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The potential of essential oil extraction methods and their bioactive compounds

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Abstract
Essential oils are natural products derived from plant materials, and they are known for their unique fragrances and therapeutic properties. The extraction of essential oils involves various methods, such as steam distillation, solvent extraction, and cold pressing. These methods are used to isolate the bioactive compounds found in the plant materials. Essential oils are composed of a complex mixture of volatile compounds, including terpenes, alcohols, aldehydes, and ketones. Essential oils and their bioactive compounds have been widely studied for their potential in alternative medicine, cosmetics, and food preservation. This article provides an overview of essential oil extraction methods and their bioactive compounds, highlighting their potential applications in various industries.

Keywords: Essential oil, bioactive compounds, extraction, *Rosmarinus officinalis*

1. Introduction
Food's importance to life cannot be disputed. Because of this, food safety is an important issue for both consumers and the food industry. According to estimates from the World Health Organization (WHO), 420 000 people die each year as a consequence of consuming tainted food, with 1 in 10 of those persons becoming unwell (WHO, 2015). The discovery of novel, nontoxic preservation compounds with significant antibacterial and antioxidant activities is urgently needed due to the increasing occurrence of the food-borne hazard and its new societal and economic ramifications. In this regard, the real synthetic compounds, which are often utilized to regulate pathogen strain, create grave concerns for human health (Prakash *et al*., 2018) [2]. (Gutiérrez-del-Río *et al*., 2018) [4] investigated that Synthetic antimicrobials, which had been certified by regulatory organizations and were utilized as food preservatives, posed a health risk to consumers. Sulfites, for example, have been linked to anti-nutritional effects such as the breakdown of thiamine or vitamin B1 in food. (Gutiérrez-del-Río *et al*., 2018) [4]. As a logical result of this, there is a rising trend of using natural and safer preservatives, giving food a natural or "green/organic" appearance. The use of plant essential oils (EOs) as food preservatives has received a lot of interest (Burt, 2004; Dhifi *et al*., 2016) [5, 6]. Plants that produce aromatic and therapeutic compounds produce EOs as secondary metabolites (Falleh *et al*., 2019) [3]. Generally, EOs make up less than 5% of the dry matter in vegetables, or a relatively minor portion of the entire composition of plants (Valderrama and Ruiz, 2018). At room temperature, essential oils are volatile, liquid, and colorless. They are insoluble in water but extremely soluble in alcohol, organic solvents, and fixed oils. They have a changeable refractive index, a strong optical activity, and occasionally a unique flavor (Adelakun *et al*., 2016; Calo *et al*., 2014) [8, 9]. Furthermore, essential oils have a distinct odor and are hence responsible for the distinct aromas that aromatic plants generate (Dhifi *et al*., 2016; Valderrama and Ruiz, 2018) [16, 7]. EOs are a complex blend of bioactive chemical components such as terpenes, terpenoids, and phenolics (Voon *et al*., 2012) [10]. Natural EOs perform a variety of vital tasks for plants, including (i) luring beneficial insects and pollinators, (ii) shielding them from some environmental stressors (heat, cold, etc.), and (iii) defending them from pests and/or microorganisms (Burt, 2004; Dhifi *et al*., 2016) [5, 16]. Antimicrobial, antifungal, antioxidant, antiviral, antimycotic, antiparasitic, and insecticidal characteristics of these bioactive EOs are well recognized across the globe (Burt, 2004; Calo *et al*., 2014; Dhifi *et al*., 2016) [5, 9, 6]. Most plant organs, especially the flowers, buds, leaves, seeds, stems, and fruits, produce essential oils (Dhifi *et al*., 2016) [16]. These EOs may be kept in glandular trichomes, cavities, and epidermal cells (Dhifi *et al*., 2016) [16]. These plant components may be processed using a variety of methods to extract EOs.

The oldest, simplest, and most popular techniques for extracting EOs are steam distillation and hydrodistillation (Dima and Dima, 2015) [11]. Additionally, unique techniques may be used for certain plants, such as enfleurage specifically for roses or cold pressing (exclusively for the peel of citrus fruits) (Perricone *et al.*, 2015) [13]. There are about 3000 varieties of EOs discovered in total, but only 300 are important industrially for uses in the food industry, often for the tastes and fragrances sector (Bakkali *et al.*, 2016) [12].

