ISSN: 2572-5971

Review Article

Advances in Nutrition & Food Science

Essential Oils and Their Applications -A Mini Review

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Submitted: 12 Sep 2019; **Accepted**: 21 Sep 2019; **Published**: 09 Oct 2019

Abstract
The wellbeing and sustenance of food amid its preparation, transport and storage are requirements for present day food handling. Essential oils (EOs) are important aromatic components of herbs and spices and their biological activities have been known and utilized since ancient times in perfumery, food preservation, flavoring, and medicine. The antimicrobial activities of essential oils clearly indicates that, they are more acceptable because of their unique antibacterial, antifungal and antiviral properties. This review paper focuses on essential oils and their applications by employing essential oils as a natural preservative that are suitable to be used in food preservation, pharmaceutical, cosmetics and among other industries. So far as factors which are responsible for food spoilage and other health related problems are still in existence, there is the need to develop sustained preservation and public health relief techniques. The recent advances in the application and alternative means of fruits and food decay, especially natural products as preservatives for fruits, essential oils as a drug as well as their antimicrobial scavenging characteristics will be reviewed. Other applications in the food, cosmetic and pharmacological industries, will also be conferred.

Keywords: Essential Oils, Antimicrobials, Preservation, Food Safety

Abbreviations
EOs: Essential oils
WHO: World Health Organization
USDA: United State Department of Agriculture
GRAS: Generally recognized as Safe
GC: Gas Chromatography

Introduction
People today are increasingly oriented towards the consumption of food commodities with characteristics of naturalness and minimal processing [1]. These features are perceived by the consumers as synonymous with health and are determining factors for food acceptance [2]. The World Health Organization, in a report published in 2015, estimated that each year about 600 million cases (almost 1 in 10 people in the world) of foodborne illnesses and 420,000 associated deaths occur globally [3]. Food spoilage is a metabolic process that causes foods to be undesirable or unacceptable for human consumption due to changes in sensory characteristics. Spoiled foods may be safe to eat, i.e. they may not cause illness because there are no pathogens or a toxin present, but changes in texture, smell, taste, or appearance cause them to be rejected [4]. The USDA Economic Research Service estimated that more than ninety-six billion pounds of food in the U.S. were lost by retailers, foodservice and consumers in 1995. Fresh produce and fluid milk each accounted for nearly 20% of this loss while lower percentages were accounted for by grain products (15.2%), caloric sweeteners (12.4%), processed fruits and vegetables (8.6%), meat, poultry and fish (8.5%), and fat and oils (7.1%) [5]. Worldwide postharvest fruit and vegetables losses are as high as 30 to 40% and even much higher in some developing countries. Reducing postharvest losses is very important; ensuring that sufficient food, both in quantity and in quality is available to every inhabitant in our planet [4]. Food safety has been an area of focus in this modern world; therefore, efforts are being made to ensure, secure and safeguard food in turn ensuring food security and availability of fresh and healthy produce. Food manufacturers rely heavily on food preservatives to safeguard and extend the shelf life of their products [6]. The

intake of food additives, including synthetic preservatives, has been linked to the rising incidence of allergies and attention-deficit hyperactivity disorder in children [7]. Plant extraction is a process that aims to extract certain components present in plants. These plant components of interest are then solubilized and contained within the solvent, the solution thus obtained is the desired extract. Plant oils and extracts have been used for a wide variety of purposes for many years; recently, they have generated widespread interest as a source of natural antimicrobials [8].

Essential oils have been used for thousands of years in various cultures for medicinal and health purposes. They are concentrated hydrophobic liquid containing volatile (easily evaporated at room temperatures) chemical compounds from plants. Because of their antidepressant, stimulating, detoxifying, antibacterial, antiviral and calming properties, they are recently gaining popularity as a natural, safe and cost-effective therapy for a number of health concerns. Essential oils (EOs) are aromatic compounds found in great quantities in oil sacs or oil glands present at different depths in the fruit peel, mainly flavedo part and cuticles [9]. In addition, essential oils (EOs) are aromatic oily liquids extracted from different parts of plants for instance, leaves, barks, seeds, flowers and peels [10]. They can be obtained by expression, fermentation, effleurage or extraction but among all the methods, steam distillation and hydro distillation are widely used for commercial production of EO's [11,12]. EOs possesses antibacterial and antiviral properties and has been screened as a potential source of novel antimicrobial compound, alternatives to hazardous chemical preservatives and agents promoting food preservation [13]. Essential oils have been in existence but its inspiration and natural possessive abilities in day-to-day life increased its study and experimental activities due to their highly concentrated version of the natural oils in plants. Currently, there is a trend in the food industry towards the use of mild preservation methods, allowing maintenance of flavor and texture of the natural products [14]. A scientific discipline describing handling, preparation, and storage of food in ways that prevent food-borne illness is in the quest and the application of EO's serve as a potential solution.

