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A Review on the Versatile Applications of Plant-Based Essential Oils in Food Flavoring, Culinary Uses and Health Benefits

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A Review on the Versatile Applications of Plant-Based Essential Oils in Food Flavoring, Culinary Uses and Health Benefits

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Abstract: Plant-based essential oils are important natural products rich in volatile compounds, and they have various applications in medicine, food, perfumery and cosmetics. These substances can be produced using various methods, such as steam distillation and solvent extraction. Their chemical composition is influenced by geographical and climatic conditions, production methods, and intrinsic factors. Published articles and literature were scanned to gather the required information. Previous studies have shown that essential oils possess chief health benefits, including antimicrobial, anti-inflammatory, antioxidant, and psychological effects. Consequently, they have wide applications in the food industry as preservatives in food systems and in active packaging, edible coating, probiotic foods, and flavoring. Essential oils can be successfully utilized in flavoring foods and beverages such as cheese, ice cream, and soft drinks. Despite their great antimicrobial and flavoring roles, it is important to further investigate their possible interactions with food components and the physiochemical characteristics of foods flavored with essential oils.

Keywords: essential oils; flavoring; volatile compounds; antimicrobial; antioxidant

Introduction

Plant-based essential oils are among the most important natural products extracted from plants. Since ancient times, essential oils have been used in perfumes and therapeutic preparations [1]. They are complex liquids formed of volatile compounds that are present in different plant parts [2]. The chemical composition of essential oils is quite complex and can vary according to conditions such as the climate, soil characteristics, and location of the cultivated plants [3]. Terpenes are the major components present in essential oils [4]. Different techniques have been adopted to extract essential oils [5]. Steam distillation is the most commonly used method for the production of essential oils [6]. Essential oils have several health benefits, including antimicrobial, antioxidant, and anti-inflammatory activities [7]. Therefore, they have broad applications in various sectors, including medicine, cosmetics, agriculture and food [8].

Recently, food producers have started implementing natural preservatives in their products with the increased demand for products that contain natural ingredients [9]. Essential oils have wide applications in the food industry, such as in active packaging, edible coatings, and probiotic foods, and as preservatives in food systems [6,7]. One of the main roles of essential oils is to impart flavors and aromas to food products. Flavor is a principal element to consider because it is necessary to provide consumers with satisfactory food products [10]. Essential oils are used in flavoring beverages, confectioneries, and savory products [11]. Essential oils play an important role in flavoring carbonated beverages because they are a substantial part of the concentrate used to prepare these drinks [12]. It is important to study the use of natural flavoring ingredients with the increased concern of using synthetic additives. Therefore, this review sheds light on essential oils and their role in flavoring. The chemical composition, extraction methods, general uses, and health benefits of essential oils are highlighted. The paper also describes the applications of essential oils in the food industry, with a focus on flavoring foods and beverages.

I. Essential Oils

Throughout history, essential oils have been used for different purposes. Ancient Egyptians used these oils back in 4500 BC in cosmetics, perfumes, and herbal therapeutic preparations. In addition, the first use of these substances in Chinese and Indian history dates back to 3000 to 2000 BC, with recordings of more than 700 substances known for their healing efficiency. Furthermore, the Greeks were the first to record the use of several essential oils, such as cumin, thyme, and peppermint, between 500 and 400 BC [1].

I.1. Definition of Essential Oils

Plant-based essential oils are complex liquids that contain a set of aromatic and volatile compounds naturally occurring in different plant parts, including flowers, seeds, peels, stems, bark, and whole plants [2]. They are dissolvable in organic solvents and lipids and are characterized by strong odors [13]. The coined nomenclature of "essential oils" is derived from the term "essence", which reflects the presence of strong scents and flavors [14].

Essential oils, also called "volatile oils", are secondary plant metabolites and are therefore essential for protecting plants from surrounding threats such as the presence of pests or pathogens [13,15]. They are usually extracted by steam distillation and are composed of hundreds of chemicals [3]. There are approximately 3000 identified essential oils, and a single oil may contain more than 400 compounds. Recent exploration revealed the presence of 4350 chemical compounds in 91 essential oils [3,7].

Several studies have shown that they also possess antimicrobial, anti-inflammatory, and antioxidant properties and can act as natural replacements for antibiotics [13]. Moreover, essential oils have diverse applications worldwide, essentially in medicine, perfumery, cosmetics, and the food industry [15].

I.2. Chemical Composition

As mentioned above, the chemical composition of essential oils is highly complex. It can vary significantly between different producers and even within the same producer. Many factors govern this diversity of chemical composition, namely, the species, geographic region, climate, soil attributes, and method of extraction adopted [3]. In addition, this compositional variation could be detected similarly at the qualitative and quantitative levels. For instance, parameters such as the stage of maturation of the plant, its genetic makeup, and the involved organ can significantly affect its composition. In fact, the majority of these factors can interact with each other, and therefore, separating them becomes very complicated [16].

