Chapter 1
Essential Oils and Their General Aspects, Extractions and Aroma Recovery

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1.1 Introduction

Essential oils (EOs) are complex mixtures of various constituents such as phenylpropanoids, esters, and homo-, mono-, sesqui-, di-, tri-, and tetraterpenes. Their therapeutic uses are related to the treatment of cancer, diabetes, and cardiovascular and neurological diseases, in addition to having anti-aging, antioxidant, and antimicrobial effects (Saljoughian et al. 2018; Benny and Thomas 2019; Bezerra et al. 2020b). The mechanisms involved in the pharmacological action of essential oils are complex due to their extensive and varied composition. Thus, *in vivo, in situ,* and *in silico* studies have been carried out to clarify and confirm the traditional ethnopharmacological uses and make them a viable alternative to current therapeutic drugs, which in their vast majority bring side effects to patients (da Costa et al. 2019; Leão et al. 2020; Araújo et al. 2020).

Essential oils have been used as a complementary therapy in the treatment of anxiety, pain, bipolar disorder, attention-deficit hyperactivity disorder, and depression through oral administration, inhalation, applied in diffusers, baths, and other uses. Their effects are due to the possible action on modulating the GABAergic system and inhibiting Na + channels, resulting in the balance between neural excitation and inhibition, culminating in the proper functioning of the central nervous

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system (Wang and Heinbockel 2018). In the study by Abuhamdah et al. (2015), the essential oil of *Aloysia citrodora* showed antioxidant activity and neuronal protection due to inhibition of nicotine binding. Anaya-Eugenio et al. (2016) intraperitoneally administered the essential oil of *Artemisia ludoviciana* in rats, and the authors found that this EO has antinociceptive effects that may have been partially mediated by the opioid system. Heldwein et al. (2012) administered *Lippia alba* essential oil on silver catfish and found that it had a central anesthetic effect related to the GABAergic system.

Regarding the upper and lower respiratory tract, essential oils can be used in the treatment of diseases such as laryngitis, epiglotitis, pharyngitis, abscesses, rhinitis, bronchitis, pneumonia, etc. The mechanism of action may be related to their high volatility that can easily reach the parts to be treated through inhalation or oral administration (Horváth and Ács 2015; Bezerra et al. 2020; Leigh-de Rapper and van Vuuren 2020; de Oliveira et al. 2021). Ács et al. (2018) performed *in vitro* tests with different EOs against respiratory tract pathogens, and they found that thyme essential oil was effective against *Streptococcus mutans* and *Moraxella catarrhalis*; cinnamon bark was efficient against *S. pneumoniae* and *Haemophilus* spp.; and clove EO had action on *S. pyogenes.* The authors also suggested their use in combination with reference antibiotics to determine the effective dose and possible side effects and toxicity.

Essential oils are also able to prevent and improve the clinical picture of atherosclerosis, vasorelaxation, heart failure, myocardial infarction, and hypotension. The pharmacological effect of EOs on cardiovascular diseases may be related to their structure. For instance, the location of OH groups on the benzene ring may influence its effectiveness; and monoterpene alcohols may be more effective than monoterpene hydrocarbons (Monzote et al. 2017; Yu et al. 2020; Kaur et al. 2021). Alves-Santos et al. (2016) investigated the cardiovascular effects of *Croton argyrophylloides* in normotensive rats. The authors reported that treatment with this EO was able to decrease blood pressure and the effect may be related to active vascular relaxation. Ribeiro-Filho et al. (2016) evaluated the antihypertensive effect of the monoterpene β-citronellol through intravenous injection in anesthetized rats, and the treatment induced biphasic cardiovascular effects and direct and endothelium-independent cardioinhibitory vasodilatation. According to the study, the effects of this essential oil are possibly related to its vasodilator effect and consequent hypotensive action.

