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Research Article

A Science Review of Selected Essential Oils and their Botanical Ingredients. Focus on Essential Oils used for Respiratory and Calming Indications

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Abstract

Interest in botanical ingredients is rapidly growing. Essential oils are a key part of this growth and are one of the most important natural products derived from plants. Rising prevalence of both mental and physical health issues is contributing to this increased demand. Essential oils have been used traditionally for millennia and scientific research is now uncovering the potential mechanisms of action of biological active ingredients in these preparations. Many thousands of such compounds, mainly terpenes, including monoterpenes and sesquiterpenes, and also phenolic compounds, alcohols, aldehydes, esters and ketones have been identified in essential oils. Thanks to their chemical composition, essential oils possess numerous biological activities (e.g., antioxidant, anti-inflammatory, antibacterial, antifungal, antiviral). Anecdotally, and in the practice of aromatherapists, they have been shown to enhance mental and physical well-being and provide refreshment from exhaustion. Increasingly they are used in aromatherapy practice in various disorders such as cardiovascular disorders, sleep disorders and Alzheimer's disease. This review evaluates laboratory and clinical evidence on a range of essential oils and their botanical ingredients.

Keywords: Botanicals; Bioactives; Essential oils; Mechanisms; Respiratory; Sleep; Sedative

Introduction

Interest in botanical ingredients is growing. Globally, the market was estimated to be worth 131 US billion dollars in 2019 and is expected to grow at a Compound Annual Growth Rate (CAGR) of 7% between 2020 and 2027 [1]. Reasons for this growth are several, including a growth in interest in health and wellness, a desire for self-care and taking better control of one's own health and the search for authentic natural ingredients to contribute to optimal health.

Essential oils are a key part of this growth in interest in natural botanical ingredients and are one of the most important natural products derived from plants. In terms of volume, demand for essential oils in 2020 was estimated at 247 kilotons, a market which is estimated to grow at a CAGR of 7.5% between 2020 and 2027 [2]. Again, interest in these ingredients is driven by the desire to use natural products in self-health care.

Rising prevalence of various health issues, including mental health issues such as anxiety, stress, poor sleep, concern about immune function and brain function, as well as health issues and conditions affecting every major organ system from the respiratory system to the cardiovascular system, including respiratory infections and high blood pressure, is also creating more demand for essential oils. Increasing interest in the use of 100% plant-based essential oils devoid of synthetic chemicals and fragrances and animal-based ingredients is also being fueled by environmental and animal welfare concerns as well as personal health.

Essential oils have been used in many cultures throughout the world for millennia, often with specific uses dependent on the regional and local culture. Exactly when they were first used and whether they were employed initially for domestic use, cosmetic use, or clinical use, or all three, is unclear. Carbon dating of cave

paintings at Lascaux in France suggests their use in everyday life as far back as 18000 BCE. Egyptians also used aromatic oils as early as 4500 BCE in cosmetics and ointments [3]. Many aromatic oils were used in embalming practice due to their antibacterial, antifungal and preservative properties.

The use of aromatic oils was first recorded in traditional Chinese and Indian (Ayurvedic) medicine between 3000 and 2000 BCE. Recorded history about China and India lists more than 700 substances, including cinnamon, ginger, myrrh, and sandalwood, as being effective for healing [4]. Greek history documented the use of different essential oils for the first time between 500 and 400 BCE, including thyme, saffron, marjoram, cumin, and peppermint. During the 18th and 19th centuries CE, chemists documented the active components of medicinal plants and identified many substances such as caffeine, quinine, morphine, and atropine, which were considered to play an important role in their biological effects. In modern times, some essential oils such as lavender, peppermint, and myrrh are used pharmaceutically and scientific research continues to uncover the potential mechanisms of action for the huge range of bioactives present in essential oils. During recent decades interest has been growing in the therapeutic potential of essential oils with research growing in France, UK, Germany and Switzerland.

What are Essential Oils?

The definition of an essential oil is 'the volatile oil produced by steam/water distillation' [5]. Essential oils are all fat-soluble and hydrophobic and will completely evaporate from the site of application leaving no visible mark or color even if the original oil is colored [5]. The term essential derives from the 'essence' or odor and flavor from a plant.

Plants produce essential oils for several reasons. Amongst others, these are as a pheromone to attract insects (e.g. pollinators); as a deterrent to insects and other predators; to prevent the growth of other plants in the vicinity; as an excretory product; or simply as a metabolic product [5]. Other functions of essential oils in the plant include antiviral, antibacterial and antifungal properties as part of the plant immune system [5]. Essential oils are a key part of communication between plants of the same species and between unrelated plants (e.g. as an alarm signal for insect attack) and additionally some can have a hormonal activity in plants (e.g. jasmone and methyl salicylate) [6].

Essential oils are stored in special glands, for example in leaves (e.g. eucalyptus, sage and thyme), berries (e.g. juniper), flowering tops (e.g. lavender), grasses (e.g. palmarosa), petals (e.g. rosemary, ylang ylang), fruit, particularly the rind and/or peel (e.g. orange, lemon), wood (e.g. cedar wood, sandalwood), resins (e.g. frankincense and myrrh), rhizomes (e.g. ginger) and seeds (e.g. dill and cumin) and they develop at various stages in the plant's life.

There are various routes of administration for essential oils. Applied in small quantities, essential oils can be used by inhalation, massage or simple application to the skin surface. Occasionally some specific, non-toxic ones can be taken internally (e.g. peppermint oil for irritable bowel syndrome). Inhalation and external application of these oils form the basis of the discipline of aromatherapy. The site of action for essential oils used via aromatherapy is the olfactory nerves that run from the nose to the brain. Essential oils bind to receptors in the nose and a signal is transmitted to the limbic system and the hypothalamus in the brain via the olfactory bulb. These signals cause the brain to release neurotransmitters such as serotonin, noradrenaline and endorphins [4].

Depending on the essential oil and its active ingredients, essential oils have well-proven antibacterial, antiviral, and antifungal activity. Additionally, they have been shown to enhance mental and physical well-being and provide refreshment from exhaustion [4]. Increasingly they are used in aromatherapy practice in the management of various conditions including cardiovascular disease [7], sleep disorders [8], Alzheimer's disease [9] and in cancer [4].

Bioactive Ingredients

Essential oils are complex mixtures of volatile compounds which are particularly abundant in aromatic plants. Many thousands of such compounds, mainly terpenes, including monoterpenes and sesquiterpenes, and also phenolic compounds, alcohols, aldehydes, esters and ketones have been identified in essential oils. They are generated within plants through various biochemical pathways mostly arising from acetyl co-enzyme A (acetyl-CoA), a key intermediary product derived from the breakdown of food components (protein, carbohydrate and fat) in both plants and animals, including humans. In plants, there is a pathway leading from acetyl-CoA to the formation of sterols with other subsidiary pathways which lead to the generation of terpenes (monoterpenes and sesquiterpenes). The terpenes can be oxidized either in the plant or during steam distillation of plant material to yield the corresponding alcohols, aldehydes, ketones and esters. Some examples of essential oil components and their plant sources are shown in Table 1.