The volatile compounds that constitute essential oils are classified into a variety of chemical classes: terpenes, phenols, ketones, aldehydes, amines, amides, ethers, heterocycles, and esters [16]. However, only a few chemical compounds are present in high quantities (20-70%) in essential oils [17]. For example, the two major compounds mainly found in *Origanum compactum* essential oil are carvacrol (30%) and thymol (27%) [14].

Terpenes represent the major component of essential oils. These molecules are composed of isoprene units and a 5-carbon branched chain, including monoterpenes (C10), sesquiterpenes (C15), and diterpenes (C20) [4]. Monoterpenes are considered the most abundant chemical component in essential oils because they can reach up to 90% of their total composition [14]. For instance, the most common component in citrus essential oil is the monoterpene limonene (32 to 98%) [18]. Linalool, limonene, camphor, and terpineol are examples of monoterpenes [16]. Monoterpenes and sesquiterpenes are responsible for the characteristic scent of essential oils. Moreover, terpinoids are produced through the oxidation or modification of the chemical structure of terpenes [3].

I.3. Methods of Production and Extraction

The volatile components present in plants can be extracted as essential oils through various techniques. The composition of the produced essential oil depends on the method used. Conventional methods have several disadvantages, namely, long duration, high energy consumption, and the need for toxic solvents. This led to the development of alternative methods that can overcome these defects and produce high-quality essential oils [5].

I.3.1. Conventional Methods

Among the most commonly used methods in the production of essential oils is steam distillation. In fact, 93% of essential oils are produced using this method. In this technique, steam is used to vaporize the volatile components in the plant. Then, the released vapor is cooled down and undergoes condensation in the condenser. Finally, the two immiscible phases (water and essential oil) are separated [6]. This method can take up to 10 hours, and the amount of produced oil varies according to the duration of distillation, the temperature, the pressure, and the plant species being used [5].

Solvent extraction is another conventional method that involves placing the plant in an organic solvent that will dissolve it. Thereafter, the extracted part is separated by filtering out the solvent under low pressure [6]. This step is usually followed by a distillation step. The solvents that are usually used in extraction are hexane, petroleum ether, ethanol, and methanol [5]. A lower temperature is used in this extraction method than in distillation, which avoids the problem of chemical alterations in the volatile components that occur with high distillation temperatures. Consequently, this method is usually applied to thermally sensitive raw materials such as flowers. Furthermore, some residual solvents persist in the produced essential oil, rendering it unsafe for food consumption. Nevertheless, if the solvent used in the extraction is alcohol, then the essential oil is labeled “food grade” [5].

Cold pressing is the oldest and most commonly used procedure for extracting citrus oils [19]. It is a physical process that breaks down the peel glands containing the essential oil to release it. The resulting solution was centrifuged to separate the essential oil [5]. Ou et al. reported that the yields of essential oils produced through cold pressing were greater than those produced through distillation. Upon cold pressing, the yield of *C. paradisi* essential oil was 16.41%, and that of *C. grandis* essential oil was 14.25%. However, the yield of distilled essential oils was 0.37% for *C. paradisi* and 0.29% for *C. grandis* [19].

I.3.2. Alternative Methods

Supercritical fluid extraction is a great replacement for traditional organic solvent extraction [20]. In the supercritical state, substances with intermediate characteristics between those of gases and liquids. Supercritical carbon dioxide is the most commonly used fluid in this technique because it is inexpensive and safe for food applications [6]. Once the pressure is released, the solvent evaporates, and thus, the extracted essential oil can be easily recovered [20]. In addition, this method is conducted at low temperatures; thus, it is commonly used for thermally labile substances. Supercritical fluids are better than organic solvents for penetrating porous solid matrices due to their lower viscosity and better diffusivity. Therefore, these methods result in faster extraction than does solvent extraction [5].

Ultrasound-assisted extraction can increase the rate at which the solvent penetrates the plant sample due to the formation of cavitation bubbles [6]. When the size of these bubbles increases, they vigorously collapse, leading to the rupture of the cell membrane containing volatile components,

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which increases the yield and rate of extraction [5]. This method reduces the extraction duration and the amount of needed organic solvent. In addition, it occurs at a low temperature, thus minimizing its effect on essential oil compounds [5,6]. Tian et al. reported that the yield of pomegranate seed oil extracted using an ultrasonic-assisted extraction technique was 25.11%. This yield is significantly greater than that obtained through the Soxhlet method (20.5%) and supercritical fluid extraction (15.72%) [21].