Essential Oils

Plants turn out to be a good type of secondary metabolites that are employed for cover against predators and to seek the attention of pollinators. Plant oils and extracts have been used for a wide variety of purposes for many thousands of years. The word essential oil was defined by Paracelsus von Hohenheim, for the first time, in the 16th century, referring to it as Quinta essential [15]. Essential oils are a mixture of volatile constituents produced by the secondary metabolism of aromatic and other variety of plants [16]. Volatile metabolites are usually isolated from plant material through steam- or hydro distillation methods; the fragrant mix of compounds obtained is referred to as an essential oil (EO) [6]. Components present in EOs mainly constitute volatile terpenes and hydrocarbons [17]. Essential oils have a long tradition of use as medicinal agents [18,19]. According to EQ de Lima et al, the antimicrobial properties of extracts and essential oils obtained from medicinal plants have been empirically recognized for centuries, but only recently have been confirmed scientifically [20]. Almeidia in 2010 added that, several researchers study the biological activity of medicinal plants from different regions of the world, guided by the popular use of native species, showing that its extracts and essential oils are effective in controlling the growth of a wide variety of microorganisms, including fungus, yeasts and bacteria [19]. Likewise, essential oils possess analgesic properties, anti-inflammatory drug, antiprotozoal drug, anticarcinogenic, medicament, inhibitor, gastro protective and acetyl cholinesterase. The latter property is of great interest in controlling Alzheimer's disease, progressive neurodegenerative disease that primarily affects the elderly population accounts for 50 to 60% of cases of dementia in people over 65 years [21,22]. Essential oils in the recent has been of great response to the food industry in controlling foodborne microorganisms and therefore keen attention is now given to plants extracts as a replacement for conventional antimicrobials.

Methods of Extraction and Isolation of Essential Oils

Essential oils have been isolated in many forms which in one way or the other enhances its bioactive and therapeutic activities. Freeze drying, rotary evaporation, steam distillation, hydrolyzation and GC chromatography assays among others are the most effective processes which are employed in these extraction process. Figure 1 describes several methods for extracting essential oils form different plants. Karen et al., indicated the effectiveness of employing GC in extracting the essential oils from leaves of edible (*Arachis hypogaea* L.) and Perennial (*Arachis glabrata Benth*.) Peanut Plants [23]. Steam distillation is a method of isolating compounds which decompose at high temperatures by distilling them in such a way that steam is introduced into the raw material. The proportion of essential oils extracted by steam distillation is 93% and the remaining 7% can be further extracted by other methods [24]. Hydrolyzation, a process which involves the complete immersion of plant materials in water, followed by boiling. This method protects the oils extracted to a certain degree since the surrounding water acts as a barrier to prevent it from overheating [10].

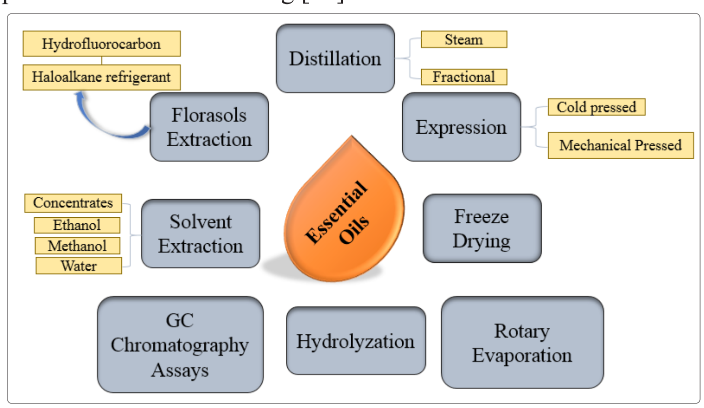

Figure 1: Several methods for extracting essential oils form different plants

Classification of Essential Oils

EOs can be classified severally based on their different methods of extraction, chemical composition, notes, aroma etc.

Classification Based on Chemical Composition

There are numerous chemicals that can be found in essential oils that a present in different plants. Citrus and pine contain hydrocarbon which are made up of only carbon and hydrogen atoms. Alcohol contains a hydroxyl group (OH) attached to the terpene structure that can be found in Coriander, tea tree and peppermint. Aldehyde contains terpenoids with a carbonyl group (C=O) and hydrogen bonded to a carbon found in Citronella, lemon balm and lemon myrtle [25]. Cyclic aldehydes contain aldehyde group attached to a benzene ring and are common in Cinnamon, bitter almond and cumin [26]. Ketone contains a carbonyl group bonded to two carbon atoms. These can be located in plants such as Pennyroyal, Thuja, sage and *Eucalyptus radiate* [27,28]. Phenol contains hydroxyl group attached to a benzene ring in Thyme and oregano [29]. Phenolic ether contains an O between C and benzene ring. Oxide has an O bridging 2 or more carbons contained in Eucalyptus, wormseed and cajeput [30]. Ester is the condensation product of acid and alcohol like Lavender, wintergreen and clary sage [31]. Phenylpropanes are found in plants such as Aniseed, clove, tarragon and myrtle leaf acts as carminative and anesthetic; Sesquiterpenes like German chamomile and yarrow acts as anti-inflammatory and antiviral; Sesquiterpene lactones such as Elecampane and arnica act as mucolytic and immune stimulating [32,33].

