Review Article

Essential Oils and Plant Extracts for Preservation of Fruits and Vegetables

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Abstract

New alternatives for preservation are now emerging, as many studies have shown that the use of synthetic preservatives and chemical additives is leading to intoxication, cancer and other degenerative diseases. This generates the need to look for conservation alternatives that cover the same antimicrobial properties and compatibility with food. In this search, new antimicrobial agents of natural origin, like essential oils (EOs) and plant extracts obtained from aromatic and medicinal plants, have been found. Essential oils (EOs) are colorless liquids, mainly comprising the aromatic of volatile compounds naturally present in all parts of the plants including seeds, flowers, peel, stem, bark and whole plants. An estimated 3000 EOs are known, of which about 300 are commercially important. Chemically, EOs are a rich mixture of numerous bioactive chemical components such as terpenes, terpenoids, and. Food products such as fruits and vegetables are now often sold in areas of the world far from their production sites, thus the need for extended safe shelf-life for these products has also expanded. The widespread use of synthetic preservatives has significant drawbacks including increased cost, handling hazards, concern about residues on, and threat to human health and environment. EOs and their plant extracts have been reported to exhibit a wide range of biological activities including antibacterial, antifungal and antioxidant activities. Thus, the potential value of these agents as secondary preservatives is considered for the safe extension of shelf-life of perishable products like fruits and vegetables and these substances can be used to delay or inhibit the growth of microorganisms for preservation.

Keywords: Essential oil, Plant extract, Antimicrobial, Antioxidant, Preservative, Fruits and vegetables

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Introduction

Fresh fruits and vegetables contain a lot of phytochemicals, vitamins and minerals that are essential to humans' health. A minimum of 400 g of fruits and vegetables per day is needed for the prevention of chronic diseases (such as heart disease, cancer, diabetes and obesity), and alleviation of several micronutrient deficiencies (World Health Organization, 2003).Fresh fruits and vegetables are perishable commodities which play vital roles in humans' diet and health. Unfortunately, the losses along the supply chain of fresh fruits and vegetables are high especially due to the decay caused by pathogens during poor postharvest handling. During postharvest, attempts have been made to combat microbial decay in fresh horticultural industry by avoiding the use of fungicides. Numerous chemical preservatives have been created and have been shown to play a substantial role in preventing this degradation. However, because they don't come from a green source, they frequently cause customers to express negative concerns. They are environmentally toxic and have the potential to cause cancer and teratogenesis in both humans and animals, thus they require long-term degradation cycles. Due to their extensive antibacterial, antifungal, antimycotoxigenic range, and antioxidant characteristics, essential oils (EOs) and their active components are being researched for their possible use as preservatives [1]. Therefore, the use of EOs in the industry is growing, as they could be directly added to edible products or used for active packaging and edible coatings [2]. EOs have primarily been used for their natural-occurring characteristics, such as their antibacterial, antifungal and insecticidal properties, low mammalian toxicity and less environmental effects [3]. Although EOs and plant extracts are widely available as preharvest fungicides for organic farming, postharvest use has received less attention in research.

What are essential oils and plant extracts?

Essential oils (EOs) are colorless liquids, mainly comprising the aromatic and volatile compounds naturally present in all parts of the plants including seeds, flowers, peel, stem, bark and whole plants [4]. EOs are secondary metabolites synthesized by aromatic and medicinal plants [5]. In general, EOs correspond to a very small fraction of plant total composition, approximately less than 5% of the vegetable dry matter.

At room temperature, essential oils are flammable, typically liquid, and colourless. They are poorly soluble in water but highly soluble in alcohol, organic solvents, and fixed oils.They have a variable refractive index and a very high optical activity and sometimes a distinctive taste. Additionally, because of their distinctive smell, essential oils are the source of the distinct odours that aromatic plants produce. Plant extracts are products derived from plant sources (leaves, bulbs, corms, flowers) with potential of control of disease and pests of public health importance.

Difference between essential oils and plant extracts

- Essential oils generally have more prominent aroma than extracts.
- There are some plants which do not have their essential oils but their extracts can be widely collected and used.
- Plant extracts are very easy to prepare by steeping a plant or flower in a solvent (usually glycerin, alcohol or water) to infuse the plant's properties but this is not the same case for essential oils. Essential oils require proper environment, equipment and machinery.
- Essential oils are pure and concentrated while plant extracts are diluted.