EOs present constituents that may also be related to chemopreventive effects due to increased detoxification, antioxidant, antimutagenic, antiproliferative, and enzyme induction properties (Bhalla et al. 2013; Bayala et al. 2014). The essential oil of *Rosmarinus officinalis* showed cytotoxic activity against three human cancer tumor cell lines (SK-OV-3, HO-8910, and Bel-7402). The authors (Wang et al. 2012) attributed this activity to the synergistic action of the EO compounds: mainly α-pinene, β-pinene, and 1,8-cineole. In the work by Chen et al. (2013), the essential oil of *Curcuma zedoaria* showed cytotoxic effect *in vitro* and *in vivo* on non-small cell lung carcinoma and on cell apoptosis that plays an important role in the effectiveness of chemotherapy. The essential oil of *Pinus Roxburghii* was evaluated in the 3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide assay and showed induction of cytotoxicity in colon, leukemia, multiple myeloma, pancreatic, head and neck, and lung cancer cells, in addition to having inhibited cell proliferation and induced apoptosis, which was correlated with NF-κB suppression (Sajid et al. 2018).

EOs also can be used in the treatment of other diseases. *Coriandrum sativum* and clove essential oils showed neuroprotective effects on patients with Alzheimer's disease (Chen et al. 2013; Cioanca et al. 2013). The essential oils of *Croton matourensis, Syzygium cumini, Psidium guajava,* and *Melissa officinalis* showed potential anti-inflammatory activity (Bounihi et al. 2013; Bezerra et al. 2020b). Also, EOs of *Citrus bergamia, Coriandrum sativum, Pelargonium graveolens, Helichrysum italicum, Pogostemon cablin, Citrus aurantium, Santalum album, Nardostachys jatamans,* and *Cananga odorata* showed antiproliferative effects on neonatal human skin fibroblast cells (Han et al. 2017; Sihoglu Tepe and Ozaslan 2020). In fact, despite the strong indications, clinical studies with patients are still necessary in order to verify the real efficacy and toxicity of EOs.

1.2 Plant Organs Where EOs Are Found

Essential oils are secondary metabolites that play an important ecological role in plant defense, mediating the relationship between the plant and abiotic (light, temperature, oxygen, CO_2, ozone, etc.) and biotic factors (competing organisms, harmful pathogens, and beneficial animals). Biosynthesis can occur in different plant organs such as leaves, bark, flowers, buds, seeds, twigs, fruits, rhizomes, and roots (Najafabadi et al. 2017; Dhakad et al. 2018; Cascaes et al. 2021a). The synthesis, accumulation, and storage can occur in secretory glands, which are specialized histopathological structures that can be located: (i) on the surface of plants, thus having exogenous secretion; or (ii) inside organs, occurring endogenous secretion. Plants may also possess other secretory structures such as epidermal papillae, secretory bristles or glandular trichomes, schizogenous or secretory pockets, secretory channels, and intracellular secretory cells (El Asbahani et al. 2015; Lange 2015; Sharifi-Rad et al. 2017). Table 1.1 shows the chemical composition of some plant species and the organ from which their essential oil was obtained.

Table 1.1 Chemical composition of some essential oils according to the species and organs used for extraction

Species	Part	Composition	References
Syzygium cumini	Leaves	α-Pinene, β-pinene, and trans-caryophyllene	Mohamed et al. (2013)
Croton matourensis	Leaves	Larixol, manool oxide, linalool, *E*-caryophyllene, α-pinene, and α-phellandrene	Bezerra et al. (2020b)
Hornstedtia bella	Leaves	Germacrene D, viridiflorene, *E*-β-caryophyllene, and α-humulene	Donadu et al. (2020)
	Rhizomes	β-pinene, α-humulene, β-selinene, and epiglobulol	
	Whole plant	β-pinene, 1,8-cineole, and α-pinene	
Eucalyptus globulus	Fruits	Globulol, aromadendrene, and eucalyptol (1,8-cineole)	Said et al. (2016)
Salvia hydrangea	Flowers	Caryophyllene oxide, 1,8-cineole, and trans-caryophyllene	Ghavam et al. (2020)
Syzygium aromaticum	Bud	Eugenol, eugenyl acetate, and β-caryophyllene	Razafimamonjison et al. (2014)
	Leaves	Eugenol, eugenyl acetate, and β-caryophyllene	
	Stems	Eugenol and β-caryophyllene	
Citrus aurantium	Green leaves/twigs	4-Terpineol, D-limonene, 4-carvomenthenol, and linalool	Okla et al. (2019)
	Small green branches	D-Limonene, dodecane, oleic acid, and trans-palmitoleic acid	
	Wooden branches	D-Limonene, dimethyl anthranilate, (−)-β-fenchol, and dodecane	
	Branch bark	D-Limonene, γ-terpinene, dodecane, and dimethyl anthranilate	