2. Processes for extraction of essential oils

A number of elements of diverse aromatic plants may be extracted to create essential oils, which have several uses in the domains of cosmetics, medicine, and food safety. The qualities and components needed in the botanical extract determine the production process and methodology used to extract essential oils. Since improper extraction techniques may result in the destruction and change the action of phytochemicals found in aromatic oils, the extraction method utilized is the major component to guarantee the quality of essential oils. Examples of the outcomes include the loss of pharmacological components, stain impact, off-flavor/odor, and physical alteration of essential oils (Tongnuanchan, P., & Benjakul, S. (2014) [14]. Both traditional procedures and cutting-edge approaches may be used to extract materials. Utilizing cutting-edge methods, like ultrasonic and microwave enhanced processes, has increased the extraction process's effectiveness in terms of the amount of time and energy used to separate the essential oil from the rest of the mixture, as well as the amount of and quality of essential oils produced (El Asbahani, A. *et al*.,2009) [15].

2.1 Hydro distillation

This extraction process is widely employed for extractions involving hydrophobic natural plant material with a high boiling point, and is thought to be a distinctive way to extract plant components like wood or flowers. This technique allows essential oils to be extracted to a certain extent without being overheated since the oils are submerged in water. This extraction method's capacity to separate plant components below 100 °C is its key benefit (El Asbahani, A *et al*., 2009) [15]. According to a few studies, the common hydro distillation process has been altered by the use of new technology. Microwave-assisted HD (MAHD), a sophisticated HD extraction process technology created by Golmakani and Rezaei, shown advantages in energy dissipation and isolation duration (75 min as opposed to 4 h in HD) (Mazidi, S. *et al*.,2012) [16].

2.2 Steam distillation

The most often used approach in the extraction of essential plant oils is steam distillation. 93% of the essential oils are extracted using this process, with the remaining 7% still available for extraction using alternative techniques (Masango, P. (2005) [17]. Essentially, the process began by heating plant material with steam that was provided by a steam generator. How well plant material structures break down, explode, and release aromatic components or essential oils is mostly influenced by heat (Babu, K. G., & Kaul, V. K. (2005) [18]. By employing the steam distillation extraction procedure, the component 2,2-diphenyl-1-picryl hydrazyl (DPPH) is utilized to assess the antioxidant qualities of essential oils. It was said to provide more antioxidant components than oils recovered using hydro distillation (HD) (Yildirim, A. *et al*. 2004) [19].

2.3 Hydro diffusion

In the hydro diffusion extraction technique, steam is given to a container containing plant materials throughout the extraction process. Only dried plant samples that may be harmed by boiling temperatures are used with this approach. While steam is given from the top of the steam generator during the hydro diffusion technique, steam is applied from the bottom of the steam generator during the steam distillation procedure. Low pressure or vacuum was used for this operation, and the steam temperature was kept below 100°C. (Vian, M. A. *et al*., 2008) [20]. Microwave technology was used to improve the steam diffusion technique even further. Innovative Microwave Hydro diffusion and Gravity (MHG) and a conventional technique like hydro distillation were compared for performance by Bousbia and research team (Bousbia, N. *et al*., 2009) [21].

2.4 Solvent extraction

This method uses common solvents such acetone, petroleum ether, hexane, methanol, or ethanol to extract delicate or fragile floral components that cannot be extracted using heat or provided steam (Tongnuanchan, P., & Benjakul, S. (2014) [14]. Usually, plant samples are combined with solvents to be extracted, the combination is lightly heated, and the solvents are then filtered and evaporated. The filtrate includes resin, which is a combination of wax, aroma, and essential oil. The essential oil is dissolved into the filter mixture by adding alcohol, and it is then distilled at a low temperature. The aromatic absolute oil is left in the pot residue while the alcohol absorbs fragrance and evaporates during the distillation process. This process for extracting essential oils is more difficult than other procedures, which makes it more time-consuming and costly (Li, X. M. *et al*. 2009) [21].