Classification Based on Extraction Methods

Essential oils can be grouped by their extraction methods. Nowadays different methods are used in extraction, but the most common and prevalent methods are Steam Distillation, Cold Pressing and Solvent Extraction. Based on these methods, essential oils can be classified into four different types: Steam-distilled, Expressed, Solvent-extracted and Absolutes or concretes.

• Steam-Distilled Oils: Steam distillation is the oldest and the traditional method of oil extraction [34]. In this method, pure aromatherapy oils extracted yield pristine oil, free from impurities. The process works by placing plant material in a container while steam is passed through it. Heat from the steam opens pockets of plant containing aromatic molecules and oils. When released, these molecules rise with the steam and pass through a closed system. The aromatic steam is then passed through a cooling process and distilled with cold water. During this process, the essential oils condense and transform into liquid state [35-37]. The liquid mixture is separated later into two-essential oils and aromatic water or hydrosol [38,39]. Steam distillation takes into account a variety of things, including the pressure of steam passed through plant material, the coolant used and the temperature of the closed system during production of oil etc., [40]. An oil's quality and purity are based on all these factors and the skill of the distiller. Reputed distillers' oils are rated high owing to the quality and purity of their extracts [41].

• Cold-pressed or Expressed oils: This method is used to extract oils from the citrus family of fruits where oils are produced from the rind of fruits like tangerines, grapefruits, lemons, oranges and others [42]. Though they are only known as expressed oils, they are classified under essential oils due to their high therapeutic value. Using mechanical pressure, oils are forced out of the fruits in juice form [43]. Since the juicy form of oils contain a lot of water, a separation process is carried out to separate oils from water. One downside to this method is that cold-pressed oils spoil quickly than other oils. Therefore, it is recommended that these oils are bought in small quantities and refilled whenever required [44].

• Solvent Extracted Oils: Some plant material cannot tolerate heat (in steam form) or be subjected to cold-pressing. When they are subjected to any such method, the oil thus produced may be contaminated or impure in quality [45]. To avoid this, some plants like Jasmine, Rose, Orange Blossom (Neroli), Tuberose and Oak are extracted through solvents. Solvents such as ethanol, ether, methanol, hexane, alcohol, and petroleum are used to extract essential oils [46,47]. This process works by passing plant materials through hydrocarbon solvents. The solvent mixture is then filtered and distilled in low pressure to produce essential oils [47]. A downside to this method is that, sometimes, solvent residues remain in the oils, which can cause allergic reactions in certain individuals.

Classification Based on Aroma

Essential Oils can also be classified based on aroma/smell of the oil. This classification of oils can be categorized into Citrus, Herbaceous, Medicinal/Camphorous, Floral, Resinous oils and Woody, Earthy, Minty and Spicy oils [48].

1. **Citrus Oils:** Essential oils that have a distinct citrus flavor fall into this category. Bergamot, Grapefruit, Lemon, Lime, Orange and Tangerine are some of the plants that produce Citrus oils [49].
2. **Herbaceous Oils:** Oils that are extracted from plants, which are otherwise most useful herbs. These oils can be extracted from plants such as Basil, Chamomile, Melissa, Clary Sage, Hyssop, Marjoram, Peppermint and Rosemary are some of this kind [50].
3. **Camphoraceous Oils:** These are essential oils with a particular healing property. Some of these essential oils are obtained from Cajeput, Tea Tree, borneol-like, earthy and mugwort-like and rosemary- like, with a fruity, dried plum-like background [48].
4. **Floral Oils:** Oils made from floral parts or which carry the floral essence of plants fall under this group. Geranium, Jasmine, Lavender, Rose, Neroli, Chamomile, Ylang-Ylang etc. are some of the plants that produce these oils [51-53].
5. **Woody Oils:** Essential oils that are woody in aromas or extracted from the barks and other woody parts of plants. Cedar wood, Cinnamon, Cypress, Juniper Berry, Pine and Sandalwood etc. produce such oils [54,55].
6. **Earthy Oils:** Essential oils that have a distinct earthy aroma or are extracted from plants' roots and other earthy parts. Angelica, Patchouli, Vetiver and Valerian produce some of these oils [56,57].
7. **Spicy Oils:** Oils extracted from spices or spicy plants such as thyme, cloves, Aniseed, Black Pepper, Cardamom, Cinnamon, Coriander, Cumin, Ginger and Nutmeg [58,59].