1.3 Chemical Composition of Essential Oils

1.3.1 Background

Essential oils (EOs), also called volatile oils, are odorous products obtained from plant materials that have already been identified by botanists. These complex mixtures, full of volatile compounds, are biosynthesized by plants in different parts and can be obtained by conventional techniques such as hydrodistillation, steam distillation, and cold pressing, as well as by innovative methods, which increase the efficiency of extraction, either concerning extraction time or to obtain higher-quality extracts (El Asbahani et al. 2015).

EOs can be obtained with variable yield (in quantity, quality, and composition). Climatic factors, soil composition, age of the plant material, stage of the vegetative cycle, and the time of the year when the material was collected can also influence the yield of EOs. In addition, one or more components can be found in high contents (from 20% to 70%) or trace amounts (Akthar et al. 2014).

As an example of the diversity of EOs, we can highlight 1,8-cineole, present in high quantity in the oil of *Eucalyptus globulus* (eucalyptus), being its main constituent; unlike *Coriandrum sativum* (coriander) that has linalool as the main component. Furthermore, the occurrence of chemotypes is common, since the same plant species may have different chemical characteristics, depending on where it was cultivated. An example is *Thymus vulgaris* (thyme), which has chemotypes related to its main compounds, such as thymol, carvacrol, terpineol, and linalool (Regnault-Roger et al. 2011).

Volatility is the main difference between EOs and fixed oils (lipid mixtures) obtained from seeds. In addition, EOs also carry pleasant and intense aromas that have led them to be sometimes called essences. These characteristics are due to their main constituents, terpenes and terpenoids, which originate from different biosynthetic pathways. Terpenes are part of the main group that constitutes EOs, and their chains are formed by the successive juxtaposition of several isoprene units (C_5), which originate other terpenes, such as monoterpenes (C_{10}), sesquiterpenes (C_{15}), and diterpenes (C_{20}). On the other hand, terpenoids, such as alcohols, esters, ketones, are terpenes that contain oxygen and that comprise a wide variety of organic functions (Baptista-Silva et al. 2020) (Fig. 1.1).

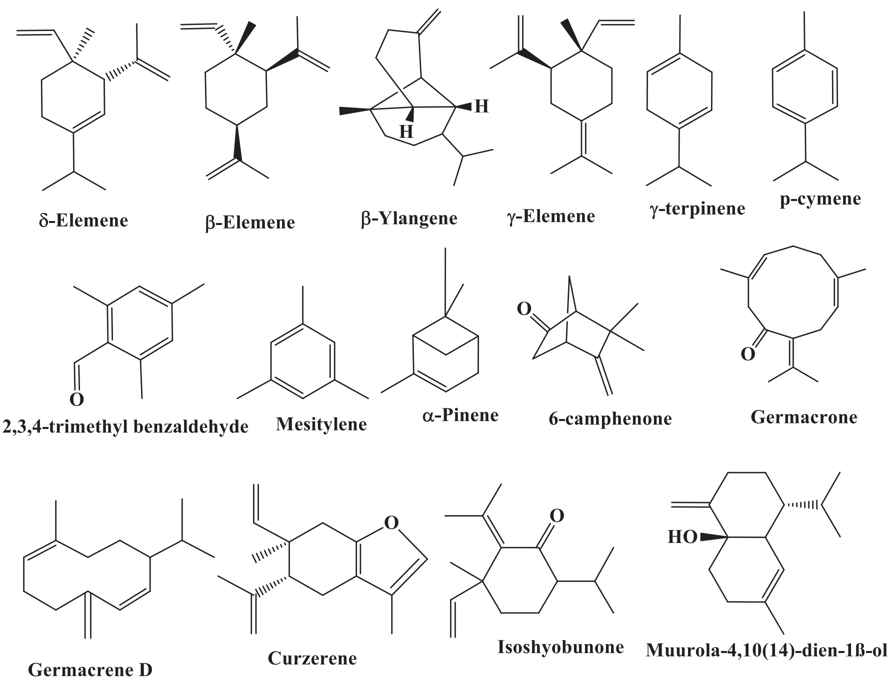

Fig. 1.1 Chemical structures found in essential oils. (Source: Adapted from Hyldgaard et al. 2012)

