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Essential oil extraction from herbs and spices: A review on pharmacological and functional properties

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Abstract
Background: Essential oils have received a lot of attention in this day and age as these oils have various bioactive compounds. These days, people prefer essential oils over synthetic compounds because they contain antimicrobial and antioxidant properties. A lot of studies have focused on the benefits of essential oils to cure diabetes, obesity, and hypertension. Proper extraction techniques are needed to preserve bioactivity.
Objective: This review paper is aimed to discuss previous studies on essential oils, extraction techniques, and functional and pharmacological properties of essential oils extracted from various herbs and plants.
Results: This review paper is categorized into three parts. After introduction, the first part discusses the techniques used in extraction of essential oils. The second part discusses related studies on medicinal properties of essential oils, and the final part discusses the use of essential oils and suggests future use of essential oils.
Conclusion: All in all, this review paper has presented an overview of the above concepts by exploring the results of various previous studies on essential oils and their properties.

Keywords: Essential oils, medicinal properties, extraction techniques, bioactive compounds, synthetic preservatives, antioxidants

1. Introduction
Essential oils extracted from plants are among the most demanded products in the agriculture industry. They are widely used as flavors in drinks, food products, pharmaceuticals, perfumes, and cosmetics (Teixeira *et al*., 2013; Burt, 2004) [1-2]. Around 2000 plant species are used to extract over 3000 essential oils and 300 plant species have a vast commercial importance. Consumption and production of such oils is rising worldwide with production of up to 60,000 tons per annum and market value of US$700 million (Djilani & Dicko, 2012) [3]. A lot of factors like plant variety or ecotype, genetic variation, use of fertilizers, plant nutrition, climate, geographic location, stress during maturity, drying and storage after harvesting, and seasonal changes affect the chemical properties of essential oils.
Additionally, extraction methods and plant material determine the composition and yield of essential oils, which decide the biological properties (Hussain *et al*., 2008) [4]. For instance, essential oils from various types of plants like leaves, flowers, roots, stems, fruit peels and fruits show various medicinal and biological properties. In the same way, solvents of various polarities have various compounds. It is not easy to analyze and differentiate the impact of such factors as they affect each other (Terblanche & Kornelius, 2000) [5]. Essential oils are complex blends of 500 daltons or lower molecular weight of compounds from hydro-distillation, solvent extraction or steam distillation (Nakatsu *et al*., 2000) [6].
Usually, they are stored in resin ducts, oil ducts, trichomes or glands of plants. Steam distillation is highly preferred to extract essential oils on a commercial scale (Masango, 2005) [7]. Essential oils may have up to 100 metabolites from different chemical categories (Carson & Hammer, 2011) [12]. Some of the major elements of essential oils are phenylpropanoids and terpenoids. Additionally, they also have some aliphatic and aromatic compounds which have oxygenated derivatives, sesquiterpenes and monoterpenes (Carson *et al*., 2006) [8]. Bioactivities of essential oil are mostly derived by either one or two of the key elements (Bakkali *et al*., 2008) [10]. Overall activity cannot be accredited sometimes to any of the key components and having a combination of molecules alter the activity to apply a vast impact. For instance, it is found that inhibitory activity of oil over larvae is an effect of synergistic impact of various chemical constituents, without any activity of individual compounds (Isman *et al*., 2008) [9].

1.1 Background

Natural products along with the derivatives of those products are vital for novel therapeutic molecules. Essential oils of plants have several applications like agriculture, health, food and cosmetic industries. Essential oils have been widely used in traditional medicine systems for ages in the history of mankind. Globally, researchers are trying to categorize various biological properties of essential oils, such as antiviral, antimicrobial, anticancer, antimutagenic, anti-inflammatory, antioxidant, antiprotozoal, and immunomodulatory activities (Bakkali *et al*., 2008) [10]. Concentrations are analyzed to determine the efficacy of several essential oils to inhibit the buildup of organisms.