I.4. General Uses of Essential Oils

Since they are rich in volatile and bioactive constituents, essential oils have wide applications in several sectors, including health, cosmetics, agriculture, and food [8]. Many types of essential oils, including clove oil, tea tree oil, and cinnamon oil, exhibit antioxidant and antimicrobial effects [15]. For example, clove oil is commonly used in dentistry due to its antimicrobial and painkilling effects, while tea tree oil is used in dermatology to fight acne [22]. Additionally, essential oils are being utilized in aromatherapy, where the inhalation of volatile compounds present in essential oils has been shown to effectively reduce physical pain and mental stress [15]. Moreover, essential oils are widely used in the cosmetics industry as preservatives or active ingredients that serve specific functions. For instance, they include face cleansers, creams, shampoos, makeup, and perfumes [8]. The highest quality perfumes are prepared from lavender and thyme essential oils [22].

Due to their antimicrobial characteristics, essential oils can play a role in controlling cereal diseases. Indeed, many studies have reported the importance of essential oils in fighting pathogenic fungi and enhancing the safety and quality of crops [15]. For instance, a study conducted by Gakuubi et al. revealed that Eucalyptus essential oil has fungicidal effects and could be used for managing *Fusarium* spp. that infect maize crops [23].

In addition, essential oils are applied in the food industry for flavoring, preservation, and packaging. As consumers are becoming more aware of the negative effects of synthetic food additives, the appeal for products containing natural additives is increasing [8]. For example, carvacrol, a bioactive compound found in several essential oils, is being used as a flavoring additive and preservative in beverages and confectionary products [15]. The applications of essential oils in the food industry will be described in an upcoming section.

I.5. Health Benefits of Essential Oils

In addition to their special aromas and flavors, essential oils possess a wide range of biological activities, which explains their use in medicine throughout history. These substances have several health benefits, including anti-inflammatory, antimicrobial, and antioxidant effects [7].

I.5.1. Antioxidant Effect

Antioxidant activity is the ability of a compound to scavenge free radicals and reduce oxidative stress [1]. Essential oils possess this capacity due to the presence of phenols, terpinoids, and sulfur-containing constituents [1]. Carvacrol and thymol, which are the main constituents of *O. tyttanthum* essential oil, are responsible for the antioxidant properties of this plant. These phenolic substances play a substantial role in the neutralization of free radicals. For example, many diseases, such as cancer, heart disease, and brain diseases, occur due to the cellular damage caused by free radicals. Therefore, essential oils can play a significant role in preventing these illnesses [16].

I.5.2. Anti-inflammatory Effect

Compared with synthetic drugs, essential oils have been used to reduce pain and inflammation with the advantage of having fewer side effects [1]. Essential oils are considered anti-inflammatory since they inhibit the metabolism of arachidonic acid, the production of cytokines, and the expression of proinflammatory genes [3]. It has been reported that tea tree oil possesses anti-inflammatory activity by inhibiting the production of the cytokine interleukin-2, which is associated with

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inflammation. On the other hand, it promotes the production of anti-inflammatory cytokines, namely, interleukin-4 and interleukin-10 [3].

I.5.3. Antibacterial and Antiviral Effects

The antimicrobial activity of essential oils usually depends on a single bioactive component. Moreover, some compounds, such as carvacrol and p-cymene, exhibit synergistic effects when combined. This effect plays a role in decreasing the resistance of microorganisms [1]. Indeed, studying the antibacterial effect of essential oils has become of great interest due to the increasing dilemma of antibiotic resistance [3]. Several essential oils have been shown to have virucidal and bactericidal effects. To explain their antibacterial activity, these oils can penetrate the bacterial cell membrane and disturb important activities such as energy production and the synthesis of certain molecules [3]. Marrelli et al. studied the antibacterial effect of the essential oils of three *Origanum* species: *O. dictamnus* and *O. microphyllum* growing in Greece and *O. libanoticum* growing in Lebanon. The results showed that *O. dictamnus* had the best antibacterial activity [24]. Moreover, several essential oils, such as thyme, tea tree, and eucalyptus, have been studied for their antiviral effects. The exact mechanism of their antiviral activity needs further investigation [3].

I.5.4. Psychological Effect

Currently, aromatherapy utilizes essential oils to manage stress, anxiety, phobia, and other psychological disorders. Moreover, several clinical studies have proven the effectiveness of different essential oils in enhancing mood and cognitive performance, whether through inhalation or oral treatments [7]. For example, in one clinical trial that studied the effect of the oral administration of sage oil, it was shown that it enhanced the mood of volunteers with increased calmness and alertness [25].

I.6. Health Risks of Essential Oils

Some essential oils can contain allergenic components, leading to symptoms such as vomiting, skin irritation, and nausea. The groups of people most prone to be affected by these allergens are pregnant women, people with allergies, and patients who are taking medicines. In addition, essential oils can contain pesticide residues such as organochlorine. Therefore, determining the levels of allergens and biocides in essential oils is important before they can be utilized for human consumption [26].