Components of Essential Oils

Every single oil normally has more than a hundred components, but the number of component changes depending on the oil in question. However, the most important active compounds are included in two chemical groups: terpenoids (monoterpenoids and sesquiterpenoids) and phenylpropanoids. These two groups originate from different precursors of the primary metabolism and are synthesized through separate metabolic pathways. Like all organic compounds, essential oils, are made up of hydrocarbon molecules and can further be classified as terpenes, alcohols, esters, aldehydes, ketones and phenols etc. [60,61]. Other components of essential oils which include Oxygenated compounds, Phenols, Alcohols, Monoterpene alcohols, Sesquiterpene alcohols, Aldehydes, Ketones, Esters, Lactones, Coumarins, Ethers, Oxides [62].

1. **Terpenoids:** Terpenes and terpenoids are the primary constituents of the essential oils of many types of plants and flowers [63]. Within terpenoids, the most important components of essential oils of the majority of plants are found in the monoterpenoid and sesquiterpenoid families [33].
2. **Monoterpene / Monoterpenoid:** These compounds are found in nearly all essential oils and have a structure of 10 carbon

atoms with at least one double bond. Examples of monoterpenes and monoterpenoids include geraniol, terpineol (present in lilacs), limonene (present in citrus fruits), myrcene (present in hops), linalool (present in lavender) or pinene (present in pine trees) [64]. They react readily to air and heat sources and for this reason, citrus oils do not last long, since they are high in monoterpene hydrocarbons and have a quick reaction to air, and are readily oxidized [65].

3. **Sesquiterpenes and Oxygenated Compounds:** These sesquiterpenes consist of 15 carbon atoms with the molecular, formula $C_{15}H_{24}$ and have complex pharmacological actions such as chamazulene, which is found in German chamomile [66]. Oxygenated groups are the most common type of functional group found in essential oils. As with terpenes, it is important to understand the different classes of oxygenated compounds that exist, as each class contributes its own unique potential health benefits [65].
4. **Esters:** Esters are compounds that result from the reaction of an alcohol with an acid (known as esterification) and are very common and are found in a large number of essential oils. They are calming and relaxing and tend to be fruity with therapeutic effects, which include being sedative and antispasmodic. Linalyl acetate, a well-known ester which is found in bergamot, clary sage, lavender as well as petit grain with geraniol acetate found in sweet marjoram are one of the beneficial compounds in essential oils [67]. Some esters also have anti-fungal and anti-microbial properties like the anti-fungal properties in geranium oil [68].
5. **Ketones:** Ketones are sometimes mucolytic and neuro-toxic when isolated from other constituents. They stimulate cell regeneration, promote the formation of tissue, and liquefy mucous. They are helpful with conditions such as dry asthma, colds, flu, and dry cough and are largely found in oils used for the upper respiratory system Essential oils that contain Ketones include Clary, sage, Hyssop, Idaho, Tansy, Rosemary and Western red cedar [69].

Effects of Essential Oils on Pathogens
Essential oils have been subject to pharmacologic studies as well as various tests of their antimicrobial activities. Evaluations via in vitro antimicrobial activities of different essential oils have been carried out. The most common methods are agar diffusion tests, serial broth or agar dilution tests, and vapor phase tests [70]. These oils are thought to play a role in plant defence mechanisms acting against phytopathogenic microorganisms [71-73].

