Chapter

Phytochemistry, Medicinal Uses, and Beneficial Nutritional Effects of Essential Oils

Saber Jedidi and Hichem Sebai

Abstract

Plants contain a considerable reservoir of secondary metabolites (flavonoids, tannins, and essential oils). These molecules exhibit variations in chemical structure as well as a very wide range of biological activities. Essential oils (EOs) are secondary metabolites produced by aromatic plants. EOs contain bioactive molecules, mainly represented by monoterpene hydrocarbons, oxygenated monoterpenes and sesquiterpenes, and sesquiterpene hydrocarbons. The organoleptic properties and biological activities of EOs are distinguished by their respective compositions. They have long been recognized for their medicinal properties such as antibacterial, antifungal, bio-herbicide, antioxidant, anti-inflammatory, antidiabetic, and hepato-nephroprotective activities. These organic compounds also exert beneficial effects on the nutrition of ruminants, by modulating digestibility and reducing the emission of methane, a greenhouse gas. This chapter is devoted to the study of chemical composition, medicinal uses, and beneficial nutritional effects of essential oils.

Keywords: essential oils, extraction method, phytochemistry, therapeutic potential, nutritional effects

1. Introduction

In recent decades, an increased interest has been given to alternative medicine. In this respect, the return to herbal care is highly recommended. Indeed, plants and their therapeutically active substances have been widely used in ethno-medicine [1]. On the other hand, researches on the benefits of physiotherapy and aromatherapy, using essential oils (EOs) for healing purposes, were constantly increasing [2]. The medicinal properties of essential oils are thus widely described.

Essential oils (EOs) are products with a rather complex composition, containing volatile active ingredients. Physically, these are volatile, which differentiates them from fixed oils. They are colorless liquids with a generally strong odor and flavor [3]. They are poorly miscible with water and well soluble in oils and organic solvents [4]. Finally, the obtained oils are separated by the difference in density, generally by simple decantation [5].

According to botanists, there are approximately 800,000 to 1500,000 plant species, 10% of which contain EOs. Indeed, they have been reported to be present in about 2000 species distributed in 60 botanical families, such as Lamiaceae, Lauraceae Myrtaceae, Rutaceae, Asteraceae, Cupressaceae, Poaceae, and Zingiberaceae [6].

EOs are located in various parts of the plant (roots, fruits, seeds, flowers, leaves, bark, and wood). The biosynthesis of these compounds realizes in plant cells via various metabolic reactions, such as isopentenyl diphosphate and its isomer dimethylallyl diphosphate. The end products of EOs are terpenoid and are synthesized with a large group of enzymes called terpene synthases. They occur in the cytoplasms of plants. Then, they localize in several organs of the plant such as trichomes, epidermal cells, and, finally, the secretory pockets [7].

According to reprts, EOs are distinguished by their smells, colors, densities, and chemotypes. Therefore, each essential oil has its characteristics, fragrance, and properties. Importantly, EOs are defined by their botanical species, part of the plant, the extraction mode, and the characteristic active principle [8].

EOs are characterized with several biological activities, such as fungicide, insecticide, herbicide, and bactericide potentials. These could be used as antiseptic and antimicrobial properties [9]. Many reports have shown that these volatile compounds have antioxidant, antiviral, and antiparasitic properties. EOs are also utilized as drugs in cancer chemotherapy [10]. These bioactive molecules have been useful in dentistry for the disinfection of dental pulp and the treatment/prevention of caries [11].

In animal nutrition, essential oils have attracted the attention of nutritionists for their potential role as an alternative to growth-promoting antibiotics. In small ruminants, essential oils are characterized for their beneficial effects on the digestion and digestibility of food. More importantly, research has shown that the inclusion of essential oils at reasonable doses modulated rumen fermentation parameters such as organic matter digestibility (OMD), volatile fatty acids (VFA), and metabolizable energy (ME) [12, 13].

On the other hand, human and animal poisoning with essential oils has been reported in several research works [14, 15]. Due to the increase uses of essential oils, the number of poisonings is expected to amplify in the future. It is therefore interesting to use EOs in animals and humans with caution.

In the available chapter, we firstly defined the essential oils, by studying their extraction methods and chemical structure, as well as their main uses. Then, in a second part, we developed their pharmacological and beneficial effects in animal nutrition.