Component	Example of Plant Source
Monoterpenes	
α - and β-pinene	Bay laurel, cajeput, cypress, juniper, niaouli, rosemary, Scots pine
*p-c*ymene	Ceylon cinnamon, thyme
γ-terpinene	Mandarin, marjoram
α-thujene	Lavender, marjoram, sage
Myrcene	Cypress, lemongrass, juniper, Scots pine
Limonene	Anise, bay, cajeput, cypress, eucalyptus, juniper, lemon, lemongrass, mandarin, neroli, niaouli, orange, Scots pine, rosewood
Sesquiterpenes	
Caryophyllene	Ceylon cinnamon
Cedrene	Cedar
Monoterpenoid Aldehydes	
Citronellal	Eucalyptus
Anisaldehyde	Anise
Cinnamaldehyde	Ceylon cinnamon
Ketones	
Menthone	Eucalyptus, geranium, peppermint
Fenchone	Fennel
Thujone	Sage
Alcohols	
Citronellol	Eucalyptus, geranium
Geraniol	Cajeput, cypress, geranium, ginger, lemongrass, rose, palmarosa
Linalool	Anise, bay, cajeput, eucalyptus, geranium, lavender, lemongrass, mandarin, neroli, orange, petitgrain, rosewood, sage
Lavandulol	Lavender
Nerol	Rose
α-bisabolol	Atlas cedar, Roman chamomile
Terpinen-4-ol	Tea tree
Esters	
Geranyl acetate	Lemongrass, palmarosa, petitgrain
Geranyl formate	Geranium
Citronellyl acetate	Eucalyptus
Citronellyl formate	Geranium
Linalyl acetate	Lavender, neroli, petitgrain
Oxides	
1,8-cineole	Cajeput, eucalyptus, lavender, rosemary, rosewood

Phenolics	
Thymol	Thyme
Carvacrol	Summer savory, thyme
Eugenol	Bay, cinnamon, clove
Chavicol	Fennel
Anethole	Anise, fennel
Estragole	Anise, fennel

Table 1: Essential oil components and examples of their plant sources [5].

Whilst essential oil components are classified according to these chemical groups for simplicity, different components within these chemical groups do not necessarily share many common features. For example, different components in one group can have different aromas, and specific bioactivities are not necessarily shared by the group as a whole. Even an individual component can have variable bioactivity.

Also, of note is that the composition of an essential oil from a given plant species can vary depending on the part of the world it is grown, the season, the amount of rainfall, altitude, soil composition and external application of fertilizers. However, commercial essential oils are usually produced from a certain species, and often from a specific variety or cultivar (chemo type), which is more likely to give rise to a similar chemical composition and hence bioactivity [5].

Essential oils are generally extracted from the source plant by steam distillation. This involves placing the plant material into a round distillation flask (glass, copper or stainless steel). The flask is then heated externally to release the volatile oils which travel down a vapor pipe (condenser) to a container (receiver) through a tank of cold water. The whole apparatus is known as a still. Water distillation can also be used in which water is introduced into the flask with the plant material. For steam distillation a separate vessel boils the water, which is then introduced into the flask via a pipe as steam. The whole process of distillation must be carefully controlled with the aroma and composition of the essential oil determined by the duration and temperature of the distillation. Steam distillation is preferred for giving a continuity of odor for one species.

Biological Activities of Essential Oil Components

Thanks to their chemical composition, essential oils possess numerous biological activities (e.g. antioxidant, anti-inflammatory, antibacterial, antifungal, antiviral) [10]. Various compounds in essential oils have been demonstrated to have antioxidant activity. These include carvacrol, 1,8-cineole, cinnamaldehyde, citronellol, eugenol, geraniol, limonene, linalool, α-pinene, α-terpinene and terpinen-4-ol [6]. Essential oil compounds including α-pinene, α-terpineol, cinnamaldehyde and limonene demonstrate anti-inflammatory activity inhibiting various signal pathways and reducing production of inflammatory cytokines [11].

The antibacterial activity of essential oils depends mainly on their bioactive single components, which are able to inhibit the growth of microorganisms and/or completely suppress pathogens [10]. However, two or more components in one essential oil may have a synergistic effect, with a distinctive biological activity. For example, thyme oil, which contains, amongst other bioactives, linalool, carvacrol and thymol is active against the bacterium *Staphylococcus aureus* [3].

Use of essential oils is often associated with a relaxant or calming effect [5]. Essential oils have effects on smooth muscle with some essential oils demonstrating spasmolytic (antispasmodic or relaxant) or spasmogenic (spasm-inducing) effects depending on the concentration and proportion the bioactive ingredients [5]. Ingredients in essential oils classified as spasmolytic include linalool, alcohols (menthol), phenols (eugenol), esters (linalyl acetate, neryl acetate, geranyl acetate, iso-amyl angelate and tiglates), ethers (trans-anethole, methyl chavicol or estragole, methyleugenol) and oxides (1,8-cineole) [12]. The main mechanisms of the antispasmodic effect appear to be inhibition of calcium channels, modulation of potassium channels and modulation of intracellular cAMP.

This remainder of this review draws together evidence on a range of essential oils and their botanical ingredients in relation to health and wellness.

All botanical names were checked according to the Kew Gardens Medicinal Plant Names Services (https://mpns.science.kew.org/mpns-portal/)

Essential Oils

Anise (*Pimpinella anisum* L. [Apiaceae])

Anise essential oil is derived by steam distillation of the fruit of the anise plant (aniseed). The oil is a clear to pale yellow liquid and a sweet characteristic aroma reminiscent of anethole (liquorice). Major components include trans-anethole (80-95%), estragole (up to 5%) and anisaldehyde (up to 1%). Minor components include the oxidation products of anethole, linalool, limonene, α-pinene and α-terpineol.

Anise essential oil is known for its health-promoting properties and aromatherapists use it for treating a variety of ailments such as migraine, back pain, menopause, arthritis, gout and indigestion [5]. Traditionally anise has also been used for its expectorant properties in the management of coughs and catarrh.

Laboratory studies show that anise seed, anise essential oil and its compounds possess potent antimicrobial properties that prevent infections and block the growth of fungi and bacteria. One laboratory study demonstrated that anise essential oil and anise seed are effective against certain strains of fungi, including yeasts and dermatophytes, a type of fungus that can cause skin disease [13]. Anethole, the active ingredient in anise seed has also been shown to inhibit bacterial growth. In one laboratory study, anethole blocked the growth of a specific multi-drug resistant strain of *Vibrio cholerae* [14]. However, further research is needed to examine how anise may affect the growth of fungi and bacteria in humans.

Taken internally, anise has shown some benefit in depression, possibly as a result of the finding that it increases levels of γ -aminobutyric acid (GABA) in brain tissue. In a clinical trial involving 107 patients taking 3 g anise seed powder three times daily was effective in relieving post-partum depression [15]. Similarly, in a 4-week study in 120 people, anise essential oil 200 mg three times daily significantly reduced mild to moderate depression compared with placebo [16]. Anise has also shown some effectiveness in pre-menstrual syndrome. A 10-day trial through two consecutive menstrual cycles in 67 18-35-year-old women found that anise 110 mg three times daily reduced pre-menstrual symptoms [17].

Atlas cedar (*Cedrus atlantica* (Endl.) Manetti ex Carrière [Pinaceae])

Atlas cedar is a large tree of the Pinaceae family, originally from North Africa (Moroccan atlas). The volatile essential oil is obtained by steam distillation of comminuted barks of the trees. The essential oil is yellowish to orange or deep amber coloured viscous liquid. It has a slightly camphoraceous-cresylic odor and tenacious woody undertone reminiscent of cassie and mimosa. Cedrene is the main component, which is converted to cedrenol on ageing. Other sesquiterpenes included thujopsene, α- and β-acoradiene, α- and g-himachalene, α- and β-chamigrene, g-curcumene, selinene, cuparene, α- and β-alaskene, widdrol, α-bisabolol and 8-cedren-13-ol.