A retrospective study conducted in Morocco reported seven cases of intoxication by essential oils intended for therapeutic reasons. The results showed that the poisoning was due to the improper use of these essential oils and a lack of knowledge to avoid crossing their toxicity limits [27].

II. Essential Oils in the Food Industry

The various health benefits exhibited by essential oils, particularly their antibacterial, antiviral, antioxidant, antidepressant, and antimycotoxin effects, undoubtedly elucidate their exploitation in the food industry [14]. Essential oils can act as preservatives, antioxidants, and flavoring agents when incorporated into food products. Indeed, they can be added directly to food systems or integrated into packaging materials [6].

II.1. Applications of Essential Oils in the Food Industry

Currently, consumers' demand for products that contain natural ingredients has not ceased to increase. This encourages food producers to apply natural preservatives in the food industry [9]. In addition to their use as flavoring agents, essential oils are considered useful tools in food preservation because they have natural antimicrobial characteristics [2]. The preservative effects of essential oils on a variety of products, including meats, baked products, fruits, vegetables, and dairy products, have been studied [14].

II.1.1. Essential Oils as Preservatives in Food Systems

Essential oils possess antibacterial and antifungal activities owing to their bioactive and volatile components, including phenols and terpenes; accordingly, they have been applied in food products to extend their shelf life by combating the growth or survival of food microbes [28]. A recent study conducted by Elshafie et al. in 2022 investigated the antimicrobial efficiency of four plant-based essential oils, namely, anise, marjoram, thyme, and fennel, against the most prevalent microbial isolates in processed meat products from five governorates in Egypt [9]. In this study, it was shown that all the essential oils have promising antimicrobial activity against some microbial isolates depending on the applied dose. In particular, marjoram essential oil exhibited the highest activity against *Pseudomonas aeruginosa*. On the other hand, at the highest dose, thyme essential oil had the most significant effects on *Escherichia coli* and *Pseudomonas fluorescence*, with growth inhibition percentages of 27.7 and 41.2%, respectively. Additionally, thyme essential oil showed inhibitory activity against all tested fungi [9]. Another study conducted by Božik et al. revealed that oregano, thyme, clove, and lemongrass essential oils exhibit strong fungal inhibitory activities, particularly against *Aspergillus flavus*, *Aspergillus parasiticus*, and *Aspergillus clavatus* in oats. Nonetheless, only the oats treated with lemongrass essential oil showed consumer acceptability [29].

Despite their considerable preservative effect in food products, some drawbacks accompany the application of essential oils, including their profound aroma, hydrophobicity, low solubility, and possible interactions with food constituents such as carbohydrates and fats, leading to negative alterations in the product's sensory attributes [14]. Encapsulation (a process in which tiny sensitive materials are surrounded by an edible coating) can inhibit undesirable interactions and protect sensitive compounds. Therefore, this technique can ensure the protection of essential oils and improve their stability [30]. Das et al. examined the encapsulation of *Coriandrum sativum* essential oil in a chitosan-based nanomatrix. The encapsulated essential oil showed a strong toxic effect on fungi growing in rice during storage. In addition, it showed improved bioefficacy compared to that of the unencapsulated essential oil. Hence, it has been suggested that this encapsulation can be applied as an eco-friendly technique to protect stored rice against fungi and aflatoxins and, consequently, extend its shelf life [31].

II.1.2. Essential Oils in Active Packaging

Food producers started utilizing essential oils in active packaging due to the increased consumer demand for food with natural additives and low processing requirements. It has been shown that essential oils are effective at extending the shelf life of processed food when incorporated into active packaging systems [32]. To elaborate, these systems can interact with food products and allow the release of active substances into food to exhibit antioxidant and antimicrobial activities. Therefore, this technology permits the delivery of packaged products to consumers with maintained or even improved quality and safety [33]. The packaging materials used for essential oils can be nonrenewable substances such as polypropylene or biodegradable and eco-friendly substances such as chitosan [33]. Biodegradable active packaging with antimicrobial substances is a valuable solution for minimizing both food-borne illnesses and environmental issues [32].

Llana-Ruiz-Cabello et al. investigated the antioxidant and antimicrobial effects of polylactic acid films containing *Origanum vulgare* essential oil used to package ready-to-eat salads. The films with the highest percentages of essential oil (5 and 10%) exhibited an antioxidant effect. Additionally, this active packaging is effective against molds and yeasts when 5 and 10% of oregano essential oil is used [34]. Another study examined the antimicrobial effect of *Eucalyptus globulus* essential oil incorporated in chitosan films as an active package for sliced sausage. The results revealed that the greatest bacterial reduction in the sliced sausage was reached with the chitosan film containing the highest percentage of the essential oil (1.5%). This active packaging system is a promising technique for managing the contamination of sliced sausage [35].