1.3.2 Terpenes

Terpenes, which have the general formula $(C_5H_8)n$, are derived from the mevalonic acid pathway from acetyl-CoA and are produced by specialized plant tissues. Isoprene (C5) is their basis and originates all other terpenes, being a subunit of these new molecules. Thus, according to the general formula, two isoprene units generate monoterpenes ($C_{10}H_{16}$); three units generate sesquiterpenes ($C_{15}H_{24}$); four isoprene units generate diterpenes ($C_{20}H_{32}$), and so on (Hyldgaard et al. 2012; Cascaes et al. 2021b).

Terpenes also present biological activities, such as anticonvulsant (De Almeida et al. 2011), anticancer (Bhalla et al. 2013), antifungal (Nazzaro et al. 2017), antibacterial (Guimarães et al. 2019), phytotoxic (with potential for biopesticide production) (Werrie et al. 2020), and several other properties and applications. This behavior guarantees a great advantage since EOs are environmentally friendly, safe when used with responsibility, natural, renewable, and biodegradable (Pandey et al. 2017).

1.3.3 Monoterpenes

Monoterpenes, as mentioned above, have in their structure two isoprene units ($C_{10}H_{16}$), and are present in 90% of the EOs. Important monoterpene hydrocarbons are limonene, p-cymene, α-pinene, and α-terpinene; and remarkable oxygenated monoterpenes are carvacrol, thymol, and camphor (Nazzaro et al. 2017). Carvacrol and thymol are some of the most active oxygenated monoterpenes ever identified, showing antimicrobial activity with MICs of 300 and 800 μg/mL, respectively (Hyldgaard et al. 2012). The *in vivo* and *in vitro* antitumor activities of 37 monoterpenes found in EOs have also been described (Sobral et al. 2014) and a recent study reports α-pinene as a compound that exhibits enantioselective biological activities, being promising for further research and consequent development of new drugs (Allenspach and Steuer 2021).

1.3.4 Sesquiterpenes

Sesquiterpenes are formed by three isoprene units ($C_{15}H_{24}$), being one of the most important terpenes (Ferreira et al. 2020). By the extension of the chain, the increase in the number of cyclizations is favored and thus, the formation of diverse structures is favored as well (Nazzaro et al. 2017). Pandey et al. (2017) reported that essential oils exhibit antifungal activity (acting by disintegration of fungal hyphae) due to the presence of monoterpenes and sesquiterpenes. There are also reports of two sesquiterpenes, valerena-4,7(11)-diene (VLD) and β-caryophyllene, that showed proven anxiolytic activity (Zhang and Yao 2019); other authors state that sesquiterpenes such as valeranone and β-eudesmol have anticonvulsant activity (De Almeida et al. 2011); and the anti-inflammatory activity of 12 sesquiterpenes, among them farnesol, was also studied (de Cássia Da Silveira e Sá et al. 2015).

1.3.5 Diterpenes

Diterpenes, formed by four isoprene units ($C_{20}H_{32}$), are called diterpenoids when they have oxygen in their structure. Compounds such as retinol, retinal, taxol, and phytol have diterpenes as the basis of their structure. According to several studies, diterpenes have the greatest antioxidant and cytotoxic capacities (Islam et al. 2016; Santana de Oliveira et al. 2021). An example is a diterpene ester, ingenol-3-angelate, isolated from the sap of *Euphorbia peplus*, which presents anticancer properties, being cytotoxic for different tumor cells (Greay and Hammer 2015). Also, diterpenes showed efficacy against ten neglected tropical diseases such as Chagas disease, chikungunya, echinococcosis, dengue, leishmaniasis, leprosy, lymphatic filariasis, malaria, schistosomiasis, and tuberculosis (de Alencar et al. 2017).