2. Methods of essential oils extraction

Several methods of EOs extraction have been previously described. This diversity is due to the plant material variety and the sensitivity of their constituents. The choice of mode depends on the nature and the plant material parts, the physicochemical characteristics of EOs, as well as the extract uses. In this chapter, we will present some techniques for the EOs extraction.

2.1 Distillation by steam entrainment

At the Sylvo-Pastoral Resources laboratory in Tabraka, the technique consists of distilling 10 to 15 kg of plant material in the alembic with 10 L of water separated by a grid in a still (**Figure 1**). The distillation temperature is 100°C. The operation leads to the release of water vapor, which plays a dual role: (i) release of the plant essence

Figure 1.
Extraction of essential oils from Pinus halepensis needles by steam distillation. A: Water filling up to separation grid level; B: Introduction of plant material in the alembic. C: Complete assembly.

and (ii) transport of the oil, which condenses during cooling. The obtained liquid contains a fraction of essential oil and another of floral water. These two constituents are separated by the difference in density.

2.2 Hydrodistillation

This technique is the oldest method used. In brief, the plant material is immersed directly in a still filled with water placed on a heat source. The mixture is then brought to a boil. The vapors are condensed in a cooler (**Figure 2**). These two obtained constituents are separated by the difference in density [17].

2.3 Hydrodiffusion

It involves spraying water vapor through plant material in a top-down position. In this case, the vapor passing through the plant material is downward, as opposed to other traditional distillation techniques (**Figure 3**). This technique is more advantageous, since it qualitatively and quantitatively improves the harvested essential oil, saving time, steam, and energy [18].

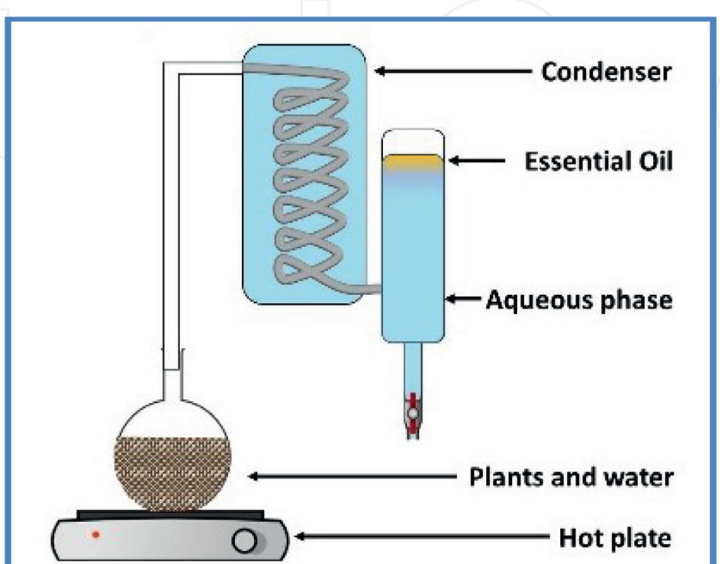

Figure 2.
Extraction of essential oils by hydrodistillation [16].

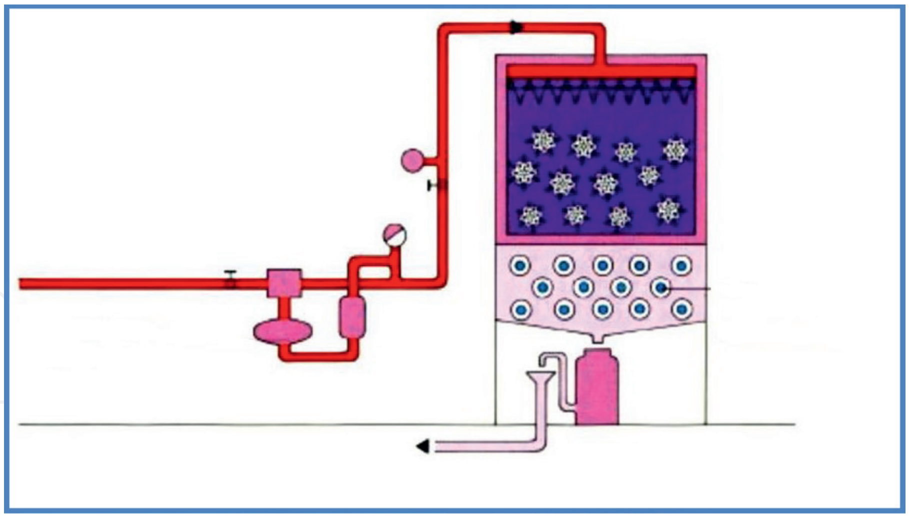

Figure 3.
Extraction of essential oils by hydrodiffusion.

