-promoting effects of essential oils have been promising in other freshwater aquaculture species. Several reports have mentioned the effects of essential oils on growth performance, feed efficiency and nutrient utilization in carp species (Cyprinus carpio), danio (Danio rerio), grass carp (Ctenopharyngodon idella) common silver barb Barbonymus gonionotus while additives oregano oil Origanum vulgare, garlic Allium sativum or ginger Zingiber officinale are recommended for use (Faheem et al. 2022). Dietary supplementation with garlic, thyme (Thymus vulgaris), and fennel essential oils increase growth, feed conversion ratio and the expression of some immune related genes in Nile tilapia Oreochromis niloticus (Dawood et al. 2022). Similarly, black cumin (Nigella sativa) and cinnamon (Cinnamomum zeylanicum) essential oils have exhibited growth-promoting activities in African catfish Clarias gariepinus and channel catfish Ictalurus punctatus species (Alnahass et al. 2023).

Marine Species (shrimp, salmon, sea bass, etc.)

Volatile compounds ascribed to essential oils have also shown potential for growth enhancement of different marine aquaculture species. Plant-derived essential oils, usually garlic (Allium sativum), thyme (Thymus vulgaris) and origanum, have been experimented on growth performance, feed utilization and disease-resistance in Pacific white shrimp Litopenaeus vannamei White Shrimp (Aktaş et al. 2022 Several studies have already shown that essential oils from thyme, oregano and rosemary could increase growth rate, nutrient digestibility or gut health in european sea bass (Dicentrarchus labrax) and gilthead sea bream [Sparus aurata] juveniles (Yılmaz et al. 2022).

Considerations for different Life Stages and Production Systems

Before using essential oils as growth promoters in aquaculture, one should take into account the specific life stages and production systems. The inclusion levels of essential oils and the type to be incorporated will depend on species, life stage (larvae or juveniles) and production system used (intensive, semi-intensive or extensive); but only at a certain level can it benefit your business. In addition, factors such as water quality, temperature and feeding regime can affect the effectiveness of Eos (Kimera et al. 2021). For example, higher doses of essential oils may be required in intensive production systems with high stocking densities due to increased stress levels and potential for disease outbreaks (Maulu et al. 2021). For instance, because stocking density is higher and stress and potential for disease breakouts are also higher in intensive production systems, those animals might require more rounds of essential oils or at a stronger dose. In addition, the method of EO application (coated with feed encapsulated form; or directly added to water) and stability of compounds during skin processing and storage using are recommended as important considerations (Tolve et al. 2021). Well formulated and encapsulated essential oils can be used as bioenhancing agents to provide better stability, safety along with maximum benefit delivery in aquaculture feeds. In conclusion, the choice and use of essential oils as growth promoters in aquaculture should be adapted to each species, stage of life and culture system considering water quality conditions, feeding regimes especially during (stressful) events like transport or handling and ways to deliver them best to maximize their effects on growt performance (Reverter et al. 2021).

Factors Influencing Efficacy

Essential Oil Source, Composition, and Quality

The source, composition and quality of essential oils may exert significant impact on their efficacy as growth promoters in aquaculture. The plant species, geographical origin of the plants and harvesting time, extraction methods applied to obtain essential oils from them can greatly influence their chemical composition as well bioactive properties (Ni et al. 2021). The bioactivity of oregano essential oil (OEO) the main phytogenic feed supplement additive can vary due to differences in carvacrol and thymol concentrations (Bauer 2020). In low-quality essential oils, the presence of Adulterants, contaminants or degradation products diminishes their biological activities and can raise concerns over safety (Ali et al. 2023).

Dosage, Administration Method, and Feed Formulation

The effectiveness of essential oils as growth promoters in aquaculture is related to the dosage, administration route and feed matrix used. The appropriated level of essential oils could be changed by the type of target species, life stage and environmental status (Dawood et al. 2022). This can cause growth performance to have sub-therapeutic or in worse case, adverse effects due to over/underdosing (Parihar et al. 2022). Besides the above, bioavailability and stability of essential oils are also influenced by incorporation methods including direct addition to feed, encapsulation or delivery via water (Fathi et al. 2021). A correct feed formulation and processing methodology are necessary to obtain the homogeneous distribution, stability and retention of essential oils in aquafeeds.

Environmental Conditions (temperature, salinity, etc.)

In the aquaculture system essential oils are proposed as growth promoters but their role is influenced by several environmental conditions, water temperature, salinity and pH. The solubility and stability of essential oils depend on the type of EO, how they are stored, temperature exposure etc., which has a significant impact to their bioavailability or potency (Kimera et al. 2021). The whole process of a particular acids or bases is shown at the same time it expands over more an entire regional chemical environment like high saline water temperature, and aromatherapy essential oils would decrease in activity. Likewise, environmental stressors (e.g., high stocking densities or poor water quality) could also influence the growth performance and condition of aquatic organisms which may change their response to essential oils (Shourbela et al. 2021). These are important considerations when using essential oils as growth promoters in aquaculture. Detailed knowledge of essential oil profile and proper concentration, route of application as well the environmental factors are pre-requisite for exerting their maximum potential in growth performance and general health status maintenance of cultured species. Hence, systematic quality control and standardization of EOs product before application is necessary in order to ensure the consistency and reproducibility of performance as well as maintain consumers' confidence on its use for aquaculture industry (Kuebutornye et al. 2024).

Practical Applications and Feeding Strategies

Incorporation into Commercial Feeds or Top-dressing

There are various ways that essential oils can be mixed into commercial aquaculture feeds, and each way has its own set of benefits as well as drawbacks. Direct mixing of the oils or their encapsulated forms into feed at manufacture is one common means. This method guarantees a uniform dispersion of the essential oils in its feed and allows calibrated dosing. However, to preserve the stability of essential oils and prevent them from being deactivated or oxidized during feed processing and storage may still require specific equipment a technology (Beltrán and Esteban 2022). On the other hand, you can top-dress essential oils by either mixing them into feed or spraying/ coating on it. This protocol is uncomplicated and could be executed on-site, allowing freedom to change doses/formulations. However, top-dressing could lead to non-uniform distribution of volatile essential oils and subsequent losses during feed handling or transportation (Marimuthu et al. 2022).

Use in Combination with other Feed Additives (prebiotics, probiotics, etc.)

Phytogenics could be used in combination with other alternative feed additives i.e. prebiotics and probiotics that may help to improve the growth-promoting effects of such diets under field conditions. They can also modify the microbiota through the use of prebiotics (Mannan-oligosaccharides, MOS and Fructo-oligosacharides FOS) therefore helping to enhance nutrient utilization. When converted with essential oils (Anti microbial and Anti-inflammatory) than there activity can be synergized in combination which may improve the gut health, nutrient absorption leading to the overall growth performance of animals (Vijayaram et al. 2022). In the same way, probiotics, like lactic acid bacteria and Bacillus species can help to balance the intestine microbiota, bolster immune function and improve feed conversion efficiency in addition of essential oils. Nevertheless, the compatibility and possible interactions of essential oils with other feed materials should be investigated thoroughly to achieve the desirable beneficial effect without interfering in adverse manners (Dasriya et al. 2024). Additonaly, the use of essential oils as growth promoters may also be combined with other sustainable aquaculture practices such as Integrated Multi-trophic Aquaculture (IMTA) or fish feed plant protein inclusion (Knowler et al. 2020). A comprehensive approach combining EOFFs with other sustainable techniques can help aquaculture to achieve the high and profitable production of disease-free stock, reducing pollution from drugs in water bodies, improving fish welfare including stress reduction and increased yields. The practical use of essential oils in aqua feed is complex and involves aspects related to dosage type, compatibility with other substances added to the diet as well as its harmony with growth management. A holistic approach is essential to allow aquaculture producers to harness the potential growth-promoting effects of EO compounds, while continuing towards optimized outcomes for better sustainability and consumer acceptance in this sector.

Challenges and Future Perspectives

Potential Toxicity and Safe Dosage Levels

Although essential oils are generally promising as growth promoters in aquaculture, their toxic effects and safe therapeutic dose concentrations need to be verified. Some essential oils or their major constituents might show toxicity at higher levels, which in turn adversely impacts the growth, survival and health of the cultured species. In this regard, excessive levels of essential oils such as garlic (Allium sativum), thyme and oregano have been shown to induce oxidative stress, histopathological changes in gills and barrel by mortality mechanisms in various fish species. It is absolutely critical to set the optimal dose range and determine maximum tolerable levels of essential oils for each target species and life stage so that they can be safely applied at a field level. Moreover, the bioavailability of EO compounds in edible tissues should be considered to ensure food safety and regard economical regulations because their is always a possibility for Bioaccumulation (Ciji and Akhtar 2021).

Variability in Composition and Bioactive Compound Content

One of the drawbacks related to practical applications of essential oils in aquaculture consists on their natural dynamic process with an enormous variabilityaffecting both its composition and bioactive compound content. The chemical composition of essential oils is mainly related to their genetic origin, plant morphology and physiology as well as the concomitant environmental parameters where they grow such harvesting season or part of the plant used in extraction. This variability can be an impediment for the growth promoters properties of essential oils, given that inconsistent composition may result in inconsistency on their biological activities and performance effects (Dawood et al. 2021). It necessitates the development of standardized production methods, quality control measures and analytical techniques to maintain consistent composition and potency of essential oils. Future research should also be directed at the isolation, identification and characterization of bioactive compounds that can stimulate growth in order to create better formulations.

Regulatory Aspects and Consumer Acceptance

Consumer acceptance and regulatory guidelines for the use of essential oils as growth promoters in aquaculture. Although essential oils are mostly recognized as GRAS (general regarded safe) for human consumption, their use in aquaculture where they exhibit to be beneficial has not been yet approved together with specific maximum limits and/or regulatory obligations. Those regulations can significantly differ from one region to another, or even between country and country; therefore compliance with the local law is a must for each target market (Angane et al. 2022). In addition, to be commercially viable, it essential that consumers perceive and accept aquaculture products containing the functional feeds with natural sources of EOs. Consumers have started asking for transparency and minimal use of synthetic additives in the making of food. Communications and education campaigns are essential indicators of the benefits that attract shareholders, investors toward natural growth promoting with ESSENTIAL OILS (Meijer et al. 2021) In the future, studies should be designed to overcome those barriers conducting full toxicological inquiries developing standardized manufacturing and quality inspection practice working with regulatory organizations or stakeholders in order to draw appropriate guidelines on essential oils application in aquaculture. Moreover, investigating the promise of a combined effect between essential oils to be used in combination with other botanicals or aquaculture practices may help improve their growth-promoting properties and sustainability. ConclusionBy confronting such challenges and harnessing the untapped potential of essential oils as natural growth promoters, aquaculture sector could put itself in a setting for more sustainable ecological friendly practices that will be necessary to deliver high-quality seafood meets without compromising on environmental impact which is vital if it wishes to instill consumer confidence.

Emerging Trends and Future Directions

Novel Essential Oil Sources and Extraction Methods

Novel plant sources and a charge in the extraction technique for essential oils especially are expected to have great potential within aquaculture. Essential oils derived from underutilized or lesser-known plant species are assessed by different research groups for their growth-promotional properties in multiple aquaculture species. This diversification of essential oil sources can unveil new effective bioactive compounds present in the oils or it may provide unique synergistic combinations, thus increasing their efficacy as growth promoters. Moreover, advances in extraction technologies such as supercritical fluid extraction (SFE), microwave-assisted extraction (MAE), and ultrasound-assisted extraction have shown potential to enhance essential oil yield, quality or selectivity of the compounds involved. This has particular relevance for the modern aquaculture and food industry by providing novel extraction techniques that will help to retain bioactive compounds, decrease thermal-based degradations as well as drastically reduce harsh solvent uses which also fits within sustainable development goals (SDB) in this sector.

Combination Strategies and Synergistic Effects

Synergistically combining different essential oils or with other natural feed additives is a fresh avenue in aquaculture research. Other studies have shown that prebiotics, probiotics or plant derived compounds combined with essential oils may further stimulate changes in the gut bacterial population due to synergistic effects (Mekonnen et al. 2024).

Encapsulation and Targeted Delivery Systems

Rising interest includes employing encapsulation and targeted delivery systems as potential strategies to improve the efficiency and bioavailability of essential oils in aquaculture feeds. Encapsulation (e.g. emulsification, liposome entrapment and nanoparticle encapsulation) can provide the essential oils with a barrier against oxidation in feed form or during storage as well benefit to control release at target location. Additionally, these delivery vehicles have the potential to enhance essential oil stability and solubility while improving their bioavailability thereby facilitating its targeted action across gastrointestinal sites in aquatic animals. Besides, targeted delivery of essential oils can allow reduction in the dosing levels and alleviation of interactions with other feed components resulting ultimately to optimize growth-promoting effects. Continuous research is being carried out for developing nanoparticle technologies, utilizing carriers to enhance retention and encapsulation loading of essential oils and in the applications with different aquaculture species production. The search for new essential oil sources, the combination of several plant-derived compounds or adjustable and efficient delivery systems represent a strong promise to improve growth promotion with limited impact on the environment in context of aquaculture production towards future sustainability including consumers' application issues about synthetic additives.

Summary of Key Findings

Abstract The application of essential oil-based functional feeds is being regarded as a potential solution for growth in aquaculture species. From different plant origins, essential oils contain a large number of bioactive compounds with antimicrobial, antioxidant, immunomodulatory and orexigenic potential. In various freshwater and marine aquaculture species, the use of these natural agents has shown to support growth performance as well feed efficiency, nutrient utilization and thereby obtained better overall health.

Key mechanisms by which essential oils promote growth include, their antimicrobial and anti-inflammatory effects; alterations in secretions of digestive enzymes and nutrient transporters… hormones pathways, metabolism etc.mapping are described about various EOs possession. The efficiency of volatile plant oils, especially natural ones can be varied from several factors including origin and chemical profile off the essential oiler; dosage in administration method feed formulation an environmental situations.

Potential Applications in Sustainable Aquaculture

Functional feeds, with essential oil as one of the functional ingredients reported numerous beneficial effects in terms of sustainable aquaculture practices. These are commonly used as direct fed microbial in animal feed:Direct-fed microbials (DFM) and have been sought after, both for their potential use to promote intestinal health within the host enteric system. In addition, combining essential oils with other sustainable approaches including plant-based protein sources and integrated multi-trophic aquaculture (IMTA) may help support a more general sustainability of the entire industry. The role of essential oils in efficient growth and feed utilization, coupled with an environmental performance aspect (decrease excessive feed waste; lower nutrient discharge), would help the sector to become more sustainable over a longer-term. Natural and sustainable perceptions may also be a motivation for consumer acceptance of these products, with potential high demand in this very active area which has long been pushing the industry to adopt more eco-friendly alternative feed ingredients.

Future Research Opportunities and Collaborations

By all means, essential oils have shown to be viable growth promoters in aquaculture till now much progress has been made and an array of research opportunities together with collaboration exist yet to never unveil. Rigorous toxicology studies and determination of safe dosages at the specific oil-calibrant-species matrix level will be essential for their successful applications under regulatory scrutiny. In addition, research activities should be targeted to establish standardization of production processes and QC measures as well as the analysis methods that will cope with the diversity in EO composition or content. Academic–industrial (as well as regulatory) partnerships might help to translate this work into concrete guidance for the use of essential oils in aquaculture. Innovative ideas for future studies are exploiting unutilized EO sources, combinatorial strategies with other natural feed additives like prebiotics and probiotics, designing the next-generation encapsulation systems and targeted delivery platforms. These progressions may serve to increase the effectiveness, bioavailability and site-specific delivery of EOs leading them more potent in enhancing the growth-conducive effects [44]. To support these research efforts intensive interdisciplinary-work with experts in plant sciences, analytical chemistry, animal nutrition as well as aquaculture production and regulatory affairs will be essential. These interactions may lead to the sharing of information and resources which, in turn, can facilitate sustainable practices with regard to environmental concerns as well as consumer interests (e.g., seafood demand) on a global scale.

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Chapter 24

Uses of Various Essential Oils along their Anti-Biofilm Potential in Poultry

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ABSTRACT

Plant-based essential oils have been recognized and fascinated people for ages for their aromatic and volatile compounds. This abstract study looks at certain essential oils in detail, covering their uses, geographical origins, historical and cultural significance, extraction techniques, and antibiofilm applications. These oils have played important roles in traditional medicine, religious rituals, and cultural practices throughout history. The volatile compounds in plant materials are carefully preserved by selecting the right extraction methods like solvent extraction, steam distillation, and cold pressing that guarantee the potency and integrity of the finished product. These oils are widely used in aromatherapy, skincare, and have both medicinal and non-medicinal uses. This book chapter provided insight antimicrobial, anti-inflammatory, and antioxidant properties while supporting health and well-being through the formation of pathogenic biofilms in poultry.

KEYWORDS Biofilm, Essential Oils, Extraction, Medicinal, Non-medicinal, Poultry	Received: 22-Jun-2024 Revised: 28-Jul-2024 Accepted: 14-Aug-2024	A Publication of Unique Scientific Publishers

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INTRODUCTION

Plant-based essential oils have been recognized and fascinated people for ages for their aromatic and volatile compounds. Essential oils from more than 500 plants are extracted and used for different purposes (Moazzam et al., 2018). These oils have played important roles in aromatherapy, skincare, and have both medicinal and non-medicinal uses. Nowadays, their applications are also seen in poultry, fish and livestock. This book chapter is covering different essential oils such as almond, basil, black paper, chamomile, clove, coffee, eucalyptus, garlic, and fenugreek with reference to uses, geographical origins, historical and cultural significance, extraction techniques, and their antibiofilm potential particularly in poultry.

Almond Oil

Almond trees are scientifically known as *Prunus dulcis* and are a rich source of almond oil (Sana et al. 2021). The plant has two species. *Prunus dulcis* is one which can be cultivated and sweet in taste while, its other species is wild and bitter in taste (Delplancke et al., 2012). The trees are native to the Middle East and South Asia (Chalak 2013). Its origin is from central Asia and from where it was shifted to all old civilizations such as Asia, Europe and Africa. However, nowadays, these are also cropped in Mediterranean, California, and parts of Asia. Additionally, these are also cropped in the Southern Hemisphere, including Chile, Argentina, South Africa, and Australia (reached in 1800) (Wirthensohn and Iannamico, 2017).

Historical Importance

Almonds have a long history of cultivation and usage, dating back thousands of years (Delplancke et al. 2013). They were highly prized by ancient civilizations such as the Egyptians (Kiple and Ornelas, 2000), Greeks (Diekman and Chelf, 2017), and Romans for their nutritional value and versatility (Gradziel, 2011). The first proof of the occurrence of wild almonds during the Pleistocene era (7.8×10^5 BCE) came from Israel. Almonds hold significant cultural importance in many societies, often symbolizing fertility, prosperity, and good fortune. In some cultures, almonds are used in wedding ceremonies and other celebrations as a symbol of blessings and abundance (Gradziel, 2017).

Extraction Methods

Several advanced and mechanical methods are in practice to extract almond oils (Table 1).

Table 1: List of essential oils with the most common extraction methods

Sr. No.	Plant	The most common Extraction Methods	References
1.	Almond oil	1. Cold-pressing or soxhlet extracted methods 2. Hydraulic press or screw press 3. Ultrasonic-assisted extraction, supercritical fluid extraction, subcritical fluid extraction, and salt-assisted aqueous extraction	Al Juhaimi et al., 2018; Barreira et al., 2019; Ouzir et al., 2021; Shrestha, 2022
2.	Basil Oil	1. Solvent-free microwave extraction (SFME). 2. Solvent extraction, hydrodistillation, and steam distillation.	Charles and Simon, 1990; Chenni et al., 2016; da Silva, et al., 2022
3.	Black paper	1. Steam distillation 2. GC-MS	Aziz et al., 2012; Balasubramanian et al., 2016
4.	Chamomile	1. Steam distillation	Singh et al., 2017
5.	Clove	1. Steam distillation 2. Hydro distillation, ultrasound-assisted extraction, microwave-assisted extraction, cold pressing, and supercritical fluid extraction	Haro-González et al., 2021
6.	Coffee	1. Cold-pressing or solvent extraction methods 2. solid–liquid and liquid–liquid extraction, ultrasound, microwave, supercritical fluid, subcritical water, pulsed electric field, and fermentation	Bondam et al., 2022
7.	Eucalyptus	1. Steam distillation	Galadima et al., 2012; Kidane, 2016
8.	Garlic	1. Steam distillation or cold pressing.	Abe et al., 2020
9.	Fenugreek	1. Cold pressing or steam distillation	Sarwar et al., 2020; Raza et al., 2022

Chemical Composition

The chemical composition of various oils is given in Table 2.

Table 2: List of essential oils their composition and applications

Sr. No.	Plant	Composition	Applications	References
1	Almond oil	Diverse types of Fatty acids (mainly oleic acid), tocopherol and phytosterol content.	1. Oxidative stress reduction 2. Cardiovascular risk management 3. Glucose homeostasis, 4. Neuroprotection, and many 5. Cosmetic and dermatologic applications	Ahmad, 2010; Chalak, 2013; Lin et al., 2017; Mohiuddin, 2019; Ouzir et al., 2021; Flores-Balderas et al., 2023; Selwyn and Govindaraj, 2023
2	Basil Oil	Diverse types of Fatty acids, antioxidant compounds and carbohydrates	1. Treatment of kidney problems 2. Treatment of colds and malaria 3. Oxidative stress reduction 4. Cardiovascular risk management 5. Anti-cancer and antimicrobial activity 6. Therapeutic applications 7. Aromatic qualities 8. Insecticide	Gebrehiwot et al., 2015; Poonkodi, 2016; Shahrajabian et al., 2020
3	Black paper	Various types of Terpenoids and caryophyllene, sabinene and terpinen-4	1. Used as preservative and biocontrol agent 2. Excellent antioxidant potential 3. Anti-fungal and anti-amoebic activity 4. Treatment of diabetic and asthmatic problems	Lee et al., 2014
4	Chamomile	Terpenoids, flavonoids, coumarins, phenolic acids, tannins, and phytosterols	1. Oxidative stress reduction 2. Antimicrobial agent 3. Anti-hypertensive, anti-allergic and anticancer activity	Sah et al., 2022
5	Clove	Eugenol, eugenyl acetate, β-caryophyllene, and α-humulene.	1. Anti-inflammatory and analgesic activity 2. Anticancer activity	Haro-González et al., 2021

6	Coffee	Fatty acid (mainly linoleic acid and palmitic acid), aldeydes, ketones, pyrroles, furans, pyrazines, pyridine, flavonoids and phenolic compounds	1. Antioxidant agent 2. Wound healing 3. Cosmetic and pharmaceutical industries	Calligaris et al., 2009; Dias et al., 2023
7	Eucalyptus	Terpenes, aromatic phenols, alcohols, oxides, ethers, esters, aldehydes and ketones such as Eucalyptol, *p*-cymene, *α*-pinene, β-myrcene, γ-terpinene and citronellal,	**1.** Used as Biopesticides in agricultural field **2.** As drugs in pharmaceutical industries **3.** As flavorants in food industries **4.** Antioxidant agent **5.** Treatment of bronchial infection	Almas et al., 2021; Čmiková et al., 2023
8	Garlic	Allyl polysulfides	1. Oxidative stress reduction 2. Antimicrobial activity 3. Antihypertensive and antihyperlipidemic activity 4. Anticarcinogenic and immunomodulatory properties	Satyal et al., 2017; Verma et al., 2023
9	Fenugreek	**S**aponins, alkaloids, flavonoids, and essential fatty acids	1. Managing diabetes 2. Cardiovascular diseases 3. Hyypercholestermi 4. Improve lactation in breastfeeding mothers, and boosting libido 5. Culinary applications	Khorshidian et al., 2016; Murad et al., 2019; Shukla et al., 2019; Shahrajabian et al., 2021; Joshi et al., 2022; Singh et al., 2022

Applications

The emollient and moisturizing qualities of almond oil makes them fit for skincare products to help hydrate and nourish the skin (Chalak, 2013; Mohiuddin, 2019; Selwyn and Govindaraj, 2023) (Table 2).

Antibiofilm Activity

The antibacterial effect of almond oil is also reported against many biofilms forming Gram positive and Gram-negative species and its use is particularly recommended in poultry feed for good health of the birds and control of various bacteria such as *L. monocytogenes* and *S. Enteritidis* (Somrani, 2020; Mezher et al., 2022; Movahedi et al., 2024).

Basil Oil

The leaves of the basil plant are used to make basil oil. This plant is known by its scientific name, *Ocimum basilicum* (Bilal et al., 2012; Ch et al., 2015; Pettman, 2010; Pushpangadan and George, 2012). It is a member of the *Lamiaceae* family, and well-known by the name "king of herbs" (Dudai et al. 2020). There are more than 150 species of the genus Ocimum of basil that are grown all over the world (Poonkodi, 2016). Basil is native to tropical regions of Asia and Africa (Ch et al., 2015) but is now cultivated worldwide, particularly in Mediterranean countries, Turkey and Southeast Asia (Tilebeni, 2011; Yıkmış et al., 2017).

Historical Importance

Basil has a long history, and it was frequently used by ancient Egyptian, Indian, and Greek civilizations. For centuries, people have prized it for its culinary and therapeutic properties (Renfrew and Sanderson, 2012). It has cultural significance in many societies and is frequently connected to spirituality, love (Italy), and protection. It is used in religious burials and ceremonies and is regarded as a blessed herb in some cultures (India) (Dudai et al. 2020; Pettman, 2010).

Extraction Methods

Several advanced and mechanical methods are in practice to extract basil oils (Table 1).

Chemical Composition

The chemical composition of various oils is given in Table 2.

Applications

Basil oil is effective in fighting infections and promoting immunological health due to its antibacterial, antiviral, antifungal, and antioxidant properties (Poonkodi, 2016; Parham et al., 2020; Sharafati-Chaleshtori et al., 2021; Zagoto et al., 2021) (Table 2).

Antibiofilm Activity

Basil oils have also potent bactericidal effects against *Pseudomonas aeruginosa* with 99.9% growth reduction and inhibiting virulence besides eradicating all stages of biofilm development and applicable in poultry as well (Pejčić et al., 2020; Oliveira et al., 2024). In chickens, basil oil has demonstrated promise as an anti-biofilm agent, especially against harmful bacteria like *Salmonella* and *E. coli*. Its bioactive ingredients help in lessening the bacterial colonization in the poultry intestine by preventing biofilm formation, which enhances general health and lowers the risk of illnesses. Relying less on artificial antibiotics and preserving poultry hygiene are two benefits of this natural intervention (Marzlan et al., 2023).

Black Pepper

Black pepper (*Piper nigrum)* is an important member of the piperaceae family. Its dried fruit is used to obtain black pepper oil (Milenković and Stanojević, 2021). It is also referred to as the "king of spices" and is well-known for many health advantages, spicy taste and scent (Umarkar et al., 2011; Hammouti et al., 2019; Takooree et al., 2019; Spence, 2024). It is one of the oldest spices in the world (Krishnamoorthy and Parthasarathy, 2010; Bosland et al., 2012). It is indigenous to the Indian subcontinent (Divakaran et al., 2018; Hammouti et al., 2019; Kumar et al., 2021). Along with Southeast Asia, Africa, and Latin America, it is also cultivated in tropical regions (26 nations) (Yang et al., 2017; Nair, 2020; Tripodi et al., 2021). Reed and Leleković, (2019) reported its status as an alien species in Pannonia.

Historical Importance

For millennia, black pepper s considered as culinary and therapeutic assets (Bosland et al., 2012; Shaffer, 2013). Ancient societies like the Greeks, Romans, and Egyptians valued it high and utilized it as a spice and a kind of money (Hammouti et al. 2019). This is typically connected to warmth, vibrancy, and prosperity and has cultural importance to ward off evil spirits and provide good fortune in many countries.