Atlas cedarwood oil has some antimicrobial activity and antibacterial, plus antifungal activity [5]. In aromatherapy, Atlas cedarwood oil is used in respiratory ailments such as coughs and bronchitis as well as in stress, calming anxiety states due to the sedative effect, which is a reflection mainly of the constituent cedrol when inhaled [18,19]. In a laboratory study, Atlas cedar essential oil was found to produce an anxiolytic effect. Analysis showed that the oil contained (-)-α-cedrene (28.11%), (+)-β-cedrene (7.81%), (-)-thujopsene (17.71%) and (+)-cedrol (24.58%). Cedrol produced a significant anxiolytic effect which appeared to be mediated through an increase in 5-hydroxytryptamine and a reduction in dopamine [19].

Basil (*Ocimum basilicum* L. [Lamiaceae])

Sweet basil essential oil is obtained by steam distillation and is pale yellow to amber in color with a sweet, greenish, faint balsamic odor. It is obtained from France, Holland, Hungary, Belgium, India, Italy, Egypt, the US, Comoro Islands and Madagascar. Main constituents in sweet basil are 1,8-cineole, linalool, estragole and β-caryophyllene.

Sweet basil essential oil shows antibacterial and antifungal activity in vitro with relatively poor antioxidant activity [5]. Aromatherapy uses including calming, focusing concentration, reducing depression, headaches and migraines; respiratory conditions (asthma, sinusitis, bronchitis, flu, catarrh), digestive complaints, muscular aches and pains. Sweet basil essential oil has been shown to bring relief from catarrh and sinusitis, possibly due to its 1,8-cineole content whilst linalool has been shown to relax smooth muscle [12]. Phenol compounds in sweet basil oil have a demonstrable effect in anxiety though to a less extent than diazepam [20]. Laboratory research has shown the impact of basil in reducing inflammation and improving pathological asthma markers [21].

Bay laurel (*Lauris nobilis* L. [Lauraceae])

Bay laurel oil is the essential oil obtained by steam distillation of laurel leaves and branches. Laurel leaf comes from Morocco, Italy, Yugoslavia, Turkey and China. (It should not be confused with bay essential oil or West Indian bay essential oil (*Pimenta racemosa* (Mill.) J.W. Moore [Myrtaceae) which comes from Spain, Morocco, USA and the West Indies (bay rum). It is native to Southern Europe and the Middle East and can sometimes reach six meters in height. The essential oil is pale yellow to very pale olive green and even colorless with a fresh, strong but sweet, aromatic camphoraceous, somewhat spicy medicinal odor. Main active constituents are principally monoterpenes and sesquiterpenes (α-pinene, β -pinene), oxides (1,8-cineole), linalool, limonene, esters (α-terpinyl acetate, methyl eugenol), phenols (eugenol) and lactones (costunolide).

Essential oil of bay has strong antimicrobial (including antibacterial, antifungal and antiviral) properties with potential sedative effects on the nervous system [22]. It is used traditionally in aromatherapy for respiratory ailments and for its effects on the nervous system (anxiety, depression, fatigue, fear).

Cajeput (*Melaleuca leucadendra* (L.) L., *Melaleuca cajuputi* Powell and closely related Melaleuca species [Myrtaceae])

Cajeput oil is the essential oil derived from the leaves of *Melaleuca leucadendra* and *M. cajuputi*, a tree growing in the Moluccas and adjacent islands. It is a colorless, pale yellow or

green liquid. The odor of the oil has been stated to resemble the combined fragrance of camphor, rosemary and cardamom. Major components include 1,8-cineole (14-69%), α-pinene, β-pinene, limonene, linalool and geraniol.

Cajeput essential oil has strong antimicrobial properties with good in vitro activity against *Listeria monocytogenes* varieties and other bacteria [5] but with more limited antifungal activity. In aromatherapy its uses include respiratory ailments, bronchitis, colds, sinusitis and also skin ailments.

One recent study has evaluated the possibility of using cajeput oil to help prevent COVID-19 [23] this was a docking study in which proteins in *M. cajuputi* oil were evaluated for their ability to bind the main proteins of SARS-CoV-2 (PDB6LU7) and its host receptor (ACE2). The SARS-CoV-2 proteins are inhibited by the individual inhibition as well as the synergistic interaction of 10 out of 24 compounds in this oil. However, the study did not show that cajeput oil can prevent the entry of the virus into the body.

Chamomile, Roman (*Chamaemelum nobile* (L.) All. [Asteraceae])

The essential oil of Roman chamomile is obtained by steam distillation of the flowers and herbal tops. It is a colorless essential oil. It has a sweet, herbaceous, somewhat fruity-warm, and tea-like aroma. Major components are mainly monoterpenols, aliphatic esters, and in particular methyl angelate, isobutyl angelate and isoamyl angelate, and ketones.

Roman chamomile essential oil has antispasmodic action on smooth muscle and that it has some relaxant properties in the human brain [24]. Taken internally, chamomile has been shown to reduce anxiety disorder [25].

Cinnamon, Ceylon (*Cinnamomum verum* J. Presl [Lauraceae])

Native of Sri Lanka, Ceylon cinnamon is a member of the laurel family. Its leaves are long and shiny; its small round flowers give dark blue berries. The essential oil is obtained by steam/water distillation of the bark or leaf of the tree. The bark oil is a yellowish or brownish liquid, becoming darker and thicker with age and exposure to the air with the characteristic odor of cinnamon-a powerful, diffusive, warm, spicy, and tenacious odor. Major components in the bark essential oil include Cinnamaldehyde (60-75%), p-cymene, α- and β-pinenes, eugenol, cinnamyl acetate, caryophyllene and benzyl benzoate [5].

Ceylon cinnamon has antimicrobial, including antibacterial properties against respiratory tract bacteria and oral bacteria, and antifungal properties [26]. It is used in aromatherapy for respiratory tract infections, skin infections and aches and pains. In a 2018 *in vitro* study cinnamon essential oil showed activity against bacteria, including *Streptococcus pneumoniae*, *S. mutans*, *S. pyogenes*, *Haemophilus influenzae*, *H. parainfluenzae*, and *Moraxella catarrhalis* that cause respiratory tract infections, such as pneumonia and influenza [27].

Clove (*Syzygium aromaticum* (L.) Merr. & L.M. Perry [Myrtaceae])

Clove oil is an essential oil obtained by steam/water distillation of the buds or stems of the clove tree. The tree is a member of the myrtle family and native of the Moluccas (Indonesia). The bud oil is colorless to yellow brown, darkening on ageing with a strong clove aroma, while the leaf oil is yellow to dark brown when fresh. The stem oil is similar-pale yellow to straw yellow with a strong spicy woody odor. Major components include eugenol, eugenyl acetate, b-caryophyllene and a-humulene with concentrations depending on whether the oil is derived from the buds or the stem.

Clove essential oil has powerful antimicrobial properties (antibacterial and antifungal) [5]. The essential oil is both a relaxant and a stimulant. In aromatherapy it has been used traditionally for respiratory ailments (sore throat, sinusitis, bronchitis and colds), skin infections, toothache and muscular aches and pains [5]. In a 2018 in vitro study clove essential oil showed activity against bacteria that cause respiratory tract infections, such as pneumonia and influenza [28].