Generally, bioactivities are compared with “minimum growth inhibitory concentrations (MICs)”, “minimum lethal concentrations (MFCs or MBCs)”, LD50, and MIC50. There are standard approaches to obtain these values. For instance, protocols with “cell viability assessment” by XTT or MTT assays and “Clinical Laboratory Standards Institute (CLSI)” are useful for “antimicrobial susceptibility testing” (Schnitzler *et al*., 2011; Hammer & Carson, 2011) [11, 12]. People have started using alternative and modern therapies with the use of essential oils due to evolution of drug-resistant strains of bacteria, issues of available drugs/antibiotics, and rise in immuno-compromised population. A complex blend of essential oils is made by secondary metabolites synthesized naturally by plants to deal with insect attacks. These metabolites of small molecules alone have great medicinal properties, and they may be helpful for chemotherapy of non-infectious and infectious diseases (Raut & Karuppayil, 2014; Samy & Gopalakrishnakone, 2010) [13, 14].

2. Discussion

There are different types of original essential oil producing plants from around 60 families. Essential oils for commercial and medicinal purposes are produced from plant families like “Alliaceae, Apiaceae, Asteraceae, Lamiaceae, Myrtaceae, Poaceae and Rutaceae” (Hammer & Carson, 2011; Vigan, 2010) [12, 15] (Table 1). All the plant families that produce essential oils are loaded with terpenoids. Though plant families like Lamiaceae, Apiaceae, Piperaceae, Myrtaceae and Rutaceae have phenylpropanoids, these plants produce essential oils for commercial purposes (Chami *et al*., 2004) [16]. For example, anise, coriander, fennel and dill oils are collected from Pimpinella anisum, Coriandrum sativum, Foeniculum vulgare and Anethum graveolens, respectively.

All of these come from the “Apiaceae” family and are popular for their antifungal, antibacterial, antiviral and anticancer activities. In addition, a lot of types of essential oils are known for antiviral, chemotherapeutic, antimutagenic, antimicrobial, anti-inflammatory and antioxidant properties as they come from “Lamiaceae family”. These essential oils can also cure bronchitis and intestinal disorders. Some of the common plants producing essential oils from “Lamiaceae” family are “Mentha piperita, Rosmarinus officinalis, Ocimum basilicum, Salvia officinalis, Origanum vulgare, Melissa officinalis, Satureja hortensis, Thymus vulgaris and Lavandula angustifolia” (Hammer *et al*., 2006; Burt, 2004; Hussain *et al*., 2008) [8, 2, 4].

Cinnamon oil from Cinnamomum verum is rich in eugenol and a vital part of the “Lauraceae family”. It contains anticancer and antimicrobial properties. A lot of commercially viable plants come from the “Myrtaceae” family. For instance, essential oils are produced with antifungal, antimicrobial, anticancer, antiviral, and antitumor properties by “Melaleuca alternifolia, Eucalyptus globulus, Syzygium aromaticum (Eugenia caryophyllus) and Myrtus communis” plants (Hammer *et al*., 2006; Burt, 2004) [8, 2].