Extraction Methods

Several advanced and mechanical methods are in practice to extract black pepper oils (Table 1).

Chemical Composition

The chemical composition of various oils is given in Table 2.

Applications

Black pepper oil is useful for reducing pain and inflammation (Adiani and Variyar, 2020). It is also utilized to enhance circulation, increase metabolism, and support digestive and cardiovascular health (Yang et al. 2019; Wang et al., 2021) (Table 2).

Antibiofilm Activity

Beneficial effects of black pepper as essential oils have been reported to show its potential use as an efficient anti-virulence strategy against prolonged *S. typhi, and L. monocytogenes* infections in poultry (dos Santos et al., 2020). Black pepper, and their common constituent cis-nerolidol at 0.01 % markedly inhibited *S. aureus* biofilm formation (Lee et al., 2014).

Chamomile Oil

The chamomile belongs to the Asteraceae family of plants. Chamomile oil is harvested from their blooms (Srivastava et al., 2010; Menge et al., 2016). It's a little shrub with fluffy leaves and flowers that resemble daisies. *Matricaria chamomilla* and *Chamaemelum nobile* are the names of two of its variations (Sharafzadeh and Alizadeh, 2011; Sah et al., 2022). It was originated in Europe and Western Asia and currently grown all over the world, especially in temperate climates with lots of sunshine and well-drained soil (Menge et al., 2016).

Historical Importance

It has a long history of use in traditional medicine and folk remedies. It was highly valued by ancient civilizations such as the Egyptians, Greeks, and Romans for its medicinal properties (Heinrich et al., 2012; Saheedha, 2019; Mekhlfi, 2023). It holds cultural significance in many societies and is often associated with relaxation, tranquility, and healing. In some cultures, chamomile tea is used as a soothing beverage to promote restful sleep and calm the nerves (Antol, 1995; Hosen and Madhu, 2023).

Extraction Methods

Several advanced and mechanical methods are in practice to extract chamomile oils (Table 1).

Chemical Composition

The chemical composition of various oils is given in Table 2.

Applications

Patients who take chamomile oil report feeling less stressed, more relaxed, and less depressed and anxious. To reduce skin irritations, itching, and speed up the healing of wounds, resole menstrual issues, it is also used topically (Martins et al., 2009; Sharafzadeh and Alizadeh, 2011; Gad et al., 2019) (Table 2).

Antibiofilm Activity

In poultry, chamomile oil has an anti-biofilm function, and it help in improving chicken health and lowering bacterial infections, this may lessen the demand for antibiotics in chicken production. Antibiofilm and anti- QS activity of chamomile is also reported in poultry and livestock (Ibrahim, 2017).

Clove Oil

The clove tree, (*Syzygium aromaticum*) is a member of the Myrtaceace family (Cortés-Rojas et al., 2014; Kaur and Kaushal, 2019). Its clove oil is derived from flower buds (Kaur and Kaushal, 2019). It is well known for its spicy scent and many health advantages (Kumar et al., 2012; Poornima et al., 2022). The clove trees are native to Indonesia's Maluku Islands (Sundari et al., 2019), presently they are also grown in tropical climates across the globe, such as Tanzania, Madagascar, India, and Sri Lanka (Charoonratana, 2022; Poornima et al., 2022).

Historical Importance

Clove has been utilized in both traditional medicine and cooking from prehistoric times (Otunola, 2022). It is highly prized in ancient cultures such as Greeks, Romans, and Chinese, for its fragrant and therapeutic characteristics (Giannenas et al., 2020). It is commonly connected to healing, purification, and protection and has cultural significance in many countries to draw in good energy and ward off bad energy (Izzah et al., 2018).

Extraction Methods

A few advanced and mechanical methods are in practice to extract clove oils (Table 1).

Chemical Composition

The chemical composition of various oils is given in Table 2.

Applications

For its antiseptic qualities, clove oil is applied topically to treat toothaches, sore gums, and oral infections (Hosseini et al., 2011; Bhowmik et al., 2012). It is also used in treating headaches, rheumatoid arthritis, and muscular aches (Milind and Deepa, 2011; Esmaeili et al., 2022; Ugbogu et al., 2022; Yadav et al., 2022) (Table 2).

Antibiofilm Activity

Clove oil has been shown to have promising antibiofilm properties against bacterial species. The oil has been reported to induce alteration in individual bacterial cells length and visible increase of their roughness and it was speculated that Clove essential oil seems to discharge exopolysaccharides from bacterial biofilm and inducing bacterial detachment from the surface. Due to anti-*A. acidoterrestris* biofilm activity, the clove oil showed potential to hinder a development of *A. acidoterrestris* biofilms on production surfaces in food industries (Kunicka-Styczyńska et al., 2020). The vivid antibiofilm effect of clove oil was also observed against *E. coli* O157:H7, *P. aeruginosa,* and *A. hydrophila* (Kim et al., 2016; Hussain et al., 2017). Clove oil have significant potential to inhibit the bacterial biofilm formation and reduce the virulence factors of the pathogens in poultry (Liu et al., 2022).

Coffee Oil

The Coffe plant is a member of the *Rubiaceae* family, and its roasted seeds, or coffee beans, are used to make coffee oil (ALAsmari et al., 2020). It has two varieties such as *Coffea arabica* and *Coffea canephora* (Anzueto et al., 2005; Lim and Lim, 2013; Dulmini, 2023). It is highly valued for its multifaceted health and skincare benefits, as well as its deep flavor and rich aroma (Esquivel and Jimenez, 2012; dos Santos et al., 2021; Sharmeen et al., 2021). Although coffee trees are native to tropical parts of Asia and Africa. However, it is also grown in many equatorial countries, such as Brazil, Colombia, and Vietnam (Wintgens, 2012; DaMatta, 2018). *Coffea arabica* is particularly famous in Ethiopia (Sisay, 2018).

Historical Importance

Coffee has a long history as in Yemen and Ethiopia it was famous for its use even from sixth century (Fregulia, 2019; Yılmaz et al., 2019). It is culturally significant and is linked to vitality, productivity, and socializing. In various cultures it is an essential component of everyday life, signifying friendliness and unity (Topik, 2009; Yoseph, 2013; Duressa, 2018; Bacha et al., 2019; Purnomo et al., 2021).

Extraction Methods

A few advanced and mechanical methods are in practice to extract black pepper oils (Table 1).

Chemical Composition

The chemical composition of various oils is given in Table 2.

Applications

According to Del Castillo et al. (2019), coffee oil is thought to possess antioxidant qualities that help shield cells from oxidative damage and lower the risk of chronic illnesses (Table 2).

Antibiofilm Activity

Extraction of green coffee beans and robusta coffee beans showed Inhibitory activity and biofilm degradation (Wicahyo et al., 2024). Coffee beans have also been found to show anti-bacterial and antibiofilm agents against multi drug resistant bacteria (extended-spectrum beta-lactamase (ESBL) and methicillin-resistant *Staphylococcus aureus* (MRSA)-positive biofilm-forming strains of *Pseudomonas aeruginosa* (P. aeruginosa), *Escherichia coli* (*E. coli*), and *Staphylococcus aureus* (*S. aureus*) obtained from foot ulcers) in Diabetes-related complications such as diabetic foot infections (Zubair, 2024). It was proven a good ingredient for the broiler chickens' live body weight, feed conversion ratio, and pathogenic bacterial counts were all increased when given 2.5 g/kg of green coffee powder (GCP). GCP changed the color characteristics and raised pH to improve the quality of meat. Moreover, coffee oil may help to improve the health and performance of chickens by reducing pathogen biofilms (Ashour et al., 2020).

Eucalyptus Oil

Eucalyptus trees are one of evergreens plant (Sunder, 1993). Different types of eucalyptus trees are used to produce eucalyptus essential oil. There are around 900 species in the genus Eucalyptus (Dhakad et al., 2018). *Eucalyptus globulus*, *Eucalyptus radiata*, and *Eucalyptus citriodora* are the three most common species that are well known. It is cropped at various places although, it is native to Australia. Origins Geographically Native to Australia, eucalyptus trees flourish there in a variety of habitats (Trivedi and Hotchandani, 2004). They are grown for a variety of uses after being brought to other regions of the world, including North and South America, Europe, and Asia (Paine et al., 2011).

Historical Importance

The leaves of eucalyptus have traditionally been used as medicine by Indigenous Australian cultures. They used them as insect repellents, wound treatments, and remedies for respiratory problems (Khan et al., 2020; Oke et al., 2021). The significance of the tree is both social and economic (Turnbull, 2000).

Extraction Methods

Several advanced and mechanical methods are in practice to extract eucalyptus oils (Table 1).

Chemical Composition

The chemical composition of various oils is given in Table 2.

Applications

It facilitates easier breathing, it can be incorporated into steam or utilized in chest rubs (Shao et al., 2020; Sudradjat, 2020). It can be used as antiviral, antifungal, antibacterial, and insecticidal (Trivedi and Hotchandani, 2004; Zhang et al. 2010; Sebei et al. 2015; Mieres-Castro et al., 2021) (Table 2).

Antibiofilm Activity

The antibiofilm effects of *Eucalyptus globulus* oil have been reported to be due to its main component 1,8-cineole, against MRSA, as well as their anti-Quorum sensing potential also noticed high (Balhaddad and AlSheikh, 2023). The activity of *Eucalyptus globulus* leaves is also reported against multi drug resistance bacteria in poultry (Ullah et al., 2021). In chicken, eucalyptus oil may prevent and interfere with the production of biofilms which reduces the load of harmful microorganisms and possibly improves the poultry’s health. Because of its antibacterial qualities, poultry environment may operate better overall and be cleaner.

Garlic Oil

The Allium sativum plant belongs to the family *Alliaceae*. Its bulbs are used to extract garlic oil. It has a long history and is used both for culinary and medicinal contexts (Satyal et al., 2017; Miri and Roughani, 2018; Saif et al., 2020). Garlic is indigenous to northern Iran and Central Asia (Shaaf et al., 2014; Sarpaki, 2021). However, China, India, Egypt, Russia, and the Mediterranean region are among the many places in the world where it is commonly farmed (Cavagnaro and Galmarini, 2007; Dhall et al., 2023). Garlic and its derivative products, such as garlic oil, are mostly produced in these regions.

Historical Importance

Garlic cultivation dates to than 5,000 years (Parreño et al., 2023). Many different cultures have placed a high value on garlic. Garlic was prized for its therapeutic qualities by ancient societies like the Egyptians, Greeks, Romans, and Chinese, who used it to cure anything from infections to stomach problems. Additionally, it was thought to protect workers from evil spirits and provide them stamina and vigor (Omar et al., 2007; Sarpaki, 2021). According to Ezeorba et al. (2022) it has been linked to energy, healing, and protection. Garlic is sometimes put under pillows to induce pleasant dreams or hung outside dwellings to fight off evil spirits (Rivlin, 2001).

Extraction Methods

Several advanced and mechanical methods are in practice to extract garlic oils (Table 1).

Chemical Composition

The chemical composition of various oils is given in Table 2.

Applications

Several studies (Fialová et al., 2016; Miri and Roughani, 2018; Espinoza et al., 2020) report on its antimicrobial, antifungal, antiviral, and anti-inflammatory qualities (Table 2)

Antibiofilm Activity

Garlic oil has been reported to inhibit *S. typhimurium* biofilm and could be applied in the food and poultry industry (Morshdy et al., 2022; Robinson et al., 2022). Garlic oil improves sensory qualities and successfully lowers coliform counts in chicken meat; a 1.5% concentration yields the best outcomes. Its antibacterial qualities help to improve the safety and quality of meat while it is being stored (Wafy et al., 2019). Similarly, nanoemulsion of garlic oil in water dramatically inhibited *L. monocytogenes* biofilm development (Liu et al., 2024).

Fenugreek Oil

Trigonella foenum-graecum, is scientific name of Fenugreek and a member of the *Fabaceae* family. It is an annual crop with small yellowish white flowers and a source of fenugreek oil Çamlýca and Yaldýz, 2019; Sarwar et al., 2020). It has a unique flavor and scent, and for ages, people have used it in food and medicine (Singh et al., 2022). Its origin is from the Mediterranean region, specifically Egypt and Greece. However, now it is widely grown in many nations with suitable climates, such as India, China, and Morocco (Hilles and Mahmood, 2021).

Historical Importance

Fenugreek was found in the writings of the ancient Greek, Roman, and Egyptian civilizations, demonstrating its great historical relevance (Kumar, 2019). In many cultures, it represents fertility, prosperity, and purity (Godara et al., 2017). Its seeds are frequently used to bring good fortune and blessings into rites and ceremonies, especially those pertaining to marriage and childbirth.

Extraction Methods

A few advanced and mechanical methods are in practice to extract Fenugreek oils (Table 1).

Chemical Composition

The chemical composition of various oils is given in Table 2.

Applications

Fenugreek oil has been used historically to treat a wide range of illnesses, including skin diseases, inflammation, and digestive disorders (Yusharyahya, 2020). It also helped in hypercholesterolemia, diabetes, cardiovascular disease, lactation improvement in nursing moms, and increased libido, according to research (Shahrajabian et al., 2021; Singh et al., 2022).

Antibiofilm Potential of Fenugreek

Fenugreek seeds have been reported to show antibacterial activities against pathogenic bacterial strains as well as anti-cancerous activity (Shapiro et al., 2001; Sharief and Gani, 2004). The seed extract has also a high potential in preservation of meat (Daneshniya et al., 2023). Fenugreek has strong antibiofilm qualities and is useful in treating biofilm-related diseases in chicken. It is a viable substitute for industrial chicken raising due to its easier availability and cheaper cost.

Conclusion

This book chapter offers valuable insights into the importance of various essential oils, their extraction methods, and applications, particularly focusing on glimpses of their anti-biofilm potential in poultry. The study highlights that essential oils such as clove, garlic, and basil have demonstrated strong anti-biofilm capabilities in poultry feed. By inhibiting biofilm formation, these oils can reduce illnesses caused by pathogens, contributing to better poultry health.

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Chapter 25

Therapeutic Potential of Coconut Oil and Amla Oil in Clinical and Sub Clinical Mastitis

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ABSTRACT

Mastitis is the Inflammation of Parenchyma of Mammary gland. There are two types of mastitis Clinical and subclinical. In clinical mastitis there are visible changes in the udder. In subclinical mastitis there is no visible change in the udder. Subclinical mastitis is one common problem in the dairy industry. It can be diagnosed by Laboratory diagnosis. In field condition mostly surf field mastitis test is used in country like Pakistan. Antibiotics are used to treat subclinical mastitis like Tylosin, Amoxicillin, Enrofloxacin, Penicillin, and Oxytetracycline. Due to emergence of antibiotics residue ethnoveterinary therapy can also be used to treat mastitis. In our study we see the effect of Coconut oil and Amal oil in treatment of mastitis. Coconut oil and Amal oil in Combination give good results. Coconut oil has better results than Amal oil in your Study.

KEYWORDS
Mastitis, Antibiotics, Ethnoveterinary therapy

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INTRODUCTION

Primary source of economic output for Pakistan is basically and primarily depends upon agricultural production. Socioeconomically Pakistani population is associated with agricultural industry. Pakistan ranks fifth in world milk production index. Livestock in Pakistan includes cattle, Buffalo, Sheep and Goat and their variants. The main purpose of livestock is to produce high quality meat, milk and wool (Rehman et al., 2017). Mastitis, Anthrax, Foot and mouth infection, Rabies, Lumpy skin disease Tetanus and Hemorrhagic septicemia are the major domestic animal diseases and most normal managemental sickness of animal.

Mastitis is associated with inflammation of parenchyma of mammary glands (Rizwan et al., 2022). Causes include multiple etiological agents, such as bacteria, viruses, fungi and yeast results in substantial economic losses in the dairy industry (Goulart and Mellata et al., 2022). Decreases milk production as well as causes undesirable changes in the milk composition (Grispoldi et al., 2019). Mastitis can manifest as either clinical or subclinical forms. Clinical mastitis is described by observable changes in milk, such as a change in color, consistency, or the presence of clots and flakes, with swelling and discomfort in the udder (De Vliegher et al. 2018). Subclinical mastits is the most prevalent managemental disorder of dairy industry (Viguier et al., 2009; Bobbo et al., 2017). During Sub-clinical mastitis milk production lessens by 10-26% (Dhakal et al., 2007). The mammary gland serves as the primary reservoir for these infectious agents, thereby increasing their prevalence in cases of mastitis. The incidence of contagious pathogens in mastitis cases is significantly higher compared to other causative factors. *Staphylococcus aureus, Streptococcus agalactiae*, *Streptococcus dysgalactiae*, *Escherichia Coli*, and *Corynebacterium pyogenes*, are repeatedly isolated from infected milk of sub-clinically mastitis lactating dairy animals (Rizwan et al., 2021; Qureshi et al., 2023). Subclinical mastitis is more prevalent in early-stage lactation animals than the animals that are in mid lactation stage (Abegewi et al., 2022).

The etiology of clinical mastitis is multifactorial with husbandry, management, feeding and hygiene as influencing factors (Gerjets et al. 2011). Coliform microbes cause up to 80% mastitis (Fahim et al., 2019).

The prevalence of both types of clinical and subclinical mastitis was observed to be greater in the hindquarters compared to the forequarters, and within the hindquarters, the left side exhibited a higher susceptibility compared to the right side. Laboratory tests and clinical signs can be used to detect mastitis. The clinical signs of mastitis include redness, swelling of udder and decreased milk production. Anorexia and fever may also be present in animals (Lago et al. 2011; Barlow 2011). In different countries of world like Uruguay after S. aureus, E. coli was one of leading cause of bovine subclinical mastitis. Subclinical mastitis in dairy animals is commonly detected after laboratory examination of the milk as there is no gross swelling of udder or apparent changes in the milk (Baloch et al., 2016). The incidence of clinical mastitis is 3 to 40 times lower than that of subclinical mastitis (Aqib et al., 2017).

Several diagnostic tests have been developed for early detection of mastitis, including the Surf field mastitis test, California mastitis test (CMT), and somatic cell count (SCC). However, the measurement of milk electrical conductivity for subclinical mastitis diagnosis is a novel technique that remains in frequently utilized by farmers in Pakistan (Suojala et al., 2011). Bacteriological culture is used to detect subclinical mastitis as well as by somatic cell count Mastitis which is subclinical is detected by test called California mastitis test in countries like Pakistan.

Cow factors incorporate Age, years Breed Parity, Month of calving, Milk yield, Lactation period, Calving stretch Dry period are risk factors that are related to mastitis. Herd factors incorporate Education of ranchers, Total number of animals, Lactating cows Lactating cows, No. of calves, Dung evacuations each day, Method took on for milk let down. residue milk in udder. Housing incorporates Evenness of floor, Type of sheet material, (Removal of sheet material each day, Length of cow standing region, Width of cow standing region, Distance from compost record to slow down. Climate incorporates Presence of flies (Gunawardana et al., 2014).

Subclinical mastitis can cause serious economic losses for small-scale farmers due to its significant financial impact. Additionally, the handling and consumption of unpasteurized coliform-contaminated milk and/or milk products have been associated with public health implications, including the potential transmission of pathogenic microorganisms to humans, resulting in foodborne illnesses such as diarrhea, abdominal cramps, and vomiting. Moreover, the consumption of contaminated milk and milk products has been linked to the development of antimicrobial resistance, which poses a significant threat to public health (Abegewi et al. 2022). Antibiotics residues are transferred after consumption of milk to humans (Rizwan et al. 2022).

Used in California mastitis test (sodium alkyl aryl sulfonate) is exorbitant and not applicable in our country. The test used for discovery of subclinical mastitis is the surf field mastitis test. 3% arrangement of house holding detergent is used for identification of subclinical mastitis. The Surf field mastitis test has the following properties: the development of a practical and accessible agricultural testing system, cheap, easily accessible, and user-friendly. In comparison to these properties, it is noted that Surf Excel, a product manufactured by Unilever Pakistan, falls short.

In addition to its economic impact, subclinical mastitis (SCM) also serves as a reservoir for zoonotic pathogens such as *Mycobacterium tuberculosis*, *Brucella* spp., *Leptospira* spp., and *Streptococcus* spp. These pathogens can be transmitted to humans through contact with contaminated milk or dairy products, so they are a significant risk to human health. Bacterial infections pose a significant threat to the cattle farming industry, resulting in substantial economic losses. In particular, dairy cattle are highly vulnerable to intramammary infections that occur within the three weeks preceding parturition and during early lactation. Changes in the mammary gland physiology and hormonal fluctuations, which can compromise the animal's immune system are the factors that make it susceptible to SCM. Such infections can lead to reduced milk yield and quality, increased veterinary costs, and a higher risk of culling. So, it is essential to take control and preventive measures to make the bacterial infection less effective. In subclinical mastitis a few treatments strategy is utilized in term of anti-microbial and home-grown treatments (Aqib et al., 2017). To treat subclinical mastitis anti-microbial are utilized (Doğruer et al., 2010). Tylosin, Amoxicillin, Enrofloxacin and Penicillin are antibiotics that are used to treat mastitis. Procaine penicillin is that antibiotic that is mostly used against mastitis, but advanced studies show that resistance develops by bacteria against Procaine penicillin (Rizwan et al., 2021). Antibiotic sensitivity testing indicated that Erythromycin, Enrofloxacin, and Gentamicin were the most effective antibiotics, while Streptomycin was found to be the least effective against these bacterial pathogens (Abdel-Shafy et al., 2014).

Therapeutic uses of Coconut Oil in Clinical Mastitis

Due to its detrimental effects on milk production and cow health clinical mastitis, is a significant concern in dairy farming, which is characterized by visible inflammation and abnormal milk. While antibiotics are commonly used for treatment, alternative therapies like coconut oil offer a natural and potentially effective approach to managing clinical mastitis.

Antimicrobial Properties

Coconut oil is made up of a unique composition of medium-chain fatty acids (MCFAs), most importantly Lauric acid, which show potent antimicrobial activity. Lauric acid damaged the lipid membrane of bacteria, including common mastitis-causing bacteria such as *Streptococcus agalactiae, Escherichia coli, Streptococcus aureus, Streptococcus dysgalactiae* and *Streptococcus uberis*. By focusing these bacteria, coconut oil helps to reduce the bacterial population in the mammary gland, thereby aiding in the resolution of clinical mastitis (Rizwan et al., 2021).

Anti-inflammatory Properties

Coconut oil possesses anti- inflammatory as well as antimicrobial properties, that can help cows suffering from clinical mastitis. coconut oil can reduce inflammation and associated symptoms and promote quick healing of the affected udder tissue.

Application Method

Gently massaging the oil into the affected udder quarters causes the great reveal in pain. It is important to ensure thorough coverage of the inflamed tissue with a thin layer of coconut oil. The application of coconut oil should be performed after each milking to increase absorption and efficacy of coconut oil (Rizwan et al., 2021).

Dosage and Frequency

For clinical mastitis the recommended dosage of coconut oil may vary depending on the severity of the condition of mastitis and the size of the affected udder quarters. As a general guideline, apply coconut oil in enough amount to form a thin, uniform layer over the entire surface of the inflamed udder tissue. Repeat the application of coconut oil twice daily for maximum results, ideally after each milking period. (Rizwan et al., 2021).

Therapeutic Uses of Coconut Oil for the Treatment of Subclinical Mastitis

Subclinical mastitis, a common disease among dairy cattle, poses significant economic and animal welfare concerns for dairy farmers. While conventional treatments often involve antibiotics and inflammatory treatments, the therapeutic use of coconut oil offers a natural and potentially effective alternative treatment.

Mode of Action

Coconut oil consists of a high proportion of medium-chain fatty acids (MCFAs), considerably lauric acid, which exhibits potent antimicrobial properties and anti-inflammatory properties. Lauric acid damaged the lipid membrane of bacteria, leading to their destruction. In the context of subclinical mastitis, coconut oil's antimicrobial property targets the pathogens responsible for the inflammation of the mammary gland, helping to reduce bacterial load and reduce symptoms of subclinical mastitis (DebMandal et al., 2011).

Anti-inflammatory Properties

Besides its antimicrobial effects, coconut oil also possesses anti-inflammatory action. The inflammation associated with subclinical mastitis led to tissue damage and compromised udder health. By mitigating inflammation, coconut oil aids in the healing process, helping in the restoration of normal mammary gland function.

Application Method

For subclinical mastitis treatment the application of coconut oil involves applying a thin layer of the oil directly to the affected udder quarters. It is recommended to gently massage the oil into the udder tissue, ensuring thorough coverage. The application of coconut oil should be performed immediately after milking to maximize absorption and efficacy.

Dosage and Frequency

The recommended dosage of coconut oil for subclinical mastitis treatment varies depending on the severity of the condition and the size of the affected udder quarters. A general guideline is to apply enough coconut oil to form a thin, uniform layer over the entire udder surface. Repeat the application twice daily for optimal results, ideally after each milking session.

Therapeutic Uses of Amla Oil for the Treatment of Subclinical Mastitis

Amla oil, derived from the Indian gooseberry (Emblica officinalis), is another natural product that has been used traditionally for various beauty and health purposes. While there is limited scientific data specifically on the use of amla oil for subclinical mastitis

Antimicrobial Activity

Amla oil consists of phytochemicals such as flavonoids and tannins, which have shown antimicrobial properties in some studies. These compounds may help to inhibit the growth of bacteria associated with mastitis, potentially contributing to the resolution of subclinical mastitis (Khan et al., 2018).

Anti-inflammatory Activity

Amla oil is rich in antioxidants, including flavonoids and vitamin C, which exhibit anti-inflammatory properties. By reducing inflammation, amla oil helps to reduce discomfort and swelling associated with subclinical mastitis (Akhtar et al., 2011).

Wound Healing Properties

Amla oil has been traditionally used to promote wound healing and tissue repair. In the context of mastitis, application of amla oil to cracked or damaged teats may help soothe irritation and help in the healing process (Rizwan et al., 2021).

Immunomodulatory Properties

Some scientific data suggests that amla extract may modulate immune function by promoting the activity of immune cells. This immunomodulatory effect could potentially support the body's natural defenses against bacterial infections, including those associated with mastitis (Khan et al., 2018).

Traditional Use

Amla has a long been used in Ayurvedic drug for colorful health conditions, including those affecting the guts. While anecdotal substantiation and conventional knowledge suggests its implicit efficacity for mastitis, further exploration is demanded to confirm its effectiveness and safety in this environment (Setayesh et al., 2023).

Therapeutic uses of Amla Oil for the Treatment of Clinical Mastitis

Amla oil painting, comes from the Indian gooseberry (Emblica officinalis), importantly used in Ayurvedic drug for its treatment parcels. While exploration on the specific use of amla oil painting for the treatment of clinical mastitis is limited, it emphasize advantages in easing inflammation, inducing crack mending, and antimicrobial parcels suggest that it give advantages in managing the cases.

Table 1: Comparison of Uses of Coconut and Amla Oil

Properties	Coconut Oil	Amla Oil	Reference
Antimicrobial Properties	Contains lauric acid, which show antimicrobial activity by damaging the phospholipid membranes of bacteria, fungi.and viruses.	Consist of phytochemicals such tannins and flavonoids, which possess antimicrobial properties that may help to stop bacterial growth.	(Rizwan et al., 2022)
Anti-inflammatory Effects	Show anti- inflammatory properties that may help to less inflammation associated with mastitis.	Abundant in antioxidants like vitamin C and flavonoids, which have anti-inflammatory effects, potentially reducing discomfort and swelling.	(Khan et al., 2018)
Wound Healing	Recognized for its moisturizing and nourishment properties, which help in healing cracked or damaged skin.	Traditionally used to promote wound healing and tissue repair, suggesting potential benefits for soothing and healing teat irritation.	(Rizwan et al., 2021)
Immunomodulator Effects	Some components, like capric acid, show immunomodulatory effects, helping the immune system's response to infections.	Data suggests that amla extract may enhance immune function, potentially helps the body's natural defenses against bacterial infections.	(Khan et al., 2018).
Moisturizing and Conditioning	Well-known for its moisturizing properties, helpful for keeping the skin hydrated and preventing further irritation of skin.	Used in skin care for its moisturizing and conditioning which can be advantageous for maintaining skin health in the view of mastitis.	(Setayesh et al., 2023).
Traditional Use	Utilized in traditional medicine systems for various health and beauty purposes, including skincare and haircare.	Has a long history of use in Ayurvedic medicine for a wide range of health conditions, reflecting its versatility and potential therapeutic value.	(Setayesh et al., 2023).