II.1.3. Essential Oils in Edible Coatings

Coating is the application of a thin layer of edible substances on the surface of food commodities to extend the shelf life of these products. A broad range of materials can be utilized in coatings, such as starch, chitosan, and alginate [36]. The main functions of edible coatings are to prevent microbial damage, inhibit moisture loss, and prevent unfavorable chemical alterations [6]. Indeed, the protective role of coatings can be enhanced through the incorporation of active substances such as essential oils [36]. In addition, the coating can increase the duration of the activity of the essential oil due to its slow release effect, and it can minimize the impact of the essential oil on the flavor of the food product [37].

Hashemi and his collaborators investigated the impact of coatings prepared with different concentrations of alginate and Shirazi thyme essential oil on fresh pistachio. The treatment reduced the growth of mold and yeasts. In addition, it contributed to preserving higher values of antioxidant activity and phenolic compounds compared to those of the control samples. In addition, the alginate coating enriched with thyme essential oil significantly decreased the free fatty acid percentage and the peroxide value in pistachio fruits compared to those of the control [38]. Another study conducted by Yemiş & Candoğan investigated the application of soy coatings containing thyme or oregano essential oils on beef cuts. This study showed that such a treatment has a promising role in controlling pathogenic bacteria in beef slices while improving their color stability. In addition, this treatment exhibited acceptable sensory attributes [39].

II.1.4. Essential Oils in Probiotic Food

A functional food, such as probiotic food, is a food that improves health and can minimize the risk of disease. Probiotics are viable microorganisms, including mainly bacteria and, to a lesser extent, yeasts, that possess several health benefits. They can occur naturally in fermented food products, may be added deliberately to the food product, or are provided as dietary supplements [7]. Additionally, it has been proven that compared with harmful microorganisms, essential oils have very high minimum inhibitory concentration (MIC) values against probiotics. Consequently, the combination of both probiotics and essential oils has promising antimicrobial potential, principally because of increasing antibiotic resistance [40]. A substantial example of a fermented product is yogurt, which contains the probiotic bacteria *Streptococcus thermophiles* and *Lactobacillus delbrueckii* subsp. *bulgaricus* [7].

Sani et al. investigated the microencapsulation of *Melissa officinalis* essential oil in yogurt. The results showed that the incorporation of the essential oil enhanced the antioxidant activity of yogurt. Therefore, this treatment is convenient for manufacturing nutraceutical food products with antioxidant characteristics [41]. In a different study, Hamed et al. investigated the fortification of buffalo yogurt with Eucalyptus and Myrrh essential oils at three different concentrations (0.3, 0.6, and 0.9%). The yogurt samples containing Eucalyptus essential oil had the most acceptable sensory characteristics. With increasing concentrations of the essential oils, the extent of syneresis decreased. On the other hand, the phenolic content, antioxidant effect, and antibacterial effect increased. The incorporation of 0.9% Eucalyptus essential oil in yogurt resulted in the greatest phenolic content and antioxidant activity [42]. In addition, yogurt fortified with 0.9% Eucalyptus essential oil had the greatest inhibitory effect on *Salmonella typhimurium* (inhibition zone of 20.63 mm). On the other hand, yogurt supplemented with 0.9% Myrrh essential oil exhibited the highest inhibitory activity against *Listeria monocytogenes* (inhibition zone of 19.21 mm). The experimental results revealed that the addition of Myrrh and Eucalyptus essential oils to yogurt can improve human health [42].

The synergistic combination of probiotics and essential oils not only provides health benefits and protection against enteric pathogens but can also extend the shelf life of the product and give it a distinctive flavor [40]. The application of essential oils as food flavoring agents will be discussed in the upcoming section.

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II.2. Commonly Used Essential Oils

Recently, with increased awareness of the possible toxicity and carcinogenicity of synthetic additives, there has been a trend toward utilizing natural additives, including essential oils [28]. Among these essential oils are citrus essential oils, which are considered the most important byproducts of the processing of citrus fruits. Examples of citrus essential oils include lemon, lime, grapefruit, orange, and bergamot essential oils. Because they are generally recognized as safe (GRAS), citrus essential oils are widely applied in foods and beverages as natural additives [43]. Citrus essential oils are composed of various compounds that can include 20 to 60 compounds in a single oil. Indeed, the major compounds of citrus essential oils are monoterpenes, which constitute approximately 97% of the essential oils. Moreover, the monoterpene limonene is the major constituent, and its percentage can range between 32 and 98% depending on the type of essential oil [44]. Citrus essential oils have considerable antimicrobial and antioxidant activities. They are appreciated for their health benefits, such as antidepressant activities, anticancer effects, liver protection properties, and anti-inflammatory activities. For instance, orange essential oil can induce the apoptosis of colon cancer cells [45]. Citrus essential oils are nonirritating and nontoxic but can cause skin allergies in some cases of topical application. Among the concerns associated with the application of citrus essential oils is their interactions with proteins in food, such as meat and fish, resulting in the production of undesirable substances. This problem could be addressed via microencapsulation technology [44].