2.4 Expression

This technique of expression or cold pressing essentially concerns the extraction of essential oils from the zest of lemons and oranges. Finally, the essence is released by a stream of water, then decanted (**Figure 4**). A new mechanical technique based on the bursting of the oleiferous bags under the effect of either a depression or abrasion of the fresh bark would eliminate water and reduce the effects of the essences compounds oxidation [20].

2.5 Solvent extraction

The solvent extraction technique consists of placing a volatile solvent and the plant material in an extractor. The product thus obtained is called "concrete". This concrete can then be brewed with absolute alcohol, filtered, and iced to extract the vegetable waxes.

After a final concentration, an "absolute" is obtained.

Among the features of this technique are:

- Yields are generally higher compared to conventional distillation.
- The use of organic solvents, which can lead to risks of artifacts and possibilities of contamination of the sample by impurities that are sometimes difficult to eliminate [21].

2.6 Microwave extraction

This technique is called Solvent Free Microwaves Extraction. It consists of extracting the essential oil using constant energy microwave radiation and a vacuum sequence. This technology is a combination of microwave heating and atmospheric pressure distillation. This method consists of introducing the part of the plant to be extracted into microwave reactor, without organic solvent/water. The increase in the

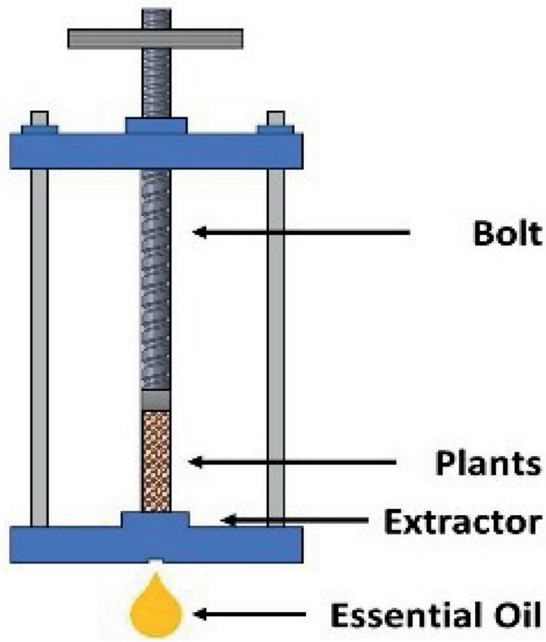

Figure 4.
Cold pressing method [19].

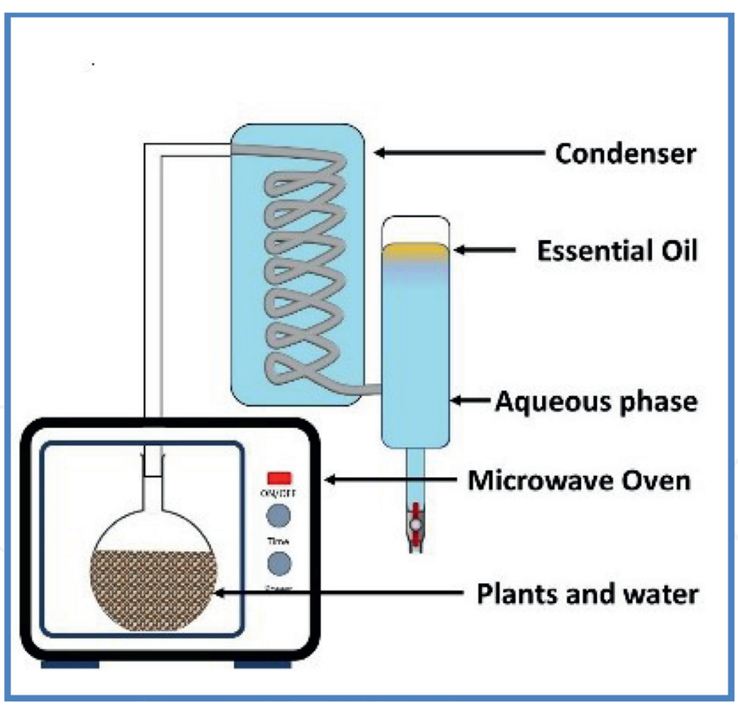

Figure 5.
Microwave-assisted hydrodistillation [16].