Cypress (*Cupressus sempervirens* L. [Cupressaceae])

Cypress essential oil is obtained by steam distillation of the leaves (needles) and twigs of the cypress evergreen tree of the Cupressaceae family. The essential oil is a pale yellow, olive green or almost colorless oil with a sweet balsamic yet refreshing odor, reminiscent of pine needle, juniper berry or cardamon essential oils. Major components include monoterpenes (a- and b-pinene, δ-3-carene) and some sesquiterpenes (sabinene, myrcene, limonene, a-terpinyl acetate). Cedrol is also present in a concentration of 0.8 to 1%.

Cypress essential oil has antibacterial activity [29]. In traditional aromatherapy cypress essential oil is used as an antibacterial and cough suppressant. Cypress essential oil contains camphene, an ingredient in some herbal cough suppressants, but cypress oil has not been directly tested for an effect on coughing. It is also used in hemorrhoids and varicose veins as well as pre-menstrual syndrome. There is no scientific basis for these uses as clinical studies have not been conducted.

Eucalyptus (*Eucalyptus globulus* Labill. and *Eucalyptus radiata* Sieber ex DC. [Myrtaceae])

Eucalyptus trees (of which there are around 700 species) are native to Australia and Tasmania, New Guinea, Indonesia and some part of the Philippines, but are now grown in Southern Europe, Brazil, South Africa and Russia. The essential oils are extracted by steam distillation of the leaves of the tree. Both *E. globulus* and *E. radiata* essential oils are colorless to pale yellow with a camphoraceous aroma. Major components include monoterpene oxides (1,8-cineole or eucalyptol), a-pinene, citronellal, menthone, citronellol, limonene, linalool and various monoterpene and

sesquiterpene hydrocarbons, monoterpene and sesquiterpene alcohols.

The essential oil of E. globulus is both expectorant, mucolytic and antiseptic [5]. It has been incorporated in many OTC inhalants and cough remedies as it promotes bronchodilation. The European Commission has approved its use in case of respiratory tract inflammation [30]. Traditionally it is also recommended in cases of cold, flu or sinusitis [5].

E. globulus and E. radiata should be distinguished from lemon eucalyptus (*Corymbia citriodora* (Hook.) K.D.Hill & L.A.S. Johnson [Myrtaceae]), which has a citrus aroma and is grown in Madagascar, the Comoros and the Democratic Republic of Congo (DRC). Major components include terpenic aldehydes (citronellol), monoterpenols (citronellol, isopulegol), terpene esters (citronellyl acetate). It has some similar uses to *E. globulus*, but is also used in aromatherapy for anxiety, sleep disorders and stress and has been shown to have high antioxidant and anti-inflammatory activity [32]. It is also used for muscular pain (4) and as an insect repellent [33].

Fennel (*Foeniculum vulgare* Mill. [Apiaceae])

The essential oil is obtained by steam distillation of the dried, ripe fennel seed, which grows in Spain, Eastern Europe and Java. The essential oil is colorless or pale yellow to greenish with a characteristic aroma of anise, fresh and spicy. Major components include trans-anethole (30-75%), fenchone, estragole and a-pinene.

It has limited antibacterial activity and some antifungal activity [34]. Aromatherapy uses include respiratory ailments such as bronchitis and asthma as well as rheumatism, period pains, dyspepsia, flatulence, hiccup and nausea. Fennel has some anti-inflammatory activity [35] and is sometimes used to reduce inflammation in the nose and throat.

Geranium oil, rose geranium oil (*Pelargonium spp*. [Geraniaceae])

The essential oil is produced by steam distillation of the leaves and flowers of the flowering herb which is grown in Egypt, China and the Comoros and more recently in India and South Africa. The essential oil is found in various shades of amber yellow to greenish yellow. The aroma is characteristic of the origin but is mainly rose-like with a minty tone. Major components include citronellol (25-58%), geraniol (7-19%), linalool (3-10%, isomenthone (4-7%), citronellyl formate (5-12%) and geranyl formate (1-4%). In aromatherapy geranium essential oil is used in respiratory tract ailments including sore throats, excess mucus, tonsillitis and asthma. It is also used in menstrual and menopausal problems and skin infections.

The essential oil has antimicrobial properties [36] and studies have shown that it has anxiolytic and physiological relaxation properties [36]. A randomized controlled trial in women in labor for the first time found that inhaling geranium essential oil reduced anxiety and induced calmness during the first stage of labor [37]. Essential oil of geranium and essential oil of lemon have been investigated for potential antiviral activity against SARS-CoV-2. Both citronellol, a key ingredient in geranium oil and limonene, a key ingredient in lemon oil downregulated Angiotensin Converting Enzyme (ACE) 2 receptor in epithelial cells. The ACE2 receptor has been found to play a crucial role in virus cell entry, and blocking of this receptor may reduce the risk of invasion by the SARS-CoV-2 virus [38].

Ginger (*Zingiber officinale* Roscoe [Zingiberaceae])

Essential oil of ginger is obtained from the dried, pulverized ginger rhizome by steam distillation, then the ginger residue is dried and solvent extracted to get the oleoresin. Ginger is sourced from India, China, Africa and Australia. The oil differs according to the origin and is pale yellow to yellow with a warm, spicy, fresh woody aromatic odor said to be reminiscent of citrus, lemongrass or coriander. Main components are the sesquiterpenes and citral. The main active sesquiterpenes are principally monoterpenes (camphene), monoterpenols (borneol, geraniol, linalool), sesquiterpenes (a-curcumene, b-sesquiphellandrene and zingiberene).

Aromatherapy uses include respiratory ailments such as colds, coughs and sore throats as well as tiredness and exhaustion, nausea and vomiting, travel sickness, poor circulation, aches and pains. Its anti-inflammatory effects are the best validated [39]. Ginger essential oil also has antimicrobial activity [40].

Juniper (*Juniperus communis* L. [Cupressaceae])

The essential oil is obtained by steam distillation of the unfermented cones (often called “berries”). The essential oil is a colorless to pale yellowish oil with a fresh, yet warm, rich-balsamic, woody-sweet and pine-like odor. Major components of essential oil of juniper are monoterpenes (a-pinene, a-thujene, myrcene, a-terpinene) (up to 50%), sesquiterpenes, alcohols and terpene esters (bornyl and terpinyl acetates). One laboratory study [41] detected over 70 compounds in juniper berry essential oil, with the monoterpenes a and b-pinene, myrcene, limonene, and sabinene making up the majority. The study found that the oil reduced cellular damage in yeast cells by increasing the activity of the enzyme’s catalase, glutathione peroxidase, and superoxide dismutase. The main role of these enzymes is to protect cells from free radical damage, acting as antioxidants.

Juniper has moderate antimicrobial activity. In one laboratory study [42] juniper berry essential oil demonstrated antibacterial and antifungal effects against 16 species of bacteria, yeasts, yeast-like fungi, and dermatophytes, causing diseases like ringworm. These effects are attributed to potent compounds in their oil, including sabinene, limonene, myrcene, and a- and b-pinene.

In aromatherapy juniper essential oil is used in anxiety, nervous tension, stress and eradicating negative thoughts. These

effects, though not directly demonstrated with juniper oil in scientific research, can be attributed to the various terpenes in juniper oil and various other essential oils which are likely to result in the modulation of glutamate and GABA neurotransmitter systems [43]. Juniper oil is analgesic and anti-inflammatory [44].

Lavender (*Lavandula angustifolia* Mill. [Lamiaceae])

Lavender essential oil is obtained by steam distillation from the fresh, recently picked flowering tops of lavender either growing wild or cultivated in France. Lavender is also grown in, amongst other countries, Spain and Bulgaria. The true lavender essential oil is almost colorless and has a sweet, floral, herbaceous, refreshing odor with a pleasant, balsamic-wood undertone and a fruity-sweet top note.