Anti-inflammatory Characters

Amla oil painting have bioactive composites same as flavonoids and tannins, which parade potentate-inflammatory goods. In the environment of clinical mastitis, inflammation of the mammary gland is a hallmark point. It may help to reduce inflammation, thereby easing symptoms same as bone pain and tenderheartedness along with mastitis.

Antimicrobial Properties

Bacterial infection is a common and major cause of clinical mastitis, with Staphylococcus aureus is a predominant pathogen. Amla oil painting possesses antimicrobial parcels that have been demonstrated against a wide range of bacteria, including S. aureus. By inhibiting bacterial growth and proliferation, amla oil painting may help combat the contagious element of mastitis, promoting resolution of the condition (Khan et al., 2018).

Wound Healing Effects

In addition to its anti-inflammatory and antimicrobial parcels, amla oil painting has been shown to promote crack mending. In cases of clinical mastitis where towel damage or nipple trauma may occur, the operation of amla oil painting topically to the affected area could potentially expedite the mending process, restoring the integrity of the bone towel and easing recovery.

Stress Reduction

Pain and discomfort associated with clinical mastitis can contribute to stress and anxiety in suckling matters. Amla oil painting has been traditionally used in Ayurvedic drug for its comforting and invigorating parcels. Incorporating amla oil painting into tone- care routines, similar as gentle massage ways, may help promote relaxation and emotional well- being in women managing with mastitis (Khan et al., 2018).

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Chapter 26

Exploring the Therapeutic Benefits of Olive Oil for Arthritis Management

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ABSTRACT

Olive Oil has been researched for its potential osteo-protective properties. The objective of this study is to present an updated summary of the available data on the osteo-protective effects of Olive Oil. Studies reveal that Olive Oil may improve the health of bones, including the prevention of osteoporosis, improvement of bone mineral density, and reduction of bone loss in various animal models. In addition, Olive Oil has been shown to possess anti-inflammatory and antioxidant properties, which may contribute to its protective effects on bone health. Olive Oil improves the bone health, like it exerts beneficial effects on osteo tumor cells, osteosarcoma in children, bone remodeling, alveolar bone loss, rheumatoid arthritis, osteoporosis, and post-menopausal osteoporosis. The phenolic and flavonoid compounds inhibit tumor cell growth and their potential therapeutic use in osteosarcoma treatment in children. Phenolic compounds like oleuropein may affect bone remodeling, a critical process that involves the resorption and formation of bone tissue. The chapter also discusses oleuropein's potential for treating osteoporosis, a widespread bone condition characterized by lower bone density and enhanced fracture risk. Specifically, examines oleuropein's impact on post-menopausal osteoporosis, a type of osteoporosis that affects women after menopause. The findings suggest that olive oil has potential as a natural osteo-protective agent and warrants further investigation.

KEYWORDS		
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INTRODUCTION

Oleaeuropaea Linn. (Oleaceae) in the mediterranean area is essential elements of Mediterranean cuisines are its fruits and oil (MDs). The MD, which has been shown to minimize the risk of several illnesses and ailments, must include olive oil as a key ingredient (Ahamad et al., 2019). The most significant hydrophilic phenolic component in olives and olive oil is the glycoside known as oleuropein.

Oleuropein may be hydrolyzed chemically or enzymatically to yield a variety of derivatives, including the aglyonic and hydroxytyrosol forms that are present in olive oils (Otero et al., 2021). The anti-atherogenic, anti-hepatotoxic, hypoglycemic, anti-inflammatory, anticancer, antiviral, and immunomodulator effects of olive tree polyphenols may be the cause of some of this plant's medically significant traits (Otero et al., 2021).The prevention of illness has taken precedence over its cure as knowledge has developed. Studies examining diverse phenolic compounds have expanded as researchers look for natural substances with potent pharmacokinetic effects.

Oleuropein is a potential phenolic substance that has a favorable impact on bone tissue in this regard (Bendini et al., 2007). Additionally to scavenging free radicals and reactive oxygen species, olive tree polyphenols particularly stimulated endogenous antioxidant enzymes including glutathione S-transferase and glutathione peroxidase (Recinella et al., 2022). Oleuropein might stop periodontitis and its associated bone loss and inflammation (Taskan et al., 2019a).

Osteoarthritis (OA) is a complicated, late-onset disease of the joints that is characterized by alterations in the synovium and subchondral bone as well as a gradual failure of the extracellular cartilage matrix (ECM). The most prevalent kind of arthritis in the world is OA, which is also the sixth biggest cause of disability (Meiss et al., 2021).Future estimates indicate that the social and economic costs associated with OA will increase. As a result, there is a pressing necessity to find novel possibilities for the adoption of preventative and intercede methods in order to control OA, especially in light of the multiple difficulties connected with its treatment (Morales-Ivorra et al., 2021). A slowly developing heterogeneous joint disease that causes severe functional impairment, joint pain, stiffness, and deformity as well as high medical expenses (Murray et al., 2012; Xu et al., 2021a). Although the exact cause of knee OA is unknown, a number of risk factors, including advanced age, obesity, joint damage, and specific activities, have been linked to an elevated risk for incident OA (Atkinson et al., 2021; Xu et al., 2021a).

The most prevalent kind of metabolic bone disorder, often known as osteoporosis, is a skeletal condition that causes weaker bones and raises the risk of fracture. Although both sexes can be affected by osteoporosis, which often results from aging and frequently affects women more than men. It can happen at any age (Osteoporosis and Prevention, 2001; Föger-Samwald et al., 2020). Due to population ageing, it is predicted that the prevalence of osteoporosis would dramatically rise in the future (Akkawi and Zmerly, 2018). Women who have postmenopausal osteoporosis (PMOP) typically have bone loss and an increased risk of bone fractures as a result of the marked decrease in estrogen in the body after menopause (Liu et al., 2022). More than 200 million women suffer osteoporosis worldwide, according to pertinent statistics. Meanwhile, the number of people who suffer from fractures brought on by osteoporosis will twofold by 2050, placing a huge financial and medical strain on the world's health system (Pisani et al., 2016).

Long-term, it was extremely likely that the medication would raise the patient's risk of osteonecrosis and their chance of developing cancer. Raloxifene and hormone replacement therapy are additional options for postmenopausal women to take in order to avoid osteoporosis (Kanis et al., 2020). Therefore, the majority of postmenopausal women search for natural plant medicines to substitute conventional medication therapy due to the pill's varied negative effects (Cano et al., 2020). New medications for the treatment of several human disorders, including PMOP, often start with components taken from natural plants. Olive oil is popular among Mediterranean coastal residents (Castejón et al., 2017).

Oleuropein, the primary component of olive oil, has been widely used in clinical medicine to combat inflammation, as an antioxidant, and as an anticarcinogenic agent. Anti-inflammatory and antioxidant treatment can reduce postmenopausal osteoporosis (Izadi et al., 2016; Schwingshackl et al., 2017). Bone cancer causes abnormalities in bone growth and destruction by drastically disrupting the healthy coupling between osteoclasts and osteoblasts. Due to these anomalies in bone remodeling, patients have intense bone pain, a higher risk of fracture, increased tumor development, and greater chemotherapy resistance in the tumor cells (Burr, 2019). Osteolytic bone disease, which can cause excruciating bone pain, numerous pathological fractures, and increased mortality, is frequently developed by multiple myeloma (MM) patients (Roodman, 2010; Adamik et al., 2019). Systemic delivery of anticancer medications, bone-modifying medicines, radiopharmaceuticals, or any combination of these may have a deleterious impact on the normal metabolic turnover of bone tissue, which might be harmful to cancer patients (Leto et al., 2021a). The need to find novel drugs that have the potential to be helpful in stopping the spread and proliferation of cancerous cells in the bone while also having minimal negative effects (Makhoul et al., 2016; D'Oronzo et al., 2019).

Natural products appear to generally be easily accessible, not harmful to healthy human cells, and have the potential to function as many targets since they could interfere with different signaling pathways that control the development of cancer (Sun et al., 2019). Due to these qualities, natural products can be used therapeutically in many ways to cure cancer. One of the primary bioactive phenolic compounds found in olive leaves (*Oleaeuropaea L., Oleaceae*), unprocessed olive drupes, and, in the aglycone form, in olive oil, reveals a broad spectrum of therapeutic benefits that may clarify the therapeutic advantages of this molecule seen in a wide range of pathological processes in people, such as persistent inflammation linked to bone damage and human malignancies (Casaburi et al., 2013; Castejón et al., 2020). In this chapter we will highlight the osteoprotective effects of olive oil, we mainly focused on the main phenolic compound Oleuropein and its beneficial effects.

Impact on Osteo-tumour Cells

After the lung and the liver, the skeleton is where metastatic illness occurs most frequently (Leto et al., 2021b). Current clinical approaches for treating primary malignant bone tumors or bone metastases include systemic therapies like chemotherapeutic, hormone replacement therapy, immunotherapy, bone-modifying medications, small amounts of radioactive materials, as well as regional treatments such radiotherapy, endovenous, and surgery (D'Oronzo et al., 2019). Sadly, to yet, none of these treatment alternatives has demonstrated to have a favorable clinical effect on patients' survival. In addition, systemic administration of anticancer medications, bone-modifying medicines, radiopharmaceuticals, or any combination thereof, may have a deleterious impact on the normal metabolic cycle of bone tissue, which would be unfavorable for cancer patients (Makhoul et al., 2016).

Thus, there is a need to find novel drugs with the potential to stop the development and migration of malignant bone cells while also having low toxicity and few adverse effects. Natural products appear, in general, to be 1), easily accessible, ii) not harmful to live cells; iii) potentially acting as several targets and may impact on biochemical reactions that control cancer progression (Sun et al., 2019; Kapinova et al., 2019).

There are several advantages to adopting natural products for medicinal purposes in cancer prevention and treatment. Several phenolic molecules generated from extra virgin olive oil (EVOO) have anti-invasive, anti-metastatic, and anti-proliferative characteristics, according to expanding experimental data (Castejón et al., 2020; Hassen et al., 2020).

These compounds therefore appear to hold promise as possible cancer therapies. Olive leaves (*Oleaeuropaea L., Oleaceae*), natural olive drupes, and, in the aglycone form, olive oil are all known to include one of the key bioactive phenolic compounds., in particular, oleuropein (OLe), demonstrates a wide range of medicinal properties that may explain the curative properties of this chemical seen in several human pathological conditions, such as autoimmune disorders linked to bone loss and cancer (Rigacci and Stefani, 2016).

Mechanism

Through several mechanisms implicated in the early stages of cancer progression and the control of bone remodeling processes, OLe may exercise its chemo-preventive and therapeutic effects on cancer-related bone disorders (Castejón et al., 2020; Hassen et al., 2020)

Due to this molecule's antioxidant, anti-inflammatory, and innate immunity capabilities, OLe appears to have protective benefits on bone health. The ability of OLe to suppress the production of reactive oxygen species (ROS), act as spontaneous redox breakers, or serve as a metal ion chelating agent, among other potential activities, has been related to its antioxidant characteristics. OLe's inhibitory action on mitogen-activated protein kinase (MAPk) and nuclear factor-kB (NF-KB) signaling molecules is what causes the anti-inflammatory and anti-carcinogenic properties of the compound (Rigacci and Stefani, 2016; Hassen et al., 2020).

As a result of these occurrences, the synthesis of several subsequent molecular signaling pathways that regulate the immune-inflammatory response is reduced. TNF (tumor necrosis factor), IL-1 (interleukin-1), IL-6 (interleukin-6), and IL-8 (interleukin-8) (IL-8), Prostaglandins and MCP-1, a monocyte chemoattractant protein (PGs), particularly enzymes and prostaglandin E2 (PGE2) for example cyclooxygenase-2 (COX-2) and matrix metalloproteinases (MMPs) as well as the inactivating form (iNOS). These findings are in line with experiments demonstrating that OLe's bone-protective benefits appear to be mostly caused by its regulatory impact on inflammatory signaling networks instead of by directly affecting bone metabolism (Chin and Ima-Nirwana, 2016; Castejón et al., 2017; Leto et al., 2021b).

The discovery that several chronic inflammatory bone conditions and cancers related to bones have shared molecular mechanisms in their pathogenesis may help to partially explain why it is believed that one of the key pathogenic mechanisms that may favor the location and proliferation of tumor cells in the bone tissue is chronic inflammation (Roca and McCauley, 2015; Ritter and Greten, 2019; Vallée et al., 2019)

Experimental research indicates that persistent inflammation may act as a catalyst for the development of cancer in its early stages. These results may also help to partially explain the observation that some cancer cell types appear to thrive and spread more readily in bone tissue when osteoporosis and other autoimmune bone diseases alter the osteo microenvironment (Leto et al., 2021b).

Osteosarcoma in Children

Among the most prevalent bone cancers in children and teens is osteosarcoma. The main clinical problem with OS is how aggressive and likely it is to metastasize (Zhang et al., 2018). Osteosarcoma is treated surgically in addition to chemotherapy, typically doxorubicin and cisplatin (Otoukesh et al., 2018). Tragically, the 5-year survival rate of 60–70% has held steady over the past two decades, and no additional improvement has been shown with the current treatment(Harrison et al., 2018). As added 2-methoxyestradiol in our tests to examine the anticancer potential of oleuropein when combined with powerful chemotherapy (2-ME). A naturally occurring 17-estradiol metabolite recognized for having anticancer effects is 2-ME. 2-ME, marketed as Panzem, is now being assessed in active clinical studies for the treatment of solid tumors (Bruce et al., 2012). 2-ME's anticancer efficacy is solely dependent on its ability to prevent angiogenesis and trigger cell death by chasing cells that are actively growing (Lis et al., 2004).

Quiescent cells are therefore less susceptible to 2-ME. Additionally, the antitumoral action of 2-ME against several cancer cell types involves the production of nitro-oxidative stress (Gorska et al., 2015). Oleuropein has the ability to inhibit the growth of both highly and lowly metastatic SaoS2 OS cell lines, although this was done without looking at the compound's ability to inhibit migration. Oleuropein was combined with the brand-new, very effective anticancer drug 2-ME to examine any potential synergism in the OS cellular model. It is yet unclear how the two chemicals work together synergistically (Przychodzen et al., 2019). The overall beneficial effects of Oleuropein on the bone’s health is schematically represent Fig. 1.

Bone Remodeling

Bone is a dynamic, complex structure that is always changing. Osteoclasts remove worn-out or broken bone from the body, and osteoblasts then replace it with freshly produced bone. To keep the skeleton healthy, there must be a suitable balance between bone growth and degradation. In order to eliminate microfractures and ischemia fractures in bones, replacing the main bone with bone remodeling appears to become crucial in order to establish a good equilibrium of Ca^+ or K^+ and secondary bone that is more mechanically strong (Ramesh et al., 2021).The coordinated action of four different cell types, including osteoblasts, osteoclasts, and bone-lining cells, is necessary for bone remodeling, which comprises four phases: activation phase, resorption phase, reversal phase, and formation phase (Parra-Torres et al., 2013).The presence of numerous nuclei, the expression of calcitonin receptor and tartrate-resistant acid phosphatase (TRAP) are distinguishing characteristics of osteoclasts, which are cells derived from the myeloid (Hayman, 2008)

The cytokines Colony Stimulating Factor-1 (CSF-1) and receptor Activator of Nuclear Factor-kappa B (NF-kB) regulate the survival and growth of osteoclast precursor cells (Raggatt and Partridge, 2010). Using alpha-v beta integrin, osteoclasts interact with the surface of bone after differentiating and transferring signals that control how the cytoskeleton is organized. Spleen tyrosine kinase (SYK), VAV3 Ras-related C-Src, guanine nucleotide exchange factor (GEF), and All of the gates are opened in response to the signals (Teitelbaum, 2007). In order to break down the bone's matrix and mineral components, proteases like cathepsin K (CTSK) and hydrochloric acid are secreted into an extracellular lysosomal area and create microscopic trenches on the bone's trabeculae surface (Boyce et al., 2009).

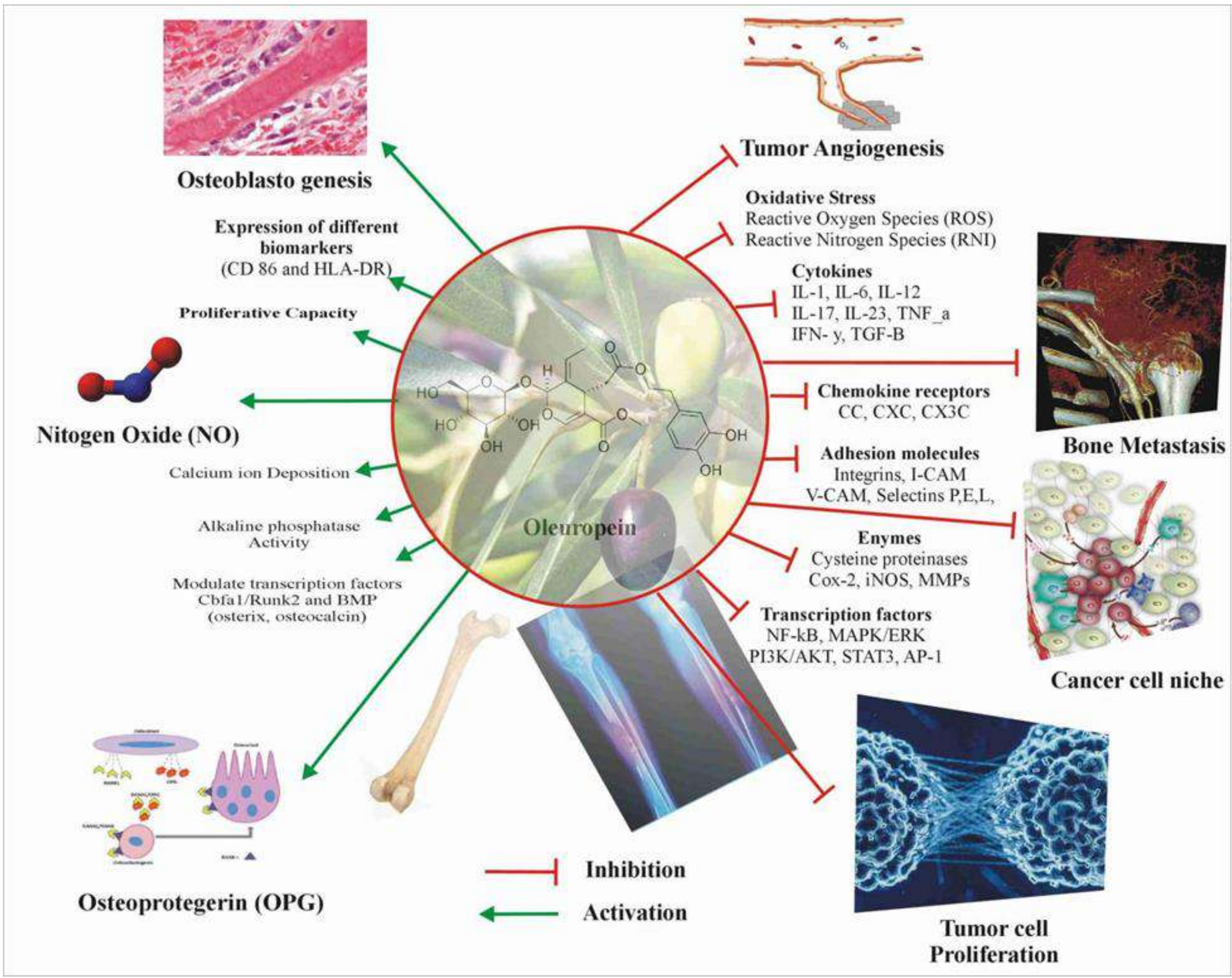

Fig. 1: Inhibition effects oleuropein on bone cancer such as tumor angiogenesis, oxidative stress, cytokines, chemokine receptors, adhesion molecules, enzymes, transcription factors, bone metastasis, cancer niche, and tumor cell proliferation. These processes are typically associated with the progression of cancer. On the other hand, activation affects processes such as osteoblast genesis, expression of different biomarkers, nitrogen oxide and osteoprotegerin production, calcium ion deposition, alkaline phosphatase activity, and proliferative capacity. These processes are typically associated with the maintenance and growth of healthy bone tissue.

A number of osteotropic substances, including Interleukin-11 (IL-11), IL-1, PTH, and 1,25-(OH)2D3, indirectly promote the production of osteoclasts by stimulating RANKL on the surface of osteoblasts and then associating RANK on osteoclast precursors(Hofbauer and Heufelder, 2000). Due to that signaling pathways like the Ak strain transforming (AKT) route, the c-Jun N-terminal kinase (JNK) system, p38 mitogen-activated protein kinase (MAPK), extracellular signal-regulated kinase (ERK) pathway, and NF-B are all active (Nakchbandi et al., 2001).

Osteoclast genesis is regulated by a number of additional proteins connected to RANK-activated signaling pathways (Boyce et al., 1992). Numerous variables, most notably osteoprotegerin (OPG), that are considered as a false receptor for RANKL, restrict the development of osteoclasts and the activation that follows. The balance of RANKL/OPG is an important factor in determining the strength of bone (Takayanagi, 2005).

Osteoblasts are produced by neural crest progenitor cells and mesodermal cells, which later differentiate into osteocytes and proliferating preosteoblasts (Komori et al., 1997). Runt-related transcription factor 2 (RUNX2) is required for the development of the Osteoblast genesis parent cell. RUNX2 controls sclerostin, dentin matrix protein 1, receptor activator of nuclear factor kappa-B ligand, osteocalcin, osteocalcin (OCN), vascular endothelial growth factor (VEGF), and RANKL throughout cell growth (Lian et al., 2006) PTH, endothelin-1, fibroblast growth factor (FGF), bone morphogenetic proteins (BMPs), insulin-like growth factor (IGF), and Osterix (OSX) all regulate osteoblast development. Wingless-related integration site (Wnt) signalling pathways are activated by BMP and PTH (Westendorf et al., 2004). Fully formed osteoblasts coexpress Type I collagen and alkaline phosphatase, which are necessary for the bone mineralization and formation of bone matrix (Murshed et al., 2005). Mineralization regulators including RANKL, osteopontin (OPN), osteonectin (ON), and OCN are produced by grown osteoblasts and are necessary for osteoclast differentiation. Osteocytes, which are immersed in mineralized matrix, or lining cells, which cover the edges of the bones, are the final forms of osteoblasts (Eriksen, 2010). As a result, the balance between bone formation by osteoblasts and bone resorption by osteoclasts, which is intricately related and regulated by a multitude of pathways, transcription factors, and released chemicals, determines the overall integrity and structure of the bone (Ramesh et al., 2021).

Alveolar Bone Loss

The permanent effect of severe inflammation, which is also present in metabolic bone illnesses including osteoporosis and rheumatoid arthritis, is alveolar bone loss. By inducing osteoclastic development and activity, which causes bone loss, NF-KB is a crucial transcriptional factor controlling inducible genes that cause inflammation and the destructive process (Taskan et al., 2019a).

Lipopolysaccharides can activate neutrophils, which increases levels of IL-8, MCP-1, and TNF, which sets off a series of inflammatory processes. Neutrophil activation is the initial stage of inflammation. Neutrophils stimulated by LPS phosphorylate p38 MAPK, ERK, and JNK and move NF-KB17. Oleuropein reduced the activity of p38 MAPK, ERK1/2, and JNK and inhibited the movement of NF-KB from the cytosol to the nucleus, which is essential for activating NF-KB.TNF, IL6, MMP1, MMP3, and COX2 levels were reduced in IL-1-induced synovial fibroblast cells along with a downregulation of the MAPK and NFKB pathway (Woźniak et al., 2018). Oleuropein suppressed NF-KB and MAPK activation and lowered the production of COX2, iNOS, MMP1, and MMP13 in both fibroblasts and the osteoarthritis chondrocytes. All of these studies point to oleuropein's potent anti-inflammatory effectiveness.

Effect on Rheumatoid Arthritis

Rheumatoid arthritis (RA), an unexplained chronic inflammatory disease, primarily affects joints and eventually results in joint deterioration. It is currently believed that immune cells and the associated proinflammatory mediators are involved in all systemic autoimmune disorders, including RA (Rosillo et al., 2019). *Extra virgin olive oil* is ingested because of its tiny yet very bioactive components. Some of them have demonstrated indications of anti-inflammatory and antioxidant properties, including phenolic compounds comprising hydroxytyrosol (HTy), tyrosol, and oleuropein. The studies have shown that consuming extra virgin olive oil (EVOO) enhanced with polyphenolic extract (PE) can decrease the progression of damage in a collagen-induced arthritis (Aparicio-Soto et al., 2016).

Synovial fluid (SF) participates in continuing inflammatory responses as a substantial cell population in the RA invasive lesion. In the current work, PE from EVOO is shown for the first time to be able to restrict the activation of SW982 human synovial cells produced by IL-1 and reduce the inflammatory response (Tanaka, 2001). SF inflammatory alterations are crucial to the development of RA. This is due to the fact that TNF-, IL-1, and IL-6, pro-inflammatory cytokines that are known to have a significant role in the pathophysiology of RA, are overproduced during the synovial response in RA patients. IL-6 levels are associated with the development of rheumatoid factors and an increase in serum c-globulin (Sommerfelt et al., 2013).Early joint swelling, chronic joint inflammation, and the ensuing erosive changes in cartilage and bone are thought to be caused by TNF-, a pro-inflammatory molecule produced by macrophages and T cells. The current work showed, for the first time, that treatment with PE derived from EVOO substantially decreased IL-1-induced TNF- and IL-6 production in human synovial SW982 cells (Rosillo et al., 2014).

According to research they identify the arthritis-related pharmacological properties of olive leaf extract. The phenolic compound in olive leaves is linked to a decreased risk of arthritis, as well as many other diseases, as antioxidants reduce the harmful effects of free radicals on the body (Alethari et al., 2021). They also act as a scavenger, suppressing the production of reactive oxygen species in various experimental systems, including cell damage from H_2O_2exposure.Arachidonic acid metabolism and phospholipase C activation are likely to be involved in the process, which lowers hydrogen peroxide. Olive leaf extract has improved and accelerated the recovery from arthritis (Tahmasebi et al., 2021).

Osteoporosis

The loss of bone mass and the microstructural breakdown of bone tissue are the two characteristics that characterize the skeletal disease known as osteoporosis. Osteoporosis, often known as "porous bone," causes bones to become increasingly brittle and prone to breaking (Jiang et al., 2021). However, considerable improvements in osteoporosis therapy over the previous 50 years, including the widely accessible nature of numerous efficient pharmaceutical therapies, have changed the perception that the condition is a natural part of aging (Clynes et al., 2020).