2.5 Supercritical fluid extraction

Traditional extraction methods, such solvent extraction and steam distillation, use a lot of organic solvents and take longer to complete the extraction process (Deng, C *et al*.,2005) [23]. In addition, there are drawbacks to these methods, such as the loss of numerous volatile components, the ineffectiveness of oil extraction, the degradation of unsaturated compounds, and the hazardous byproducts of the extraction process (Usai, M, *et al*., 2011) [24]. The critical pressure, Pc, and critical temperature, Tc, of a fluid determine its supercritical state primarily. Critical fluid qualities include low viscosity, high diffusivity, and densities that are closer to liquids. These fluids also display other extremely fascinating characteristics (El Asbahani *et al*., 2015) [15].

2.6 Solvent Free Microwave Extraction

Common extraction methods, such solvent and hydrodiffusion, are hindered by the loss of a number of evaporative ingredients, poor isolation coherence, and toxic solvent residues at the stage of the final product. Solvent-Free Microwave Extraction (SFME) was taken into consideration for numerous applications due to these difficulties (Bousbia, N. *et al*., 2009) [21]. It has been shown that microwave extraction offers a shorter isolation time for the essential oil (30 min as opposed to 3 h for hydrodiffusion and 1 h for cold pressing); 0.24% of yields from SFME, which is significantly better than hydrodiffusion and cold pressing with 0.21% and 0.05%, respectively; high energy consumption for performing hydrodiffusion and cold pressing (using mechanical motors) as compared to rapid microwave extraction; and no water or solvent used in SFME make the process environmentally friendly (Ferhat, M.A. *et al*., 2007) [25].

2.7 Subcritical Extraction Liquid

Numerous studies have reported using water in a subcritical state and discovered that it is a more effective and superior alternative to the traditional method of extracting essential oils (Özel, M. Z. *et al*., 2006) [26]. When a liquid is at the subcritical stage, it is at a pressure higher than the critical pressure (Pc) and a temperature lower than the critical temperature (Tc), or vice versa. This technique uses CO2 and water as the fluids to extract essential oils. reduced viscosity, reduced density, and improved diffusivity between liquids and gases are just a few of the advantages that the subcritical condition of a fluid provides.This method of extraction is regarded as the finest choice since it allows for a quick separation of the essential oils at a low operating temperature. Additionally, it is an easy, straightforward, and environmentally beneficial extraction method. (Kubatova *et al*., 2001) [21] investigated that The extraction of lactones from a Piper methysticum root using subcritical water extraction was compared to water-based Soxhlet extraction. The working temperatures for subcritical water extraction were 100°C and 175°C, respectively, while the extraction times for the lactones were 20 min. and 2 h. When compared to the subcritical water approach, the soxhlet extraction process took much longer to extract the oils, taking 6 hours, and yielded yields that were 40% to 60% lower.

3. Bioactive compounds of essential oil

The enormous variety of volatile, aromatic, and low-molecular-weight chemicals found in EOs, which are produced from plants, have been extensively studied for use in cosmetics and medications (Zengin, G. *et al*.,2018) [28]. and for use as flavorings and preservatives in the food sector (Khorshidian, N. *et al*., 2018) [29]. EOs are extracted from all sections of the plant and are characterized as liquid, volatile, clear, and occasionally tinted (Nazzaro, F. *et al*., 2017) [30]. The antioxidant-active EO chemicals constitute a significant portion of their chemical makeup (Miguel, M. G. (2010) [31]. Because of their anti-inflammatory properties, these components have been identified as a promising source for the creation and identification of novel bioactive compounds with pharmacological and aesthetic applications (Han, X., & Parker, T. L. (2017) [32]. Natural plant EO compounds with biological properties and potential pharmaceutical uses include (E)-cinnamaldehyde (antifungal activity) (Qu, S. *et al*.,2019) [33]. Some well-known chemicals present in EOs have lately been identified with novel biological actions, for example, monoterpenes such as thymol, carvacrol, and p-cymene have been observed to decrease pulmonary emphysema and inflammation (Games, E *et al*., 2016) [34]. These natural substances' antioxidant properties are connected to their capacity to prevent oxidative stress. Oxidative stress is a disruption in the oxidant-antioxidant balance that causes an increase and subsequent attack of reactive oxygen species (ROS) such as alkoxyl (RO), superoxide anion (O_2), hydroxyl (HO), and peroxyl (RO_2) radicals on cell structural components and some reactive nitrogen species (RNS) such as nitric oxide (NO) and peroxynitrite (ONOO). The existence of oxidative stress has been linked to the onset of various human illnesses, including Alzheimer's disease and cancer (Poprac, P. *et al*., 2017) [35]. Plants used as condiments have been found to belong to several botanical families and to have a wide range of antioxidant chemicals capable of preventing oxidative stress (Qasim Barkat, M *et al*., 2018) [36]. Geraniol, thymol, p-cymene, menthol, eucalyptol, and carvacrol are some of the antioxidant chemicals.Because of the presence of hydroxyl groups in their structures, certain substances have been shown to have antioxidant action (Zhang, H.-Y. *et al*.,2005) [37].