Antimicrobial Effects of Essential Oils
Selected essential oils seem to have the advantage of inhibiting the growth of potential pathogens while only moderately influencing beneficial members of the intestinal micro biota. This was observed after *Clostridium perfringens* strains were found to be sensitive to carvacrol, cinnamaldehyde, citral, limonene, thymol, particularly at the higher concentration tested (500 mg/l) and to oregano oil, rosemary oil and thyme oil [74]. Clove oil, an essential oil extracted from the clove plant, *Syzygium aromaticum* (L) Merr & Perry, and has been reported to act as a bioactive substance especially its active component monoterpene eugenol against *B. cinerea*, *M. fructigena* Honey, *P. expansum* Link and *Phlyctema vagabunda* Desm. In apples [75]. In addition, essential oils from basil (*Ocimum basilicum* L), fennel (*Foeniculum sativum* Mill), lavender (*Lavandula officinalis* Chaix), marjoram (*O. majorana* L), oregano (*O. vulgare* L), peppermint (*Mentha piperita* L), rosemary (*Rosmarinus officinalis* L), sage (*Salvia officinalis* L), savory (*Satureja montana* L), thyme (*T. vulgaris* L) and wild mint (*Mentha arvensis* L) showed a potentially significant antifungal activity which is higher than that available from chemical treatments in post-harvest treatments against *B. cinerea* and *P. expansum* on apples [76]. The diverse efficacies of the various essential oils are due to the contrasting antimicrobial properties of each single dynamic constituent, as well as their synergic impact. In addition, even though antimicrobial property of essential oils is often attributed to their major compounds, interactions between different major and minor constituents may also play an important role in essential oils antimicrobial activity and should not be ignored [77,78]. Ömer and Fethi investigated the essential oil aerial parts of *Marrubium astracanicum* subsp. *Astracanicum* on some selected gram-negative bacteria and concluded on the antimicrobial activity and its potential usefulness [79]. According to Nataša et al., thyme, cinnamon bark and clove bud essential oils were effective against *Colletotrichum acutatum* mycelial growth of strawberry [80]. The cell destruction of these pathogens is as a result of the ability of the hydrophobic compounds in the essential oils to disrupt the microorganism's cell membrane, which results in change of cell morphology, alteration of membrane permeability and leakage of electrolytes [81]. Furthermore, the addition of essential oils of citrus films promoted to the inhibitory effect of fungi and bacteria growth after 15 days of storage, without changing quality parameters [82]. The antimicrobial standards of several essential oils tested against food borne pathogens as well as spoilage microorganisms indicates a broad potential of their use in the food industry under strict evaluations to enhance their efficacies. In the recent, literature review studied over the past five year revealed that EOs and their bioactive compound exhibited strong efficacy against food born bacteria, molds and oxidative deterioration [83-87]. Table 1 summarizes some selected essential oils and their antibacterial activity against human pathogens.

Table 1: Selected Essential Oils and Their Antibacterial Activity against Human Pathogens

Plants	Part used	Major chemical compound	Inhibited microorganisms	Reference
Artimisia cana	Aerial parts	Santolina triene, α pinene, camphen	Escherichiacoli, Staphylococcusaureus, Staphylococcus epidermidis	[88]
Achillea ligustica	Aerial parts	Viridiflorol, terpin-4-ol	Streptococcus mutans	[89]
Artimisia frigida	Aerial parts	1,8-cineole, methylchavicol, camphor	E. coli, S. Aureus, S.epidermidi	[88]
Achillea clavennae	Leaves and Flowers	Camphor, myrcene,1,8-cineole, βcaryophyllene,linalool, Gerenyl acetate	Klebsiella pneumonia, Streptococcus pneumonia, Haemophilus influenza, Pseudomonas aeroginosa	[90]
Cyperus longus	Aerial parts	β-Himachalene, α-humulene, γ-himachalene	S.aureus, Listeria monocytogenes,, Enterococcus faecium, Salmonella enterica,E.coli, Pseudomonas aeruginosa	[91]
Cuminum cyminum	Leaves	γ-Terpin-7-al, γ-terpinene, β-pinene, Cuminaldehyde	Salmonella typhimurium,E. coli	[92]
Cymbopogon citrus	Leaves	δ-cadinene, germacrene D, α-humulene, α-copaene, germacrene B, βcaryophyllene, β-bisabolene	S.aureus, Enterobacteriaceae	[93]
Dracocephalum foetidum	Leaves	limonene, n-mentha1, 8-dien-10-al	Enterococcus hirae,S. aureus, Micrococcus luteus,E.coli, Bacillus subtilis, Streptococcus mutans	[94]
Eugenia caryophllata	Flower buds	Thymol, eugenol, carvacrol, cinnamaldehyde	S.epidermidis	[95]
Eremanthus erythropapps	Leaves	viridiflorol, p-cymene germacrene D, γterpinene (Z)-caryophyllene	S.epidermidis	[96]
Foeniculum vulgare	Leaves	limonene, methylchavicol, Trans-anthole	E. coli, Salmonella typhimurium	[93]
Juniperus phoenicea	Arial part	α-terpinyl actate, α- pinene β-phellandrene	P.aeruginosa,E.coli, S.aureus,E.faecium, Salmonell Enteriditis	[97]
Mentha piperita	Arial part	-	S.typhimurium,S.aureus, Vibrio parahaemolyticus	[98]
Momordica Charantia	Seed	germacrene D, Trans nerolidol, cis-dihydrocarvacol	S.aureus,E.coli	[99]
Laurus nobilis	Arial part	linalool, Eucalyptol (1,8-cineole)	Ecoli. Mycobacterium smegmatis	[100]
Nigella sativa	Seeds	longifolene, Thymoquinone thymohydroquinone, α-thujene,p-cymen	P.aeruginosa,S.aureus E.coli, Bacillus cereus	[101]
Ocimum basilicum	Leaves, stems	methylchavicol, γ-terpinene	Pseudomonas putida, Mariniluteicoccus flavus, Listeria innocua,E. coli S.typhimurium, Brochothrix thermosphacta	[102]
P.amboinicus	Leaves	viridiflorol, γ-terpinene, germacrene D,pcymene (Z)-caryophyllene	S.epidermidis	[103]