Clove essential oil, which is also classified as a GRAS by the Food and Drug Administration (FDA), has many applications in perfumes, medicine, and the food industry. It possesses important biological activities, including antioxidant, anticancer, and antimicrobial effects [46]. The major component of clove essential oil is eugenol, which comprises at least 50% of the essential oil. Eugenol is a volatile compound characterized by its intense scent and flavor. Clove essential oil has been successfully applied in baked foods, dairy products, meat, vegetables, and edible coatings due to its antimicrobial and antioxidant properties [17].

Thyme essential oil is considered one of the most traded essential oils in the world market because it is utilized as a natural preservative and has significant antimicrobial and antioxidant effects. It is applied as an aromatic additive in foods, perfumes, soaps, and cosmetics [47]. Thyme essential oil is classified as a GRAS by the FDA. It is composed of more than 60 compounds that show considerable benefits, including anticancer, antiseptic, and antioxidant effects. However, the bioactive compounds that receive the most economic attention and have the greatest effect on the quality of the oil are the phenolic monoterpenes thymol and carvacrol [48]. Moreover, the monoterpene thymol is one of the major compounds in thyme essential oil (40 to 80%). It exhibits important antimicrobial and antioxidant effects [49]. Thymol is a colorless crystalline compound characterized by its strong aroma, high solubility in alcohol and organic solvents, and low solubility in water [50]. Thyme essential oil has been applied in meat and meat products and infused within marinades by direct incorporation or through encapsulation or active packaging to ensure the microbiological safety and quality of these commodities [49]. A summary of the major components and the biological activities and health benefits of the discussed essential oils is presented in **Table 1**.

Table 1. Major Components and Biological Activities of Citrus, Clove, and Thyme Essential Oils.

Essential oil	Main component	Biological Activity and health benefits	Citation
Citrus essential oils	Limonene (32 to 98%)	Antioxidant, antimicrobial, antidepressant, anticancer, anti-inflammatory, liver protecting	[44,45]

Clove essential oil	Eugenol (at least 50%)	Antimicrobial, antioxidant, anticancer	[17,46]
Thyme essential oil	Thymol (40 to 80%)	Antimicrobial, antioxidant, antiseptic, anticancer	[48,49]

III. Flavoring

Throughout history, herbs and spices have been widely used to impart flavor and color to food. These substances can supply food with a characteristic aroma and taste [51]. In the middle of the nineteenth century, flavor additives began to be applied in the food industry for the flavoring of soft drinks, confectionary products, and candies, among other products. In the middle of the twentieth century, flavoring agents became widespread in a large variety of processed food products, and a global industry specializing in the production of food flavorings was born [52]. The incorporation of flavorings into food and beverages paves the way for endless innovations and creations in this industry, as flavor is a fundamental element for providing consumers with satisfactory products [10].

III.1. Definition

Food additives are substances that are deliberately added to food for a specific function or are accidentally added to food during the manufacturing, packaging, and storage steps [53]. They include preservatives, food colorants, flavoring agents, antioxidants, emulsifiers, and anti-caking agents. Historically, people preserved food by salting, pickling with vinegar, and adding sugar to sweets. Salt and sugar are the most utilized food additives. Currently, with the evolution of food processing, many natural and artificial additives are being applied. When food is intended to have an extended storage period, it is important to incorporate additives into its processing to maintain its organoleptic characteristics and ensure its safety. Food additives play various roles in processed food. For instance, they can improve flavor, maintain or enhance nutritional characteristics, provide color, and control the pH of food products [54].

Moreover, flavoring agents and adjuvants are additives added to food to convey a flavor or aroma or aid in imparting a taste or aroma. The origin of flavoring substances could be either natural or synthetic [55]. A flavor additive is composed of a single compound or a mixture of compounds of natural or artificial origin used to improve a food's natural flavor, impart a new flavor or substitute for a flavor that was lost during the manufacturing steps. The two main elements of flavor are taste and smell. The five basic flavors that are perceived by our taste cells are sweet, salty, sour, umami, and bitter flavors [56]. Furthermore, flavor enhancers are substances that do not impart a distinctive odor or taste to food, but they can enhance or modify its existing flavor [55]. Monosodium glutamate (MSG), a flavor enhancer, contributes to the unique umami flavor of food. It is widely used to strengthen the natural flavors of food, namely, spice mixes, gravies, meat, poultry, sea food, soups, and sauces. Sweeteners are also a type of additive added to food products to impart a sweet flavor. They could be nutritive sweeteners such as sucrose or artificial sweeteners that are either low in calories or noncaloric [56].