3.1 Cinnamomum Zeylanicum

True cinnamon (C. zeylanicum, C. verum Lauraceae), commonly known as Ceylon cinnamon, is a plant native to India and Sri Lanka, where it is used as a spice and in traditional medicine to cure a variety of human ailments (Ranasinghe, P *et al*.,2013) [38]. Cinnamon spice is derived from several plant components, including the trunk bark, root, leaves, and flowers (Liyanage, T. *et al*., 2017) [39]. The plant is used to cure numerous gastrointestinal, respiratory, and gynecological disorders in several parts of the globe via traditional medicine (Kumar, S. *et al*., 2019) [40] Parts of cinnamon are often used in culinary applications as a seasoning and condiment when preparing dishes like liqueurs and chocolates (Ranasinghe, P *et al*., 2013) [38]. Due to its antibacterial properties, the total amount of its EO has also been researched in the vapor phase for the cleaning of historical textiles (Matusiak, K. *et al*., 2018) [41]. True cinnamon essential oil's primary chemical components vary depending on the plant organ, region of origin, environmental factors, extraction techniques, and drying procedures, but in general, it comprises (E)-cinnamaldehyde and (E)-cinnamyl acetate as key molecules (Table 1). According to reports, some substances like cinnamaldehyde and camphor make up the majority of the volatile oils found in stem bark and root, respectively. On the other hand, eugenol has been identified as a significant component of the leaves (Jayaprakasha, G. K., & Rao, L. J. M. (2011) [42]. (El-baky, H.H.A *et al*., 2010) [43] investigated that assessed the DPPH radical-suppressing ability of 45 EOs from various species. According to this research, cinnamon and clove bud essential oils (EOs) had the greatest inhibition rates (about 96%), and they also contained more than 80% eugenol. The real cinnamon essential oil's antioxidant properties have been discussed in several recent research. Comparing the EO to BHA, -tocopherol, and BHT, the DPPH radical scavenging and -carotene bleaching tests revealed the EO to have excellent antioxidant activity.

3.2 Mentha Piperita (Peppermint)

Mentha piperita, a member of the Lamiaceae family, is another name for peppermint.

Despite being grown all over the globe, the plant is native to Europe and the Middle East (Mahendran, G., & Rahman, L. U. (2020) [44]. In certain cuisines, peppermint leaves are used as a garnish. They are also used to flavor ice cream and liqueurs. In traditional medicine, Mentha L. EOs and extracts are often used to treat gastrointestinal and respiratory disorders, colds, muscular discomfort, and oral mucosal irritation (McKay, D. L., & Blumberg, J. B. (2006) [45]. These applications have been connected to the existence of secondary metabolites such monoterpenoids and phenolic chemicals in its Eos (Mimica-Dukic, N., & Bozin, B. (2008) [46]. (Benzaid *et al*.,2019) investigated the ability of M. piperita L. EO to fight off yeast and bacterial strains like Candida albicans. Menthol (32.93%), menthone (24.41%), cis-caran (8.08%), and eucalyptol (1,8-cineole, 7.89%) were the EO's principal constituents. It was also shown that the EO inhibited the development and biofilm formation of several bacterial species and Candida albicans yeast. Depending on the studied microorganism, the growth decrease varied from 40% to virtually 100%.