Salvia lavandulifolia	Essential oil	camphene, terpineol, α-pinene, α-thujone camphor, β-thujone	Enterococcus faecalis,P. aeruginosa P.vulgaris, Klebsiella pneumoniae	[104]
Trachyspermum ammi	Seeds	-	S.aureus,E.coli, K.pneumoniae	[105]
Thymus zygis	Seeds	-	E.coil,S, typhimiriu, Salmonella choleraesuis	[106]
Warionia saharae	Aerial part	terpine-4-ol, p-cymene, trans-nerolidol,camphor, 1,8-cineole,linalool, β-Eudesmo	P.aeruginosa,B.cereus E.coli, S.aureus	[107]
Rosmarinus officinalis Leaves, flower	Leaves, flower	linalool, borneol, limonene, camphene, myrcene, camphor, gereniol, α-pinen, bornyl acetate, α-terpinolene, linalool benzoylacetate	linalool, borneol, limonene, camphene, myrcene, camphor, gereniol, α-pinen, bornyl acetate, α-terpinolene, linalool benzoylacetate	[108, 109]

Applications of Essential Oils

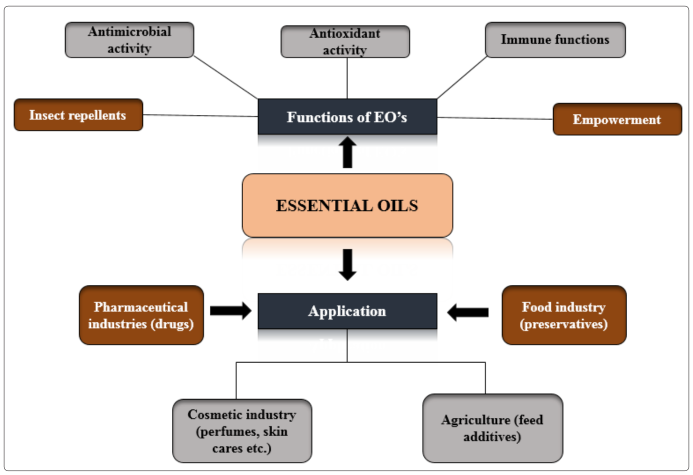

Figure 2: Schematic diagram showing the applications of essential oils in different industries

Application of essential oils in the food industry

The use of essential oils as antimicrobial additives in food, has been categorized as GRAS (Generally Recognized as Safe) by the US Food and Drug Administration and are rich sources of biologically active compounds, with known antimicrobial and antioxidant properties, which attracts interest as additives in the food industry [109-112]. However, their application as a food additive is the recent growing interest in view of their strong antimicrobial and antioxidant properties [113]. The basic approach to ensure food safety is to minimize the initial microbiological load and/or to inhibit the growth of the remaining microorganisms during post-process applications, like production and storage, by the use of an active packaging [114]. Cinnamon essential oils have been characterized as the most relevant essential oils used in both food and cosmetic industries, and in particular as an antimicrobial agent due to its many applications: as a flavoring agent and as an aroma [115]. According to Simionato, the encapsulation of cinnamon oil in cyclodextrin nanosponges serve as a potential use for antimicrobial food packaging [116]. Furthermore, garlic essential oil nanophytosomes as a natural food preservative, with its application in yogurt as food model, showed its potential as a possible natural food preservative by effectively displaying suitable physicochemical properties, particularly in acidic food products [110,117]. Studies have shown that essential oils exhibit a strong antimicrobial activity towards foodborne pathogens, which can be exploited by the food industry to use it as a preservative or to incorporate it in the food packaging as antimicrobial agent [116,118]. Figure 3 describes how essential oils interact with pathogens on food and fruit surfaces. Active edible coatings containing natural antioxidants could improve meat product stability and therefore have potential use in the food industry [119].