Table 1: Plant families and their Essential Oils with Medicinal Values

S. No.	Plant Families	Essential Oils	Medicinal properties
1.	“Asteraceae”	“*Artemisia judaica; A. annua; A. absinthium* (Wormwood); *A. dracunculus* (Tarragon)”	Anticancer, antifungal and antiviral
2.	“Apiaceae”	“*Carum nigrum* (Black caraway); *Anethum graveolens* (Dill); *Apium graveolens* (Celery); *Foeniculum vulgare* (Fennel); *Pimpinella anisum* (Anise); *Cuminum cyminum* (Cumin); *Corriandrum sativum* (Coriander)”	Antifungal, antibacterial, antiviral, anticancer and anti-diabetic properties
3.	“Lamiaceae/ Labiateae”	“*Origanum vulgare* (Origano); *Melissa officinalis* (Lemon balm); *Salvia officinalis* (Sage); *Mentha sp.; Mentha longifolia* (Wild Mint); *M. piperita* (Peppermint); *M. spicata* (Spearmint); *Ocimum basilicum* (Sweet Basil); *O. sanctum; Rosmarinus officinalis* (Rosemary); *Lavandula officinalis* (Lavender); *Lavandula sp.; Salvia sclarea* (Sage Clary)”	Antidiabetic, Anti-inflammatory, Antifungal, Antiprotozoal, Antimutagenic, Antioxidant, and Anti-inflammatory
4.	“Geraniaceae”	*“Pelargonium graveolens* (Rose Geranium)”	Antibacterial
5.	Lauraceae	“*Cinnamomum sp*. (Cinnamon)”	Anti-inflammatory, Antimicrobial, and antimutagenic
6.	Liliaceae	“*Allium sativum* (Garlic); *Allium cepa* (onion)”	Antiviral, Antifungal, and antiprotozoal
7.	Myrtaceae	“*Syzigium aromaticum* (Clove); *Thymus vulgaris* (Thyme); *Thymus sp.; Melaleuca alternifolia* (Tea tree); *Eucalyptus globulus* (Blue gum); *Myristica fragrans* (Nutmeg)”	Antifungal, antibacterial, antiviral, anticancer, anti-inflammatory, anti-mutagenic, and antiprotozoal
8.	“Piperaceae”	*“Piper nigrum* (Black pepper)”	Antifungal, antibacterial, antiprotozoal and anticancer
9.	Oleaceae	*“Jasminum sp.; Olea europaea (*Olive*):*	Anticancer and antibacterial
10.	Pinaceae	*“Cedrus libani* (Cedar wood oil)”	Antifungal

The Poaceae family of grasses produces palmarosa, citronella and lemongrass oils. These essential oils have medicinal components like geraniol, geranyl aetate and citral with anticancer and antimicrobial properties. Citrus oils have linalool and limonene, which are derived from peels of fruits from the Rutaceae family. These components have antimicrobial properties. Santalum spp. from Santalaceae and Pelargonium graveolens from Geraniaceae have sandalwood and geranium oils (Bedi *et al*., 2010; Hussain *et al*., 2008) [18, 4]. Some other families like “Fabaceae, Hypericaceae, Liliaceae, Pinaceae and Zygophyllaceae' may be used to produce essential oils with great biological properties (Hammer & Carson, 2011) [12].

3. Related Studies

A lot of traditional and innovative approaches have been used to extract essential oils in the past. Traditional extraction methods include water distillation in which volatile compounds are separated which are brought by a steam current which is heated at various levels. Some of these techniques are steam distillation, hydro-distillation, solvent extraction and hydro-diffusion. Hydro-distillation is still commercially used to produce essential oils from various sources (Wang *et al*., 2017) [29]. The innovative extraction techniques were introduced to replace traditional approaches to deal with some of the cons. Some of those demerits are vast energy consumption to reduce extraction time, carbon emissions, and use of solvents. Some of the innovative techniques are "subcritical extraction liquid, supercritical fluid extraction, microwave-assisted hydro-distillation and solvent-free microwave extraction (Aziz *et al*., 2018) [30]".