III.2. Natural and Synthetic Flavors

By definition, a natural flavor is the essential oil, oleoresin, extract, distillate, protein hydrolysate, or any product resulting from heating, roasting, or enzymolysis, which encompasses flavoring compounds obtained from a spice, fruit, or vegetables or their respective juices, edible yeast, plant materials, meat, poultry, seafood, dairy products, eggs or fermentation products that have a principal flavoring function in food rather than a nutritional function [57]. An example of a natural flavor is vanilla extract, which is composed of four constituents, among which vanillin is the major component [58]. Vanillin is a principal flavoring and aromatic compound obtained from vanilla beans. It is widely utilized in the flavoring of carbonated beverages and various confectionary products, including cakes, ice cream, and cookies. Additionally, vanillin can be employed as a precursor in the production of other flavors. For example, it can be used to produce the major flavoring components found in ginger and jasmine essential oils. However, the production of natural vanillin is costly due to diverse causes, including the limited accessibility of vanilla pods, economic and political reasons, and the instability of crop yields due to the climate [59]. Another natural flavoring ingredient is paprika, which is obtained by grinding dried bell or chili peppers. It is added to sausages, soups, and stews and has potential anti-inflammatory and anticancer benefits [58].

Artificial flavors are not derived from natural sources; instead, they are synthesized through chemical processes. They are chemically formulated to mimic natural flavors [56]. Mainly, artificial aroma and flavoring additives are composed of a complex mixture of preservatives, solvents, coloring agents, sweeteners, flavor enhancers, and food acids [60]. Artificial flavors are low-cost, sensory pleasing, not associated with the plant harvesting season, and stable for prolonged periods. In some cases, flavoring ingredients that are found in nature can be produced artificially in the laboratory with a higher purity and superior quality compared to their natural equivalents. An example of this is ascorbic acid, which can be utilized to impart an additional flavor and color to processed food [58]. Another artificial flavor that is widely used in the food industry is vanillin. Artificial vanillin is produced from wood waste and waste from paper mills and the petroleum industry [59]. Synthetic chocolate additives are utilized in the food industry, small-scale factories, and bakeries in the production of various types of confectionaries. In general, synthetic chocolate flavoring is composed of flavoring ingredients such as ethyl vanilla and magnesium diglutamate, sweeteners, coloring agents, homogenizing substances, food acids such as citric acid, preservatives, and diluents [60]. Additionally, artificial sweeteners, including aspartame, acesulfame K, and cyclamate, are widely used in the food industry as substitutes for natural sucrose. These sweeteners are more widely used due to the increasing incidence of diabetes and obesity worldwide. Additionally, the utilization of these artificial sweeteners is cost-effective because most of these substances are much sweeter than sucrose [61]. For instance, aspartame is approximately 200 times sweeter than sucrose, and acesulfame K is 130 to 200 times sweeter than sugar [54].

III.3. Health Risks of Flavoring Agents

Although flavoring additives are a turning point in the development of the food industry, these substances have led to the spread of several health concerns. Monosodium glutamate is associated with burning and tingling sensations, an increase in the blood sodium level, and obesity. In addition, MSG can affect brain development in children [56]. Frâncica et al. evaluated the mutagenic and genotoxic effects of a synthetic chocolate flavoring that is widely used in Brazil. The flavoring concentrations studied ranged between 100 and 0.25 μL/L. The effects of these concentrations on the root cells of onion bulbs were studied. The highest evaluated concentration (100 μL/L) was 100 times less than the recommended commercial concentration. The tested concentrations were much lower than those suggested by the manufacturer to approach the actual amounts absorbed by the human body. A concentration of 100 μL/L decreased cell division after 24 to 48 hours of exposure. Concentrations between 100 and 0.5 μL/L resulted in cellular alterations and chromosomal breakage. The results revealed that all studied concentrations except for 0.25 μL/L induced genotoxic, cytotoxic, and mutagenic effects in the root cells [60].

III.4. Essential Oils in Food and Beverage Flavoring

For many years, people have been using herbs to season food and add distinctive flavors to it [8]. The major role of essential oils, which are naturally found in plants, is to add various flavors and aromas to food products. Essential oils are widely used in flavoring several types of beverages, confectioneries, and savory products. For instance, sweet basil essential oil is applied to generate a characteristic aroma and taste in pizza, salads, soups, and meat. In addition, berry essential oil is used to increase the flavors of meat and sweet products [11].