Osteoporosis-related fractures are expensive, costing the US and the UK $17.9 billion and £4 billion, respectively, each year (Clynes et al., 2020; Chandran and Kwee, 2022). Osteoporosis is challenging to diagnose clinically because fracture criteria may exclude populations that would benefit from therapy and because the original 1994 World Health Organization (WHO) account by bone mineral density (BMD) alone (2.5 standard deviations below the young adult female mean) may not have taken other risk factors into account (Aggarwal et al., 2021). A person's risk of a fracture may now be quantified using clinical risk variables like age and alcohol consumption, with just a partial focus on BMD (Chotiyarnwong et al., 2022), thanks to risk calculators such as the online FRAX® algorithm (Clynes et al., 2020). According to a study by the United States surgeon general, 10 million Americans older than 50 are thought to be suffering from osteoporosis, and a further 34 million could be at risk (BRANNON, 2020). Approximately 1.5 million fractures caused by fragility in the USA occur annually as a result of osteoporotic fractures. In the UK, epidemiological studies indicate that a single in 5 men and one in two females older than 50 may sustain a fracture due to osteoporosis over their lifetime, indicating a comparable disease burden (Wu et al., 2019).

An individual's peak skeletal growth occurs during their fourth decade, and their following rate of bone loss determines their bone mass in old age. Bone mass is a recognized sign of bone strength (Yu and Wang, 2022). The likelihood of fractures should be highest when bone mass (and thus bone strength) is at its lowest points. In reality, there is a bimodal age-related variation in fracture incidence, with the young and the elderly experiencing the highest rates (Rizzoli et al., 2021). Younger males get fractures more frequently than females, but above the age of 50, female fracture rates are nearly twice as high as male rates. Long bone fractures, which are the most frequent type of fracture in young individuals, are brought on by serious trauma. According to studies, bone mass is still a substantial and important risk factor for fracture in this cohort, in addition to the severity of the trauma. The forearm, hip, and spine are the places where older persons are most vulnerable to fractures (Clynes et al., 2020). Bone remodelling is directly influenced by bone cells such osteoclasts, osteoblasts, and osteocytes (Kitaura et al., 2020). Together, osteoblasts from mesenchymal stem cells (MSCs) and osteoclasts from tissue-specific macrophage polykaryons develop and disintegrate bone to maintain the mineral balance and strength of the bone. The malfunctioning of each cell type may cause bone loss (Noh et al., 2020).

The oleuropein has ability to stimulate the activity of bone-forming cells (García-Martínez et al., 2016), known as osteoblasts(Horcajada and Offord, 2012), while also inhibiting the activity of bone-resorbing cells (Hagiwara et al., 2011), known as osteoclasts. This oleuropein helps to promote bone growth and prevent bone loss. The supplementation with oleuropein was able to improve bone mineral density and reduce the risk of fractures in rats with induced osteoporosis (Chin and Ima-Nirwana, 2016). Similarly, the oleuropein may have a positive effect on bone mineral density and may help to prevent bone loss (Taskan et al., 2019b). While the research on the effects of oleuropein on osteoporosis is promising, more studies are needed to determine its effectiveness and safety in humans.

Post-Menopausal Osteoporosis

The metabolic bone disease (Xu et al., 2021b) osteoporosis, which is becoming more and more of an epidemic due to a constant rise in incidence, is a major social and medical issue in advanced economies (Rossi et al., 2018). Once a person reaches the age of 50 and above (Cannarella et al., 2019), their bone mass begins to naturally decline (Aspray and Hill, 2019). As a result, the bone remodeling cycle alters, making their bones more brittle and increasing their risk of bone fractures (Bijelic et al., 2017).

Numerous factors that may be divided into the categories of risk factors that can be changed and those that cannot be changed are involved in osteoporosis (Pisani et al., 2016). Recent studies (Li et al., 2020) demonstrate that smoking (Li et al., 2020) holds a significant place among the various risk factors for osteoporosis that are linked to unhealthy lifestyle choices (Lems, 2015) because it causes alterations in the level of microarchitecture of trabecular bone (Rupp et al., 2019) that reduce the bone's resistance to mechanical stress and friction (Li et al., 2020). Smokers have an increased chance of developing osteoporotic fractures regardless of their gender (Ratajczak et al., 2021). Women who smoke are approximately two times more likely than women who don't smoke to develop osteoporosis (Bijelic et al., 2017). Findings (Bijelic et al., 2017) are in line with those of previous academic research, which found that smokers (31.3%) had a substantially greater prevalence of osteoporosis than did ex-smokers (28.6%) or non-smokers (7.5%).

The olive oil and its polyphenols may have a beneficial effect on bone health, particularly in postmenopausal women (Chin and Ima-Nirwana, 2016).

The oleuropein, a polyphenol compound found in olives and olive oil, may have a positive effect on bone health (García-Martínez et al., 2016), particularly in postmenopausal women with osteoporosis (Chin and Ima-Nirwana, 2016). The oleuropein on bone cells in postmenopausal women helps to promote bone growth (Basharat et al., 2019) and prevent bone loss in postmenopausal women with osteoporosis (Chin and Ima-Nirwana, 2016). The supplementation has ability to improve bone mineral density and reduce the risk of fractures in the rats (Chin and Ima-Nirwana, 2016), suggesting that it may have potential as a treatment for postmenopausal osteoporosis. The literature on the effects of oleuropein on postmenopausal osteoporosis is limited. The available evidence suggests that oleuropein may have a positive effect on bone health in this population. However, more research is needed to determine the optimal dose, duration of treatment, and safety of oleuropein supplementation for postmenopausal osteoporosis prevention and treatment. Nonetheless, these findings suggest that oleuropein may be a promising area for further investigation as a potential natural agent for the prevention and treatment of postmenopausal osteoporosis. The overall, olive oil on various bone-related conditions is diagrammatically represented in Fig. 2.

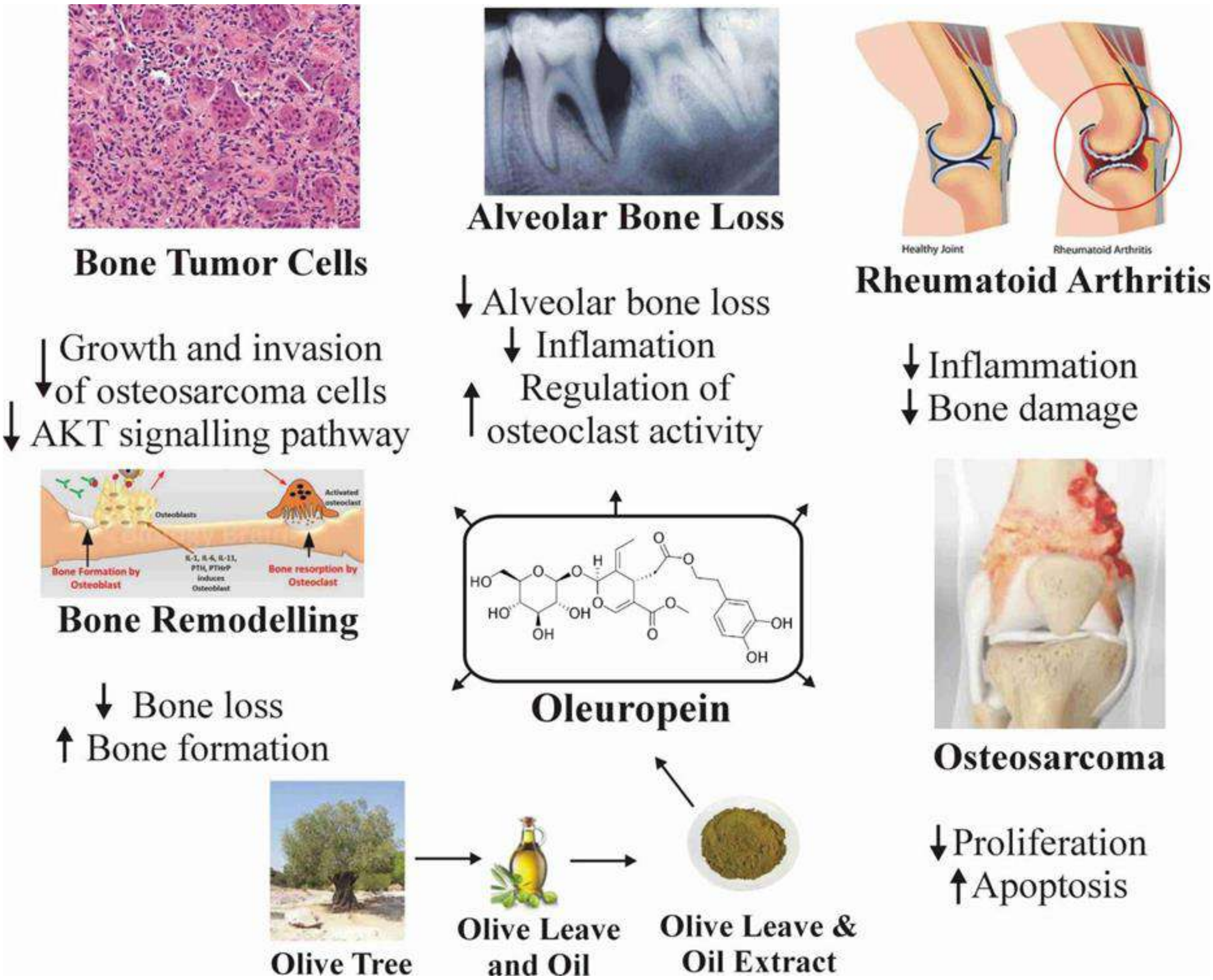

Fig. 2: Effects of oleuropein on various bone-related conditions, such as bone tumor cells, alveolar bone loss, rheumatoid arthritis, bone remodeling, and osteosarcoma.

Table 1: Biological effect of Olive Leaves Extract on Bone Health

Effect of Oleuropein on Bone Health	Study Type	Result/Conclusion	Dosage and duration	References
Bone Tumor Cells	MG-63 an osteosarcoma cell line	↓ MG-63 cells proliferation ↓ The growth and invasion of osteosarcoma cells ↓ AKT signaling pathway	20 mL for 24 h olive oil	(Gioti et al., 2021; Zheng et al., 2022)
Osteosarcoma in Children	osteosarcoma (OS) cells	↑ Metastatic OS cells ↓ Proliferation ↑ Apoptosis of MG-63 human osteosarcoma cells	1 µM - 250 µM for 24 to 48 h Oleuropein	(Przychodzen et al., 2019; Gioti et al., 2021)
Bone Remodeling	Rats	↑ Protective effects on bone mass ↓ Inflammation ↓ Bone loss ↑ Stimulates bone formation	2.5 ml for 100 days olive oil	(Puel et al., 2004, 2006)

Alveolar bone loss, inflammation, and apoptosis	Rats	↓ Alveolar bone loss in experimental periodontitis in rats ↓ Inflammation and regulating osteoclast activity ↓ Caspase-3 expressions ↑ Radiotherapeutic effects ↓ Osteoclastic activity ↓ Apoptosis ↑ Osteoblastic activity ↑ BMP-4 and bcl-2 expressions	15 mg /kg for 15 days or 12 mg/kg/day to 24 mg/kg/day for 14 days OLE	(El-Hady et al., 2018; Taskan et al., 2019a)
Bone loss in ovariectomy/inflammatory model	Rats	↓ Bone loss ↓ Inflammatory biomarkers	2.5 ml for 100 days Olive Oil	(Puel et al., 2006)
Anti-osteoclastogenic effects	in vitro	↓Transcriptional gene ↓ Osteoclastogenesis blood monocytes	25 and 50 µM for 6 days Oleuropein	(Rosillo et al., 2020)
Postmenopausal osteoporosis	Rats	↓ IL-6 ↓ MDA ↓ ALP ↓ P	200 µg/kg/dose Oleuropein	(Liu et al., 2022)
Antiproliferative activity	human osteosarcoma cell lines (MG-63 and Saos2)	↑ Regression ↓ Proliferation	247.4-475.0 µM and m 798.7-359.9 µM for 24, 48, 72 hours Oleuropein	(Moran et al., 2016)
Arthritis	Mice	↑ Anti-inflammatory effects ↓ Bone damage ↓ Oxidative and Nitrosative damage	40 µg/kg for7 Oleuropein	(Impellizzeri et al., 2011; Haloui et al., 2011)
Inflammation-induced bone loss	Rats	↓ Inflammation-induced osteopenia in OVX rats	0·15 g/kg for 80 days OLE	(Puel et al., 2004)
Antioxidant and Antimicrobial activities	In vitro	↓ ROS production ↑ Disturbance to cell membrane structure of bacteria	102.36 and 325.02 mg for 18–24 hr OLE	(Topuz and Bayram, 2022)

AKT: protein kinase B (PKB), also known as Akt, is the collective name of a set of three serine/threonine-specific protein kinases; OS: osteosarcoma; BMP4: bone morphogenetic protein 4; BCL2: b-cell leukemia/lymphoma 2 protein; IL-6: interleukin-6; MDA: malondialdehyde; ALP: nitrate, alkaline phosphatase; P: phosphorus; OVS rats: ovariectomized In order to study mandibular alterations, rats have been employed as a preclinical model of postmenopausal people; ROS: reactive oxygen species.

Conclusion and Future Directions

In conclusion, this book chapter provides a valuable contribution to the current understanding of oleuropein's potential role in promoting bone health and preventing bone-related diseases. The chapter highlights the need for further research to explore the mechanisms underlying oleuropein's effects on bone cells and the potential for developing oleuropein-based therapies for various bone-related conditions. Future research could focus on conducting clinical trials to evaluate the effectiveness of oleuropein-based interventions for preventing and treating bone-related diseases, such as osteoporosis and rheumatoid arthritis. Additionally, research could investigate the optimal doses and delivery methods for oleuropein to maximize its therapeutic potential. Moreover, further studies could explore the potential synergistic effects of oleuropein with other natural compounds found in olives and olive oil, as well as their interactions with conventional treatments for bone-related diseases. Overall, the findings of this review paper suggest that oleuropein holds promise as a natural compound with potential osteo-protective effects, and further research in this field could have significant implications for improving bone health and preventing bone-related diseases.

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Chapter 27

The Diverse Applications of Essential Oils

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ABSTRACT

The essential oils of plants extracted through different methods have a strong history going back many millennia and have been well utilized for their therapeutic properties in traditional medicine of various cultures. This article will familiarize you with some of the more frequently used essential oils and where they come from, showing some of the different ways they can be combined or used in holistic care such as aromatherapy, massage therapy other medicinal treatments, and cosmetics. Further, the text discusses domestic and industrial uses of essential oils which highlights clean and non-toxic alternatives of essential oils in cleaning and pest control and preserving the quality of food for various sectors. Along with this, the cultural and spiritual essence of essential oils held in religious ceremonies and traditional healing practices is also discussed, which underpins our association with nature. To conclude, the considerations and safety precautions in using essential oils to give them the safest and most effective ways to stimulate health and wellness are explained.

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INTRODUCTION

Such oils are the result of the extraction process, which yields aromatic compounds from plant sources like flowers, leaves, and ripe fruits. The main methods to extract oil such as steam distillation, expression, solvent extraction, CO2 extraction, and hydrodistillation, are among the most frequently used. Every approach features an individual technique of the like such as infusing plants with their healing essence (El Asbahani et al., 2015; Ríos, 2016; Aziz et al., 2018).

Essential oil has a background deep in the history of mankind and cannot only be utilized to heal or provide fragrance for stillness but is also used for cooking purposes (Brud, 2020). Ancient nations such as Egypt, India, China, and Greece formulated treatments and other forms of medicine utilizing essential oils as they were believed to reduce and relieve ailments. The incorporation of essential oils in Ayurveda practices in India and TCM (Traditional Chinese medicine) are classic examples of using these oils. Figures such as Hippocrates in Greece were very reckoning in exploring the use of essential oils for medicinal purposes (Carson and Hammer, 2011). During the middle Ages, the Islamic scholars' continued investigations into essential oils have widened the scope of knowledge. In the Renaissance, the interest in botanical studies and natural healing led to the blossoming of herbal medicine in Europe (Franz and Novak, 2020). Advancements in the 20th century (century) technology brought them to be available to extra industries (representing all of them) such as therapeutics, perfumery as well as personal care products (Giannenas et al., 2020). Today essential oils are highly thought of for their medicinal values and have been extensively studied for the sake of their health benefits, which only goes to show that people will always regard essential oils as very essential in human culture and being. (Sadgrove and Jones, 2015).

Essential Lavender oil is very famous for soothing mentally and relieving stress. Pseudo-headaches and intestinal pain may be eliminated using peppermint oil. Tea tree oil can be very good for treating pimples and bringing relief to skin irritations. Eucalyptus oil contributes to the elimination of jam and enhances breathing proficiency. Lemon oil is a multitasker of the essential oils. It is a powerful cleanser and can improve many people's moods. Frankincense oil will open up your spirit to consider deeper things and meditate. Marignin oil reduces inflammation and also helps in relaxation. This oil aids in maintaining focus and to combat against stress, making it recommended for nootropic blends and aromatherapy (Manion and Widder, 2020; Aljaafari et al., 2021).

Therapeutic Uses of Essential Oils

Essential oils, since ancient times, have been successfully applied for different scopes, for example, aromatherapy, massage therapy, home remedies, and many more. The use of essential oils, e.g. lavender and chamomile, in aromatherapy can help people relieve stress and experience relaxation (Koulivand et al., 2013). Essential oils like peppermint and eucalyptus are often employed in massaging therapy to alleviate muscle pains and stress. Essential oils such as tea tree oil, for instance, are shown to be effective acne treatment (Enshaieh et al., 2007), while peppermint oil is mostly used for treating digestive system problems (Grigoleit and Grigoleit, 2005). Similarly, some oils such as lavender and frankincense are known for their relaxing nature, which explains why their use is common during stress reduction (Kasper and Anghelescu, 2015). Among the most important advantages of essential oils to one's mood are an uplifting feeling, which citrus oil is well known for its energizing capabilities, and a calming state, which floral oil can quite efficiently trigger (Perry and Perry, 2006).

Cosmetic Applications

Essential oils are now famous in the cosmetic industry for their multiple reflective benefits on skin, hair, and perfumery. These natural emollients are extracted from the plants and have always been used for their healing properties. In the past few years, essential oils have been used in cosmetic products as their skincare benefits such as Acne treatment and anti-aging process have been realized. Perhaps, the first skincare usage of essential oils we meet in our minds is acne therapy. Aromatherapy with essential oils like tea tree oil, lavender oil, and rosemary oil may be utilized to combat acne and improve overall skin appearance, given these oils have properties against bacteria and inflammation (Khan et al., 2019). You can employ these oils in your facial washing substance, toner, or spot therapy to specifically deal with acne-prone areas. Acne treatment is not the only ability of essential oils with anti-aging properties. The oils such as frankincense, rosehip and geranium can prove helpful in increasing skin elasticity, diminishing the visibility of wrinkles, and promoting a fresh-looking complexion (Babu et al., 2018). These oils are frequently used in anti-aging serums, moisturizers, and face oils among other skincare products to stop the effects of mature skin. Although we mostly associate essential oils with skin or digestive health, they can also be very helpful for hair care, thus preventing dandruff and stimulating hair growth. Oil like peppermint, cedar wood and rosemary can help soothe your scalp, stop dandruff and boost your hair follicles performance for better hair growth (Hay et al., 2018). They can simply be added to shampoos, conditioners and scalp treatments to improve the health of the hair and scalp. Mainly, in addition to this, they are most often used in perfumery where natural scent and aromatherapy are of paramount importance. Oils like lavender, jasmine, and ylang-ylang have been a preferred choice among many to create natural perfumes and scents themselves (Bakkali et al., 2008). With these oils, one can blend them to develop a signature or personalized scent that not only smells like a beauty queen but also enhances psycho-physical well-being through their therapeutic properties.

Household Uses

Aside from medicinal applications, these extracts have been applied in household products to do the functions of cleansing, control of pests, and food preservation due to their natural properties. These oils are a go-to option for people who want to use safe and natural solutions for all their household cleaning and finishing needs. The essential oils are likely to be used by most households for cleaning purposes. Products with ingredients such as lemon oil, tea tree oil, and eucalyptus ensure natural disinfection. It means that those microorganisms are killed (Carson et al., 2006). These oils can be used in different household cleaning solutions, including both all-purpose and floor cleaners, for effective cleaning and sanitizing of the areas at home. Along with the lavender and citrus essential oil, this natural freshener would replace strong odors and create a nice-smelling environment. Another popular use of essential oils is for pest control purposes since many oils have natural repellant properties that deter insects and other organic invaders. The favorite essential oils for keeping the bugs away (mosquitoes, ants and flies) are peppermint, citronella and cedarwood (Regnault-Roger et al., 2012a). These oils, after dilution, can be used as sprays in the house or around the garden for pest regulation without harming the environment with chemicals. Many essential oils as well have antibacterial properties which can be used to discourage the growth of molds and mildew in areas of the home that are excessively damp, such as bathrooms and kitchens. Moreover, essential oils can be applied for food preservation to maintain the perishable goods and at the same time, taste can be intensified. Oils from oregano, thyme, and cinnamon possess antimicrobial activity which can restrict the growth of fungi and bacteria in the food (Fisher, et al. 2018). These oils can be infused with preservation agents like vinegar or oil, which can help prolong food life for a longer time. On the other hand, they are capable of flavoring dishes and beverages, giving a special, aroma to the vivid dishes. To sum up the topic, essential oils have many applications and benefits in the home that stretch from cleaning and controlling pests to food preservation. These special characteristics of essential oils mean they are such a healthy and viable substitute for commercial products as far as daily tasks are concerned, ensuring a safer and less toxic environment.

Industrial Applications

Essential oils are now getting recognition in industrial use because of their unique properties and advantages which they portray. In other words, essential oils, prominent ingredients in the pharmaceutical industry, are widely used in cough syrups and balms because of their antimicrobial and anti-inflammatory characteristics (Bakkali et al., 2008). For instance, eucalyptus essential oil can be found in some over-the-counter cough syrups, known to be decongestant and expectorant (Juergens, 2014). In the food and drinks business, essential oils are a bouquet of aroma and taste, improving product flavor. For example, peppermint essential oil is generally used in candies and chewing gums to create a refreshing and cooling aftertaste (Göbel et al. 2016). Also used for that purpose are essential oils – lemon and orange – for their refreshing flavor and aroma (Burt, 2004). In this area, essential oils are used as plant growth stimulators and natural pesticides that particularly promote healthy crop growth and protect crops from pests and diseases. The oils of neem wood and tea tree that have insecticidal and antibiotic properties replace the synthetic pesticides (Isman, 2000). Microorganisms' spider webs, essential oils and other natural pesticides are not harmful to the environment and have no residues on crops (Regnault et al., 2012b). In brief, essential oils take part in the different techniques of industrial application, for instance, in the fields of pharmaceuticals, food and beverages, as well as agriculture. Such diverse properties make them valuable components of diverse products naturally able to cure coughs, add flavor and act as phyto growth enhancers or natural pesticides.

Cultural and Spiritual Significance

The scent of essential oils has long been utilized in religious ceremonies and cultural events around the world. In religious ceremonies, essential oils are generally used as anointing oils or incense. Anointing oil is a religious practice that reaches many traditions, like Christianity, Judaism, and Islam, to dedicate people, objects, and a place. In Christianity, anointing oils are used in sacraments like baptism and confirmation and also in other rituals like the anointing of the sick. In Judaism, anointing oils are mainly used in the consecration of priests and the anointing of kings. In Islam, anointing oil is utilized in rituals such as the anointing of the dead before burial (Battaglia, 2003).

Furthermore, the fragrances extracted from plant sources are also often used in various religious rituals around the world. The purpose of incense burning is thought to clean air, create a consecrated environment and open a channel for communication with supernatural beings. In Hinduism, incense is widely used in daily ritualistic and ceremonial practices where the gods are being honored and their blessings are sought. In Buddhism, incense is an essential part of meditation which is done to create a calm and focused state of mind. In Native American tribes, the purifying of individuals and space is achieved with incense made from sage and other herbs during smudging rituals (Guenther, 2016).

Besides being used as a part of the religious rituals they are also prevalent in healing practices and ceremonies of a culture. Many ethnic groups worldwide use essential oils for medical nature and body relaxation. Such as in Chinese traditional medicine, they use essential oils in aromatherapy for the balancing of the body's energy and for promoting health and well-being. According to Ayurveda, which is a classical school of medicine in India, essential oil is used in massage therapies, herbal remedies, and spiritual rituals to bring harmony and balance to the body, mind, and soul (Lawless, 2013; Tisserand and Young, 2014). Essential oils perform an important role in ritual and spiritual discourses, either as a means for providing a healthy state, cleansing or linking a person to the divine. The use of plants in religious ceremonies and cultural rituals from ancient times till now is a testament to the deep connection between humans and nature, and also the belief that plants have magical powers of healing the body and soul.

Safety and Precautions

They are powerful plant concentrates that are employed for their healing or beneficial effects. They should be used carefully to make sure we do not get into any side effects, adverse reactions, or unwanted consequences in our bodies (Vostinaru et al., 2020).

Proper Dilution and Application Methods

The issue of proper essential oils dilution is one important thing to consider for safety when following recipes and applying essential oils by oneself. The purity of the essential oils is very high, while the use of them in an undiluted form directly on the skin is prohibited. Generally, the recommended ratio is 1-3% for adults, again specific to the different essential oils for example it applies to all intended uses. It is necessary to make use of the dilution guidelines so that skin irritation or sensitization can't occur. After applying the essential oil to the skin directly, a patch test is also required to check if your skin can tolerate the use of the oil over a larger part. This, in turn, will facilitate and detect allergies or sensitization. Furthermore, oils that the person inhales should never be swallowed except with the assistance of a healthcare professional qualified (Tisserand and Young, 2013).

Potential Side Effects and Contraindications

However, even though essential oils have many health benefits, there are also situations when they can trigger side effects in certain users. As with any other treatment, essential oils can also have undesired effects like skin irritation, allergies, and respiratory issues. This is because of some important oil types that are considered contraindicated for use during pregnancy, nursing, or people with complicated medical backgrounds like epilepsy or high blood pressure).

You must research the safety precautions before the usage of each oil and you must contact a qualified aroma therapist or health care provider if you have concerns about the possible adverse effects or contradictions (Cuba., 2001).

Regulatory Aspects and Quality Control

In the United States which means that essential oils for therapeutic claiming are not regulated by the FDA. This being unregulated allows manufacturers to rise and set the standards that govern the quality and purity of essential oils so they can vary widely among different brands. It is crucial to buy oils from quality-tested and legit sellers who provide clear details of the product's origins, as well as its extraction and handling processes to ensure the oil's safe and disciplined use. Try to avoid essential oils which are labeled as synthetic, or marked only as grade 6 or below, or even fragrance oils. Choose either pure essential oils or organic ones to avoid exposure to toxic components. This way of labeling means that oil brands are end-products of devoted production and do not contain any other additives such as artificial materials or pollution ones (Barbieri and Borsotto, 2018)

Future Prospects

The prospects of essential oils look bright as they continue to be valued for their therapeutic, cosmetic, household, industrial, and cultural significance. Continued research and innovation in the field of essential oils are expected further to expand their applications and benefits in various industries

Conclusion

Essential oils are not new to the world and have been used in wide range of functions right from medical, aroma therapy, cosmetics to cleaning and industrial purposes. The extraction techniques used in obtaining their scents include steam distillation, expression and solvent extraction, which offers powerful oil aromatics that have served various purpose in the past rites, medicine, religion and culture. In the modern world, essential oils are still used to cure various diseases as they were used in the past, and they are known to have various uses such as stress relievers, curers of pains, skin treatments and most importantly repellants of pests. But, with such strength they have come with warnings that need to be taken so seriously. Since it's such a strong solution, its dilution and use have to be carefully done to avert side effects such as skin rash, allergies or respiratory problems. Particular caution should be taken with those people who are pregnant, breastfeeding or have certain health issues. Currently, essential oils have not received much attention when it comes to regulation provided in various countries, and that is why individuals must try as much as possible to get the best quality essential oils, and consult with the right professionals when using essential oils. Hence, the future of essential oils can be said to be bright as further studies continue to be conducted in a bid to discover other uses of essential oils and their effectiveness. Since they continue to play an important role in religious and secular ceremonies, and are already embraced in the health and beauty sector and in industry, one can be assured that essential oils will always part of the cultural life of the world into a distant future.