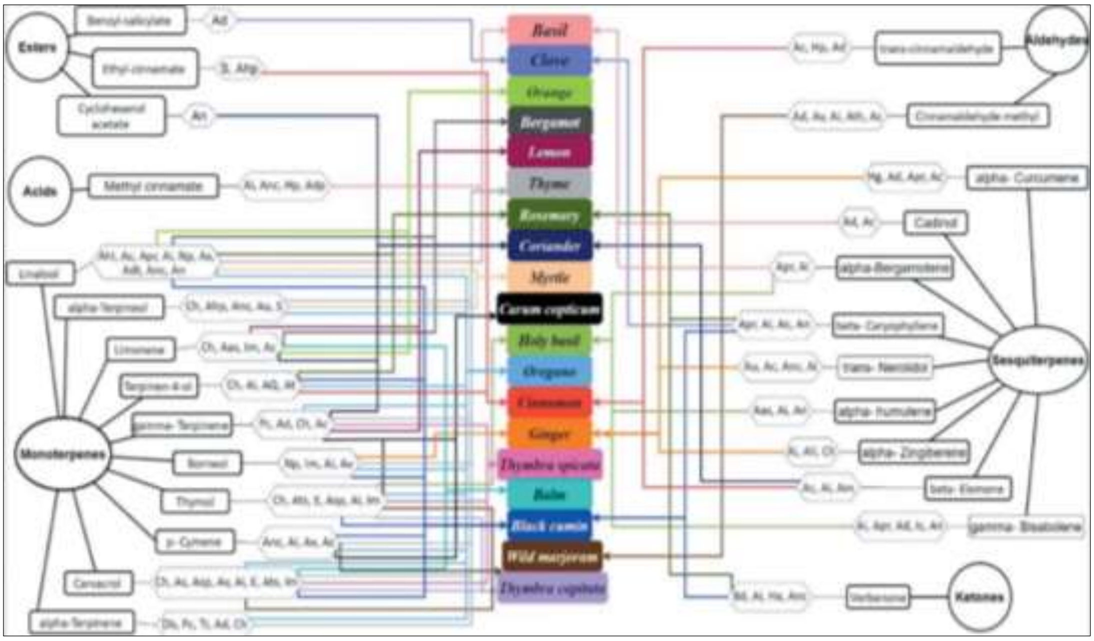
Some of the eco-friendly innovative techniques are "microwave-assisted extraction (MAE), solvent-free microwave extraction (SFME), and ultrasound-assisted extraction (UAE)" to extract essential oils. Higher yields of essential oils are found with these techniques rather than conventional ones. Table 2 describes some of the widely used essential oil extraction techniques. Tongnuanchan & Benjakul (2014) have explained extraction techniques and mechanisms precisely. After extracting essential oils, the composition is generally analyzed with "gas chromatography", which is connected to a "mass spectrometer" to detect such compounds known for antioxidant properties (Wang *et al*., 2017; Szewczyk *et al*., 2016; Uysal *et al*., 2010; Cardoso-Ugarte *et al*., 2013) [29, 26, 27, 28].

Table 2: Essential Oil Extraction Techniques with Sources and Recent studies on them

Extraction Techniques	Source of Essential Oil	Recent Studies (Reference)
"Microwave-assisted extraction (MAE)"	"*Chenopodium ambrosioides* leaves, and *Ocinum basilicum* leaves"	"Cardoso-Ugarte *et al.* (2013) [32]"
	"Vicia dadianorum"	"Kahriman *et al.* (2012) [39]"
	"*Lavandula intermedia*"	"Périno-Issartier *et al.* (2013) [40]"
	"*Laurus nobilis*" leaves	"Franco-Vega *et al.* (2019) [41]"
	"Piper nigrum" seeds	"Sánchez-Pérez *et al.* (2014) [42]"
"Hydrodistillation"	"*Impatiens* spp."	"Szewczyk *et al.* (2016) [26]"
	"*Acorus calamus* leaves and rhizomes"	"Parki *et al.* (2017) [43]"
	"Thymus vulgaris, Eugenia caryophyllata, Cinnamomum parthenoxylon, Melissa officinalis, Cedrus libani, Citrus limon, Rosmarinus, and *Citrus reticulata"*	"Olszowy & Dawidowicz (2016) [44]"
"Ultrasound-assisted extraction (UAE)"	*"Carum carvi* seeds"	"Assami *et al.* (2012) [45]"
	"*Melissa officinalis* aerial parts, and *Laurus nobilis* leaves"	"Uysal *et al.* (2010) [27]"
	"Elettaria cardaomum"	"Sereshti *et al.* (2012) [46]"
	"Lavandula intermedia"	"Périno-Issartier *et al.* (2013) [40]"
	"Citrus sinensis peel"	"Allaf *et al.* (2013) [38]"
	"Syzygium aromaticum"	"Tekin *et al.* (2015) [37]"
	"Iberis amara seeds*"*	"Liu *et al.* (2019) [35]"
"Solvent-free microwave extraction (SFME)"	"*Rosmarinus officinalis*"	"Okoh *et al.* (2010) [36]"
	"*Melissa officinalis* aerial parts, and *Laurus nobilis* leaves"	"Uysal *et al.* (2010) [27]"
	"*Citrus sinensis* peel"	"Aboudaou *et al.* [29]"
"Supercritical extraction (SCE)" with CO_2	"Iberis amara seeds"	"Liu *et al.* (2019) [35]"
	"Syzygium aromaticum"	"Tekin *et al.* (2015) [37]"
	"*Myrtus communis* leaves"	"Ghasemi *et al.* (2011) [34]"
	"*Anoectochilus roxburghii*"	"Shao *et al.* (2014) [33]"