III.4.1. Essential Oils in Food Flavoring

A large number of essential oils are classified as GRASs by the FDA and are safe for human consumption. Therefore, there is great interest in their utilization in the food industry. Among the crude essential oils that are labeled GRAS are clove, basil, cinnamon, and oregano essential oils. Some essential oils have regulatory limits, while others do not [55]. For instance, the maximum allowable percentage of berry essential oil in food products is approximately 0.025%. The European Commission has identified individual compounds, such as thymol, limonene, carvacrol, and eugenol, as essential oils for application in food flavorings. These compounds do not pose any risk to human health [11].

Ibrahim and his colleagues developed a novel peppermint-flavored cheese since peppermint leaves are highly appreciated and widely used in Egypt. They used low concentrations of peppermint essential oil to flavor the cheese. The applied concentrations ranged between 20 and 100 ppm. The major compound found in the essential oil was menthol (37.62%). Sensory analysis revealed that the flavor and texture of the flavored cheeses were more acceptable than those of the unflavored cheeses [62]. Another study showed that marjoram, thyme, and basil essential oils can be used as natural ice cream flavoring agents since all the treatments yielded high scores for all the sensory attributes. The most preferable ice cream by the panelists was the one flavored with marjoram essential oil. Therefore, functional naturally flavored ice cream that has benefits for human health can be produced with the incorporation of essential oils [63]. A study conducted by Ilmi et al. (2017) investigated the sensory attributes of milk chocolate supplemented with cinnamon essential oil at three different concentrations (0.1%, 0.3%, and 0.5%). As the concentration of the essential oil increased, its acceptance decreased. The results revealed that milk chocolate enriched with 0.1% essential oil had the highest acceptability [64]. Another study showed similar results, where the addition of 0.25% cinnamon essential oil to dark chocolate had the greatest effect on taste. However, with increasing concentration, the acceptability decreased [65].

III.4.2. Essential Oils in Flavoring Beverages

The consumption of flavored beverages has increased over the past few decades. Beverages constitute a broad range of products, including synthetic beverages, dairy-based beverages, fruit-based beverages, stimulating beverages, and alcoholic beverages. Among these products, soft drinks are considered the most popular type with the highest profitability for producers [66]. The general constituents of soft drinks are water, sugar or sweeteners, carbon dioxide, colorants, preservatives, and essential oils. In some cases, a certain amount of natural fruit juice is also included in carbonated beverages [12]. Synthetic and natural flavors are utilized in beverages to impart a new flavor, improve an existing flavor, or mask an unwanted flavor. Flavors are used in very low concentrations, but they are fundamental in processed beverages. Among the natural flavors used in flavoring juices are fruit juice concentrates. Another beverage flavoring ingredient extracted from plants is essential oils [66]. A study conducted by Niyibituronsa et al. (2020) investigated the sensory acceptability of soy milk flavored with basil, mint and citronella essential oils. These flavoring substances enhanced the taste of the soy milk, with the mint and citronella flavors being the most preferred. Therefore, these two essential oils can be utilized as flavoring agents to enhance the taste of soy milk and mask its beany flavor [67].

In the soft drink industry, essential oils are a part of the concentrate and contain other ingredients, such as colorants, and buffering agents, such as citric acid. The cola concentrate contains a complex blend of essential oils, including cinnamon, coca, nutmeg, lemon, lime, orange, vanilla, coriander, and neroli flower essential oils. The interaction between these essential oils and sweeteners, acids, and carbon dioxide gives the carbonated beverage its characteristic aroma and flavor [12]. Citrus peel essential oils are widely used in flavoring carbonated and noncarbonated beverages, candy, ice cream, bakery products, and chewing gums [68]. Lemon-lime soft drinks contain lemon and lime essential oils as their main flavoring ingredients, and they can contain orange essential oil as a minor flavoring compound. On the other hand, orange soft drinks contain orange essential oil as the principal flavoring agent and may contain lime and lemon essential oils as minor flavoring agents [12].

Conclusion

In conclusion, plant-based essential oils are important complex natural products that have wide applications in different sectors. Chemical composition is affected by climatic and geographical conditions and extraction methods. They are rich in bioactive compounds that exhibit important health benefits, including anti-inflammatory, antimicrobial, antioxidant and psychological effects. Therefore, they have various applications in the food industry. However, they can contain allergenic compounds and pesticide residues. Thus, it is important to assess their levels before incorporating essential oils in food products. If the essential oil has a regulatory limit, it is crucial to use it within this limit to avoid toxicity. Microencapsulation could be a great solution for preventing undesirable interactions between essential oils and food systems. Plant-based essential oils can be successfully implemented in flavoring foods such as cheese and ice cream. They also play an important role in providing soft drinks with distinctive flavors. Further research is required to study the application of various essential oils and individual volatile compounds in flavoring foods and beverages, their impact on organoleptic properties, and their possible interactions with food components.

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