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Chapter 28

Essential Oils for Health

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ABSTRACT

Essential oils, aromatic compounds extracted from various parts of plants, have been utilized for centuries across diverse cultures for their therapeutic properties. Essential oils possess a myriad of bioactive components, including terpenes, phenolics, and ketones, which contribute to their pharmacological effects. Research indicates that essential oils exhibit antimicrobial, anti-inflammatory, antioxidant, and analgesic properties, among others. These properties make them valuable in managing various health conditions, including respiratory ailments, skin disorders, anxiety, and stress. Different mechanisms of extraction of oils are present like steam distillation, Hydro distillation, superfluid extraction, microwave assisted and Ultrasound assisted extraction. Essential oils represent a promising avenue for promoting health and well-being, offering natural alternatives for managing a wide range of health concerns. Continued exploration and integration of these botanical extracts into healthcare practices hold the potential to enhance holistic approaches to health maintenance and disease management. This chapter provides an overview of the current understanding of essential oils and their potential health benefits.

KEYWORDS
Essential Oils, Composition; Extraction methods; Health; Benefits

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INTRODUCTION

In reference to the notion of "Quinta essentia" developed by the renowned German-Swiss physician and alchemist Paracelsus (1493–1541), the term "essential oil" was coined in the 16th century. Paracelsus established the function of alchemy through the creation of herbal remedies and plant extracts. According to him, the distillation method was utilized to extract the most vital component of the plant, which he termed the "soul" or "essence for healing." This was achieved by distinguishing the "essential" and "non-essential" constituents (Dhifi et al., 2016).

According to the European Pharmacopoeia (Ph. Eur.) and the "Association Francaise de Normalisation" (Association Francaise de Normalisation, 2000), "essential oil" is a substance derived from a naturally occurring raw material derived from plants. It can be extracted through dry distillation, mechanical extraction, or distillation with water or steam from the epicarp of citrus sp. fruits. Subsequently, the aqueous phase is physically isolated from the essential oil (Buch, 2022; Do et al., 2015).

Concept of Actual essential oil

Frequently, every plant is capable of producing essential oils, albeit in minute quantities and in unhealthy proportions. The assemblage of plants that yield essential oil, which holds significant commercial value, is referred to as the oil producing plants (Chlodwin and Novak, 2010). In general, essential oils are found in higher plants, of which there are approximately 17,500 known species. However, certain plant families, such as *Zingiberaceae, Poaceae, Apiaceae, Umbelliferae, Asteraceae, Lamiaceae, Rutaceae, Compositae, Lauraceae, Cupressaceae, Acoraceae, Rosaceae, Oleaceae, Myristricaceae, Myrtaceae,* and others, contain essential oils in healthy quantities (Butnariu and Sarac, 2018; Nieto, 2017; Rahman, 2016).

Variety of Essential Oil

Two types of oils are synthesized by plants: regular and essential oils. Fixed oils are esters composed of a glycerol molecule that is triacylglycerols or triglycerides, to which three fatty acids are affixed. Essential oils (EOs), which are also referred to as fundamentals, flammable oils, ether oils, or aetheroleum, are intricate amalgamations of lipophilic, odoriferous, and volatile constituents that are frequently encountered in aromatic plants (Schmidt, 2010). Except for cinnamon, sassafras, and vetiver, a great deal of oils that are essential are colorless to light yellow, watery at the ambient temperature, and are lighter than water. Furthermore, certain chemical constituents of essential oils are optically active, soluble in the majority of organic solvents (e.g., ether, alcohol, acetone), and do not dissolve in water (Such, 2022).

Part of plant from where we extract EO's

Typically, essential oils constitute a negligible portion of the dried matter of plants (less than 5%). They are found within specialized secretory structures, including glandular trichomes, oil cells, and secretory ducts or cavities. Seeds, foliage, the bark, fruit, vegetation, tree blossoms, roots, forests, and bulbs can all yield volatile or oily substances shown in table 1 (Souiy, 2023).

Table 1: Parts of plant material containing EO's.

Parts	Plants	References
Leaves	Cinnamon, eucalyptus, mint, oregano, pine, tea tree, lemon grass, basil etc.	(Souiy, 2023; Durczyńska et al., 2024).
Flowers	Clove, cumin, rose, lavender, jasmine, orange, tarragon etc.	
Fruit	Black pepper, nutmeg and xanthoxylum.	
Bark	Cinnamon and cassia.	
Wood	Atlas, camphor, sandal, rosewood etc.	
Seeds	Cumin, nutmeg, fennel, anise, almond etc.	

Composition of Essentials oils

Essential oils (EOs) consist of a diverse array of lipophilic and nonpolar components (60–300) with low molecular weight and varying concentrations. Among these components, two or three appear to be the most significant: terpenoids, which are straight-chain compounds devoid of side chains; aromatic and phenolic components; sulfured derivatives; and straight-chain compounds (without side chains) (Baptiste, 2020). The variation in flavor and aroma of essential oils is profoundly influenced by factors such as the type of plant, harvest season, geographic location, dehydration methods, and extraction techniques (Baptiste, 2020; Dima and Dima, 2015). Terpenoids and polypropanoids comprise the primary volatile components of essential oils (Pandey et al., 2023).

Terpenoids and terpenes

Terpenes are secondary metabolites found in plants and are composed of isoprene (2-methylbuta-1,3-diene) units as their carbon backbone (Sadgrove, 2022). In plant cells, the mevalonic acid pathway leads to the synthesis of terpenes. Terpenoids are produced through a variety of biochemical processes, including oxidation and rearrangement of terpenes. Terpenoids are produced through biochemical modifications of oxidized derivatives of terpenes, including esters, ethers, acids, alcohols, ketones, and aldehydes.

Terpenoids constitute the most extensive category of phytochemicals, consisting of approximately 40,000 distinct compounds that have been identified through the process of metabolism (primary and secondary) (Lichtfouse, 2013). An annual addition is made to this category of natural products. Terpenoids can be broadly categorized into four distinct groups: authentic terpenes, saponins, cardiac glycosides, and steroids. These four classes of compounds are typically found in essential oils derived from plants and are found in virtually all biological systems (Sousa et al., 2023).

Hemiterpenes

Hemiterpenes constitute a negligible portion of the terpene composition found in essential oils. In general, these consist of the ester, aldehyde, and alcoholic groups attached to the 2-methylbutane skeleton (Sell, 2010). Hemiterpenes are exceedingly rare in essential oils, comprising fewer than one hundred (Ludwiczuk et al., 2017).

Monoterpenes

Certain essential oils contain monoterpenes, which are molecules with a low molecular weight and larger concentrations (>90%). Consequently, these molecules play a role in the development of a distinct odor exhibited by an herb (Bakkali et al., 2008). Monoterpenes are nearly ubiquitous in plant essential oils and contain a pair of bonds in their structural moiety. These monoterpenes are commonly implicated in plant-to-plant and plant-to-animal interactions, including allelopathic agents, seed dispersal, and fruit dissemination. Monoterpenes, which have over thirty fundamental skeletons, can be classified into three distinct subgroups: acyclic, monocyclic, and bicyclic (Sousa et al., 2023).

Sesquiterpenes

Another significant category of principal constituent terpenes found in essential oils are sesquiterpenes, which have a lower volatility than monoterpenes. These are generated through the fusion of three isoprene units, thereby enhancing their structural versatility. Different forms of sesquiterpenes result from combining all of these three isoprene units: linear, monocyclic, bicyclic, and tricyclic (Sousa et al., 2023).

Diterpenes

Diterpenes, which are chemically and structurally more complex, are rarely encountered as leftovers during the process of essential oil extraction and are typically found in association with plant resin. The high molecular weight of these compounds is a result of the C20 skeleton, rendering these individuals less volatile as well as less abundant in comparison to monoterpenes and sesquiterpenes (Avila, 2020).

Extraction Methods

Extraction procedures are applied to aromatic herbs or their constituent parts, including fruits, leaves, flowers, bark, and seeds, which are gathered at particular phases of maturation and then preserved under controlled conditions (including temperature, light, and humidity). Extraction techniques can be broadly categorized into two groups: traditional, conventional methods and novel approaches. Traditional approaches involve the thermal distillation of water to extract essential oils (EOs) from plant material. However, there have been advancements in extraction technologies that aim to address certain drawbacks associated with conventional methods. The procedure is conducted using energy sources that contribute to its environmental friendliness (Faugno, 2019).

Classical Methods

Hydrodistillation

EO extraction by hydrodistillation is the most ancient and straightforward process. By submerging the raw material in scalding water, which ensures an immediate interaction between the solvent being used and the plant stuff, this technique is distinguished (Presti, 2005). Here, the cellular walls are shattered, the oil and water evaporate, and the resulting vapor is a combination of water and volatile vegetable raw material chemicals. The immiscibility of volatile chemicals and water allows for additional separation by differential intensity (McLellan, 2016). Despite being the most ancient technique, hydrodistillation continues to be employed in the present day to extract hydrocarbons from various matrices. By employing this methodology, the essential oils of *Zingiberofficinale, Rosmarinusofficinalis L., Ziziphoraclinopodioides L., and Citrus latifolia Tanaka* are extracted.

Steam Distillation

Distillation by steam is one of the most popular techniques for extracting EOs. The extraction process operates on the identical principles that govern hydrodistillation. Primarily, the distinction is that the time required to extract the substrate from the water is shortened due to the lack of physical contact between the two. The specimen is positioned within a column, with the lower portion being linked to a beaker containing water that is being heated. The steam is directed through the sample, transferring essential oils to the condenser, which is attached to the top section. The water-oil mixture undergoes condensation as a result of this procedure; this mixture is amenable to liquid-liquid extraction (Irmak, 2008). Commercial and industrial-scale applications of this approach include essential oil (EO) extraction from hops and other plants, including lavender and patchouli.

Organic Solvent Extraction

Certain essential oils (including jasmine and rose) lack thermal stability and cannot tolerate high temperatures. When this is the case, inexpensive organic solvents with low boiling points and chemical inertness may be utilized. Organic solvent extraction involves subjecting the sample to immersion in an organic solvent for a designated duration, such as hexane, benzene, toluene, or petroleum ether, among others. This contact facilitates the transfer of the sample's soluble components. Evaporation of the solvent from the liquid phase concentrates the extracted matrix. The conventional method most frequently employed in the field of cosmetics is solvent extraction (Zhang et al., 2018).

Cold Pressing

By cold pressing, essential oils are extracted mechanically, through which the oil glands are ruptured and volatile substances are liberated. During this procedure, an aqueous dispersion is generated, from which the oil can be extracted using fractional distillation, centrifugation, or decantation. The cold pressing technique is primarily employed for the purpose of extracting oils from citrus produce (Faugno, 2019).

Innovative Methods

Microwave-Assisted Extraction (MAE)

In response to the demand for energy-efficient and environmentally sustainable extraction techniques, microwave-assisted extraction has emerged as a viable substitute for traditional methods. By subjecting the sample to a microwave reactor devoid of any solvent, the internal temperature of the sample cells is elevated as a result of the process of evaporation of the moisture induced by the electromagnetic energy conversion to heat. The rupture of the glands results in the discharge of the essential oil as the internal pressure rises (Kataoka, 2018). This methodology was employed to extract various essential oils from plant matrices, including basil, laurel, lemon, orange, rosemary, and mint (Sakkas and Papadopoulou, 2017).

Table 2: List of advantages and disadvantages of EO;'s extraction methods

Method type	Method Name	Advantages	Disadvantages	References
Conventional	Hydrodistillation	- versatile - Easy to apply - selective	- no complete extraction - high cost of energy - long duration	(Sousa et al, 2022; Souiy, 2023; Murti et al., 2023).
	Steam distillation	- less cost - less time	- longer extractions - higher cost compound to long time	
	Organic solvent extraction	- simple cheap - efficient - suitable for small scale	- more time - more use of solvent - toxic effects	
	Cold pressing	-inexpensive - simple - suitable for production of citrus oils	- Not complete extraction - Not feasible for low oil samples	
Innovative	Microwave-assisted	-High reproducibility - low solvent use - low energy - simple - more yield	- filtration required at the end	
	Ultrasound-assisted	- simple - Inexpensive -Less time - Less solvent use	-difficult to scale up - high energy use	
	Superficial fluid extraction	- less time - less toxic - solvent free extract	- high cost of equipment, installation and operation	

Ultrasound-Assisted Extraction (UAE)

With the help of ultrasound, essential oil extraction can be amplified. So, to speed up mass transfer and the extraction process, it is typically used in conjunction with other extraction procedures. Under ultrasonic scanning, the sample is immersed in a solvent. Essential oils are released by mechanically vibrating the sample's walls and membranes, which is accomplished by rapidly moving the solvent through the sample. It is already being utilized on a big scale in various fields, like the food and medical industries, to improve the extracted substrate's quality, cut down on labor time, and boost yield (Picó, 2013).

Supercritical Fluid Extraction (SCFE)

Supercritical solvents include a variety of chemicals, including water, CO2, methane, ethylene, and ethane. The most used solvent, however, is carbon dioxide (CO2) because of its cheap cost, lack of flammability, low toxicity, and ease of reaching its critical point (low temperature, 31.2°C, and pressure, 72.9 atm, respectively. The oils are dissolved and extracted by passing the sample through supercritical fluid once the optimal extraction temperature and pressure have been chosen. When the pressure in the extraction solution drops below the critical point, the supercritical fluid becomes a gas and can no longer be used as a solvent; this process is then repeated (Yanga and Hu, 2014). This technique is finding more and more commercial usage in the extraction of essential oils from a variety of plant leaves, including those of the horseradish tree, laurel, rosemary, sage, and blooming plants (Baskar et al., 2019).

Examples of different plants to get EO's

Rosemary essential oil

There were two different ways that the essential oil may be retrieved from the various plant components.

Hydrodistillation

A solution will be prepared by combining water with rosemary powder or leaves. The essential oil would be extracted at a temperature of 80^{0}C. It is possible to run the process in a Clevenger-type equipment until no more oil can be extracted. Steam has the ability to evaporate essential oils. Essential oil plus steam vapors condensed as they traveled through a condenser. Separation of the oil-and-water condensate is the next step. Because it is lighter than water, essential oil can be collected by settling it on top (McLellan, 2016).

Steam Distillation

When the steam is turned on, a batch of 100–200 g of ground and dried rosemary leaves will be put into the column by 2000 ml of water. The packed bed will be formed using the raw material. Once the cover is shut, steam is injected into the column to initiate the distillation process. Various steam flow rates will be applied to each plant bed. Every 5,15,30,60, and 100 minutes, we will collect the condensed steam and essential oil. The mixture will decant into its respective oil and water phases after condensation. After collection, the essential oil will be dried using anhydrous sodium sulfate as the drying agent and kept at 4oC until analysis (Aasima et al., 2024).

Lavender essential Oil

The fresh or partially dried leaves of the lavender plant are steam distilled to release their essential oil. As a result of less polar component loss, this method produces more oil than others. Lavender is usually harvested in the month of June. A still is filled with compressed lavender blossoms. With fewer pockets of air in the still, the oil production is increased. After that, the lavender flower is filled to the base and steam-rolled at low pressure using a boiler. Once the heating process is complete, a pipe carrying cold water is threaded through the still's core, releasing the oil-filled lavender flower pockets. After passing through a cold pipe with water, the steam from the heated lavender oil condenses into a reservoir where it can cool and settle. The oil and water will separate in the holding tank as a result of their different densities and polarities; then, the water will be piped out, leaving just the lavender essential oil (Jagdish, 2019).

Castor Oil

The solvent extraction method is the most typical approach. These involve mixing ground seeds with organic liquid chemicals like hexane (C6H14), filtering the mixture, and finally heating it to about 150 °C to evaporate the solvents. In order to refine the retrieved castor oil, hydrochloric acid is utilized to activate the clay. The extracted oil is neutralized by adding sodium hydroxide and sodium chloride. The oil obtained from the extraction procedure is modified using concentrated sulphuric acid (H2SO4), which is subsequently neutralized with sodium hydroxide (NaOH) (Qian et al., 2010). This method is often reserved for usage in laboratories because to its expensive cost and the fact that it utilizes solvents and operates at high temperatures.

Tea tree Essential Oil

Tea tree oil is obtained by steam distillation of the leaves and the ends of the branches. The condensed water distillate is next filtered to remove the oil, which ranges in color from clear to pale yellow. Oil typically extracts between 1% and 2% of the dry plant matter. Although solvent extraction, CO2 supercritical extraction, and distillation are alternative methods of essential oil extraction, steam distillation is still the method of choice for most commercially available oils. It is the best method for distilling vegetative materials because it is the most traditional, easy-to-use method of obtaining essential oils. In addition to producing steam that is readily available, inexpensive, safe, and recyclable, this process also causes no modifications to the essential oil's content during extraction. Consequently, stream distillation can be used to recover crude TTO, which accounts for 35-45% of the volume of Terpinen-4-ol (Hammer et al., 2006).

Mode of action of EO's

A distinct action mechanism for EOs is difficult to describe because of their highly varied compositions. It is true that a chemical may impact some tumor types while having no effect on others. To illustrate the point, research by Murata et al (2014) demonstrated that 1, 8-cineole/eucalyptol can cause human colon cancer cells to undergo apoptosis. On the other hand, according to Bayala et al (2014), this molecule does not impact the survival of prostate cancer and glioblastoma cells. The cell cycle, cell proliferation, and/or death are some of the mechanisms that could be observed, depending on how the active chemicals are enriched. The chemical makeup of an essential oil, specifically its principal functional groups (alcohols, phenols, terpene compounds, and ketone), is typically associated with its biological action.

Bioactivity and different Applications of essential oils

Place in biological research related activities

Due to their extraordinary potential of pharmacological actions and inclination to operate as natural preservatives, essential oils are currently a subject of significant relevance in research and various sectors (Rathore et al., 2023). Numerous studies have confirmed the beneficial effects of essential oils on the environment. Interactions between plants and animals, such as those that serve to ward off predators or restrict germination, or between plants and insects, such as those that aid in pollination, are among the most well-known (Gasmi et al., 2013).

Because microbial degradation can be harmful to customers' health, industries always seek out cosmetics with antimicrobial safety. Cosmetics formulated with essential oils can provide natural antibacterial protection due to their potent antimicrobial properties. Aromatherapy, agriculture (as an insecticide), food technology (as a flavoring agent for drinks, foods, spices, and preservatives), perfumery (as a perfume), and pharmacy (as a healer) all rely heavily on drugs containing essential oils. Essential oils are widely esteemed in the field of plant chemotaxonomy due to their life and significance (VWni et al., 2020).

For cancer cure

Inflammatory and oxidative disorders were the initial targets for the identification and use of most EOs. According to Sharma (2022), there is a connection between the formation of reactive oxygen species and the oxidation and inflammation that can cause cancer, suggesting that these essential oils may also possess anticancer properties. Essential oils (EOs) induce programmed cell death of cancer cells via apoptosis, necrosis, arrest of cell cycle, and dysfunctioning of main cell organelles as shown in figure 2). This is coordinated by an increase in membrane fluidity of the affected cell, reduced adenosine triphosphate (ATP) generation, alteration in pH gradient, and loss of mitochondrial potential, which are the major precursors of cell death (Sharma, 2022).

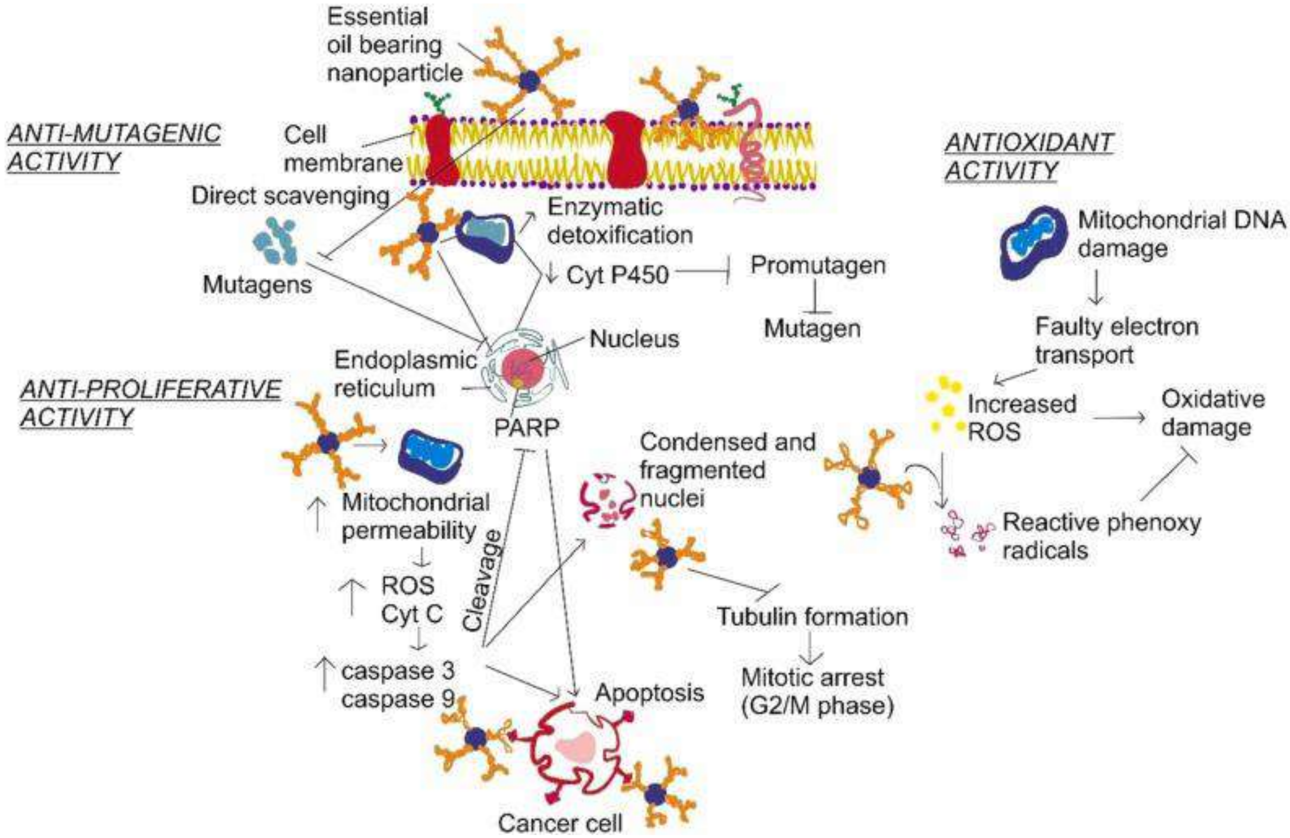

Fig. 2: Apoptosis in cancer cells due to Essential Oil (Sharma, 2022).

Prostate cancer

According to a study conducted by Quassinti et al (2013), the essential oil of *Hypericumhircinum L.* subsp. Majus exhibited antiproliferative effects in human prostatic adenocarcinoma (PC3). The apoptotic effect was observed in human prostate cancer cells that were hormone-dependent (LNCaP) or hormone-independent (PC-3), but not in epithelial cells (RWPE-1), when exposed to jacaric acid and four of its octadecatrienoic geo isomers (Gasmi, 2013). There was a notable reduction in prostate cancer cell proliferation when Pinus wallichiana EO was administered.

It was shown that the volatile oil of Solanum Eryanthum leaves had a strong inhibitory effect on PC-3 cells (Essien et al., 2012). According to Quassinti et al. (2013), Hypericum hircinum's glioblastoma essential oil showed antiproliferative effects on T98G human.

Colon Cancer and Ovary Cancer

Geraniol, a monoterpene present in essential oils of many plants, has the potential to represent a novel class of cancer chemo preventive medicines due to its antiproliferative effects on Caco-2 colon cancer cells (Garzoli et al., 2022). The ovary cells of Chinese hamsters were killed by the essential oil of Cymbopogon Citratus. The CHOK1 cells were inhibited by 68.3% when exposed to the essential oil of Malus Domestica leaves at a concentration of 1000 µg/ml. According to research conducted by Poviessi et al. (2014) the most potent inhibitor of human ovarian cancer cells HO-8910 was the volatile oil derived from the roots of Patrinia Scabra Bunge.

Liver Cancer and Bone Cancer

Essential oils extracted from N. variabillima leaves had a cytotoxic effect on human liver cancer. The essential oils of Zanthoxylum Schinifolium caused human hepatoma cells to undergo cell death (Su et al., 2013). HepG2 cell line relies on reactive oxygen species (ROS) generation rather than caspase activation (Junior, 2024). The anticancer activity of the volatile oil from Pyrolaeherba against SW1353 cells was found to be dose- and time-dependent. These EOs reduced the number of cells that entered the S phase and lowered the levels of cyclin D1, cyclin-dependent kinase (CDK)4, and CDK6, while raising the levels of p21 (Cai et al., 2013).

For Nervous Disorders

In persons younger than 60 years old and older than 60 years old, respectively, prior research has demonstrated that EOs effectively alleviate symptoms of sadness, anxiety, and stress. For example, people over the age of 60 who inhaled essential oils of chamomile and lavender reported less tension, anxiety, and despair. Suppression of sympathetic nervous system activity was proposed as a possible mechanism for the anxiolytic and antidepressant effects. Furthermore, studies have shown that inhaling lavender essential oil during a panic attack might have positive impacts on physiological health, including lowering blood pressure and respiratory rate (Ebrahimi et al., 2021).

Against Corona Virus

The lung and airways are the initial organs infected with SARS-CoV-2, hence it's beneficial that essential oils are mostly inhaled to target these places. In this way, essential oils have a good opportunity to deflect the binding of SARS-CoV-2 spike proteins to their corresponding ACE2 receptors on the parenchyma of the lung. It is possible to concentrate and distribute EOs with anti-COVID-19 activity into the lung, where they will be able to do their activities. The antimicrobial activity of essential oil vapor is superior than that of liquid EO. The formation of micelles by lipophilic molecules in the aqueous phase of essential oils inhibits their attachment to microbes. On the other hand, fungi are particularly targeted by the vapor phase of EOs because of their surface growth (Reyes- Jurado et al., 2020).

Conclusion

In conclusion, the exploration of essential oils for health within this book chapter underscores their remarkable potential as natural remedies for promoting physical, emotional, and mental well-being. Throughout history, these aromatic extracts have been revered for their therapeutic properties, and modern research continues to unveil their diverse pharmacological effects. From their antimicrobial and anti-inflammatory actions to their ability to alleviate stress and enhance relaxation, essential oils offer a holistic approach to health maintenance and disease management. Their integration into various healthcare practices, including aromatherapy, massage therapy, and herbal medicine, highlights their versatility and accessibility Moreover, ongoing research is necessary to deepen our understanding of their mechanisms of action and potential interactions with conventional medications. As we journey forward, the continued exploration and integration of essential oils into healthcare practices hold the promise of enhancing our ability to address a wide range of health concerns while promoting overall well-being. Through an embrace of nature's wisdom and the healing potential of essential oils, we can set out on a journey towards a more balanced, healthier way of living.