1.3.6 Alcohols

Alcohols in EOs may appear in their free form, combined with terpene chains or with esters. Thus, terpenes are called alcohols when they bind to hydroxyl and may assume the nomenclature of monoterpenols, sesquiterpenols, diterpenols, etc. for the varied structures (Hanif et al. 2019). Guimarães et al. (2019) reported that the presence of hydroxyl groups, in phenolic and alcoholic compounds, such as carvacrol, l-carveol, eugenol, trans-geraniol, and thymol, induced significant antimicrobial activity. Also, there are reports of the occurrence of synergism, i.e., interaction of antimicrobial compounds that present greater activity in combination than individually. In this case, linalool or menthol combined with eugenol is more effective, suggesting that a monoterpenoid phenol combined with a monoterpenoid alcohol presents greater antimicrobial activity (Hyldgaard et al. 2012).

1.3.7 Esters

Esters can also be extracted from EOs and as mentioned earlier, can be combined with alcohols, which may exhibit antimicrobial activity (Hanif et al. 2019). Esters can be found in plants such as lavender (*Lavandula angustifolia*) and, sometimes, they can occur as lactones (in the cyclic form derived from lactic acid): γ-lactones (five-membered rings), δ-lactones (six-membered rings), or as coumarins (Zuzarte and Salgueiro 2015). Studies focusing on *Lavandula angustifolia* oil have shown anxiolytic effect, being used for the production of drugs such as Silexan. Esters are also found in ylang-ylang (*Cananga odorata*) oils, relieving and reducing symptoms of stress and anxiety (Zhang and Yao 2019).

1.3.8 Ketones

As one of the constituents of plant EOs, ketones have different activities and can even be toxic. They may present expectorant and wound-healing properties (Hanif et al. 2019). Some examples of ketones that are expectorants and have intense aroma are camphor, carvone, fenchone, and mentone. With toxic effects, we can mention pulegone, which can cause changes in the central nervous system, as well as liver and kidney failure, lung toxicity, and finally lead to death. Thujone, which has two isomeric forms, α-thujone and β-thujone, has greater toxicity in its alpha form. α-Thujone is used in the production of absinthe (an alcoholic beverage prohibited in many countries) (Zuzarte and Salgueiro 2015; da Silva Júnior et al. 2021).

1.4 Extraction Methods of EOs

Essential oils (EOs) obtained from aromatic plants represent a diverse and unique source of natural products, which are widely used for bactericidal, fungicidal, antiviral, antiparasitic, insecticidal, medicinal, or cosmetic applications, especially in the pharmaceutical, health, cosmetic, food, and agricultural industries. Their use is boosted by the growing interest of consumers in natural substances (Reyes-Jurado et al. 2015).

Before EOs can be used or analyzed, they must be extracted from the plant matrix, which might be its leaves, bark, peels, flowers, buds, seeds, and other parts (Tongnuanchan and Benjakul 2014). The main methods for extracting essential oils are hydrodistillation (HD), steam distillation, water-steam distillation, maceration, and empyreumatic distillation. Among these methods, HD has been the most common approach to extract essential oils from medicinal plants (Djouahri et al. 2013). Although these techniques have been used for many years, their application has some drawbacks, such as loss of some volatile compounds, low extraction efficiency, degradation of esters or unsaturated compounds by thermal or hydrolytic effects, and possible toxic residual solvents in extracts or EOs (Reyes-Jurado et al. 2015).

New approaches, such as microwave-assisted extraction, supercritical fluid extraction, and ultrasound-assisted extraction, which emerged from the so-called green extraction techniques, have been applied to shorten extraction time, improve extraction yields, and reduce operating costs, optimizing production over traditional methods (Li et al. 2014; Reyes-Jurado et al. 2015). In the next sections, we will discuss in detail hydrodistillation and steam-distillation techniques, the most traditional methods, and supercritical fluid and microwave-assisted extraction, the green methods with more current use, addressing their main aspects.