3.3 *Ocimum basilicum* (Basil)

O. *basilicum* (Lamiaceae), sometimes referred to as basil or sweet basil, is a fragrant plant that is native to Asia but has since spread around the globe (Pushpangadan, P, & George, V. Basil 2012) [47]. Basil is grown mostly for the manufacturing of EO in East Asia, Europe, America, and Australia. After harvest, basil cannot be kept in storage for extended periods of time because the quality will suffer. Basil is collected while it is in full bloom when it is grown for essential oil extraction, and the timing of the harvest is crucial to getting the right quality and quantities (Pandey, A. K *et al*., 2017) [48]. Traditional Chinese medicine has utilized basil to cure colds, coughs, and headaches. Its tea has been used as a remedy for inflammation, nausea, and flatulence as well as for dysentery, hyperlipidemia, and dysentery. Additionally, O. basilicum is known to be used in the culinary, aromatherapy, and fragrance sectors as a flavoring ingredient for dishes such soups, cheeses, vinegar, oils, and food preservation (Pushpangadan, P, & George, V. Basil 2012) [47]. Basil essential oil may be used with other spices to make ice cream, bakery goods, and other foods. The US FDA and European Commission deemed the basil EO's ingredients to be safe (Li, Q.X &Chang, C.L 2016) [49]. The cultivars, geographic distribution, development stage, harvesting season, growing circumstances, and other variables may all affect the chemical makeup of basil essential oils.Linalool, methyl chavicol (estragole), methyl cinnamate, and eugenol are the main chemicals that have been used to categorize basil oils in general (Ahmed, A. F. *et al*., 2019) [50].

3.4 Piper Nigrum (Black Pepper)

Black pepper, also known as P. nigrum, is one of the most popular spices in the world and is found all across the tropics and subtropics, including Southwestern India. There are known occurrences of this plant in many phytogeographic regions of Brazil, including the Pantanal, the Atlantic Forest, and the Amazon (Andriana, Y., *et al*., 2019) [51]. Since ancient times, P. nigrum has been used to treat a variety of human illnesses, including migraine, sporadic fever, gastrointestinal issues, and muscle discomfort. Its fruits are often used as a spicy, acrid spice to season cuisine. Typically, its fruits are dried and used as seasonings and spices (Takooree, H. *et al*., 2019) [52]. The black pepper constitution contains the vitamins A, C, E, K, choline, folic acid, pyridoxine, riboflavin, thiamin, and niacin. Minerals including copper, calcium, magnesium, manganese, iron, phosphorus, and zinc are also present in P. nigrum (Qasim Barkat, M *et al*.,2018) [36]. The main chemical component of black pepper essential oil (EO) is (E)-caryophyllene (sesquiterpene), which is also present in a number of plants. A recent research revealed its potential use in the management of Alzheimer's disease. The authors showed that this substance inhibited prostaglandin E2 and nitric oxide production in BV-2 microglial cells, and concurrently increased the expression of inducible nitric oxide synthase and cyclooxygenase-2, as well as significantly reducing the secretion of pro-inflammatory cytokines like IL-, TNF-, and IL-6. (Hu, Y. *et al*.,2017) [53].

3.5 *Rosmarinus officinalis* (Rosemary)