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Chapter 29

Role of Essential Oils in Aquatic Health: New Technique for Management of Disease without Inducing Resistance in Pathogens

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ABSTRACT

Because of increased incidence of antibiotic resistance and environmental contamination in aquaculture industry the application of essential oils (EOs) has become a popular alternative approach. This chapter provides comprehensive details about potential of EOs to combat the fish diseases, highlighting the best alternative to traditional antibiotics. This antimicrobial activities of EOs is due to their unique mode of action, as they disrupt regular cellular functions and structures, hence, show equal tendency against Gram-negative and Gram-positive bacteria. Bacterial motility and invasion mechanisms along with virulence is inhibited after the application of EOs, indicating higher efficacy of EOs against these aquatic pathogens. A number of studies have reported the controlling impact of EOs against infections induced by bacterial species including *Pseudomonas*, *Vibrio*, *Flavobacterium* and *Aeromonas* species. Other than this, efficacy of EOs against various fish pathogens i.e., *Nocardia*, *Lactococcus* and *Streptococcus spp* is notable. Anyhow, it is important to consider practical applications of EOs such as selected dose, application methods and expected impacts on aquaculture. The main challenge in establishing the EOs industry is to standardized formulations and optimization of their efficacy with regards to diverse aquatic conditions. Essential oils provide an alternate options for disease management in aquaculture and by harnessing their antimicrobial properties we can overcome antimicrobial resistance along with environmental contamination, ensuring the sustainability of aquatic environments.

KEYWORDS
Essential Oils; Reproductive Disorders; Menstrual Disorders; Polycystic Ovary Syndrome; Infertility; Menopausal Symptoms; Hormonal Balance

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INTRODUCTION

Essential oils (EOs) are those compounds that are derivative of plants and known since ancient times due to its applications in folk medicine and perfumery industries. Numerous parasitic diseases afflict animals, and essential oils play a vital role in their treatments (Toor et al., 2024). EOs compositions depend on various factors including environmental situations (temperature, humidity, sunlight and soil quality), plant part that used for extraction (fruits, leaves, roots, bark and wood), extraction technique and harvesting season. Because of this much variabilities, there always remains a need to adjust doses accordingly to maximize the therapeutic impact of these compounds. Overall, it is important to adjust the required dose carefully and selection should be done by considering composition and efficacy of EOs against selected pathogens accordingly.

Substantial variations have been detected not only among various bacterial species but also among strains within a single species. Essential oils mainly disrupt the bacterial cellular structure, resulting in compromised membrane integrity and the disruption of various cellular functions, together with membrane transport and energy production. Additionally, ruptured cell membrane can result cellular component leakage along with ions loss (Ebani and Mancianti, 2020). Thus, EOs play a significant role in reducing bacterial virulence and impeding mechanisms related to bacterial invasion and motility (Bektaş and Özdal, 2022). The investigation into the antibacterial properties of EOs has garnered growing attention, particularly due to the need for alternative treatments against antibiotic-resistant strains infections as these strains pose a serious threat in both veterinary and human medicine.

In Gram-positive bacteria, the unique cell wall structure facilitates the diffusion of hydrophobic molecules like EOs, allowing them to be functional both in cytoplasm and on the cell wall (Nazzaro et al., 2013). Anyhow, Gram-negative bacteria due to complex bilayer membrane show resistance against antibacterial compounds when compared with Grampositive bacteria as they have single membrane (Savage, 2001). However, it's noteworthy that the second membrane of Gram-negative bacteria is not entirely impermeable to hydrophobic molecules, as some can slowly penetrate through porins (Sutili et al., 2018).

Harnessing the Power of Essential Oils for Enhanced Aquatic Health

Essential oils usually extracted from geranium (*Pelargonium graveolens*) and lemongrass (*Cymbopogon citratus*) leaves by using hydro-distillation method, and through gas chromatography/mass spectrometry (GC-MS) their chemical compositions analyzed. The findings from Al-Sagheer et al. (2018) study indicate notable improvements in growth performance, enhanced antioxidant and immune activities and reduced pathogenic bacterial loads in *Oreochromis niloticus* fish through the supplementation of their diets with essential oils extracted from *P. graveolens* and *C. citratus*. Both Geranium and Lemongrass EOs in vitro application revealed inhibitory effects against pathogenic *Aeromonas sobria* and *A. hydrophila*. Moreover, there was a clear reduction of oxidative stress in fish that were receiving EOs as indicated by increased catalase activity and reduced glutathione activity in fish plasma. Similarly, EOs applications enhanced IgM level and lysozyme activity in fish. Water and intestinal analysis indicated reduced bacterial counts, specifically *Aeromonas* and *Coliform* species. The beneficial effects of dietary supplementation of *Thymus vulgaris* EOs is remarkable in rainbow trout (*Oncorhynchus mykiss*). Thymol, cymene and terpinene are the key compounds and use of *Thymus vulgaris* EOs significantly enhanced the growth of fish as indicated by parameters such as weight gain, length gain, daily growth coefficient and specific growth rate. In fish, gene expression analysis indicated a high regulation of immune related genes including interleukin-1β (IL-1β), component C3, CD4, and lysozyme**.** Moreover, serum lysozyme activity was notably higher and enzyme assays indicated varying levels of aspartate transaminase, alkaline phosphatase and alanine transaminase. Following challenge with *Aeromonas hydrophila*, fish fed TVEO-supplemented diets exhibited significantly higher relative percent survival (RPS) compared to the control group, suggesting enhanced disease resistance (Zargar et al., 2019).

The microbial presence in fish is significantly influenced by the level of microbiological contamination in their aquatic habitats and the hygienic conditions maintained during various stages such as cultivation, harvesting, during processing, in storage and in transportation process (Alerte et al., 2012; Fuertes Vicente et al., 2018). Various bacterial infections affecting fish, such as Aeromonas septicemia, Edwardsiellosis, Columnaris, Streptococcosis, and vibriosis, pose significant challenges to the aquaculture industry. Despite the diverse range of pathogens, few of these are responsible for substantial economic losses globally (El-Ekiaby, 2019).

Targeting *Aeromonas* Species: Harnessing Herbal Essential Oils for Pathogen Control

Aeromonas species, for instance, are prevalent bacterial pathogens found in freshwater and tropical fish species, often leading to bacterial hemorrhage in fish populations. Among these, *Aeromonas salmonicida* stands out as one of the oldest and most widespread fish pathogens, affecting both freshwater and marine species, infection commonly include skin ulceration and hemorrhages (Menanteau-Ledouble et al., 2016). This bacterial species has long been identified as the primary agent responsible for induction furunculosis in fish. Motile Aeromonas septicemia in fish is commonly caused by bacteria such as *A. hydrophila*, *A. veronii* and *A. sobria*. Moreover, various *Aeromonas* species are known to induce disease in fish (Mzula et al., 2019). Infections caused by *A. hydrophila* are linked to a range of symptoms, including red body disease, hemorrhagic septicemia, epizootic ulcerative syndrome, edema and hemorrhagic enteritis. These infections impact various cultivable finfish species such as Goldfish, Common Carps, Catfish, Eel, and Tilapia (Thirumalaikumar et al., 2021).

Antimicrobial properties of certain herbs derived EOs have been evaluated by certain experts against *A. salmonicida*. Hayatgheib et al. (2020) reported minimum inhibitory concentration and minimum bactericidal concentration fall between 113 to ≥3628 μg/mL. Those herbs which shown maximum efficacy include *Thymus vulgaris*, *Eugenia caryophyllata, Cinnamomum zeylanicum/verum*, *Origanum compactum*, *O. heracleoticum* and *O. vulgare*. Moreover, against *A. salmonicida* 18 isolates, antimicrobial properties of essential oils derived from *O. vulgare, O. onites* and *Thymbra spicata* have been reported. In a study, Tural et al. (2019) reported that essential oils collected from *T. vulgaris*, *Petroselinum crispum*, *Laurus nobilis* and *Laurus nobilis* have significant inhibitory effects against *A. salmonicida* with a zone diameter of 30mm. Starliper et al. (2015) reported a higher inhibitory activity of *Cinnamomum cassia* EO against *A. salmonicida* with zone diameter of 56mm.

Essential oil collected from *T. vulgaris* shown efficacy against *A. sobria* and *A. veronii* (Tural et al., 2019). Additionally, Gulec et al. (2014) determined 32.7mm zone diameter of *Origanum acutidens* essential oil against *A. hydrophila*. Moreover, *C. aromaticum*, *C. cassia*, *O. vulgare* and *Cymbopogon citratus* essential oils have found to be effective to control various strains of *Aeromonas*, including *A. salmonicida*, *A. hydrophila* and *A. veronii* with mean percentage minimum bactericidal concentration (MBC) values ranging from 0.02% to 0.65% ((Starliper et al., 2015).

Potential of Essential Oils in Mitigating Vibrio-induced Vibriosis

Throughout history, members of the Vibrionaceae family have posed significant infectious threats to marine fish species (Schiewe et al., 1981). Vibriosis poses a significant challenge to fishery market worldwide, impacting a diverse group aquaculture animals. Two main species including *Vibrio anguillarum* and *V. harveyi* are survivor of both marine and freshwater environments and induce vibriosis in a number of economically important fish species. The more severe hemorrhagic septicemia cases in Rainbow trout (*Oncorhynchus mykiss*), Atlantic salmon (*Salmo salar*) and Japanese seaperch (*Lateolabrax japonicus*) are usually induced by *V. anguillarum*. In aquaculture industry, its outbreaks usually result in extensive fish mortality and substantial economic losses (Yang et al., 2007; Yang et al., 2021).

Research investigating the antimicrobial properties of EOs from *C. verum, C. citratus*, *T. vulgaris, M. alternifolia* and *O. vulgare* against *V. parahaemolyticus, V. harveyi*. *V. campbellii* and *V. vulnificus* and the results against *Vibrio* spp. have revealed moderate to weak inhibitory impacts of these selected EOs (Domínguez-Borbor et al., 2020). Similarly, Wei and Wee (2013) demonstrated that EO from *Cymbopogon nardus* revealed potent inhibitory effects against *Vibrio damsel* and *Vibrio spp*. with 0.488μg/mL and 0.244μg/mL MIC values, respectively. Likewise, *T. vulgaris* EO with MIC values 80 μg/mL against *V. parahaemolyticus* and 320μg/mL against *V. ordalii* was reported to induce strong inhibitory effect (Navarrete et al., 2010). Lee et al. (2009) reported a significant activity of *Syzygium aromaticum* EO against six different *Vibrio* spp. isolates, with 0.015μg/mL MIC values.

On the other hand, EOs of *O. vulgare* subspecies including *O. marjorana, O. Hirtum* and *O. onites* EOs shown inhibitory effects on *Listonella anguillarum*, *V. splendidus* and *V. alginolyticus* with 9.1-14.1mm, 7.3-14.3mm and 7.8-13.6mm zone diameters, respectively (Stefanakis et al., 2013). Additionally, Öntaş et al. (2016) reported marked activity for EO of *Argania spinosa*, with 62.5μL/mL MIC value against *L. anguillarum*.

Potential of Essential Oils in Combating *Pseudomonas* Infections in Aquaculture

Pseudomonas anguilliseptica is commonly categorized as opportunistic pathogen that impacts a number of fish species in both brackish and marine water aquaculture operations globally. Initially in Japanese eel farming it was identified as the causative agent behind red spot disease, since then it has been detected in various other regions, infecting both wild and cultured fish. Among affected species are Black Sea Bream, European Eel, Atlantic Salmon, Whitefish, Ayu, Sea Trout, Rainbow Trout, Baltic Herring, Orange-Spotted Grouper and Striped Jack (López-Romalde et al., 2003; Fadel et al., 2018). Moreover, *P. fluorescens* poses a threat to various farmed fish species. El-Ekiaby (2019) testified that EO of *Ocimum basilicum* with 9 μL/mL MIC value displayed potent inhibitory activity against *P. fluorescens*. Additionally, Wei and Wee (2013) and Lee et al. (2009) found EOs from *Syzygium aromaticum* and *Cymbopogon nardus* shown marked activity against *P. aeruginosa* and *Pseudomonas spp.*, respectively. The EO from *T. vulgaris* with 640 μg/mL MIC value against *Pseudomonas spp.* exhibited moderate inhibitory effect (Navarrete et al., 2010). In a study, Tural et al. (2019) compared the activity of EOs of *L. nobilis*, *T. vulgaris*, *P. crispum* and *R. officinalis* against *P. fluorescens*, and the EO of *T. vulgaris* demonstrated 26.5mm the highest zone diameter among all. Moreover, EO of *T. vulgaris* also shown 13mm zone diameter and prove to be most effective against *P. aeruginosa*.

Essential Oils in Mitigating *Citrobacter* Infections in Diverse Fish Species

Citrobacter spp. poses a threat to fish species as an opportunistic pathogen. *C. freundii* is frequently isolated in fish leading to significant damage and high mortality rates. Notable among the *Citrobacter* species, two species *C. freundii* and *C. braakii* cause diseases in fish species (Jeremić et al., 2003; Lü et al., 2011), former is associated with various fish afflictions, including gill lesions, severe kidney disease, severe enteritis and episodes of hemorrhagic septicemia, particularly in catfish species such as *Pseudoplatystoma spp*. (Pádua et al., 2014).

In catfish (*Rhamdia quelen*), this bacterial group induce leukopenia with neutropenia, anemia degenerative disease, reduced renal hematopoietic tissue, leucoblastosis, protein loss, lymphocytosis, liver degeneration, and the presence of melanomacrophage centers in cephalic kidney and spleen, ultimately result in mass mortality of fish (Junior et al., 2018). Tilapia species, including *Oreochromis mossambicus*, often exhibit symptoms such as body reddening, septicemia, tail necrosis and hemorrhage. Due to these infection the Nile tilapia (*O. niloticus*) frequently experiences high mortality rates. Similarly, economically important Rainbow trout (*O. mykiss*) may display dark pigmentation, gastroenteritis, unresponsiveness to external stimuli, incoordination, intestine petechial hemorrhage, bilateral exophthalmia, pale spleen and ultimately mass mortality. Moreover, in cyprinids like *Cyprinus carpio*, the main infection includes systemic infection and hemorrhagic gastroenteritis (Puello-Caballero et al., 2018). For other species such as Eels (*Anguilla japonica*), Angelfish (P*terophyllum scalare*), Freshwater Rays (*Potamotrygon motoro*), Pacu (*Piaractus mesopotamicus*) and shrimp (*Litopenaeus vannamei*) infection can lead to bleeding and the formation of hepatic and splenic granulomas (Bandeira et al., 2017).

To overcome various bacterial strains application of essential oils is a better option due to attack mechanism. Anyhow, it is crucial to find out which essential oil is effective against which bacterial strain and species before the selection. It is possible that one specific EO shows moderate, low or high inhibitory effects at the same time against different species. For example, against *C. freundii*, the *O. gratissimum* and *H. ringens* essential oils revealed weak to moderate inhibitory impacts (Bandeira et al., 2017). Nonetheless, *L. origanoides* EO showed moderate inhibitory effect (Majolo et al., 2019). Similarly, Öntaş et al. (2016) testified that *Argania spinosa* EO is operational to overcome *C. freundii* as demonstrated by zone diameter of 15mm. Furthermore, it was reported that *C. nardus* EO revealed MIC=0.244µg/mL for *C. freundii* (Wei and Wee, 2013).

The applications of Essential Oil to Mitigate Risks associated with *Raoultella ornithinolytica*

Raoultella ornithinolytica, is an encapsulated bacterium that belong to family Enterobacteriaceae. It is an aerobic gram-negative bacillus that is non-mobile and frequently establish its colonies in aquatic habitats. This bacterial species displays high resilience to maintain viability even at 4°C remarkably (Silva et al., 2016). This bacterium is recognized worldwide as a freshly evolving and potentially life-threatening pathogen. Its impact are not only limited to aquatic environments, but also induce infections in humans. It has the conversion ability and do convert histidine to histamine, ultimately induce skin flushing and poisoning leading to scombroid syndrome. The damage induced because of this bacterium create complications and there is urge need to understand and manage *R. ornithinolytica* induced infections (Kanki et al., 2002; Haruki et al., 2014). This pathogen cause considerable losses to aquaculture operations. There are a number of antibiotics available in market to treat this pathogen but there always remains considerable evidence of drug resistance. Anyhow, essential oil derived from *Ocimum gratissimum* shown significant inhibitory effects against *R. ornithinolytica*.

The application of Essential Oils to Combat *Nocardia seriolae* Infections

In fish the nocardiosis disease is primarily caused by *Nocardia seriolae*, linked through production of granulomas in kidney, spleen, epidermis and gills of crowded fish species. The spreading speed of this disease is slow, hence cause mortalities throughout the culture period gradually (Chen and Tung, 1991; Wang et al., 2007). Due to this disease significant loses have been reported in aquaculture and fisheries sector each year (Wang et al., 2009). A number of fish species including Gray Mullet (*Mugil cephalus*), Japanese Perch (*Lateolabrax japonicus*) and Striped Bass (*Morone saxatilis*) faces mass mortality because of *N. seriolae* infections. Moreover, both wild and culture species have faced an upsurge of *N. seriolae* induced infections. Most commonly affected species include *Trachinotus blochii*, *Epinephelus spp*., *Scatophagus argus*, *Terapon jarbua*, *Lutjanus erythropterus Leionathus equulus*, and *Lates calcarifer* (Tanekhy et al., 2010). Ismail and Yoshida (2017) conducted a study to assess the efficacy of various essential oils (EOs) against 80 isolates of *Nocardia seriolae*. Their investigation unveiled a broad spectrum of minimum inhibitory concentration (MIC) values for EOs of *Thymus vulgaris*, *Cinnamomum zeylanicum*, *Melaleuca alternifolia* and *Cymbopogon flexuosus* ranging from 5 to >5120 µg/mL. Notably, EOs of *C. zeylanicum* and *T. vulgaris* emerged as the most potent among the tested herb species to overcome the bacterial species.

Confronting *Flavobacterium* Challenges by Essential Oils for Aquaculture Health

In marine and freshwater environment the Flavobacterium species are commonly found, presenting significant challenges in aquaculture industry. Within the genus Flavobacterium, three distinct species have been identified as pathogens affecting freshwater and wild fish populations on a global scale. Among this group *F. columnare* cause columnaris disease, while bacterial gill disease induced by *F. branchiophilum* and similarly for cold-water disease *F. psychrophilum* is well known. Research has highlighted that these pathogens exhibit a remarkably broad spectrum of hosts and geographic distribution, making them significant threats to aquatic ecosystems (Orieux et al., 2013; Viel et al., 2021).

The essential oil of *Thymus vulgaris* has been shown to possess potent inhibitory effects with 320µg/mL MIC value against *F. psychrophilum* (Navarrete et al., 2010). Furthermore, *Syzygium aromaticum* EO demonstrated high efficacy against *Flavobacterium spp*., exhibiting 0.031µg/mL MIC value (Lee et al., 2009), while *Cymbopogon nardus* EO showed susceptibility at 0.977µg/mL MIC value (Wei and Wee, 2013). Moreover, *Rosmarinus officinalis* EO displayed a moderate zone of inhibition, measuring over 18 mm against *F. psychrophilum* (Ostrand et al., 2012). Notably, *Allium tuberosum* EO exhibited significant activity against various isolates of *Flavobacterium columnare*, within 20µg/mL-80µg/mL MIC value range (Rattanachaikunsopon and Phumkhachorn, 2009).

Applications of Essential Oils to Combat *Staphylococcus* Challenges

The members of *Staphylococcus* presents a notable challenge as a Gram-positive opportunistic pathogens within aquaculture settings. Noteworthy species from both clinical and food safety perspectives include *Staphylococcus aureus*, *S. epidermidis*, *S. cohnii* subsp. *urealyticum*, *S. lugdunensis*, *S. intermedius*, *S. capitis* subsp. *ureolyticus*, *S. haemolyticus*, *S. hominis* subsp. *hominis*, *S. saprophyticus*, *S. warneri*, *S. simulans* and *S. auricularis* (Sánchez et al., 2017). Among these *S. aureus* stands out as significant opportunistic pathogen prevalent in natural environments. Known for its virulence factors, *S. aureus* when coupled with compromised host defenses, leads to colonization and various diseases. These diseases encompass septic arthritis, pneumonia, abscesses, osteomyelitis, meningitis, pericarditis, empyema, endocarditis and most importantly the toxin-mediated conditions like scarlet fever, food poisoning, toxic shock syndrome and scalded skin syndrome (Arteaga Bonilla and Arteaga Michel, 2005). Notably, *S. aureus* considered to be accountable for numerous instances of foodborne illnesses, including food poisoning, which is usually spread by consuming contaminated food. Consumption of contaminated fish has also been implicated in inducing poisoning (Macori et al., 2016). It was observed that *Ocimum acutidens* EO demonstrated a substantial inhibitory effect, evidenced by a zone diameter of 28mm against *S. aureus* (Gulec et al., 2014). Anyhow, *Syzygium aromaticum* and *Eruca sativa*, showed no discernible inhibitory effects on *S. aureus* (Shehata et al., 2013).

Confronting *Streptococcus*, *Lactococcus* and *Vagococcus salmoninarum* Challenges in Aquaculture

Streptococcus species pose significant concerns for both cold and warm water salmonid species, having zoonotic implications too. One important species include *Lactococcus garvieae*, which is linked to warm-water streptococcosis, results in considerable mortalities, amounting to thousands of tons. On the other hand, cold-water streptococcosis is induced by *Vagococcus salmoninarum*, which causes chronic disease as well as significant broodstock mortality, leading to devastating impacts on aquaculture operations (Saticioglu et al., 2021).

Species belonging to the Streptococcaceae family represent significant Gram-positive pathogens in fish species. Various *Streptococcus* species, including *S. iniae*, *S. parauberis*, *S. agalactiae*. *S. dysgalactiae*, *V. salmoninarum* and *L. garvieae* have been documented across various regions globally (Baeck et al., 2006; Agnew and Barnes, 2007; Nho et al., 2013; Li et al., 2015). Streptococcosis in fish is a complex disease influenced by factors such as host species, pathogen type (strain and species), age, immune status and importantly environmental conditions (Vendrell et al., 2006). Initially, Streptococcal infections in fish manifest on the fins, skin, external organs and gills. It was determined that among nanoemulsions and EOs of *Lavandula angustifolia*, *Eucalyptus globulus*. *Melaleuca alternifolia* and *O. vulgare*; nano-emulsion exhibited the highest effectiveness against *S. iniae* (Gholipourkanani et al., 2019). Additionally, EO of *Oliveria decumbens* displayed 69mm zone of inhibition, with 0.5mg/mL MIC and 2mg/mL MBC values against *S. iniae*, as reported by Vazirzadeh et al. (2019).

Lactococcus spp. have been identified as causative agents of fish diseases. *L. garvieae* is a gram-positive bacterium characterized by hemolytic, chain-forming cocci. Severe hemorrhagic septicemia has been associated with this bacterial species and it can also lead to meningoencephalitis in a number of fish species. Hence, it poses a significant threat, impacting a wide array of freshwater and marine species and ultimately leading to economic losses. Emergence of warm water lactococcosis, primarily attributed to *L. garvieae*, has become a major concern, especially during summer when temperature of water increase directly above 21°C. Because of this illness significant loss of production of rainbow trout occur during last few decades (Halimi et al., 2020). To control the *Lactococcus garvieae* by application of *Thymus vulgaris* EO a study was conducted by Gulec et al. (2014). Results of this experiment shown a zone diameter of 36.7mm against *L. garvieae*. Furthermore, Tural et al. (2019) compared the activity of essential oils collected from *T. vulgaris*, *Rosmarinus officinalis*, *Petroselinum crispum* and *Laurus nobilis* against *L. garvieae*. Outcome of this study exhibited *T. vulgaris* have more potential to control the colonies of *L. garvieae* with a zone diameter of 29.5mm.

One more genus of Gram-positive cocci is *Vagococcus* that have been discovered recently and is famous because of absence of catalase enzyme activity. Within this genus, the total identified species includes; *V. acidifermentans*, *V. salmoninarum*, *V. fluvialis*, *V. lutrae*, *V. elongates*, *V. fessus*, *V. penaei* and *V. carniphilus*. Of these, the most popular bacterium is *V. salmoninarum* because it not only causes disease outbreaks in rainbow trout, but also have been associated with widespread incidence among salmonid species across the globe (Didinen et al., 2014). A number of studies have been conducted to evaluate the impact of essential oils on this selected genus of bacterium. Effects of essential oils including *Eugenia caryophyllata*, *Zingiber officinale*, *Rosmarinus officinalis*, *Origanum vulgare*, *Lavandula hybrid*, *Hypericum perforatum*, *Nigella sativa* and *Mentha piperita*; importantly *O. vulgare* and *E. caryophyllata* EOs shown high potential to control colonies of *V. salmoninarum*.

Conclusion

In aquaculture industry, the role of essential oils to combat the aquatic diseases is undebatable as it is safe and environmental friendly method. The use of antibiotics pose environmental pollution and chances of antibiotic resistance are maximum, while at the same time, the essential oils provides an alternative approach to control fish diseases without the fear for induction of resistance in pathogens. Essential oils shown efficacy against both Gram-negative and Grampositive bacteria because of its unique mode of action including disruption of structures and functions of host pathogens. It is crucial to understand efficacy and composition of EOs against specific host pathogen along with the need of proper information regarding application method and standardized formulations. Application of EOs induce disease resistance in fish and continuous research is required in this area to explore the full potential of EOs for wellbeing of different aquatic environments.

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Chapter 30

Use of Essential oils for the Treatment of Female Reproductive Disorders

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ABSTRACT

Because of their natural healing properties, essential oils have gained attention as complementary therapies for the treatment of female reproductive disorders. Plant essential oils have anti-inflammatory, antibacterial, and hormone-regulating properties that can help improve symptoms such as menstrual disorders, PCOS, infertility, and menopause. Lavender, sage, rose, and geranium oils are often used for menstrual disorders. Lavender and sage can be used to relieve menstrual cramps and regulate menstrual cycles. Cinnamon improves insulin resistance in PCOS and peppermint reduces hirsutism. Geranium oil supports hormonal balance, which is essential for managing PCOS. Sage, geranium, and Roman chamomile are used for infertility. Sage improves fertility by balancing hormones and reducing stress. Geranium oil supports reproductive health and Roman chamomile reduces stress and anxiety that can affect fertility. For menopause symptoms, essential oils can relieve symptoms such as hot flashes, night sweats, and insomnia. Use essential oils like clary sage to balance hormones, peppermint for cooling, and lavender for relaxation and sleep. Use through aromatherapy, topical application or massage. Important safety measures such as dilution and patch testing are necessary to avoid adverse reactions. Essential oils should complement medical treatment. A medical expert, particularly one who specializes in aromatherapy, must be consulted for the safe and efficient application of aromatherapy to treat reproductive disorders.