vegetable aqueous fraction allows the rupture of the glands containing the essential oil. Finally, a cooling system outside the microwave allows the condensation of the distillate (**Figure 5**). This process seems to be more competitive and economical than the conventional methods [22].

Figure 6.
Enfleurage of rose petals.

2.7 Extraction by fatty substances

This enfleurage technique is used in the extraction of EO from flowers, fragile parts of plants. It takes the advantage of the fat-soluble odorous components of plants in fatty substances. The principle consists of bringing the flowers into contact with a fatty substance to saturate it with plant essence (**Figure 6**). The obtained product is a floral ointment that is then exhausted by a solvent, which is eliminated under reduced pressure [23].

3. Chemical structure of essential oils

The chemical composition of EO can be identified by chromatographic analysis such as gas chromatography and mass spectrometry (GC/MS) [12]. EO are complex and variable mixtures of constituents that generally belong to two groups characterized by different biogenetic origins, the groups of terpenoids and aromatic compound derived from phenylpropane, which are much less frequent.

3.1 Terpenoids

Terpenes are formed from n multiples of the C_5H_8 isoprene; they are multicyclic structures that differ not only in the functional groups but also in the basic structure of their hydrocarbon skeletons. When n = 2, the terpene corresponds to monoterpenes $(C_{10}H_{16})_2$. Monoterpenes and their derivatives are therefore linear chains or cycles formed from two isoprene units.

3.1.1 Monoterpenes

Carbides are almost always present. They are acyclic, monocyclic, or bicyclic. They sometimes constitute more than 90% of the essential oil (**Figure 7**).

Figure 7.
Acyclic (myrcene) and monocyclic (thymol) monoterpene [3].

3.1.2 Sesquiterpenes

They consist of 3 isoprene units. Chain elongation increases the number of possible cyclizations (**Figure 8**).

3.1.3 Other terpenoids

These subgroups contain more than three isoprene units. They are presented as follows:

- 4 isoprene units: diterpenoids,
- 5 isoprene units: sesterterpenoids,
- 6 isoprene units: triterpenoids,
- 8 isoprene units: tetraterpenoids,
- Compounds whose number exceeds 8 isoprene units: polyterpenoids

3.2 Aromatic compounds

Phenylpropane derivatives (C_6–C_3) are much less common than the previous ones. Very frequently, these are allyl and propenylphenols, sometimes aldehydes, characteristics of certain essential oils, such as that of clove (eugenol). On the other hand, the safarole is a compound with the chemical formula C_6-C_1 has been rarely identified in essential oils composition [24].

3.3 Compounds of various origins

Depending on their mode of extraction, essential oils can contain various aliphatic compounds, generally of low molecular mass, which can be carried away during

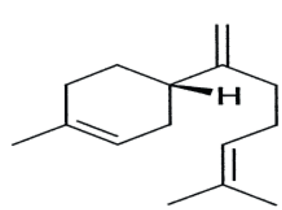

Figure 8.
Sesquiterpene (β-besabolene) [3].

hydrodistillation, such as carbide, acid (C3 to C10), alcohols, aldehydes (octanal, decanal), esters, lactones, nitrogen, or sulfur products [25].

4. Biological activities of EO

The biological activity of EOs depends on their chemical compositions and structures and on the synergistic effects between their major and minor compounds.