Main components are linalool (25-40%) and linalyl acetate (25-45%). Essential oil of lavandin has a linalyl acetate content of 27-37% and linalool of 28-38% with camphor at 7-11% concentration and 1.8-cineole at concentrations of 6-20% (up to 37%).

In aromatherapy lavender and lavandin essential oils are used for their pharmacological sedative effects, causing drowsiness and in people who are agitated. This is based on the ingredient linalool. Research commissioned by Puressentiel, manufacturers of Rest and Relax Air Spray, which contains 12 essential oils including True Lavender has shown that linalool increases sedation and reduces anxiety [45]. This peer-reviewed paper further found that linalool has anesthetic, cholesterol lowering activity, and anti-inflammatory activity. Other research has shown that linalool is effective in depressive mood [46]. In human's inhalation of lavender essential oil and linalool causes sedation, increases relaxation and improves sleep [47,48] via an effect on the autonomic nervous system and also improves mood. The paper commissioned by Puressentiel also found that linalool has antibacterial and antifungal activity as well as antioxidant and analgesic activity with proven benefits in migraine headache [45]. Moreover, lavender essential oil is commonly used in hygiene, including Purifying Air Sprays, due to its high content of linalool, linalyl acetate and camphor [45].

Lemon (*Citrus x limon* (L.) Osbeck [Rutaceae])

Lemon essential oil is obtained by cold expression, without the aid of heat from the fresh peel of lemons, with or without the previous separation of the pulp and the peel. The peels can be steam distilled to give an essential oil of different composition. Lemon is sourced mainly from Sicily, California, Argentina and Spain. The essential oil is yellow to orangey to greenish yellow if distilled. Expressed oil has a short-lasting, light, fresh odor reminiscent of peel. Major components include limonene (67%) and various monoterpenes, including a-, b- and g-terpinene. Cold pressed oil has a limonene content of 80% maximum.

Aromatherapy uses for lemon essential oil run into the hundreds, including sore throats, coughs, cold and influenza, catarrh and sinus infections as well as stimulation of the parasympathetic nervous system (which can cause sedation). Other aromatherapy uses include circulatory issues such as varicose veins, hemorrhoids, phlebitis, thrombosis, broken capillaries, warts, boils and corns.

Lemon essential oil is considered to be sedative. A laboratory study showed that lemon oil was calming and mood improving following a stress test [49]. A small study in 82 patients about to undergo orthopedic surgery found that inhalation of lemon oil reduced anxiety [50].

Lemongrass (*Cymbopogon citratus* (DC.) Stapf [Poaceae])

Lemongrass essential oil is a volatile oil obtained by steam distillation of the dried or partly dried grass. It is sourced mainly in Guatemala, Madagascar and India. The essential oil is yellow/brown with a tinge of red, if unrectified, otherwise is almost colorless. It has a fresh, strongly citrusy, lemon-like and pungent odor with herbal and leafy aspects and fatty grassy notes. Lemongrass is related to palmarosa and citronella and has an aroma reminiscent of *Melissa officinalis* L. [Lamiaceae] and *Litsea cubeba* (Lour.) Pers. [Lauraceae]. Major components include: terpenic aldehydes (geranial 40-70%; neral 25-42%, citral), monoterpenols (geraniol), monoterpenes (myrcene, limonene), traces of linalool and terpene esters (geranyl acetate).

Aromatherapy uses include stress, irritability, headaches and fatigue, respiratory issues such as sore throats, and also digestive upsets and poor appetite. It has proven antibacterial activity with research showing its activity against a range of drug-resistant bacteria [51]. It may also have benefits in stress and anxiety which are likely mediated by an action at the GABA-benzodiazepine receptor [52]. A 2015 study evaluated the effects of lemongrass and sweet almond massage oils during massage. Study participants who received a massage using the oil once a week for 3 weeks had lower diastolic blood pressure than those in the control group. Systolic blood pressure and pulse rate were not affected [53]. Laboratory studies have shown that lemongrass essential oil has powerful anti-inflammatory and antioxidant activity [54].

Mandarin (*Citrus* × *aurantium* L. [Rutaceae]

Essence of mandarin is obtained by cold expression of the fresh peel of the fruit. Mandarin trees grow mainly in China as well as Spain, the USA and Mexico. The essential oil obtained is red, yellow or green depending on the maturity of the fruit. The essential oil obtained by distillation of mandarin tree leaves gives essential oil of mandarin petitgrain. Main constituents are of mandarin essential oil are monoterpenes (limonene, 75% to 85%, gamma-terpinenes, approximately 10%), monoterpenols (linalool, a-terpineol), esters and aldehydes (decanal) with overlap with other Citrus essential oils in its constituents. Aromatherapy uses for essential oil of mandarin petitgrain are relaxant, sedative and slightly hypnotic. It is used for insomnia as well as anxiety and dyspepsia.

Mandarin essential oil has demonstrated antibacterial activity against, amongst other bacteria, *Escherichia coli* and *Staphylococcus aureus* [55] and exhibits powerful antioxidant activity in laboratory studies [56]. Scientific evidence for its traditional aromatherapy uses is limited and further studies are needed.

Marjoram (*Origanum majorana* L. [Lamiaceae])

The essential oil is obtained by steam distillation of the flowering tops of the herb, which are sourced from France, Spain, Egypt and Turkey. The sweet or French marjoram is a yellow to yellow-green essential oil with warm, spicy, aromatic-camphoraceous and woody odor, reminiscent of nutmeg and cardamom. Spanish marjoram oil is orange to amber in color. Major ingredients include monoterpenes (40%) and monoterpenols (50%), including terpinen-4-ol.

Aromatherapy uses include respiratory infections, irritability, insomnia and depression. Scientific studies on these traditional aromatherapy uses are required.

Myrrh (*Commiphora myrrha* (T.Nees) Engl. [Burseraceae])

The essential oil is obtained from the oleo-resin derived from the cuts in the myrrh tree. The oleo-resin is then steam distilled to produce the essential oil, which is a pale yellow, pale orange, light brown to green essential oil with a peppery, warm spicy, pungent, sharp balsamic aroma. It is sourced from Arabia, Yemen and Somalia. Major components include various sesquiterpenes including α-pinene, cadinene, limonene, cuminaldehyde, eugenol, m-cresol and heerabolene and: terpenes including furanoeudesma-1,3-diene (13%), curzerene (12%), curzerenone (12%) and lindestrene (4%).

Aromatherapy uses include respiratory tract ailments such as coughs, colds and flu and improving immune function. Traditionally myrrh was used for embalming and burning the oil was believed to cleanse the atmosphere. Modern science has confirmed the antibacterial properties of myrrh. One study found that burning myrrh and frankincense reduced airborne bacterial counts by 68% [57]. Preliminary laboratory research suggests that myrrh can directly kill bacteria and stimulate the immune system to produce more white cells [58]. Components in myrrh essential oil have been found to show antibacterial activity against *Escherichia coli, Staphylococcus aureus*, and *Pseudomonas aeruginosa* and antifungal activity against *Candida albicans*, as well as local anesthetic activity [58]. Well-controlled studies on myrrh essential oil are lacking so more research is needed.

Neroli Oil (*Citrus* × *aurantium* L. [Rutaceae])

Neroli essential oil is obtained from steam distilled flowers of the bitter orange tree. It is sourced in France, Bulgaria, Morocco, Turkey, Italy and Tunisia. It is also known as orange blossom oil. It is a colorless to pale yellow, slightly fluorescent essential oil, becoming reddish-brown on exposure to heat and light. It has a powerful, light, fresh, floral, sweet, faintly citrusy aroma. Major constituents include limonene, linalool, linalyl acetate, geraniol, citral and farnesol.