KEYWORDS
Essential Oils; Reproductive Disorders; Menstrual Disorders; Polycystic Ovary Syndrome; Infertility; Menopausal Symptoms; Hormonal Balance

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INTRODUCTION

Through an assortment of extraction strategies, fundamental oils are natural, normal compounds determined from plant sources. These organisms' therapeutic qualities have been utilized for centuries (Pathania et al., 2021). The application of basic oils to treat women's regenerative clutters has gathered critical academic consideration in later a long time (Bapat, 2022). Surveying the chronicled significance of basic oils within the treatment of women's regenerative clutters is the point of this chapter (Chhabra, 2023). A careful and in-depth analysis will be given, together with an assessment of different methods and the distinguishing proof and basic examination of striking figures that have made noteworthy commitments to this field. Exploring the different benefits and disadvantages related with utilizing fundamental oils to treat women's regenerative disarranges is the point of this paper (Soares et al., 2021). This paper points to investigate conceivable roads for future research improvement in this area. An antiquated civilization's worth of hone can be found within the authentic utilize of fundamental oils to treat women's reproductive disorders. (Auzanneau, 2020). A variety of gynecological disarranges, such as barrenness, postpartum care, and menstrual spasms, were treated with basic oils within the progressed Egyptian civilization. Reestablishing the body's qi, or vitality, to balance and enhancing common physical and mental well-being are objectives of conventional Chinese pharmaceutical, which employments fundamental oils (Patrick, 2023). Fundamental oils have gotten to be increasingly prevalent within the present-day time for treating female regenerative issues. An expanding sum of insightful investigate shows basic oils may be valuable in treating a number of wellbeing issues, such as PMS, fruitlessness, menstrual spasms, and menopausal symptoms (Colles, 2020). Basic oils are viable in treating a number of reproductive disorders such as premenstrual syndrome, menstrual issues, barrenness and menopausal indications. Furthermore, fundamental oils can be utilized in a number of ways, such as fragrance-based treatment, topical application and knead (Patel et al., 2023). Assorted perspectives exist concerning the application of basic oils within the treatment of female regenerative wellbeing concerns. A number of essential oils can be used in ordinary restorative medicines and are both safe and viable. A point of view states that the use of basic oils ought to as it were be carried out beneath the supervision and direction of a certified healthcare professional (Kumar et al., 2022). The utilization of essential oils to treat female regenerative disarranges could be a theme of noteworthy contention. Thinks about are needed to decide the security and adequacy of basic oils some time recently utilizing them to treat a wide range of sicknesses, indeed in spite of the fact that there's a few prove to back them utilize. Prospects for treating women's regenerative disarranges with fundamental oils are empowering (Chukwu, 2021). More examinations are anticipated to supply more data around the security and viability of fundamental oils within the treatment of a wide extend of sicknesses. This investigate may have imperative repercussions for the creation of advanced treatment approaches for female regenerative clutters. A zone of inquire about that appears guarantee is the application of basic oils to the treatment of female regenerative clutters (Misra et al., 2020). The application of basic oils to different restorative conditions is upheld by experimental prove; be that as it may, extra investigation is required to decide the security and adequacy of these applications. Further examination is anticipated to development information of the restorative application of fundamental oils for the treatment of female regenerative clutters (Baldil, 2021).

Table 1: Different essential oils can be used to treat various reproductive disorders in females

Sr.No	Plant Name	Essential Oil	Application	Treatment of Reproductive Disorders	References
1	Lavandula angustifolia	Lavender	Antispasmodic, anti-inflammatory	Menstrual pain, PMS, menopause symptoms	(Firoozeei et al., 2021)
2	Salvia sclarea	Clary Sage	Hormonal balance, stress relief	Menstrual pain, infertility, menopause symptoms	(Ovidi et al., 2021)
3	Rosa damascena	Rose	Mood-lifting, antispasmodic	Menstrual pain, PMS	(Akram et al., 2020)
4	Pelargonium graveolens	Geranium	Hormonal balance, anti-inflammatory	PMS, PCOS	(Jaradat et al., 2022)
5	Cinnamomum verum	Cinnamon	Improves insulin resistance	PCOS	(Pathak and Sharma, 2021)
6	Mentha piperita	Peppermint	Anti-androgenic, cooling	PCOS, menopause symptoms	(Mahendran and Rahman, 2020)
7	Chamaemelum nobile	Roman Chamomile	Calming, anti-inflammatory	Infertility, stress-related menstrual disorders	(Tai et al., 2020)
8	Cananga odorata	Ylang Ylang	Mood regulation, stress relief	Menstrual pain, PMS	(Jiea et al., 2022)
9	Boswellia carterii	Frankincense	Anti-inflammatory, stress relief	Menstrual pain, PMS	(Huang et al., 2022)
10	Foeniculum vulgare	Fennel	Hormonal regulation, antispasmodic	Menstrual pain, hormonal imbalance	(Mehra et al., 2021)
11	Ocimum basilicum	Basil	Antispasmodic, anti-inflammatory	Menstrual pain, PMS	(Shahrajabian et al., 2020)
12	Thymus vulgaris	Thyme	Hormonal balance, antimicrobial	Menstrual pain, hormonal imbalance	(Silva et al., 2021)
13	Origanum majorana	Marjoram	Antispasmodic, calming	Menstrual pain, PMS	(Bouyahya et al., 2021)
14	Citrus limon	Lemon	Mood-lifting, stress relief	PMS, menopause symptoms	(Paw et al., 2020)
15	Salvia officinalis	Sage	Hormonal balance, antispasmodic	Menstrual pain, menopause symptoms	(Mendes et al., 2020)
16	Eucalyptus globulus	Eucalyptus	Anti-inflammatory, pain relief	Menstrual pain, PMS	(Shala and Gururani, 2021)
17	Juniperus communis	Juniper Berry	Detoxifying, anti-inflammatory	Menstrual pain, PMS	(Goncalves et al., 2022)
18	Cupressus sempervirens	Cypress	Circulation improvement, antispasmodic	Menstrual pain, PMS	(Farahmand, 2020)
19	Citrus aurantium	Neroli	Calming, hormonal balance	PMS, menopause symptoms	(Maksoud et al., 2021)
20	Citrus bergamia	Bergamot	Mood-lifting, stress relief	PMS, menopause symptoms	(Cebi and Erarslan, 2023)

Reproductive Disorders in Females

There are numerous variables that influence the reproductive health of women. These factors can effect physical and mental health of females. Barrenness, menstrual issues, endometriosis, polycystic ovarian disorder (PCOS) and hormonal awkward nature are among the regenerative conditions that ladies experience on a customary premise (Dinsdale and Crespi, 2021). These disarranges can disturbed the fragile adjust of the female regenerative framework and cause indications like sporadic feminine cycle, pelvic torment, trouble conceiving, and other issues. The ectopic expansion of endometrial tissue, which is ordinarily show inside the uterine depression, to destinations exterior the uterus, most commonly including the ovaries, fallopian tubes, and adjoining pelvic structures, is the trademark of endometriosis, a constant and regularly serious restorative condition. Intemperate menstrual dying, extreme cramping, and barrenness seem all result from this phenomenon (Ahmad et al., 2023). Menstrual inconsistencies, raised testosterone levels, and challenges with conception are side effects of Polycystic Ovary Disorder (PCOS), an endocrine clutter stamped by the advancement of modest, fluid-filled blisters on the ovaries. Menstrual issues, moreover called dysmenorrhea, are a common issue that numerous ladies experience and can extend in seriousness from minor distress to horrifying misery (Fabricius, 2020). The uterus contracts muscularly amid the menstrual cycle to help within the lining's common shedding, which causes the spasms that are experienced amid the period. Regenerative complications like temperament swings, unpredictable menstrual cycles, and inconvenience getting pregnant are all connected to hormonal lopsided characteristics, which are characterized by either tall or moo levels of progesterone or estrogen (Hammer, 2023).

Endometriosis and the use of Essential oils

Around the world, endometriosis influences approximately 176 million ladies and may be a diligent and frequently weakening regenerative brokenness. When endometrial tissue, which is regularly restricted to the uterine lining, duplicates exterior of the uterine depth, it regularly influences the ovaries, fallopian tubes, and other pelvic organs (Berek et al., 2021). This condition is known as endometriosis. In spite of the fact that it needs a implies of being removed from the body, the uprooted tissue shows highlights of the endometrium's structure and work, counting thickening, debasement, and feminine cycle (Nobleletort, 2021). Greatly excruciating and sporadic menstrual stream, extreme pelvic torment, and as often as possible barrenness are all conceivable results of this marvel. Numerous ladies with endometriosis are investigating elective and all-encompassing approaches to oversee their indications, in expansion to conventional medicines like hormonal treatments and surgery (Hawkey et al., 2022). Basic oils have picked up footing as a promising complementary treatment for endometriosis, with oils like lavender, clary sage, and chamomile showing anti-inflammatory, pain relieving, and antispasmodic properties that will offer assistance lighten serious pelvic torment and menstrual spasms related with the condition. Investigate proposes that fundamental oils seem possibly direct hormonal awkward nature and restrain the development of endometrial lesions (Forgie, 2021). Fundamental oils can be connected in a assortment of ways to assist with the wide extend of indications that are associated to endometriosis since of their versatile nature. Localized pain relief and inflammation reduction have been demonstrated by applying diluted oils to the lower abdomen, back, and pelvic area. The long-term pain associated with endometriosis often exacerbates symptoms of stress and anxiety, which can be effectively managed by inhaling blends of essential oils (Irshad et al., 2020). Because essential oils may be used in baths, body lotions, and diffusers, incorporating them into regular self-care routines may help some women feel better. Since there is a chance that essential oils will interact with medications and cause negative effects, using them as a complementary therapeutic approach for endometriosis requires careful coordination with healthcare professionals to ensure safe and effective use. In the comprehensive treatment of this complex and often incapacitating reproductive disease, essential oils can be a useful adjunct when used appropriately and customized to the patient's needs (Heshelow, 2023).

Essential oil Treatments of Polycystic Ovarian Syndrome

Five to ten percent of women in the reproductive age range suffer from the complex endocrine disorder known as polycystic ovarian syndrome, or PCOS. The hallmark of polycystic ovarian syndrome (PCOS) is the development of ovarian cysts, which can lead to high testosterone levels, irregular menstruation, hormonal imbalances, and difficulties conceiving (Abraham et al., 2021). A number of comorbidities, including insulin resistance, metabolic disorders, and an increased vulnerability to diseases like type 2 diabetes and cardiovascular disease, are linked to polycystic ovarian syndrome (PCOS) (Maqbool and Gani, 2022). Essential oils are becoming a natural and helpful therapeutic option for more and more women seeking symptom relief from PCOS, even though traditional management usually consists of a regimen of hormonal therapies, lifestyle changes, and sometimes surgical interventions. Inflammation can be reduced, hormonal imbalances can be regulated and ovarian and uterine health can be promoted these are just a few of the therapeutic benefits of several essential oils that have been found to have the potential to alleviate symptoms associated with PCOS (Bunse et al., 2022). Applying essential oils topically, internally, or through inhalation are some of the ways that they can be used to treat Polycystic Ovary Syndrome (PCOS), provided that a licensed healthcare professional is watching over and guiding the process. A few drops of the essential oil of their choice mixed with carrier oil and massaged into the lower abdomen have helped some people find relief (Rao, 2021). A few individuals, on the other hand, select to diffuse the oils all through their homes in an exertion to move forward their common prosperity. The utilize of fundamental oils for polycystic ovarian disorder (PCOS) requires meeting with a healthcare proficient since a few oils have the potential to connected contrarily with drugs or cause side impacts. To completely comprehend the useful impacts of basic oils within the administration of polycystic ovarian disorder (PCOS), more investigate is required (Wang et al., 2020). On the other hand, accessible information recommends that these natural substances might be valuable in an integrator, all-encompassing approach to treating this complex affliction. When ladies with Polycystic Ovary Disorder (PCOS) work at the side therapeutic experts, they can investigate the helpful benefits of utilizing basic oils as portion of a all-encompassing approach to make strides their regenerative wellbeing and common quality of life (Kumar et al., 2023).

Role of Essential oils in Menstrual Cramps

A number of females are facing menstrual issues like dysmenorrhea, amenorrhea, menorrhagia, oligomenorrhea or premenstrual syndrome (PMS). The withdrawal of the uterus in response to the lining shedding amid the menstrual cycle is capable for the onset of extreme pelvic torments. Delayed utilize of this strategy can cause critical distress because it discharges fiery chemicals into the body (Mizuta et al., 2023). Other than conventional over-the-counter painkillers and hormonal treatments, increasingly ladies are looking into utilizing basic oils as a common arrangement for controlling menstrual spasms. The strength of menstrual cramps may be lessened by the essential oils of chamomile, lavender, and clary sage, which have demonstrated strong anti-inflammatory, analgesic, and antispasmodic qualities (Sigdel et al., 2023). Research indicates that clary sage has relaxant effects on the uterine muscles, which may help ease the discomfort of cramping during menstruation. Thanks to its anxiolytic and sedative properties, lavender oil can help relieve stress and encourage relaxation during the menstrual cycle. Apigenin, an antioxidant compound that has been shown to inhibit prostaglandin production the agents that cause menstrual cramps is one of chamomile's most well-known properties (Demattio, 2020).

The calming scents of these essential oils can be diffused into the surrounding air, or they can be added to a bath in small amounts, or applied topically to the lower abdomen. Women can choose how to incorporate these oils into their self-care routines. Since herbs like fennel and ginger have anti-inflammatory qualities, many people find that drinking herbal tea with these infusions relieves their menstrual pain (Dewanjee et al., 2023). Essential oils can be a powerful natural solution to relieve the often debilitating symptoms of menstrual cramps when used regularly in conjunction with complementary holistic practices like exercise, stress reduction, and healthy eating habits. It is basic to push that, in spite of the fact that fundamental oils are by and large considered secure when utilized capably, individuals with delicate skin or pre-existing restorative conditions ought to utilize caution when including them to their wellness regimen. As with any supplemental treatment, it is best allude to">to allude to a healthcare supplier some time recently joining fundamental oils into the administration of menstrual issues (Wal et al., 2024).

Essential oil Remedies and Hormonal Imbalances

An sporadic menstrual cycle, temperament swings, changes in weight, and issues getting to be pregnant are fair many of the concerning indications that can emerge from hormonal awkward nature that can have a negative impact on a woman's regenerative wellbeing. The utilize of medicine medicines to treat hormonal lopsided characteristics is the standard in customary treatment strategies; be that as it may, a developing number of ladies are investigating the potential points of interest of fundamental oils as a more characteristic and holistic alternative for overseeing these complex issues (Irshad et al., 2022). There's prove that certain essential oils can adjust hormone generation and reestablish homeostasis within the endocrine system. Studies on clary sage oil have inspected its ability to alter the adjust of progesterone and estrogen, two imperative hormones included within the control of the menstrual cycle and regenerative functions (Critchley et al., 2020). Hot flashes and temperament swings related to the menopausal move can be calmed by fennel oil, which includes a tall concentration of phytoestrogens and has illustrated guarantee in treating side effects regularly connected to hormonal awkward nature. One condition that should particularly concern women with polycystic ovarian syndrome (PCOS) is excessive testosterone synthesis, which thyme oil has shown promise in reducing (Minocha, 2020). Women can investigate various modes of administration, such as topical application, inhalation, and possibly internal consumption, to harness the therapeutic properties of essential oils for addressing hormonal imbalances (under the supervision of a qualified healthcare professional). Diffusion is a method of dispersing essential oils into the environment to promote holistic wellness. Targeted relief can be obtained by applying diluted essential oils to specific areas, such as the lower abdomen, back, or temples, through massage (Bunse et al., 2022).

The use of essential oils to treat hormonal imbalances should be discussed with a healthcare provider because some oils can cause negative side effects or interfere with medication (Ramsey et al., 2020). The processes by which essential oils influence the endocrine system and help to restore hormonal balance are the subject of ongoing research. Thus, among women who are looking for a more all-encompassing approach to managing their reproductive and general health, these natural remedies have become increasingly popular. Women can use essential oils to harness the healing qualities of natural compounds to balance their hormones, reduce associated symptoms, and achieve better balance and health by incorporating them into a holistic self-care routine (Heshelow, 2023).

Potential Benefits of Essential oils and Infertility

After a year of regular, unprotected sexual activity, infertility—which is defined as the inability to become pregnant—is a very personal and often complex issue that affects a significant portion of couples worldwide (Lin et al., 2021). As an alternative to conventional medical interventions like hormone therapy and assisted reproductive technologies, an increasing number of people are turning to holistic and natural ways of improving fertility. Essential oils are currently acknowledged as a potentially beneficial complementary therapy for those who are struggling with infertility. Research on the possible effects of various essential oils on various aspects of fertility has been conducted (Hategekimana and Erler, 2020). Research has indicated that clary sage oil may have a modulatory impact on the menstrual cycle, possibly fostering hormonal homeostasis through adjustments to the concentrations of important hormones like progesterone and estrogen, which are involved in ovulation and implantation directly. Stress and anxiety are known to have a significant impact on both male and female reproductive health (Koyama and Heinbockel, 2020). Ylang-ylang essential oil, with its anxiolytic and mood-enhancing properties, has been found to be helpful in reducing these effects. Studies on frankincense oil's ability to support ovarian and uterine health have been done; these findings may have consequences for raising the chance of a successful conception and implantation (Phelan et al., 2021). Essential oils have the potential to enhance the daily routines of infertile individuals in a variety of ways when included into a comprehensive regimen designed to support fertility. Some efficient ways to harness the potential benefits of these natural compounds are by applying diluted oils topically to the lower abdomen, diffusing them throughout the home, or consuming them internally while under the guidance of a qualified healthcare provider. Before using essential oils for infertility, it is important to understand that you should speak with a healthcare provider because there could be drug interactions or adverse effects (Noh et al., 2020).

Menstrual Disorders and Essential oils of Lavender, Clary Sage, Rose, and Geranium

The utilization of essential oils for addressing reproductive disorders in females has garnered attention as a complementary therapeutic approach. Essential oils, sourced from botanical sources, are purported to possess diverse therapeutic qualities, such as anti-inflammatory, antimicrobial, and hormone-regulating effects (Dosoky and Setzer, 2021). An analysis of the potential applications of essential oils in the treatment of specific reproductive disorders in women reveals that lavender oil, renowned for its sedative properties, has demonstrated efficacy in alleviating menstrual pain (dysmenorrhea) and premenstrual syndrome symptoms through its antispasmodic and anti-inflammatory attributes (Nath, 2024). The nearness of common phytoestrogens is known to contribute to hormone direction, giving potential alleviation from menstrual issues and the foundation of customary menstrual cycles. Since of this substance's capacity to promote disposition, it may moreover offer assistance decrease enthusiastic indications related with premenstrual disorder (PMS) and menstrual torment (Maqbool et al., 2022). Hormone control has been appeared to altogether diminish premenstrual disorder (PMS) indications, such as weakness and temperament swings. Thinks about have shown that affront resistance a issue habitually seen in polycystic ovarian disorder (PCOS) may progress, which may have a positive effect on menstrual cycle direction (Sanchez et al., 2023) The anti-androgenic properties of spironolactone may be advantageous within the administration of hirsutism, a common indication of polycystic ovary disorder (PCOS). It is hypothesized that the advancement of hormonal adjust and decrease of push may possibly increment ripeness. Improving in general hormonal wellbeing is fundamental for legitimate regenerative work. Recognized for its anxiolytic properties, this substance is capable of mitigating stress and anxiety, thereby potentially enhancing fertility (Bashir et al., 2023). Assists in the regulation of hormonal levels, resulting in a decrease in occurrences of hot flashes and nocturnal perspiration. The phenomenon of cooling demonstrating efficacy in mitigating hot flashes. The promotion of relaxation and improvement of sleep can effectively address insomnia commonly experienced during the menopausal transition (Proserpio et al., 2020).

Application Methods

The diffusion of essential oils can offer sustained respiratory benefits through inhalation. The process of diluting essential oils in carrier oils, such as coconut or jojoba oil, and topically applying them to the skin, particularly on the abdomen or lower back, can effectively target the reproductive organs (Mahmoud et al., 2022). The synergistic impacts of integrating essential oils with massage therapy can be attributed to the heightened circulation and increased relaxation that transpire as a result. It is imperative to dilute essential oils prior to topical application in order to prevent potential skin irritation. It is recommended to utilize high-quality, therapeutic-grade essential oils (Soares et al., 2021).

It is advisable to perform a patch test in order to identify and assess potential allergic reactions. Certain essential oils are not advisable for use during pregnancy or lactation.It is advisable to seek guidance from a qualified healthcare professional prior to utilizing the product. An array of reproductive disorders has been acknowledged to benefit from the adjunctive effects of essential oils. They are not meant to replace conventional medical treatments, it is crucial to remember that. Ensuring the safe and effective application of aromatherapy requires consulting with a healthcare professional, especially one with experience in the field (Nguyen, 2020).

Conclusion

When treating a variety of female reproductive disorders, such as irregular menstruation, infertility due to polycystic ovary syndrome and menopausal symptoms, essential oils have been demonstrated to be a useful adjunctive care option. These oils include lavender, sage, rose, geranium, cinnamon, peppermint and chamomile. With programs like aromatherapy, topical application and massage, the use of these natural remedies can be integrated into regular health routines in a flexible manner. Following safety precautions when using essential oils is crucial, as patch testing and appropriate dilution are key to minimizing the risk of adverse effects. For those who are pregnant or nursing, in particular, we advise using premium therapeutic oils and consulting a professional. Even though studies on essential oils and reproductive health have shown promise, conventional medical treatments should not be replaced with essential oils. It may be possible to improve general wellbeing and lessen symptoms related to reproductive disorders by incorporating essential oils as a supplemental therapeutic intervention under the supervision of a physician skilled in aromatherapy. In addition to additional resources for health care, physical relief, and psychological support, this holistic approach may be able to offer women additional benefits.

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Chapter 31

Use of Essential oils an Alternate Approach against Parasitic Infections

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ABSTRACT

Parasites are potentially harmful organism for both humans and animals. Different treatment protocols have been used to treat diseases caused by parasites. Essential oils are one among them. Essential oils are lipophilic chemical extractions obtained from various plant sources have beneficial effects on human or animal health. Essential oils have been observed to have anti-parasitic properties in various studies. In this chapter therapeutic properties, usage form and effects of some selected essential oils extracted from different plants (Tea tree oil, Lavender oil, eucalyptus oil, Cedar wood oil, Lemongrass oil, Citronella oil, Clove oil, oregano oil, thyme oil and peppermint oil) have been discussed. In addition to these limitations and future prospectus of these oils have also been discussed particularly in the filled of both human and animal parasitology.

KEYWORDS		
Parasites, Botanicals, Essential Oils, Therapeutic, Veterinary Medicine, One Health	Received: 12-June-2024 Revised: 18-July-2024 Accepted: 12-Aug-2024	A Publication of Unique Scientific Publishers

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INTRODUCTION

Parasites are the organisms causing fatal diseases in both humans and animals worldwide (Shah and Khan, 2019). They not only cause diseases through their infestation but also cause major socio-economic losses (Pisarski, 2019). These organisms are the major threat to public health, and their prevalence is of health importance (Hazards et al., 2018). The concept of one health can play an important role in controlling these disease-causing organisms as many parasites affect both humans and animals or have zoonotic potential (Dafale, Srivastava, and Purohit, 2020; Organization, 2022). Humans have been using essential oils for aromatherapy for centuries and no one can deny the therapeutic advantages of these oils for the treatment and control of diseases caused by different parasites (Akram et al., 2023; Ebani and Mancianti, 2020).

In parasitology, the use of essential oils and their potential therapeutic effects has also been observed and the results achieved on application of these oils in the control of parasites have been impressive (Dawood et al., 2021; Sorour et al., 2018). This chapter discusses the qualities and therapeutic use of several essential oils in treating parasitic illnesses (Panda, Daemen, Sahoo, and Luyten, 2022). These oils have ability to alter the life cycle of parasites by affecting their reproduction, thus minimize transmission to the susceptible host (Baptista-Silva, Borges, Ramos, Pintado, and Sarmento, 2020; Sandner, Heckmann, and Weghuber, 2020).

Essential oils are widely used in parasitology for therapeutic purpose. However, there are some limitations are associated with these oils e.g. proper dosage, concentration and purity for better result and to avoid undesirable effects (Filip Štrbac et al., 2023a; Filip Štrbac, Petrović, Stojanović, and Ratajac, 2021). Although, in filed there is limited use of these oils because of lack of standardization, field application and approval from international agencies like Federal Drug Regulatory Authority (FDA). After proper testing and approval these oils can be added in parasite control and managemental programs all over the world (Yangilar, 2021).

Commonly Used Essential Oils

Tea Tree Oil

"*Melaleuca alternifolia"* commonly known as Tea tree (TT) is a native plant of Australia. Leaves of *Melaleuca alternifolia* used for oil extraction. It is reported that oil extracted from *Melaleuca alternifolia* leaves possess anti-parasitic properties against variety of parasites including, mites, flea and ticks (Boito et al., 2016; Puvača et al., 2019). Oil extracted from TT is applied topically for treatment of ectoparasites like mites and fleas (Gopinath, Aishwarya, and Karthikeyan, 2018). It has been observed that TT oil is an effective remedy against ear mite infestation in pets (Batista et al., 2016). TT oil is also effective against parasite when used on the parasite dwellings (Nascimento, Gomes, Simões, and da Graça Miguel, 2023).

TT oil can also be applied as an antiseptic for cleaning of wounds and prevent maggot growth (Kon and Rai, 2014). It is suggested that before field application some considerations must be practiced towards TT oil use i.e. proper dilution, topical use and supervision of qualified veterinarian(Robinson, 2020). In addition TT oil can be used very carefully as some of the animals species are sensitive to TT oil (Lemmens-Gruber, 2020; Liuwan et al., 2020).

Lavender Oil

Lavender oil (LO) is obtained from the "*Lavandula angustifolia"* flowers. It is reported that LO oil has antiparasitic and antimicrobial properties. LO has repellent power against ectoparasites generally and bugs specifically (Batiha et al., 2023; Crișan et al., 2023). Khan et al., 2024 discussed dermatological applications and significance of LO oil against control and treatment of parasitic infections. In addition to repellent LO is suitable candidate for the treatment and control of ectoparasites including mosquitoes, insects, and vermin (Tăbărașu, Anghelache, Găgeanu, Biriș, and Vlăduț, 2023). LO can be used locally to overcome redness, swelling, irritation and promote healing at site of infection associated with parasites (Irshad, Subhani, Ali, and Hussain, 2020; Malakar, 2024). In addition, it is noticed that LO is also good choice for the treatment of intestinal protozoa for example Giardia in vertebrates and birds (Hüsnü and Franz, 2020).

Eucalyptus Oil

Eucalyptus oil gets from "*Eucalyptus globulus"*, which has serious solid areas for fragrance and has strong antiparasitic and antimicrobial effects (Adenubi, Abolaji, Salihu, Akande, and Lawal, 2021; Jafari et al., 2021). This oil additionally makes germ-free and mitigating impacts when applied (Göger, Karaca, BÜYÜKKILIÇ, Demirci, and Demirci, 2020). Eucalyptus oil can reduce parasitic infestation by inhibiting egg hatching and interfering with the developmental stages of helminth larvae (de Godoi et al., 2022). The bug repellent property of this oil is more prominent; consequently, it is by and large used as a bug repellent sprinkle in homes and working environments (Salvatori et al., 2023).

This oil should be used in the right concentrations since it can develop sensitivities and antagonistic responses when ingested in higher fixations (Ahmad et al., 2023). The calming impact of eucalyptus is valuable for applying to wounds with maggot infections (Ahuja, Gupta, and Gupta, 2021; Laudato and Capasso, 2013). Eucalyptus oil could help respiratory prosperity; along these lines, it will in general be used in patients encountering respiratory parasites.

Cedarwood Oil

Cedarwood (CW) oil is derived from different parts of "*Cedrus atlantica"* plant (Chauiyakh et al., 2023). In literature it is reported that CW oil exhibit various medicinal properties. This oil has good fungicidal, molluscicidal and repellent activity against insects (Hammam, El-Shouny, El-Sayed, and Ali, 2017). This oil also exhibits anti-inflammatory properties that makes it a suitable natural remedy against wound caused by ectoparasites (Flor-Weiler, Behle, Eller, Muturi, and Rooney, 2022). Furthermore, (Dolan et al., 2014 and Baker et al., 2018), also reported CW oil as an potent repellent against fleas and mosquitoes. Moreover, CW oil in combination with LG oil, can be used for control of flea in household pets (Nollet and Rathore, 2017). CW oil can also be used as soothing agent against itching and irritation caused by parasites (Vishali, Kavitha, and Selvalakshmi, 2023).

Lemongrass Oil

Lemongrass (LG) oil are extracts of "*Cymbopogon citratus*" plant. Gaba et al., (2020) reported antimicrobial, antiparasitic, antioxidant and anti-inflammatory properties of LG. Patoliya et al., (2022) observed that LG oil is an effective oil for insect control. In addition, LG oil exhibit anthelminthic efficacy in animals as reported by Mukarram et al., (2021). Moreover, LG oil has ability to reduce pain and inflammation (Pelvan et al., 2022). Furthermore, LG oil is a valuable agent used for the treatment of skin infections and wound healing (Li et al., 2020). As LG oil contains caleed citral as an active ingredient that effect on insect nervous systems and disrupt feeding activity of ectoparasites (Patoliya et al., 2022).