4.1 Antioxidant capacity

The antioxidant activity was evaluated, *in vitro*, by various tests. In this respect, Louail et al. [26] assessed antioxidant activities of *Ammodaucus leucotrichus* EO by measuring by inhibiting the β-carotene bleaching. The value of the essential oils showed a better antioxidant activity when compared to ascorbic acid, used as reference antioxidant molecule. In another experiments, Selmi et al. [13], Aloui et al. [27], and Jedidi et al. [28] assessed the antioxidant activities of essential oils obtained from aerial parts of *Junepeus phoenicea*, *Pinus halepensis*, and *Rosmarinus officinalis*, using 2, 2-diphenyl-1-picrylhydrazyl ($DPPH^{\bullet}$) and 2,2′-azino-bis [3-ethylbenzthiazoline-6-sulphonic acid] (ABTS) tests. Essential oils of the four species exhibited strong antioxidant abilities to reduce the studied radicals. It has been demonstared that 1,8-cineole, α-pinene and camphor have the dominant components of the EO of a few commercial species. These identified molecules are powerful scavengers of free radicals and therefore responsible for the strong antioxidant activities observed [29].

4.2 Antimicrobial activity

The EO of many species were screened for their antimicrobial activities against different microorganisms, including Gram-positive and Gram-negative bacteria. Essentail oils exhibited strong inhibitory action against most tested organisms. Furthermore, the essential oil showed significant antibacterial activity against Gram-negative and Gram-positive bacteria. It has been shown that Gram (+) bacteria are more sensitive to essential oils isolated from the species *Pinus pinea* [27], *Ammodaucus leucotrichus* [30], and *Rosmarinus officinalis* [31]. The authors suggested that this finding can be explained by the fact that Gram (−) bacteria have hydrophobic lipopolysaccharide in the outer part of their membranes, which provides effective protection against different agents.

In addition, listerine, which is a solution consisting of thymol and eucalyptol essential oils, has a high bactericidal activity on microorganisms in saliva and dental plaque [32].

On the other hand, it also demonstrated that the sesquiterpenoids identified in the essential oils of *Cyperus iria* leaves exerted a potential fungicidal action against Fusarium graminearum [33].

4.3 Anticholinesterase activity

Limonene, a monoterpene isolated from Ammodaucus leucotrichus essential oils, has been shown to induce high acetylcholinesterase inhibitory activity with an IC_{50} of about 51.6 μg ml^{-1} [34]. Additionally, Aazza et al. [29] proved that 1,8-cineole, α-pinene, and camphor were the dominant components of sage essential oils and were responsible for strong antiacetylcholinesterase activity.

5. Medicinal uses

5.1 Antiulcer ptentiel

Essential oils are widely used in the treatment/prevention of digestive pathologies. Terpenes and phenylpropanoids found in many essential oils have been shown to have potential for use in peptic ulcer disease [35]. The authors suggested that the anti-ulcer action is due to bioactive volatile molecules and their mechanisms of action, such as restoring the activity of antioxidant enzymes and the level of nonenzymatic antioxidants, recovering the level of mediators intracellular, and restorating pH. Essential oils also exerted an effect against *Helicobacter pylori* bacteria and improved the gastric mucosal barrier.

5.2 Antidiabetic capacity

EOs have shown a series of biological properties with health-promoting conduct in humans. Among the chemical groups that make up essential oils, terpenoids are characterized by their hypoglycemic effect. These molecules inhibit enzymes responsible for the development of insulin resistance and normalization of plasma glucose and insulin levels [36]. These bioactive molecules exert an inhibitory effect in the process of carbohydrate metabolism and prevent the phenomenon of insulin resistance and finally of the serum glycaemia level [37]. In addition, it has been suggested that triterpenes have contributed to the treatment of diabetic neuropathy and nephropathy by inhibiting several pathways involved in the diabetes and associated complications [36]. On the other hand, the *Aegle marmelos* leaves' volatile molecules showed strong antidiabetic activity [38]. In another report, it was demonstared that the antidiabetic effetct of *Lavandula stoechas* essential oil is due, partly, to its potent antioxidant properties [39].