Aromatherapists use neroli essential oil as a sedative in anxiety, depression, stress, insomnia, menopausal symptoms and high blood pressure. Neroli oil has been shown to have anxiolytic activity in laboratory studies mediated by the 5HT(1A) receptor [59]. The aroma is pleasant and may also help to enable relaxation and induce calmness through an impact on the hypothalamic-pituitary-adrenal axis by reducing glucocorticoid (including cortisol) levels [60].

Niaouli Oil (*Melaleuca quinquenervia* (Cav.) S.T. Blake [Myrtaceae])

The essential oil is obtained by steam distillation of the leaves of the tree known as the paperbark tree which is native to Australia. The fragrance of essential oil of niaouli is balsamic, with a strong note of eucalyptus.

Essential oil of niaouli consists mainly of terpene oxides (1,8-cineol: 38 to 48%), monoterpenols, sesquiterpenols including viridiflorol (6 to 15%) and monoterpenes (a- and b-pinene, limonene) (up to 70%) that are eliminated to obtain "purified" oil. This composition corresponds to the essential oil from Madagascar, that from New Caledonia consisting mainly of sesquiterpenols (65 to 70%) and monoterpenols (approximately 20%). It has demonstrable anti-inflammatory activity [31].

Aromatherapy uses center on respiratory ailments including sinusitis, sore throat, bronchitis and catarrh. It is not generally used for relaxation or emotional wellness.

Orange, Sweet (*Citrus* × *aurantium* L. [Rutaceae])

The essential oil of sweet orange is obtained mainly as a by-product of the orange juice industry by cold expression from the fresh peel of the sweet orange (which is a berry and should be distinguished from the bitter orange-see petitgrain, below). Sweet orange oil is deep yellow to orangey, olive yellow and even brownish with citrus-like aroma reminiscent of the species. Orange trees are cultivated in the Mediterranean area, the Maghreb, China, South Africa and Australia. They were introduced into California, Florida and Brazil. The main active constituents of essence of sweet orange are monoterpenes (limonene: 92 to 97%), monoterpene alcohols (linalool), aldehydes and coumarins.

Aromatherapy uses are for calming and soothing, as well as digestive upsets, skin conditions and insect bites. In scientific studies orange essential oil has been found to have antibacterial [61, 62] and antifungal [63] activities. Orange essential oil has been found to reduce anxiety and stress. One study found that aromatherapy with orange essential oil reduced salivary cortisol and pulse rate in children undergoing a dental procedure [64]. A study in 100 women in labor found the women exposed to essential orange oil were less anxious than those exposed to distilled water

[65]. A study in 60 patients with fracture found that inhaled essential orange oil reduced pain more than placebo [66].

Palmarosa (*Cymbopogon martinii* (Roxb.) W. Watson [Poaceae]

The essential oil is obtained by steam distillation of the fresh or dried palmarosa grass. It is sourced from India, Madagascar, Central America and Brazil and is a pale yellow to yellow or olive essential oil with a sweet, floral-rosy odor and various herbaceous undertones. Major components include geraniol and geranyl acetate. Aromatherapy indications include stress-related conditions and respiratory health as well as skin and digestive issues. Scientific study indicates that palmarosa has antibacterial activity [67]. Geraniol, the main ingredient in palmarosa has been found to have depressant activity in laboratory research [68] as well as antioxidant, anti-inflammatory, cardioprotective and neuroprotective activity [69].

Parsley (*Petroselinum crispum* (Mill.) Fuss [Apiaceae])

The essential oil is obtained by steam distillation of the herb or seeds. The seed oil is a yellow to light/dark brown liquid with a warm woody, sweet-herbaceous aroma, not like the original herb. Major components include mono-and sesquiterpenes, including a-pinene, myristicin, apiole and b-phellandrene. Very few aromatherapy texts mention parsley oil, but it is used to treat stress-like conditions, and for pre-menstrual syndrome, rheumatism, broken capillaries and hemorrhoids. Parsley essential oil has demonstrable antibacterial activity [70,71] as well as antifungal activity [72].

Peppermint (*Mentha* × *piperita* L. [Lamiaceae])

An essential oil is obtained by steam distillation of freshly harvested, flowering sprigs. It is a colorless to pale yellow oil with a strong, grassy-minty odor with a deep balsamic undertone. Mints of which there are 25 species are grown throughout the world, including the USA, China, India, South America, Italy and Japan. The chemical composition of peppermint strongly varies depending on the soil and the time of harvest. Essential oil of peppermint is mainly composed of menthol (30% to 40%), menthone (20% to 65%), esters, coumarins and sulfur compounds.

Peppermint is widely used in aromatherapy for indications including nervous stress, respiratory ailments (colds, sinusitis, bronchitis) skin conditions, dyspepsia, flatulence, ulcers, nausea and colic [73]. Scientific studies on its use in aromatherapy are limited to date. Some research shows the essential oil improves some spirometric measures linked to exercise performance [74], nausea associated with surgery [75] and pregnancy [76], sleep quality of cardiac patients [77]. Peppermint oil is taken internally and is a safe and effective therapy for irritable bowel syndrome (IBS) [78,79]. According to the German Commission E monographs, peppermint oil (as well as peppermint leaf) has been used internally as an antispasmodic (upper gastrointestinal tract and bile ducts) and to treat irritable bowel syndrome, catarrh of the respiratory tract, and inflammation of the oral mucosa. Externally, peppermint oil has been used for myalgia and neuralgia [80].

Petitgrain (*Citrus* × *aurantium* L. [Rutaceae])

The essential oil is obtained by steam distillation of the leaves and twiglets from the bitter orange tree (see neroli oil which is obtained from the petals of *Citrus* × *aurantium*). Source countries include Paraguay and other South American countries and the USA. Petitgrain essential oil is a pale yellow or amber-color liquid with a pleasant, fresh-floral, sweet odor reminiscent of orange flowers. The main active constituents of essential oil of bitter orange are terpene esters (linalyl, geranyl and geranyl acetates) and monoterpenols (a-terpineol, linalool) [81].

In terms of scientific evidence, one study in 42 administrative university workers found that aromatherapy (including with petitgrain essential oil) improved performance in the workplace, possibly due to reducing stress and increasing attentiveness and alertness [82]. An overview of clinical trials conducted with *Citrus* × *aurantium or Citrus* × *sinensis* on people with anxiety showed that inhalation or oral administration of *Citrus* × *aurantium* and inhalation of Citrus × sinensis can exert beneficial effects on anxiety; however, because of incomplete accuracy in the reporting of methodology, further more complete clinical studies are warranted [83].

Scots pine (*Pinus sylvestris* L. [Pinaceae])

The essential oil is obtained by steam distillation of the needles of the pine tree. It is a colorless to pale yellow oil with a strong, dry, balsamic, turpentine-like odor. It grows in several European countries (France, Germany, Austria, Hungary, Poland), Russia and the USA. Major components of Scots pine include monoterpenes (a-and b-pinenes, camphor, d-3-carene, limonene, myrcene), terpene esters (bornyl ester) and sesquiterpenes.

Scots pine essential oil enjoys widespread use in aromatherapy including respiratory system ailments (asthma, bronchitis, catarrh, coughs, colds, sinusitis, sore throat) as well as the nervous system (fatigue and nervous exhaustion), stress-related conditions and neuralgia. Evidence demonstrates that Scots pine has activity against mosquitos [84, 85], anti-inflammatory and wound healing activity [86], and antioxidant activity [87].