3.1. Pharmacological and Functional Properties

Essential oil has been used for ages. The earliest-known middle eastern and eastern civilizations were started with essential oils. The term "Essential Oils" was coined in the 16th century by "Paracelsus von Hohenheim". There are around 3000 essential oils across the world and only 300 varieties are commercially viable (Nazzaro *et al*., 2017) [25]. Essential oils are widely used as flavors in food items, cosmetics and perfumes, pharmaceutical industry, home care, as insect repellents, and in traditional medicinal purposes to treat various conditions. Using individual essential oil components, both fabricated and extracted from plants, has also been reported (Sharifi-Rad *et al*., 2017) [22]. There are numerous health benefits of essential oils like anti-inflammatory, anti-cancer, antidiabetic, expectorants, immunostimulants, increasing circulation, and antiseptic properties. However, consumers must take care of dosage as some compounds might be toxic in excess amounts (Fathi *et al*., 2021; Ashraf *et al*., 2016; Arivoli *et al*., 2019) [19, 20, 21]. Figure 1 illustrates some of the most popular health benefits of compounds of essential oils.



Source: Cardoso-Ugarte & Sosa-Morales (2022)

Fig 1: Major health benefits of specific compounds of essential oils and sources

Sharifi-Rad *et al*. (2017) [22] described the most vital biological properties of essential oils along with their mechanisms. These bioactivities are credited to their strong cytotoxicity, in which membrane structure is disrupted as the primary mechanism, which causes permeabilization of cells. Hence, cytotoxicity of essential oils can be assessed for antifungal, antibacterial, and antiparasitic benefits. In addition, anti-inflammatory and antioxidant properties of various essential oils and their "apoptosis-induction potential" have been vital for curing cancer and other inflammatory diseases. Additionally, due to their antifungal, antibacterial and antioxidant activity, essential oils have been investigated to be used in the food sector. Buchholtz conducted one of the first studies on antimicrobial performance of essential oils in 1875 (Shojaee-Aliabadi *et al*., 2017) [23]. Since then, a lot of studies have found antimicrobial activity against several gram-positive and gram-negative bacteria and fungus.

3.2. Antioxidant Activity during storage

The frying process of oil consists of oxidative and thermolytic reactions at the same time. In this process, the fried food, oil, and frying conditions affect oxidation level (Bensmira *et al*., 2007) [50]. However, lipid oxidation doesn't usually need pro-oxidants due to its autocatalytic nature and it may take place in different storage temperatures (Vieira *et al*., 2017) [51]. In addition, factors like energy of light or heat, fatty acids in oil, oxygen level, diacylglycerols, free fatty acids, peroxides, transition metals, pigments, oxidized compounds, and antioxidants interact to affect oxidation process (Choe & Min, 2006) [49].