Despite being a member of the Lamiaceae family and a native of the Mediterranean, R. officinalis is widely used in food preparation, medicine, cosmetics, and other fields (Gezici, S. *et al*2017) [54]. R. Officinalis leaves, both fresh and dried, are often used as a condiment to flavor food, in herbal teas, and as a food preservative. As a natural antioxidant, rosemary extracts are used to extend the shelf life of goods (Habtemariam, S. (2016) [55]. Rosemary has been used in traditional medicine around the globe to cure a variety of human maladies as well as in culinary applications to improve and alter tastes. Greeks and Europeans used rosemary extract and EO to boost memory, as a tonic, as a stimulant, and in the treatment of nervous stress. Traditional Chinese medicine utilized it for headaches. In Brazilian traditional medicine, rosemary was said to be an abortion inducer (Andrade, J. M. *et al*., 2018) [56]. Traditional therapies have used Rosmarinus species as an expectorant, diuretic, antiepileptic, carminative, renal colic, antirheumatic, and treatment for diabetes, dysmenorrhea, heart conditions, and respiratory illnesses (Karadağ, A. E. *et al*., 2019) [57]. Rosemary has minimal levels of toxicity and works well as a food preservative. Additionally, the antioxidant, antibacterial, and antifungal properties of its extract significantly characterize this species (Hamidpour, R. *et al*., 2017) [58]. EOs and R. officinalis extracts are sources of natural chemicals with a variety of biological activity (De Oliveira, J. R. *et al*., 2019) [59]. The phenolic chemicals in rosemary are thought to be responsible for its biological qualities. The amount of these antioxidants in the leaves depends on a number of factors, including the season, the habitat, the species, and the region of origin of the plants (Pérez-Fons, L. *et al*., 2010) [60]. (Nieto *et al*., 2018) [61] investigated that revealed how antioxidant components in rosemary extracts and essential oils postpone the oxidation of lipids in dietary and biological systems. However, they noted that the antioxidant activity of rosemary is influenced by the fruiting stage, the kind of extracts used, the extraction process, the presence of an inhibitor, synergistic effects, and the quantity of the active extract ingredients.

3.6 Thymus Vulgaris (Thyme)

Thyme is a blooming, scented plant that is indigenous to southern Europe and the Mediterranean area (T. vulgaris, Lamiaceae) (Stahl-Biskup, E.,& Venskutonis, R. P. (2004) [62]. Thyme is often used to flavor meat, salads, and soups in cooking. In culinary arts, the leaves may be utilized as an attractive green herb. Due to its fragrant and therapeutic qualities, thymus species have been used as spices, insecticides, herbal teas, and incense for ages. They are also rich in bioactive chemicals. Due to the presence of their naturally occurring preservation chemicals, the EOs of Thymus spp. are often utilized in traditional medicine (Almanea, A., *et al*., 2019) [63]. Traditional medicine has utilized thyme leaves, both dried and fresh, to treat gastrointestinal, respiratory, and skin conditions. In various areas, T. zygis, T. serpyllum, and T. pulegioides are also used for comparable reasons. These species are used commercially for things like EO products, oleoresins, landscaping plants, and herbs (Golkar, P *et al*., 2020) [64]. Thyme EO is a suitable food additive and taste enhancer for foods and drinks because of its antibacterial and antioxidant characteristics. It is also used for medicinal, perfumery, and cosmetic reasons (Golkar, P *et al*., 2020) [64]. Thymus essential oil's chemical makeup varies depending on the organ from which it came, the environment, the extraction process, and other factors, but in general, it has been said to include monoterpenes like m- and p-cymene and monoterpenoids like thymol and carvacrol as its main constituents (Aprotosoaie, A. C. *et al*., 2019) [65]. The chemical composition of Thymus sp. EO is directly impacted by several of its biological activities, including the vegetative stage, seasonal variations in temperature and humidity, harvesting, and post-harvest variables (drying and storage) (Lemos, M. F. *et al*.,2017) [66]. Thyme EO, which is high in thymol and carvacrol and has antibacterial action against germs including Bacillus cereus, Staphylococcus aureus, S. epidermidis, E. coli, Salmonella enteritidis, and S. typhimurium, was recently shown to be a potential food preservation ingredient (Gedikoğlu, A *et al*., 2019) [67]. (Lemos *et al*., 2017) [66] investigated that examined the effects of thyme EOs on both Gram-positive (S. aureus) and Gram-negative (S. typhimurium and E. coli) bacteria. The samples that had the greatest concentrations of thymol and carvacrol showed the best results. An *in vitro* experiment and SAR analysis were used to explore the antioxidant activity of certain phenolic compounds, and the results showed that thymol and its isomer carvacrol block 35.0% and 33.9% of DPPH free radicals, respectively. Furthermore, these authors pointed out that no matter the alkyl group's position (ortho, para, or meta), these compounds stabilize phenoxyl radicals by inducing an effect that increases the anti-radical activity; as a result, both thymol and carvacrol, as well as their other position isomers, have strong antioxidant properties (Ali, H. M. *et al*., 2013) [68].