Ravintsara (*Cinnamomum camphora* (L.) J. Presl [Lauraceae])

The essential oil should not be confused with ravensara essential oil. Ravintsara essential oil is a clear, colorless liquid with an aroma reminiscent of eucalyptus. The main source countries are France and the USA. Main active constituents of the essential oil of *Cinnamomum camphora* are terpene oxides (1,8-cineole), terpene alcohols (a-terpineol) and terpenes (pinenes).

Ravintsara is used widely in aromatherapy for preventing and treating all forms of viral infection, particularly respiratory-cold, flu, chills, pharyngitis, laryngitis and bronchitis, rhino pharyngitis-along with seasonal gastroenteritis (always viral), herpes and herpes zoster. It is also a tonic, helping relieve states of

extreme fatigue and accelerating convalescence. Scientific studies demonstrate antibacterial [88,89] and insecticidal [90] activity. A review found that Ravintsara possesses astringent, warming stimulant, carminative, blood purifier, digestive, antiseptic, antifungal, antiviral, antibacterial, antioxidant, anti-inflammatory and immunomodulatory properties and can also help to reduce cholesterol and blood sugar levels [91].

Rosemary (*Salvia rosmarinus* Spenn. [Lamiaceae])

The essential oil is obtained by steam distillation of the herb. Source countries include Spain, France, Tunisia, Morocco, Yugoslavia and Italy. There are several types of rosemary essential oils, including rosemary camphor, rosemary cineole and rosemary verbenone. It is a pale yellow or almost colorless essential oil with a strong, fresh, woody, herbaceous, somewhat forest-like aroma.

Major components vary by type and depending where the plant is cultivated. All types contain camphor but in different proportions. Rosemary camphor contains 20%, rosemary cineole approximately 10% and rosemary verbena between 3 and 8%. Other main constituents include monoterpenes (a- and b-pinenes, camphene), sesquiterpenes, terpene oxides (1,8-cineol) and monoterpenones (camphor).

Aromatherapy uses are widespread including respiratory conditions (sinusitis, bronchitis and colds), mental stress and chronic fatigue, dyspepsia, muscular aches and pains, backache, cuts and wounds.

Scientific studies have shown that rosemary oil can ease stress, improve brain function and reduce pain. A study in nursing students who inhaled rosemary essential oil before and during an examination found that pulse rate reduced by 9% with no change where rosemary essential oil was not inhaled [92]. In a further study, when 22 adults inhaled rosemary essential oil for 5 minutes their saliva had 22% less of the stress hormone cortisol present [93]. A study in 20 healthy volunteers found that inhaling rosemary increased blood levels of the active ingredient 1,8-cineole with performance on cognitive tasks related to 1,8 cineole concentrations. These associations were found for speed and accuracy in conducting mental tasks [94].

Rosewood (*Aniba rosaeodora* Ducke [Lauraceae])

Rosewood essential oil is obtained by steam distillation of comminuted wood (wood chips) of the rosewood tree. Following a period of overexploitation, Brazil now protects rosewood, and it has become the almost exclusive producer. The essential oil is colorless to pale yellow, sweet smelling, slightly woody, somewhat floral-spicy essential oil; the top note sometimes has a peppery-camphoraceous note reminiscent of cineole and nutmeg terpenes. The major component is linalool (up to 92%) with smaller amounts of 1,8-cineole (up to 1.6%), limonene (up to 1.5%), geraniol (up to 1.5%) and a-terpineol (1-3.5%).

Rosewood essential oil, due to its content of linalool, has antioxidant and antimicrobial activities, including against bacteria, fungi and viruses [5]. Linalool is also a general relaxant whose effects have been demonstrated in many laboratory studies [45]. The mechanism has been thought to be due to absorption into the bloodstream via the airway when used in aromatherapy leading to direct effects on brain receptors, such as GABAARs. However, newer laboratory studies have indicated that stimulation of the olfactory neurons by linalool vapor induces relaxation [45]. A small trial in 8 human beings indicated a positive effect of linalool in depression and stress relief and that its mechanism of action might include activation of central oxytocin neurons [45].

Sage (*Salvia officinalis* L. [Lamiaceae])

The essential oil is derived by steam distillation of the tops of the sage herb plant. Source countries include Yugoslavia and Spain giving rise to two types of sage essential oil-Dalmatian and Spanish. Dalmatian age essential oil is a pale-yellow liquid and has a fresh herbaceous, warm spicy, somewhat camphoraceous aroma. Spanish sage is a pale-yellow liquid and has a fresh-herbaceous aroma, with cineole and camphor notes. 1,8-cineole and camphor are the major components of both Dalmatian and Spanish sage essential oils. Spanish sage components also include linalool, a- and b-pinene, camphene and p-cymene; a- and b-thujone are additionally found in Dalmatian sage oil.

Aromatherapy literature covers sage essential oils to varying degrees with some aromatherapists using/recommending it for use by inhalation for depression and externally for skin conditions, flu, catarrh and toothache. Scientific studies indicate that sage essential oil has some antibacterial, antifungal and antioxidant activity [5]. Taken internally, sage essential oil is being investigated for a therapeutic impact on dementia with several of its constituents known to impact on cognitive function [95]. Laboratory studies have identified a wide variety of pharmacological activities for sage oil including anticancer, anti-inflammatory, antioxidant, antimicrobial, antimutagenic, antidementia, hypoglycemic, and hypolipidaemic effects [96].

Sandalwood (*Santalum album* L. [Santalaceae])

The essential oil is obtained by steam distillation of comminuted dried wood chips of the sandalwood trees. The true sandalwood, *S. album* is an evergreen semi-parasitic tree native to Southwestern Asia, the other varieties growing in Australasia and the Pacific. The slender trunk (heartwood) and roots have the greatest oil content. Sandalwood is a pale yellow to yellow viscous essential oil with a soft, sweet-woody, warm, animal-balsamic aroma. Major components are a- and b-santalol and their derivatives.

Aromatherapy uses include calming, antidepressant, sedating, insomnia, stress; chest infections, catarrh, dry cough, sore throat, stimulating the immune system, digestive and genitourinary problems.

Sandalwood has been shown to have some limited antibacterial and antifungal activity. Research from a pilot study in 34 individuals indicates that massage with sandalwood essential oil (compared with sweet almond carrier oil) may reduce anxiety but the results were not significant [97]. In a small pilot study, sandalwood essential oil was shown to alleviate the reactions to the physiological effects of stress and speed recovery from stress [98]. In a systematic review, sandalwood essential oil was identified as having shown promise in clinical trials for treatment of acne, psoriasis, eczema, common warts [99].

Summer savory (*Satureja hortensis* L. [Lamiaceae])

Obtained by steam distillation of the tops and leaves of the herb, the essential oil is a light yellow to dark brown essential oil with a spicy aromatic odor resembling thyme and oregano. Major components include carvacrol and g-terpinene with to a lesser extent p-cymene, myrcene, camphene and a-pinene.

Savory essential oil is less widely used in aromatherapy than many other oils but uses include depression and exhaustion, cold sores, arthritis, cuts, bites and burns. The essential oil has antimicrobial [100], antioxidant [101] and anti-inflammatory activity and has been shown to reduce the lesions associated with denture stomatitis [102].