1.4.1 Hydrodistillation

Hydrodistillation (HD) has been used since ancient times for the extraction of essential oils. Despite the intrinsic limitations of this technique, it remains the most common method applied both in the laboratory and on an industrial scale (Orio et al. 2012; Azmir et al. 2013; de Oliveira et al. 2020). The principle of extraction is based on azeotropic distillation. Indeed, at atmospheric pressure and during the extraction process, the oil molecules and water form a heterogeneous mixture that reaches its boiling temperature at a point near 100 °C. The EO/water mixture is then simultaneously distilled as if they were a single compound (El Asbahani et al. 2015; Rassem et al. 2016; Bezerra et al. 2020c). Hydrodistillation is a variant of steam distillation, indicated by the French Pharmacopoeia for the extraction of essential oils from dried plants. The distillation time depends on the plant material being processed. Prolonged distillation produces only a small amount of essential oil, but adds unwanted high-boiling point compounds and oxidation products (Rassem et al. 2016; Silva et al. 2019; Castro et al. 2021).

In hydrodistillation, the plant materials are packed in a distillation flask; and water is then added in sufficient quantity to boil. Alternatively, direct steam is injected into the plant sample. Hot water and steam act as the main influencing factors in the release of bioactive compounds from plant tissues. An indirect water cooling system condenses the mixture of water vapor and oil, which flows from the condenser to a separator, where they are separated (Azmir et al. 2013).

In short, the hydrodistillation system consists of a container, usually a volumetric flask, connected to a Clevenger-type apparatus coupled to a cooling system, with temperatures ranging from 10 to 15 °C. The solid-liquid mixture is heated, at atmospheric pressure, until it reaches the boiling temperature of water, allowing the odor molecules to evaporate together with the water, forming an azeotropic mixture. This combination is led to the condenser, where it liquefies and is collected at the end of the process. Due to its hydrophobic character, the oil does not mix with water and can be separated by decantation. After separation, the oil is completely dehydrated with anhydrous Na_2SO (Rassem et al. 2016).

1.4.2 Steam Distillation

Steam distillation has some characteristics that make it one of the most widely used methods for obtaining essential oils on an industrial scale, such as low cost, simplicity, and ease of design when compared to other advanced techniques (Muhammad et al. 2013).

There are two types of steam distillation: direct and indirect. In the indirect method, the plant material is soaked in water and heated to boiling. The resulting steam from the boiling water carries the volatile compounds with it. Then, cooling and condensation separate the oil from water. The disadvantage of this technique is the degradation of materials and unpleasant smell due to constant exposure to heat. On the other hand, in direct steam distillation, the most commonly used method for obtaining essential oils, no water is placed inside the distillation flask. Instead, steam is directed into the flask from an external source. The essential oils are released from the plant material when the steam bursts the sacs containing the oil molecules (Chemat and Boutekedjiret 2015; do Nascimento et al. 2020).

In the steam distillation process, water boils above 100 °C, at a pressure higher than atmospheric pressure, which facilitates the removal of the essential oil from the plant material, reducing the formation of artifacts (El Asbahani et al. 2015; Yadav et al. 2017).

1.4.3 Supercritical Fluid Extraction

Supercritical fluid extraction (SFE) has become the most widely used method for extracting and isolating EOs from aromatic plants. This technique provides fast and effective extraction, requires only moderate temperatures, eliminates cleaning steps, and avoids the use of harmful organic solvents (Yousefi et al. 2019; de Oliveira et al. 2019; de Carvalho et al. 2019). Due to these attributes, SFE is considered environmentally friendly in various fields such as natural material extraction (Ghasemi et al. 2011; Sodeifian et al. 2017).

Generally, the solvent used in supercritical extraction is CO_2 because this gas has ideal properties, such as low viscosity, high diffusivity, and density close to that of liquids. In addition to being non-toxic, non-aggressive, non-flammable, bacteriostatic, non-corrosive, non-explosive, CO_2 is chemically inert, available in high purity at a relatively low cost, and its polarity is similar to pentane, which makes it suitable for the extraction of lipophilic compounds (El Asbahani et al. 2015; Sodeifian et al. 2017; Yousefi et al. 2019). Furthermore, the extraction is performed at temperatures and pressures above the CO_2 critical point, 7.4 MPa and 31.1 °C, or close to this region (Sovová 2012); so a simple pressure relief is able to separate CO_2 from the extracted essential oils, leaving no solvent residue and providing a high-purity product (El Asbahani et al. 2015). The low viscosity and high diffusivity of the supercritical fluid increase the penetration power based on the high mass transfer rate of the solutes into the fluid, allowing efficient extraction of compounds (Sovilj et al. 2011; Silva et al. 2021).