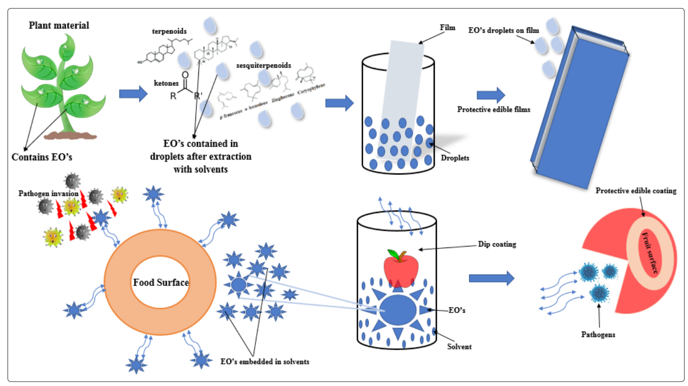

Figure 3: Essential oils and their interaction with pathogens on food and fruit surfaces

Essential Oils as Edible Coating Materials in Food

Edible films and coatings are generally based on biological materials such as proteins, lipids and polysaccharides, alone or, more often, in combination [120]. The utilization and selection of EOs ought to contemplate the buyer sensory acceptability to the ultimate product. In fact, due to their sturdy flavor, their direct use is usually restricted. Therefore, EOs can be added into edible coatings, which have been suggested as an alternative food packaging to improve food safety and quality [121,122]. According to Polat and Kezban, the application of edible coatings containing oregano and thyme EO's on fresh beef cuts could have a potential for controlling pathogenic bacteria and enhancing color stability with acceptable sensory characteristics [123]. A critical need of the food industry is to prevent the development of spoilage microorganisms related with fresh food and their products. Bioactive bundling systems have been considered as a promising innovation that has a critical impact on shelf-life expansion and security of product. Desirable effect of microbial and enzyme inactivation results in the loss of organoleptic and nutrient level of the produce. Therefore, it is important to develop effective storage methods and alternative technology to preserve and improve the storage quality and shelf life of foods. Essential oils (EOs) and their components have great potential as natural antimicrobial agents to control the growth of pathogenic and spoilage bacteria in foods [123]. The antimicrobial properties of many plant EOs have been reported [124,125]. Essential oils and their application in food and their products for controlling the development of foodborne pathogens and microorganisms have been performed by including an EO directly into the product as an ingredient or consolidating it into an edible coating material and films to protect the surface of the product.

Table 2: Application of Essential Oils as a Preservative Agent in Food and Fruits

EO's	Mode of Application/ Product	Effects	Drawbacks	References
Oregano and Rosemary	Edible coatings in beef steak	Decrease lipid oxidation, reduction water losses and shear force, increase consumer perception of odor, flavor and overall acceptance	Edible coatings create a gelatinous layer around the meat, which adheres to the meat after cooking	[126]
Gelatin-based edible coating incorporated with Mentha pulegium Essential Oil	Bioactive Packaging for Strawberries	Inhibition of total flora and molds and yeasts.	The microbial inhibition magnitude was dependent on the concentration of EO	[127]
Chitosan–lemon essential oil	Storage-keeping quality of strawberry	Slowed down respiration rate and enhanced antifungal activity both in in vitro tests and during cold storage	The use of microfluidization to prepare chitosan–lemon essential oil FFD did not improve the water barrier properties of the films. Lemon oil should be incorporated at a lesser concentration in the film (lower than 1:3, CH:LO ratio) to minimize its impact on the olfactory perception.	[128]
Quince seed mucilage film (QSMF) containing oregano (O) or thyme (T) essential oil	Shelf life extension of refrigerated rainbow trout fillets	Lowest bacteria growth counts with a significant shelf life extension up to 11 days.	Bacteria growth and shelf life extension of trout fillets were dependent on concentration of thyme essential oil. Antioxidant activity was dependent on the concentrations of oregano essential oil	[129]
Lemongrass essential oil incorporated into alginate-based edible coating	Shelf-life extension and quality retention of fresh-cut pineapple	Significantly reduced respiration rate, weight loss, total plate count, yeast and mold counts during low temperature storage.	Coated samples contain 0.5% (w/v) lemongrass essential oil decreased the firmness and sensory scores (taste, texture and overall acceptability) of fresh-cut pineapples	[130]
Oregano oil	Fresh Lettuce	Reduced presence of *L. monocytogenes, S. Typhimurium, and E. coli*	-	[131]
Carvacrol/Eugenol	Spinach leaves	Reduction of *E. coli* and *S. enterica* achieved by washing	-	[132]
Lemongrass	Apple pieces	Inactivation of *E. coli* Immediately after coating which remained undetected during 2 weeks of refrigerated storage	-	[133]
Carvacrol	Green beans	The application of bioactive coating showed a synergistic effect in the radiosensitiza tion of *E. coli* and S. Typhimurium	-	[134]

Table 2 shows some EOs used as edible coating materials. Saki et al., reported that, the coating composed of chitosan and thymol can provide an efficient alternative for quality maintenance and shelf life extension of fresh fig fruits [135]. Furthermore, EO of thymol together with chitosan had a significant impact against pathogenic bacteria. Therefore, active coatings are a promising technology that could extend fresh meat shelf life, keeping its quality and safety [136]. Gomes et al., also reported that, the application of the EO films improved post-harvest quality of raspberry [82].