Citronella Oil

Citronella (CN) oil is extracted from "*Cymbopogon nardus"* plant. This plant is important due to its high potency against ectoparasites specially bugs (Mahmud et al., 2022). CN oil has proven repellent properties against ectoparasites including mosquitoes, fleas and flies (Agnihotri, Ali, Das, and Alagirusamy, 2019; Lee, 2018). Tadee et al., (2024) have been reported that CN oil effects growth and development of parasites by disrupting their metabolism. In addition to repellent properties CN oil has shown anthelminthic properties against poultry helminths (Raza et al., 2022).

Clove Oil

Clove oil is obtained from the buds of "*Syzygium aromaticum"* plant (Boughendjioua, 2018). Clove oil is customarily known in integrative veterinary medication for its strong antimicrobial and antiparasitic impacts (Panda et al., 2022). Clove oil contains a compound called eugenol, which has expansive range antiparasitic impacts against parasites, including GIT nematodes, ticks, bugs and mites (Hari et al., 2022). Eugenol acts on the nervous system of the parasites and stops metabolic processes, thusly prompting to the death of the parasitic organism (Cox-Georgian, Ramadoss, Dona, and Basu, 2019; Mustapha, 2017). In any case, the oil ought to be utilized in little amounts; consequently, high amounts of oil can create harmfulness in administered animals (Horky, Skalickova, Smerkova, and Skladanka, 2019).

Oregano Oil

Oregano plant oil is extracted from the leaves and shoots of the plant "*Origanum vulgare*" through the process of steam distillation (Knez Hrnčič et al., 2020). This oil is famous among renowned among veterinary parasitologists for its strong antioxidant, anti-inflammatory, and surprising anti-cancer properties (Alekseeva, Zagorcheva, Atanassov, and Rusanov, 2020; Karadayi, Yildirim, and Güllüce, 2020). Its high anti-parasitic potential has attracted the attention of veterinary parasitologists to integrative application of this oil in the field (Palomo-Ligas et al., 2023). Oregano oil can be used in smaller and controlled doses for parasitic control in animals (Filip Štrbac et al., 2022).

Carvacrol an active ingredient present in oregano oil has shown antiparasitic activity against several species of parasites (Mondal, Bose, Mazumder, and Khanra, 2021; Tomiotto-Pellissier et al., 2022). In addition, Milunovich, 2014 and Rostro-Alanis et al., 2019 have been reported anti protozoal and anti nematodal efficacy of oregano oil. Furthermore, a few studies have been presented repellent effect of oregano oil against ticks and fleas (Conceicao et al., 2020; Selles et al., 2021). It is suggested that oregano oil should be used on the reccomendation of veterinarian (Ellse and Wall, 2014).

Thyme Oil

Thyme oil (TO) is derived from parts of "*Thymus vulgaris*" plant. TO contains various compounds. However, thymol which is principal constituent of TO have shown *invitro* antiparasitic (Jarić, Mitrović, and Pavlović, 2015). Thyme oil is an effective botanical remedy against many protozoan species including Trypanosoma, Toxoplasma, Giardia, and Coccidiosis (Hikal et al., 2021; Nurdianti, 2023). In addition to antiprotozoal properties TO is also effective against ascariasis (Özkan, Gökpinar, Sibel, Akanbong, and Erdal, 2023). SO far there is no report on the toxicity of TO (Sisubalan, Sivamaruthi, Kesika, and Chaiyasut, 2023).

Peppermint Oil

Peppermint Oil (PO) is extracted from leaves of "*Mentha piperita"* plant (Ibrahim, Ankwai, Gungshik, and Taave, 2021). Peppermint oil is known in veterinary parasitology for both antiparasitic effects and anthelminthic therapeutic effects (F. Štrbac et al., 2023b). This essential oil can be considered for oral administration in small doses in animals. Peppermint oil can be used as effective alternative for treating gastrointestinal nematodes in sheep (Ferreira et al., 2018). The effects of Peppermint oil against parasites including Dactylogyrus sp. has been proven in research (Harmansa Yilmaz and Yavuzcan Yildiz, 2023). Research has also shown that this oil exhibit effective anthelminthic activity against anisakiasis in animal models (Romero, Navarro, Martín-Sánchez, and Valero, 2014). The dosage of peppermint oil should be controlled and used only if recommended by the specialist (McCaskill, 2021).

Challenges and Opportunities

Essential oils on one hand can be proven potentially beneficial if used in optimum quantities but on the other hand, they can be toxic and even fatal if given in a higher amount than prescribed (Sartori Tamburlin et al., 2021). Essential oils should only be used on the recommendation of a licensed veterinary practitioner, because some essential oils can be beneficial, but one species of animal can be proven toxic or allergic to another (Lanzerstorfer *et al*., 2021). For example, cats may show signs of toxicity even when essential oils are given in small amounts. There is a lack of standardization protocols for dosing and prescribing essential oils and their derivatives in veterinary practice (Silver, Silcox, and Loughton, 2021). This makes it difficult for veterinary practitioners to ensure the safe and optimum administration of essential oils to different species of animals hence reduces their usage in clinical presentations (Nehme et al., 2021). In current scenario, there is a lack of regulatory bodies for ensuring the quality and potency of essential oils that raises concerns about the field application of essential oils in veterinary practices (Jackson-Davis et al., 2023; Kanfer and Patnala, 2021). Essential oils can be utilized as better alternatives to traditional veterinary practices in future as many antiparasitic agents also leave undesirable and harmful effects on animals administered with antiparasitic and anthelminthic drugs (Ramdani, Yuniarti, Jayanegara, and Chaudhry, 2023). These oils can be implemented as an eco-friendly and sustainable approach to controlling parasitic diseases. Many essential oils have specific antiparasitic properties, and many have broad-spectrum potency against parasites and worms (Marjanović *et al*., 2020). Hence, they can be administered for treating a targeted parasitic treatment approach as well as for treating multiple parasitic species infestations. Essential oils can be used for preventive care and as stress-relieving agents against parasitic diseases to improve the overall wellbeing of animals (Darrell, 2022). A reasonable amount of essential oils can be added to animal feed to increase the nutrient profile and as a parasite-preventive strategy in animals (Horky et al., 2019).

Future Research

There is a limited research bank proving the antiparasitic properties of essential oils. There is evidence that essential oils exhibit antiparasitic and anthelminthic properties but are not well defined (Matté, Luciano, and Evangelista, 2023). There is a need to establish proper procedures to testify essential oils use in veterinary medicine following proper application methods and calculation of proper dose (Bunse *et al*., 2022). In addition, further research studies will be carried out to evaluate toxicity of these essential oils in controlled and field conditions (Rojas-Armas et al., 2019; Teke, Elisée, and Roger, 2013).There is a need for the development of assessment protocols through clinical trials describing the efficacy of essential oils for usage in veterinary practices for parasitic diseases. It is crucial to conduct research focusing on the adverse effects and allergic reactions of essential oils, if any, consequently ensuring the safety of these antiparasitic armors (Calvo-Irabien, 2018). It is also important to have trials to investigate the long-term potential effects of essential oils in veterinary parasitology (Nechita, Poirel, Cozma, and Zenner, 2015). There is a huge gap in research and studies on the practical application of essential oils in the field of veterinary medicine for the control of parasites have been observed. This chapter identifies the properties; clinical applications and adverse reactions of commonly used essential oils and paves the way for future research by identifying gaps and by proposing required research implications for the development of these potential natural resources for treating parasitic diseases and improving animal welfare.

Conclusion

Essential oils are one of the options used for the treatment of parasitic infections in filed along with other treatments regimes and protocols if administered under the supervision of veterinary and health practitioner. They can be used generally and specifically for the treatment and control of parasitic infections. On the basis of literature review and studies conducted so far, it is generally concluded that essential oil extracted from plant sources are one of the best alternatives to synthetic ant-parasitic agents. In addition to this there is minimum chance of anti-parasitic resistance associated with these essential oils. Veterinary health professional must communicate to the farming community about the safe usage of these oils against parasitic infections.

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Chapter 32

Essential Oils as Alternative Treatments for Common Parasitic Infections in Animals

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ABSTRACT

Essential oils are reported to be effective for the natural, alternative treatment of common parasitic infections in animals. These are plant derivatives endowed with properties against the parasitic population, anti-inflammatory, and antimicrobial properties that could reduce reliance on synthetic chemical treatments. These oils have been shown to have effects against a number of ectoparasites, such as ticks, fleas, and mites, and endoparasites, such as roundworms and hookworms. These varied active compounds from the essential oils act on the different pathways of the parasites, causing a hindrance in their life cycles, reproduction, and host-infesting ability.

Among the main benefits that have been derived from the use of essential oils are reduced risks of resistance to parasites and, in some cases, synergistic effects when applied in combination with other natural compounds or conventional drugs. These would, however, come with major challenges requiring quality control of oils with variable compositions, possible animal toxicity or side effects, correct dosing and administration recommendations, and suitability for a large-scale production setting. Comprehensiveness in aspects such as safety, modes of action, and clinical trials is necessary for their development.

The essential oils are not an absolute substitute for veterinary care, but they are quite promising in a complementary approach, and it is under professional guidance that they should be used judiciously. These limitations can be taken care of by rigorous study, standardization, and collaboration with stakeholders to uncover the applications of these natural remedies in the fight against parasitic infections and in promoting animal health and well-being. In this regard, continuous research will disclose several sustainable options for parasite control.

KEYWORDS Essential oils, Parasitic infections, Antimicrobial properties, Resistance reduction, Animal toxicity	Received: 15-June-2024 Revised: 08-July-2024 Accepted: 02-Aug-2024	A Publication of Unique Scientific Publishers

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INTRODUCTION

Essential oils have gained importance as alternatives for the management of several afflictions in both humans and animals (Koul, Walia, and Dhaliwal, 2008). Although the aromatic properties of these plant-derived oils have been used extensively, their prospects in medical applications, especially as alternative treatments for common parasitic infestations in animals, are becoming more and more interesting. Parasites can become serious health hazards in animals, affecting growth, behavior, and well-being. Most of the conventional approaches are based on the use of synthetic chemicals and hence have negative effects. Essential oils stand out as a natural approach that may reduce our dependence on synthetic compounds (Sarkic and Stappen, 2018).

The applied essential oils to the parasitic infections in animals are all extracted from different plants, all with specific characteristics. Some widely known ones are tea tree, eucalyptus, lavender, and peppermint (Ellse and Wall, 2014). These oils have been noticed as anti-parasitic, anti-inflammatory, and antiseptic properties, which have made them quite attractive in comparison to traditional treatments (Upadhyay, 2010). The key point to their efficiency is in their active compounds, such as terpenes, which are known for their biological activities (Maimone and Baran, 2007).

The entire gamut of animal health problems is caused by different kinds of parasites (Smith, 1970). Classic chemical treatments are effective, but side effects and resistance make alternative, more natural solutions necessary. In this sense, evidence is also given for the potentials of essential oils, considering that many of them have antiparasitic properties that can be exploited for the treatment and prevention of the most common parasitic infections in the animal world (Ramdani, Yuniarti, Jayanegara, and Chaudhry, 2023).

Among the most researched anti-parasitic agents in the essential oils is neem oil (Etewa and Abaza, 2011). Neem oil is obtained from the tree of neem. It has been widely used through generations in the field of traditional medicine, especially in India and other parts of Asia, to carry out its insecticidal, anti-inflammatory, and antiseptic activities. Scientific research has indicated that this oil has the ability to fight off several parasites such as ticks, fleas, mites, and intestinal worms (Selles et al., 2021).

The active ingredient in neem oil is azadirachtin along with other limonoids, which is known to disturb the life cycle and reproduction of the parasite, acting as feeding and molting deterrents (Muhammad and Kashere, 2020). For instance, neem oil has killing and repelling effects on ticks, fleas, and mites. It holds the potential as an alternative method to conventional chemical acaricides or treatments administered against ectoparasites (Gupta, Doss, Srivastava, Lall, and Sinha, 2019).

Additionally, neem oil has been found to act against internal parasites, namely roundworms and hookworms (Sunita, Kumar, Khan, Husain, and Singh, 2017). Given orally or applied topically, neem oil kills these parasites inside the animal's body, thus reducing the likelihood of gastric parasites and other health-related problems associated with internal parasitic infestations. Another major essential oil that will be focused upon is that of the clove plant, Syzygium aromaticum, which is highly rich in eugenol, a compound of very strong antibacterial, antioxidant, and anti-inflammatory activity. These factors make the oil of the plant very interesting for treatment of parasitic infections in animals (Gurib-Fakim, 2006).

Other studies have reported clove oil to have proved as an effective acaricide in killing and repelling several ectoparasites, including ticks, fleas, and mites, on contact. Due to its strong smell and insecticidal characteristics, it has the potential to be an ideal natural repellent, and animals do not contract the parasites (Mele, 2020). Secondly, it has been shown effective against internal parasites, especially roundworms and hookworms, so it can be used against gastro parasitism treatment. The other very important essential oil is garlic oil, which is likely to harbor some potential benefits as an antiparasitic. Allium sativum, popularly known as garlic, is one of those plants that have been known to harbor several medicinal uses since time immemorial. In addition to its medicinal uses, its oil has several sulfur-containing compounds, such as allicin, that exerts strong antimicrobial and anti-inflammatory effects (Lemar, 2005).

The studies confirmed the effect of garlic oil on a vast spectrum of parasites, from ticks and fleas to mites and intestinal worms. Some components in the oil will interfere with the life cycle and the ability of the parasites to reproduce; hence, they shall not be able to survive in or on the host animal (Hrckova and Velebny, 2012). In addition, garlic oil may stimulate the animal's immune system in the fight against parasitic infection. Although essential oils have been reported as a potential natural alternative in the treatment of animals' parasitic infection, the effectiveness of essential oils may vary with the host species, dosage, method of administration, and individual host response. Therefore, it is important to consult with a veterinarian or animal health professional prior to the inclusion of any essential oil in a treatment protocol for parasites (Singh, Gupta, and Singh, 2004).

Essential oils should be applied correctly on animals, in the right dosage, and with the right procedure (Tisserand and Young, 2013). Many of the essential oils are highly concentrated and can cause irritation or be toxic in inappropriate dosages. Often, it is recommended to dilute them into carrier oils, such as coconut or almond oil, which further helps in reducing the risk for any adverse reactions. Also, there should be the consideration in the method of application as well as the specific invasion of the parasitic disease or the totality of health condition of an animal (Stevanović, Bošnjak-Neumüller, Pajić-Lijaković, Raj, and Vasiljević, 2018).

Of significant note is the possibility of the interaction of essential oils with other drugs or treatment. Some could interfere with the drugs or potentiate their action, leading to side effects or lack of effectiveness. The veterinary officer should be informed of all other drugs and treatments the animal is on before using essential oils in the management of the animal (Edris, 2007).

Moreover, reputable suppliers are there to be found, and they can always ensure high quality, pure essential oils. Poor extraction or even adulteration of the oils has the potential to create contaminants within the oil or to reduce the amount of available active ingredients, therefore reducing efficacy and potentially causing harm to the animal. However, their use to treat common parasitoses in animals should be approached with care and under the guidance of a veterinary professional. Suitable doses, methods of application, and the potentiality of the interactions and adverse effects must be considered before safe and effective application of any natural medicine (Tisserand and Young, 2013).

Research on the mechanisms of action and optimal application of these various essential oils in the treatment of parasitic infections of animals continues to provide revealed scientific evidence to support more practical application of essential oils within conventional treatment protocols and, most likely, further the health and well-being of animals while reducing the use of synthetic chemical treatments (Bassolé and Juliani, 2012). In addition to the anti-parasitic potential, most essential oils possess an antimicrobial, anti-inflammatory, and analgesic effect, adding value in relation to the treatment of secondary problems to the parasitic infection, such as skin irritation, inflammation, and pain (Chouhan, Sharma, and Guleria, 2017).

For example, lavender oil is believed to be calming and also carries some extremely powerful properties in the case of anti-inflammatory and analgesic actions. Added to the therapies against parasites, it will aid in the reduction of pain and inflammation in the skin associated with these organisms, helping the affected animal heal more quickly and be less stressed (Grecu, Henea, Trifan, and Rimbu, 2021).

For instance, while tea tree oil has been studied extensively for its potent antimicrobial and anti-inflammatory activity, it can possibly exert an anti-parasitic effect. This all-purpose oil can prevent secondary bacterial or fungal infection due to skin irritation or open wounds created by parasites and offer a fuller scope of treatment of these infections (Lam, Long, Griffin, Chen, and Doery, 2018).

For instance, thyme (Thymus vulgaris) essential oil contains many monoterpenes, thymol, and carvacrol, which have been highly efficacious against a wide range of parasites, including ticks, fleas, and intestinal worms (Gonçalves et al., 2017). Indeed, this can potentially interfere with membrane permeability, enzymatic activities, and energy production in the parasites, thus offering difficulty in developing resistance due to the multiplicity of action (Sardari, Mobaiend, Ghassemifard, Kamali, and Khavasi, 2021).

In the same way, oregano essential oil from Origanum vulgare has high amounts of phenolic compounds, mainly carvacrol and thymol, together with other terpenes such as p-cymene and γ-terpinene. These different compounds act in a synergistic way in the different aspects of the physiology and metabolism of the parasite, which can reduce the likelihood of resistance development (Štrbac et al., 2022).

The advantage of EO-based alternative treatments may rely on the possibility of synergistic interactions of EOs with other natural compounds or with conventional treatments. Therefore, the beneficial effects of the essential oil-based treatment, used in combination with other natural remedies and selective conventional treatments, might have an additive effect on the control of the parasite population with a low risk of resistance development (Ju et al., 2022).

For instance, synergistic effects regarding combinations of essential oils and plant extracts, or other natural molecules, have been studied. The combination of thyme essential oil with grapefruit seed extract has shown good results against a wide spectrum of parasites, including ticks and fleas. This combination may potentiate their anti-parasite activity at lower concentrations compared with the individual components (Yuk, 2021).

Moreover, they may be combined with conventional treatments so that the fight against resistance can be ascertained. Essential oil treatments, in rotation or in combination with synthetic chemical treatments, may target the parasites from different fronts, thus reducing selective pressure and extending the life of conventional treatments by lengthening the time until the development of resistance to them (Isman, Miresmailli, and Machial, 2011).

It is worth noting, however, that the use of essential oils as alternatives for treating parasitic infections in animals still remains at its infancy stage, and more research studies are needed to elucidate further the mechanisms of their action, to find the ideal formulations, and eventually establish their interaction with other treatments (Alviano and Alviano, 2009).

This consideration, therefore, brings to significance the role of standardization and quality control when using essential oils for therapeutic purposes. Essential oils may have varying composition and strength because of factors such as the species of the plant, the growing conditions, extraction procedures, and storage conditions among others. These variations might interfere with efficacy and safety hence the need for high-quality standardized products that were derived from reputable suppliers (Sachan, Sachan, Kumar, Sachan, and Gangwar, 2010).

Furthermore, care and caution are taken when applying and dosing the oils according to the veterinary officer's opinion. Essential oils are very concentrated; therefore, if applied incorrectly, they can lead to toxicities or even adverse reactions. Dilution, application methods, and calculations on the dosage follow to make sure the application of these natural remedies is safe and effective (Hanif, Nisar, Khan, Mushtaq, and Zubair, 2019).Consider also that there are some animals which are not compatible with treatments based on essential oils, and the efficacy depends on the type and degree of the parasitic infection.

The consultation of the pet and animal owner with qualified veterinarians or equally competent animal health professionals on the use of essential oils in their program of treatment in the animals concerned cannot be overemphasized. These said professionals shall also assist them in the selection, dosing, and proper utilization of the essential oil relevant to their needs (McCaskill, 2021).Likewise, more research should be done, along with the collaboration of veterinary experts, researchers, and other professionals who have knowledge in essential oils, to gather more information on potential application and limitations of EO products.

While there is great potential in the use of essential oils as alternative treatments in common parasitic infections in animals, caution in their use and professional guidance regarding scientific rigor is in order. Integrating traditional veterinary care with evidence-based practices of integrating essential oils and other natural remedies is going to help us advance overall health in animals and deal with the growing concern of resistance to conventional, pathetic chemical treatments (Bakkali, Averbeck, Averbeck, and Idaomar, 2008).

Since more and more research is being directed toward the anti-parasitic activity of essential oils, it becomes obligatory to take into account the parasite-destroying potential of natural compounds against specific parasites. Essential oils of different plants have been tested against different parasites and have been shown to possess variable potentials. The knowledge of such specificities becomes very important to help in developing targeted treatment strategies

(Azadbakht, Saeedi Akbarabadi, Motazedian, Monadi, and Akbari, 2020).

The most important group of parasites for which the treatments with EO have been widely studied is the ectoparasites, including ticks, fleas, lice, and mites. These parasites because considerable physical annoyance, skin irritation, and may, through this discomfort and irritation, be transmitting a disease to the host animal, therefore high priority is given to measures that control them (Selles et al., 2021).

Some of the essential oils with a potential role in the control of ectoparasites include neem, tea tree, and lavender essential oils (Gupta et al., 2019). They have evidenced strong potential for having insecticidal and repellent activities against ticks and fleas. Essential oils can interrupt the life cycle of these parasites and keep them from infesting animals, thus reducing the incidence of potential tick-borne diseases (Etewa and Abaza, 2011).

Other parasites that fall into this class, treatable by the same treatments, are the endoparasites in nature, which include the intestinal worms, such as roundworms, hookworms, and tapeworms. These internal parasites cause serious gastrointestinal disturbances, malnutrition, and in general, poor health if untreated (Braga de Oliveira et al., 2021).Other essential oils with good potential as anti-helminthics include garlic, wormwood, and clove. These contain active principles that suppress the survival and reproduction of intestinal worms (ND, DeGrandpre, and DeGrandpre, 2010).

It is worth noting that EO can also be effective in the treatment of some parasites, depending on the species, life stage, concentration, and application method. There is, therefore, a need for further targeted research and clinical evaluation to establish the optimal formulation of EOs and a treatment protocol for many types of parasitic infections (Ellse and Wall, 2014).

Another advantage of using essential oils for alternative treatments is that they can be blended for possible synergistic effects or possibly in combination with other natural compounds, or with conventional treatments. A few studies report synergistic anti-parasitic activity of combined blends of the oils; combined effects of a number of oils were much better compared to combined effects of their individual effects (Miller, 2020).

An example is the blend of thyme, oregano, and clove essential oils, which showed increased anti-parasitic activity against the activity of different ecto- and endoparasites compared to the single oils. The broad spectrum of active ingredients in these oils may act in a concerted way, thus increasing the overall effect in a synergistic manner on various pathways in the parasites (de Almeida et al., 2023).

However, in most cases, essential oils are combined with other bioactive natural compounds, for example, plant extracts or phytochemicals, to possibly increase their activity in anti-parasitic effects. For example, neem oil could be combined with the extracts from other plants, such as wormwood or black walnut, to multi-targetedly work on intestinal worms. Apart from their anti-parasitic property, their immunomodulatory effects could potentiate this therapeutic effect. Essential oils, including frankincense and myrrh, stimulate immune responses and promote normal immune health in animals (Diniz do Nascimento et al., 2020).

Thus the use of such essential oils in therapeutic regimens is probably useful not only directly against the parasites but also for potentiation of natural defense mechanisms of the animal, which would enhance the ability to resist and recover from parasitic infections (Edris, 2007).

However, it is cautious to use a mixture of essential oils or in combination with other natural compounds or conventional treatments. In the latter case, the possible interactions, contraindications, and the establishment of an appropriate dosing and administration protocol need to be adequately evaluated by the guidance of veterinary professionals to be safe and effective (Seow, Yeo, Chung, and Yuk, 2014).

As research in this area advances, the rigorous scientific studies, which should be conducted to validate the antiparasitic effects of essential oils and to develop evidence-based treatment protocols, should be conducted. Also, very important, to improve our knowledge about the possible applications and limitations of EO as a real treatment alternative to common parasitic infestations in animals, is that the collaborations of veterinary researchers with EO experts together with animal health professionals have to be enhanced. While the antiparasitic potentials of the essential oils bring hope to alternative treatments, their use might be met with some challenges and limitations. Understanding such challenges is a way for researchers and veterinary professionals to approach the development of more effective and safe applications of essential oils in combating parasitic infections in animals (Dawood et al., 2021).

This is one of the main problems with the use of essential oils in alternative treatments: there is variability in their composition and quality. Essential oils are complex mixtures of volatile compounds, and their chemical composition may greatly differ depending on the botanical source, geographical location, growing conditions, extraction methods, and storage conditions. This will result in variations in their potencies and effectiveness, which makes it hard to standardize any treatment protocol (Zuzarte and Salgueiro, 2015).

The two major considerations, during the synthesis of essential oils for therapeutic uses, include standardization and strict quality control. This may be achieved, for example, by the employment of analytical methods such as GC-MS to establish the chemical composition of the essential oil accurately in order to achieve batch-to-batch consistency. The employment of standardized extraction and processing methods could also minimize variability of the end product (Daferera, Ziogas, and Polissiou, 2000).

Other problems that can occur are possible adverse reactions and toxicity with the use of essential oils in animals. Most of the essential oils are generally recognized as safe in humans; however, the safe margins in animals may be different because of the variations in metabolism, absorption, and sensitivity. Some of these may be toxic with the application at high concentration topically, or in some species when ingested. Such potential risks can be offset through safety studies in their entirety, researching the potential toxicity and undesired effects of the oils in animals. Factors that need to be researched include lethal doses and organ-specific toxicity, in addition to interactions that could possibly be instigated from other medications or treatments. Safe dosing, dilution, and methods of application need to be put into place and advised appropriately by the veterinary professional (Lemmens-Gruber, 2020).

Another challenge is the administration and dosage of the essential oils, which is properly diluted since they are of a high concentration and potency. They cause ineffective treatment or even damage to the animal because of the wrong application or dosing. Proper calculation of dosages to be used, based on the weight and condition of the animal, is very important. Proper and safe veterinary application of essential oils in the treatment of parasitic infections in animals is assured when experts in essential oils are part of the team that determines appropriateness, dosage, and method of administration as well as considers the parasitic infection and the status of the animal. Such close collaboration between the essential oil expert and the veterinarian may be considered a bridge between traditional knowledge and modern scientific understanding to secure a responsible, evidence-based use of natural remedies (Tisserand and Young, 2013).

Besides, the risk of developing resistance to essential oils should not be underestimated. Although essential oils provide a very good alternative to the conventional treatments with chemicals, their massive, non-selective use could lead over time to the selection of parasites that develop resistance. Strategies to decrease the development of resistance, such as rotation or integration into more conventional treatments, should be researched and implemented (Woolf, 1999).

However, there may be limits to how scalable and accessible these treatments are, as the numbers of animals being produced or farmed are very large. However appropriate they are for an individual pet owner or small-scale operation, their cost-effectiveness and practical use at a higher level of implementation need to be scrutinized and optimized (Marincaş and Feher, 2018).

In conclusion, it is also important to remember that essential oils are not a total replacement for the conventional care and treatment through a vet. This means that complementary treatments and/or alternatives to be used with the traditional methods should be under the guideline of competent veterinary professionals. An integrative approach to holistic care could possibly combine the beneficial features of both the conventional and alternative therapies and offer the most effective strategy in the management of parasitic infections in animals (Tisserand and Young, 2013).

This will only be achieved if these challenges are looked at with lots of research, standardization efforts, and also collaboration of different stakeholders in the process. Essential oils will therefore be able to achieve their full potential as alternative treatments of common parasitic infections in animals, hence improving animal health and welfare.

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