The laboratory-scale SFE system basically consists of a carbon dioxide cylinder, cooling bath, high-pressure pump, oven, extraction vessel, flask, air compressor, flow meter, and flow control valves (Cruz et al. 2020).

The extraction process begins when the liquefied CO_2 contained in a cylinder enters a high-pressure pump. The liquid carbon dioxide is then compressed to a desired pressure by the pump and is also heated to a determined temperature. Optionally, a required volume of co-solvent can be added to increase its solvation properties. Then, supercritical CO_2 containing the extracted solutes flows through a depressurization valve at the extractor outlet. This results in the precipitation of solutes, which are collected in a separator, whereas CO_2 is easily released (Fornari et al. 2012; Ahangari et al. 2021).

Despite being an efficient extraction technique with high-purity products, the elevated cost of equipment installation and maintenance is still an obstacle to the development of supercritical fluid extraction, which makes the final product more expensive (El Asbahani et al. 2015).

1.4.4 Microwave-Assisted Extraction

Another extraction technique considered green and sustainable that has didactic, scientific, and commercial applications is microwave-assisted extraction. EO obtaining under microwave irradiation, without organic solvent or water, is an extraction method that can offer high reproducibility in shorter times, with simplified manipulation, reduced solvent consumption, lower energy input, and lower CO_2 emission (Cardoso-Ugarte et al. 2013; Kokolakis and Golfinopoulos 2013). It also provides high-value products and higher yields when compared to traditional extraction techniques (Karimi et al. 2020).

Microwaves are a form of non-ionizing electromagnetic radiation at frequencies ranging from 300 MHz to 30 GHz and wavelengths ranging from 1 cm to 1 m. However, the frequency commonly used in extractions is 2450 MHz, which corresponds to a wavelength of 12.2 cm. This energy is transmitted in the form of waves, which can penetrate biomaterials and interact with polar molecules in materials such as water to generate heat (Cardoso-Ugarte et al. 2013; El Asbahani et al. 2015). Although in most cases dried plant materials are used for extraction, plant cells still contain microscopic traces of moisture that serve as a target for microwave heating. These residual water molecules, when heated due to the microwave effect, evaporate and generate tremendous pressure on the cell wall due to the swelling of the plant cell (Mandal et al. 2007).

The heating of microwave-assisted hydrodistillation is based on its direct impact on polar materials/solvents and is ruled by two phenomena: ionic conduction and dipole rotation, which in most cases occur simultaneously (Rassem et al. 2016). Ionic conduction refers to the electrophoretic migration of ions influenced by the varying electric field. The resistance offered by the solution to ion migration generates friction, which ultimately heats the solution. Dipole rotation represents the realignment of the dipoles with the changing electric field. Heating is affected only at 2450 MHz frequency. The electrical component of the wave changes 4.9×10^4 times per second (Mandal et al. 2007).

Advances in microwave-assisted extraction have led to the development of various techniques such as compressed air microwave distillation (CAMD), vacuum microwave hydrodistillation (VMHD), microwave-assisted hydrodistillation (MWHD), solvent-free microwave extraction (SFME), microwave accelerated steam distillation (MASD), and microwave hydrodiffusion and gravity (MHG) (Cardoso-Ugarte et al. 2013; Reyes-Jurado et al. 2015).

1.5 Conclusion

The present review allowed us to evaluate several aspects of essential oils, such as their diversified chemical composition, which presents phenylpropanoids, homo-, mono-, sesqui-, di-, and tri-tetraterpenes, alcohols, esters and ketones, which can be obtained from organs present in vegetables such as leaves, bark, flowers, buds, seeds, twigs, fruits, rhizomes, and roots. The extraction process can be performed using conventional methods such as hydrodistillation and steam distillation or more innovative methods such as supercritical fluid extraction and microwave-assisted extraction. In this scenario, it can be concluded that essential oils have great potential to be used in place of synthetic inputs, because studies demonstrate their antimicrobial (bactericidal, fungicidal), antiviral, antiparasitic, insecticidal, antioxidant, anticancer, antitumor, neuroprotective, anti -inflammatory, among others, so that they can be used as inputs with less toxicity in pharmaceutical, cosmetic, food and agrochemical products.

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