Tea tree *Melaleuca alternifolia* (Maiden & Betche) Cheel [Myrtaceae])

The essential oil is obtained by steam distillation of the leaves and twiglets of the tree. It is a white to pale yellow, yellow-green liquid with an acrid odor (which can be described as spicy, camphoraceous by those who like it) with an occasional hint of citrus. Source regions includes Australia and Indonesia. Major components are terpinolene, 1,8-cineole, a-terpinene, g-terpinene, p-cymene, terpinen-4-ol, a-terpineol, limonene, sabinene, aromadendrene, d-cadinene and a-pinene.

Aromatherapy uses include colds, flu, infections, skin wounds, acne, nail infections, cold sores, warts, insect bites, parasitic infection, insect repellent. Scientific research shows that tea tree essential oil has strong antibacterial properties mainly attributed to its content of terpinen-4-ol [103,104]. These properties explain the traditional use of tea tree oil in infections, including those of the respiratory tract and the skin. Terpinen-4-ol is thought to improve immune function by increasing the activity of white blood cells [105].

Thyme (*Thymus vulgaris* L. [Lamiaceae])

The essential oil is obtained by steam distillation of the flowering tops and leaves of the herb to give an oil of different composition depending on the cultivar and species used. Source countries include France, Spain, Italy, Turkey and the US. Red thyme, crude and white thyme essential oil have a medicinal herbal aroma whilst sweet thyme essential oil is colorless and has a slightly sweeter odor. Major components are (in red thyme): thymol, carvacrol, p-cymene, 1,8-cineole, terpinolene, a-pinene and b-caryophyllene [5]. Sweet thyme oil contains geraniol and geranyl acetate with minor amounts of other compounds [5-106].

Aromatherapy uses include fatigue, depression, exhaustion, coughs, colds, sore throats, clearing the lungs and sinuses from mucus, upset stomach, inflammation, sports injuries. Thyme essential oil has excellent antimicrobial (antibacterial and antifungal) properties and antioxidant properties [5]. Taken internally, thyme essential oil has shown efficacy in productive cough in small single-blind clinical trials [107,108].

Wintergreen (*Gaultheria procumbens* L. [Ericaceae])

The essential oil is obtained from water distillation from the leaves of the small creeping plant. It is a pale yellow to pinkish essential oil with an intense sweet, woody, antiseptic aroma which differs from that of synthetic methyl salicylate. Wintergreen is used mostly for joint stiffness and various skin problems (eczema, acne). The major component is methyl salicylate. Wintergreen has limited antimicrobial activity, but well established use in muscular pain, including lower back pain [109,110].

Essential Oil Mixtures

Essential oils are often used simultaneously rather than separately. In a study conducted by Puressentiel in France [111], a preparation indicated for air purifying and containing 41 essential oils and its bioactive ingredients was evaluated. Main bioactives were: monoterpene hydrocarbons, limonene (14.40%), α-pinene (3.52%), monoterpene alcohols, linalool and menthol (8.40 and 2.52%, respectively), α-terpineol (1.27%), thymol (0.69%), carvacrol (0.32%), monoterpene eucalyptol oxides whose major component (32.80%), esters, linalyl acetate (7.76%), monoterpene ketones with camphor (2.29%), and eugenol.

This mixture was found to possess antimicrobial activity against *Aspergillus flavus*, *Aspergillus nidulans*, *Candida albicans*, *Enterococcus hirae* A TCC 10541, *Escherichia coli* ATCC 10536, *Klebsiella*, *Salmonella enterica* CIP 80.39, *Staphylococcus aureus* ATCC 9144, *Streptococcus* D, non-regroupable Streptococcus, and especially with very significant levels of antibacterial activity compared to the effects of the reference antibiotic used in the study (gentamicin). This mixture of essential oils has also been found to have activity against viruses [112], including influenza virus [113] and has antifungal activity [114]. A further study indicated that this preparation improved quality of life in terms of reduced anxiety and sleep disturbance in people with poor respiratory health and with no adverse events detected [115].

Discussion

Botanical ingredients including essential oils are gaining popularity as people seek better self-care, including a reduced risk of adverse effects from natural ingredients. Essential oils have been used for thousands of years for health and wellness but it is

only relatively recently that their beneficial effects observed by practitioners and experienced by users have begun to be understood from a scientific perspective.

During the last 50 years, scientific research has begun to identify a large range of bioactive ingredients in essential oils which help to explain the rationale for their traditional use. Many thousands of such compounds, mainly terpenes, including monoterpenes and sesquiterpenes, and their related compounds have been identified in essential oils [5]. Many, if not most, of these compounds display antimicrobial (antibacterial, antifungal and antiviral) properties as well as antioxidant and anti-inflammatory properties. These properties help to explain the use of several essential oils (e.g. Atlas cedarwood, basil, bay laurel, cajeput, cinnamon, clove, eucalyptus, ginger, myrrh, palmarosa, ravintsara, tea tree) in respiratory tract health. Essential oils such as cajeput [23], geranium and lemon [38] are being investigated for potential preventive activity in SARS-CoV-2.

Sedative and relaxant effects have been widely noted over time with essential oils with research now able to identify the compounds which may contribute to the effects. Various terpenes present in essential oils have been shown to influence the GABA neurotransmitter system with a similar mechanism to prescription benzodiazepine medications [43-52]. The calming effect of Atlas cedar, for example, is considered to be a reflection of its cedrol content. Linalool, a compound present in several essential oils, including lavender, lemon and mandarin oils, has been shown to cause sedation, relaxation and improve sleep [45]. Neroli essential oil has been shown to have anxiolytic activity mediated by the 5sHT(1A) receptor [59].

Much of the research evaluating the health benefits of essential oils to date comes from laboratory studies which have and continue to investigate mechanisms of action. However, there appears to be a growing body of evidence from clinical trials for botanicals and essential oils and aspects of health and wellness. Clinical trials have shown, for example, that inhalation of lavender essential oil or linalool increases relaxation and improves sleep [45,47,48]. Anise essential oil taken internally has been shown in small clinical studies to relieve post-natal depression [15] and pre-menstrual syndrome [16]. Thyme essential oil, taken internally has shown efficacy in small clinical trials in cough [107,108].

There is an increasing body of evidence, particularly experimental, on botanical ingredients, essential oils and respiratory health and for the purposes of initiating calmness and relaxation. Mixtures of essential oils, as found in Puressentiel Rest and Relax and Air Purifying Sprays, are also efficacious in terms of antimicrobial [111-114] and relaxant activity as well as improving quality of life [115].

There is still a paucity of evidence from clinical trials. Ongoing research is needed in the form of larger well controlled trials to build the evidence base.

Conclusions

The present review has collated evidence from peer reviewed research in relation to selected essential oils and their bioactive ingredients. Overall, it appears that selected essential oils, as well as specific mixtures, and their botanical ingredients have a range of effects including antimicrobial, respiratory, and relaxant effects which could improve respiratory wellness and help to maintain calmness and relaxation. Numerous studies have evaluated the mechanisms associated with these effects, including the stimulation of brain receptors such as GABAARs and stimulation of olfactory neurons in the case, for example, of linalool which is found in several essential oils and helps to explain the respiratory and relaxant effects of lavender essential oil and also that of a range of other essential oils including bay, cajeput, geranium, lemongrass, mandarin, neroli, orange, petitgrain, rosewood and sage. Mechanistic studies demonstrate real effectiveness of essential oils in respiratory health and in relaxation due to the content of a range of bioactives of which linalool is a key example, alongside a range of terpenes, esters and aldehydes. Further clinical research in human beings is needed to corroborate these findings and provide scientific validation for their effectiveness in human beings which has been known in practice for centuries.

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