5.3 Anti-inflammatory properties

The different compounds of essential oils are also characterized by powerful anti-inflammatory effects. In this context, Baricevic et al. [40] proved that ursolic acid isolated from the *Salvia officinalis* EO was the main component of its anti-inflammatory power. On the other hand, certain terpenoids such as scropolioside like iridoids have shown potential for anti-inflammatory, hepatoprotective, and wound-healing activity [41, 42]. Terpenes and terpenoids are promising in the treatment intestinal inflammatory and have been also shown to display a broad range of biological activities in various human disease models [43]. Few other volatile terpenes and terpenoids, mainly monoterpenes, oxygenated terpenes, terpene esters, and sesquiterpenes, showed anti-inflammatory properties [44]. In addition, the anti-inflammatory effect of the *Ammodaucus leucotrichus* fruits' EOs has been demonstrated by the evaluation of the antiedematogenic response of essential oils in Carrageenan-induced hind paw edema in animal model [45].

5.4 Anticancer activity

In vitro, certain terpenoids isolated from the roots of *Salvia officinalis* exerted a protective effect against cellular and DNA damage during human carcinomas. On the other hand, the α-humulene, a sesquiterpene compound identified in officinal sage essentail oils, demonstrated strong cytotoxic activity in human prostate carcinoma cells. Trans-caryophyllene, isolated from *Salvia officinalis*, also exerted high cytotoxic activity against renal cell carcinoma cells [46, 47]. In addition, research work conducted by Li et al. [48] showed that natural bicyclic sesquiterpenes exhibited potential anticancer activity.

5.5 Hepato-nephroprotective effect

Volatile compounds are known for their hepato-hepato-nephroprotective actions. In this regard, Fahmy et al. [49] evaluated, on animal model, the potential effect of essential oils extracted from sage plant against carbon tetrachloride (CCl4)-induced hepato/renal toxicities. This study confirmed that *Salvia officinalis* essential oils (SOEO) represent a potential candidate to reverse CCl_4-associated hepato/renal damage. This effect may occur via an antioxidant defense mechanism that is partly related to the complexity of its chemical constituents.

6. Beneficial nutritional effects of EO

6.1 In broiler chickens

EOs are natural bioactive molecules that can be included as alternatives to antibiotics during broiler rearing. Results published by Puvača et al. [50] confirmed that these compounds have beneficial effects on nutrient digestibility, microbiota, and gut function. Authors also suggested that EOs have positive effects, but knowledge of their use in poultry feed is still limited and requires further research.

6.2 In ruminants

EOs could be used as additives in ruminant feed, to modify the activity of microorganisms responsible for ruminal fermentations and to improve digestion in small ruminants.

Essential oils have been shown to exert beneficial effects on ruminal fermentations. In fact, these molecules are involved in improving the amino acids' quantity available for animal's needs, increasing the volatile fatty acid (VFA) levels, providing sources of energy for animals, and reducing methane and ammonia emissions [51]. These results are similar to those published by Jedidi et al. [12] and Selmi et al. [13] who worked on the effect of essential oils from many plants. These authors found that the inclusion of volatile compounds, at reasonable doses, stimulated parameters of ruminal fermentation in vitro, such as digestibility of organic matter (DOM), metabolisable energy (ME), and volatile fatty acids (VFA). In addition, EOs exerted the decrease in greenhouse gas emissions in a dose-dependent manner. The authors mentioned that all of these beneficial effects of essential oils are attributed to the synergistic effects of these components.

In this respect, a mixture of volatile compounds extracted from several aromaticplants has been shown to significantly improve food bioavailability. This beneficial effect exerted by this preparation is due to the changes in the intestinal ecosystem [52].

In the field of animal production, EOs are mainly used to improve zootechnical performance, such as growth rate, consumption index (CI), feed intake level, feed digestibility, and animal health status [53].

7. Conclusions

This chapter has shown that monoterpenes, sesquiterpenes and their derivatives, aromatic compound, and compound of various origins are the main chemical constituents of essential oils identified in plants. Several reports demonstrated that EOs exhibit a range of pharmacological actions, such as antiulcer, hepato-nephroprotective, anti-inflammatory, antidiabetic, antioxidant, antibacterial, antifungal, and anticholinesterase activities, supporting their traditional uses. In addition, essential oils exerted beneficial effects on nutrient digestibility and intestinal function in broilers, improved digestibility parameters in ruminants, as well as decreased NH_4^+ emissions.

However, further improvements are needed to adjust the doses of inclusion/administration because misuse can lead to severe human and animal toxicities. Finally, it is strongly recommended to keep these bioactive molecules well and to keep them away from children.

Conflict of interest

The authors declare no conflict of interest.

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