Pharmacological Applications of Essential Oils

Essential oils have been described to contain diverse pharmacological properties. In the recent, individuals and companies have developed means of impacting their effects in pharmacological products. In China, six Lamiaceae species commonly used are *Perilla frutescens* (L) Britt, *Pogostemon cablin* (Blanco) Benth, *Mentha haplocalyx* Briq, *Rosmarinus officinalis* Linn, *Lavandula angustifolia* Mill, and *Scutellaria baicalensis* Georgi. These herbs and their extracts have been utilized as antitumor, antioxidant, antimicrobial, and anti-inflammatory agents [137]. Luo et al., demonstrated the anti-inflammatory activities of six essential oils by 12-O-tetradecanoylphorbol-13-acetate (TPA)-induced ear inflammation model and their results indicated that these six essential oils inhibited inflammation to some extent in a dose-dependent manner markedly relieved ear edema [138]. According to Chen at al., essential oils of *S. baicalensis* are anti-tumorigenic and showed an inhibition of growth of HeLa cells and A549 cells [139]. Some essential oils and their components might be potent natural antioxidants [140]. Bacterial pathogens nowadays become resistant to multidrug antibiotics and this has led to the increase to the severity of diseases. They have ability to form biofilm associated drug tolerance and also weak immunity in host cell leads to increase in number of life-threatening bacterial infection in human body [141]. In view of this, essential oils and their chemical composition have been obtained from plants as a potential to control multi drug resistant pathogenic microorganism to combat various infectious diseases [142]. In addition, essential oils derived from medicinal aromatic plants e.g. Peppermint (*Mentha piperita*), thyme (*Thymus vulgaris*), fennel (*Foeniculum vulgare*), are reported to be effective against Gram-negative and Gram-positive bacteria viruses, fungi and yeast. EO's are reported to aid in defense mechanism in higher plants [143]. Bisht, indicated that *Copaifera officinalis* essential oil contains δ-cadinene, germacrene D, α-humulene, α-copaene, germacrene B, βcaryophyllene, β-bisabolene with an inhibition property against *E. coli* and *S.aureus* [144]. In addition, essential oils of contains camphene, terpineol, α-pinene, α-thujone camphor, β-thujone which inhibits *Enterococcus faecalis*, *P.aeruginosa P.vulgaris*, *Klebsiella pneumoniae* [145]. These EOs among others have been used for oral and dental treatments [146]. Their antioxidative properties of EO's and their insect-repellent properties have been confirmed [147].

Conclusion and Future Trends

This review summarizes essential oils, its relevant components and extraction methods, and their applications in the food industry as a preservative tool to extend the shelf life of food and as well as the postharvest decay of fruits and vegetables. Food sustainability and its security has been a major issue under the United Nations, Sustainable Development Goals (SDG's). Therefore, ensuring food availability all year round need to be addressed and this makes food preservation a major concern. At present, in order to ensure food safety there is the need to minimize the microbiological load at initial stage and/or to inhibit the growth of the remaining microorganisms during production and storage, by the use of an active packaging in the food industries.Development of EOs and their implementation are dependent on whether or not their bioactive compounds present has a potential to serve the intended purpose. EOs have been researched on and applied in diverse fields including food, pharmaceutical and the cosmetic industries and their existence have seen to combat against foodborne pathogens and other microorganisms to a greater extent. However, there is still the need to research on more diverse EOs since these pathogens could possess the inherent ability to build resistance to these EOs. The application of essential oils in the study of edible coatings and films for preservation, as perfumes and skin repairs in the cosmetic industries, as herbal and drug enhancers in the pharmaceutical industries etc., coupled with other plant extract formulations and emulsions serve as the best tool to understand the extensive benefits of EOs in food preservation and safety. EOs are natural and safe and recognized by GRAS and can therefore be applied in small or large quantities depending on the effects of the bioactive compounds reported to improve product quality and safety without causing nutritional or sensory losses.

The introduction of systems of biochemistry coupled with biotechnology is a critical tool in the future improvement of edible coatings. Safe and effective protective measures could be engineered to conceal microbial interactions responsible for food and postharvest decay. Hence essential oils can be applied in the food industry as a preservative tool to combat microbial deterioration and ensure food safety to an extent possible.

Author Contributions: RAH (Richard Ansah Herman) conceived of and designed the review and wrote the manuscript with fundamental contributions from all authors for the final version; EA (Ellen Ayepa), SS (Saidi Shittu) and SSF (Sandra Senyo Fometu) equally contributed in the writing of the manuscript and the design of the tables and figures.

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