3.7 *Origanum vulgare* (Oregano)

The term "oregano" refers to a range of different plant species that are used as seasonings all over the globe and are members of six different botanical families. The most commercially significant families are identified as the Lamiaceae and Verbenaceae, and O. vulgare (Lamiaceae) is one of the most researched oregano species. Although O. vulgare is a native to the Mediterranean area, it is grown all over the globe (Leyva-López, N *et al*.,2017) [69]. The dried leaves and petals of *Origanum vulgare* are commonly used as seasonings to flavor many cuisines, including pizza, salads, sausages, and fried potatoes. They are also an essential component of traditional Mediterranean, Mexican, and Italian cuisine. The species of origanum have also been used to cure a variety of human ailments, including wounds, coughs, skin conditions, and digestive issues (Cinbilgel, I., & Kurt, Y. (2019) [70]. Due to the variety of ways oregano flowers and leaves are used as a condiment, its essential oils have undergone extensive research as a food preservative (Asensio, C. M. *et al*., 2015) [71]. Additionally, several studies have shown that oregano essential oils have antibacterial properties against bacterial types that are relevant to medicine (Teixeira, B *et al*., 2013) [72]. Despite their antioxidant properties, they also have antidiabetic, anti-inflammatory, and cytotoxic effects on cancer cell lines, according to current research (Han, X., & Parker, T. L. (2017) [32]. The drying processes (Figiel, A. *et al*., 2010) [74] and species of origin have an impact on the volatile constituents of oregano EOs, which are quite variable (Quiroga, P. R. *et al*., 2011) [75]. A natural antioxidant named p-cymene has been identified as a neuroprotective agent (de Oliveira, T. M. *et al*., 2015) [76]. Due to their antioxidant properties, the food industry has extensively researched using carvacrol and thymol as additives (Ramos, M. *et al*.,2014) [77]. The EO of many oregano species has shown inhibitory actions against bacterial and fungal strains with regard to the antibacterial properties, indicating their potential use as a preservative in the food business. (Rodriguez-Garcia, I. *et al*., 2016) [78] a few current investigations on the antioxidant properties of EOs from O. vulgare. Different techniques, including free radical scavenging (DPPH and ABTS tests) and reducing power (FRAP and CUPRAC assays), were used to assess the antioxidant activity of the EO from two O. vulgare subspecies (subsp. vulgare and subsp. hirtum). They discovered that O. vulgare vulgare (thymol: 58.31%) shown considerably greater activities (p<0.05) than O. vulgare hirtum (linalool: 96.31%) in terms of radical scavenging ability and reducing power. The authors assert that good reductants include thymol and carvacrol (Sarikurkcu, C. *et al*.,2015) [79]. The production and antioxidant activity of oregano EO are significantly influenced by drying techniques. According to a recent research, shade-dried Origanum species produced the maximum oil output and antioxidant activity ratings. Fresh plants were found to have the lowest EO output and antioxidant activity for O. vulgare. O. vulgare EO, which has around 45% carvacrol, exhibited the greatest DPPH anti-radical activity (31.48%), followed by oven drying (26.19%) when it was dried in the shade (Ozdemir, N. *et al*.,2018) [80].

4. Conclusion

In conclusion, essential oils are valuable natural products that can be extracted from various plant materials and used in a wide range of applications. The bioactive compounds found in essential oils possess numerous biological activities and potential benefits, such as antimicrobial, antioxidant, anti-inflammatory, and anticancer properties. The extraction of essential oils can be performed using different methods, such as steam distillation, solvent extraction, and cold pressing, depending on the type of plant material and desired outcome. The use of essential oils and their bioactive compounds has gained increasing attention in alternative medicine, cosmetics, and food preservation. However, it is important to note that the safety and efficacy of essential oils depend on their quality, purity, and proper use. Therefore, further research is needed to fully understand the potential benefits and risks associated with the use of essential oils and their bioactive compounds.

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