Lipid oxidation adversely affects fat and oil quality from various aspects, such as lower level of nutrition. This way, in some oils, nutrition profile is highly improved by consumers, especially in oils with high amount of "polyunsaturated fatty acids (PUFA)" or in the oils which are balanced with "saturated fatty acids (SFA)" (Keramat & Golmakani, 2016) [48]. Omega-3 and Omega-6 are well known PUFAs for their cholesterol-controlling potential. They also have immunomodulatory and anti-inflammatory properties (Jurić *et al*., 2022) [47]. Hence, it is relevant to delay or reduce oxidation to preserve most of the nutritional and health-beneficial properties of oils.

4. Suggestions

Essential oils are basically the extracts of plants made by steam distillation process and usually have a blend of terpiniods, terpenes, alcohols and aldehydes and a lot of them are volatile in nature. Their anti-microbial impacts are popular and reviewed well by Bakkali *et al*. (2008) [10] and Burt (2004) [2]. The key disadvantage of using essential oils in liquid form is that they are usually very effective antimicrobials, when they are tested in culture than tested in food systems. So, the same effect needs similar concentrations.

Essential oils and their volatile components are the foundations of the characteristics of their vapors, which ultimately impact the antimicrobial properties (Tullio *et al*., 2007; Burt, 2004) [62, 2]. 88A lot of studies have confirmed that vapor stages are more effective than liquid stages like "*Eucalyptus Globulus* EO" (Tyagi & Malik, 2010; Inouye *et al*., 2003) [59, 61], lemongrass essential oil (Tyagi & Malik, 2011a; Inouye *et al*., 2003) [67, 61], and several other essential oilse like lavender, fennel, and thyme (Tullio *et al*., 2007; Soylu *et al*., 2006) [62, 63]. Lipophilic molecules in aqueous form are the main reason to make the vapor stage more effective to form micelles and suppress that attachment of essential oils to the organism while vapor form provides free attachment (Inouye *et al*., 2003) [61]. There is some evidence on the efficiency of essential oils in liquid form and the benefits of vaporized form of essential oil is not yet proven much, even though it is gaining a lot of interest.

Inhaling essential oils in the form of vapor as smoke made by bay leaves was highly responsible for visions which came to Delphi (Thompson, 2003) [64]. The initial record of essential oils has medicinal purposes and it was found by Theopharustus in 4th Century BC, when essential oils were basically used as antidotes to poisons as vapors to relieve throat infection. Essential oil vapors and essential oils have been used as treatment to be either inhaled or consumed before eating to cure stomach cramps and nausea due to food poisoning, which was recommended by Pliny in 23-72 AD (Arias and Ramón-Laca, 2005) [65].

Ancient Egyptians used essential oil vapors for perfumery, medicine, and spiritual purposes (Edris, 2007) [66]. In the pharmacopeia, essential oil was first mentioned in the 13th century, even though it was usually in Europe. They were not used originally as medicines until the 16th century (Burt, 2004) [2]. Antimicrobial potential of EO vapors was first reported in 1960 (Maruzzella and Sicurella, 1960) [58]. There is a lack of evidence related to toxicity of vaporized form of essential oils *per se*. It should be explored in the future before using them as antimicrobials commercially. Essential oils are termed as a complex mixture of components. Hence, each volatile compound should be tested as a common allergen.

Currently, 24 allergens have been listed by the "European Flavor and Fragrance Association (EFFA)" related to essential oils, but all of these are based not on inhalation, but on skin contact (EFFA, 2011). According to a study testing the five essential oil vapors like rosemary, lemon, rose, and tea tree oil, a popular carcinogen, benzene, was released in the air but in significantly lower concentrations than extreme and acute amounts of 7.6 ppm (Chiu *et al*., 2009) [56]. Hypersensitive patients have been exposed to perfume either with eye exposure or airways at intervals of 5 minutes for 30 minutes in total. They have been known to increase coughing, dyspnea, and eye irritation in comparison to the group of placebos (Millqvist *et al*, 1999) [55].

It is worth noting that volatile compounds like d-limonene, terpenes, alcohols, hydrocarbons, etc. can form secondary aerosols with contact to oxidants like hydroxyl, ozone, and nitrate radicals and lead to pollutants like formaldehyde (Su *et al*, 2007) [60]. It is also observed that volatile monoterpenes of essential oils, which have one unsaturated carbon bond, can react with nitrite, hydroxyl and ozone oxidants. It can form formaldehyde to make secondary pollutants (Su *et al*., 2007) [60], along with oxidation of linalool and limonene, which can make oxidation products with high molecular weight like ketones, organic acids, and aldehydes.

In food products, using vaporized form of essential oils is associated with antimicrobial nature over both organisms spoiling food and food pathogens, especially species of fungus. In vapor form, one benefit is that the components are not likely to affect organoleptic properties of food items to an extent of essential oil liquids (Goñi *et al*., 2009) [52]. Like liquid form of essential oils, vapors are not necessarily effective on food items as compared to *in vitro*. For example, thyme vapor of essential oils totally avoids "*Alternaria alternate* growth *in vitro"* but mitigates growth on "cherry tomatoes" (Feng *et al*., 2011) [54]. Similar findings are observed on a citrus essential oil vapor over "A. *alternate*".

Lemongrass and mustard were highly effective in a study that tested 10 essential oils in vapor form to find out their activity over fungi spoiling rye bread. They didn't show any buildup after 14 days of any five fungi on the bread with exposure to such vapors (Suhr & Nieisen, 2003) [53]. It is also observed that vapor phase of essential oils are effective as microbial systems and they also play a vital role over liquid form of essential oils like rise in activity, ability to be used in different settings, and required to be used in lower amounts. Due to their volatile nature, they can be used as air fresheners and reduce changes to sensory activity of food items. However, there is a lack of consistency on which vapor phase of essential oils will be effective on which kind of microorganism. This way, the range of activity of each essential oil vapor should be identified well.

4.1. Future Use of Essential Oils

Because of the benefits of essential oils over oxidation and due to consumer trends for natural additives in food items rather than artificial, essential oils are known to have promising future. Essential oils have been found effective in previous studies in different food items and they can also improve organoleptic properties of food. However, further studies are needed to study allergic implications and toxicity of essential oils to find out the right dose for each variety of essential oils. Manufacturers are already required by the law to have proper labels on their essential oils and products. But more efforts are required to add essential oils to be used as per local and international u tf standards (Cardoso-Ugarte & Sosa-Morales, 2022) [24]. 0` `11

Several efforts have been made to further discover a huge array of biological performance of essential oils and their potential use in industries. Novel methods are important like chemoprevention and chemotherapy in the advancement of drug resistance due to non-infectious and infectious conditions. It is also important to improve awareness about the benefits and risks of essential oils for medicinal purposes among healthcare and medical professionals, along with common people using it. It could be great to use plant molecules to treat both non-infectious and infectious conditions. A lot of essential oils from spices and herbs are widely used in food items as ingredients. Some of the proven benefits of essential oils are less genotoxicity and less toxicity, cost-effective production, and potential to act on several targets.

A lot of plant molecules can be used as chemo-sensitizers when used with a partner drug. Combining two essential oils may significantly improve the activity rather than using them individually. It is important to assess and record such synergy trends for essential oils used in medicinal purposes. Efforts are needed on high-throughput testing and automation to look for recent bioactivity of essential oils.

5. Conclusion

Using essential oils in the food sector has seen tremendous growth from common use as flavors to be one of the most common natural additives to extend shelf-life of the products. Studies should be directly concerned with the antioxidant activity of essential oils in different compositions as they have been effective to control lipid oxidation in various storage and processing situations. They also showed more effectiveness as compared to their synthetic and commercial counterparts. Even though directly adding essential oils to food may be the matter of concern related to their impact on sensory organisms, studies have observed that adding essential oils to food not only improves impact on sensory quality, but also improves the acceptability. However, further studies are needed to determine the use of essential oils for various purposes, explore essential oils from several spices and herbs, and assess the use of them in developing clean food items.

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