Chemical composition of essential oils

The chemical composition of EOs is complex; there may be around 20 to 60 different bioactive components in each EO. However, generally only 2-3 major components are present at a fairly high concentration (20-70%) compared to other components present in traces. Some factors that may affect these constituents include the geographic location; the environment, the stage of maturity harvest season or extraction method. EOs are a mixture of over 300 different compounds; primarily consisting of volatile compounds with low molecular weights about below 1000 Da (usually 300 Da). [6] Basically, few compounds are present as major ones at about 20%–70% compared to other compounds, which are present in trace amounts. For example, Origanum compactum has carvacrol (30%) and thymols (27%) as the major chemical components, linalool is the major component in Coriandrum sativum and other EOs such as α, and β, a- and b-thuyone (57%) and camphor (24%) are present at high concentrations in Artemisia herba alba. These major components are responsible for the various biological activities of EOs. Generally, these major components are classified as three groups of distinct biosynthetic origins such as - terpenes, terpenoids and aromatic/aliphatic compounds. [7-10]

Terpenes

Terpenes are one of the major groups of chemical components, which are both structurally and functionally different. The basic structures of terpenes are 5-carbon based units, known as isoprenes. Terpenes are represented by the chemical formula $(C_5H_8)_n$ and are composed of isoprene units. These compounds are classified into several groups, such as monoterpenes ($C_{10}H_{16}$), sesquiterpenes ($C_{15}H_{24}$), diterpenes ($C_{20}H_{32}$), and triterpenes ($C_{30}H_{40}$). The major bioactive components (~90%) of EOs oils are monoterpenes, that are synthesized within the cytoplasm of the cell. Some compounds include monoterpene hydrocarbons (p-cymene and †-terpinene), oxygenated monoterpenes (camphor, carvacrol, eugenol and thymol). Monoterpenes are formed by combining the two basic two-isoprene units (C_{10}) and they act as major compounds (90%) of EOs and are significantly associated with the formation of a great variety of structures.

Terpenoids

Terpenoid is another type, which contains oxygen. Terpenoids are derived from terpenes. The key difference between terpenes and terpenoids is that terpenes are simple hydrocarbons whereas terpenoids are modified terpenes containing different functional groups and oxidized methyl groups.

Aliphatic/Aromatic Compounds

Hydrocarbons are the next major constituents of EOs and are composed of only two basic structures namely, carbon and hydrogen atoms. They are highly soluble in lipids and very poorly soluble in water. The simple hydrocarbons such as alkanes, alkenes, and benzenoids are also known as non terpenoid hydrocarbons.

Based on the presence of open chain of carbon atoms, hydrocarbons are classified into -

- Aliphatic
- Alkanes
- Aromatic hydrocarbons.

Aliphatic hydrocarbons are linear chains, which do not have an aromatic ring. Aliphatic molecules are C_8, C_9, and C_{10} aldehydes, which contribute to the acid-smelling and are found in citrus oil in trace amounts. Usually, aliphatic compounds are present in EOs in very small quantities and are responsible for odour due to the presence of oxygenated functional groups.

In alkanes, all the atoms are linked together by a single bond between the two carbon atoms in their structures while alkynes have more than one carbon-carbon triple bond. In addition, the EOs have one or more ring structures and are called as mono-, bi-, tri-, tetracyclic, and so on.

The third class of hydrocarbons are aromatic compounds such as benzyl, phenylethyl, and phenylpropyl; usually, they have a benzene ring (C_6H_6) as well as polycyclic structures such as naphthalene and benzopyrene, which are the first benzene derivatives isolated from plants and are responsible for pleasant smelling. [11]

Mode of action of essential oils

Antimicrobial activity of essential oils

EOs and their constituents play a key role in exerting antimicrobial activity. Due to their hydrophobic nature, EOs migrate through the lipids of bacterial cell membranes substantially, damage the architecture of the cell walls, and make them more permeable [12]. This membrane permeability change leads to the leakage of ions and other cellular materials [13], leading to cell death. EOs show both single and multiple target activities. Additionally, the antibacterial effects of EOs result in the modification of proton pumps and the depletion of ATP [14]; this modification may have a cascading effect, affecting other cell organelles.

The antimicrobial activity of lemon peel EO against four common pathogenic bacteria, including E. coli, B. subtilis, S. typhimurium, and S. aureus was studied. The results showed that the EO obtained from mature lemon peel was endowed with good inhibitory activity against four microorganisms. EOs from thyme, rosemary, clove, and oregano showed significant antibacterial effects against Gram-positive and Gram-negative bacteria, fungi, and yeast. [15]

In recent investigations, scientists have focused more on the antibacterial mechanisms exhibited by various EOs. Different components found in EOs may have different antibacterial mechanisms. As a result, the antibacterial mechanism of EOs typically consists of several different effects rather than a single mode of action. Moreover, the antibacterial activity of EOs may be due to the synergistic effects of the main components of EOs or various components. The possible mechanisms used by EOs to inhibit the bacterial growth are depicted in **Figure 1**.

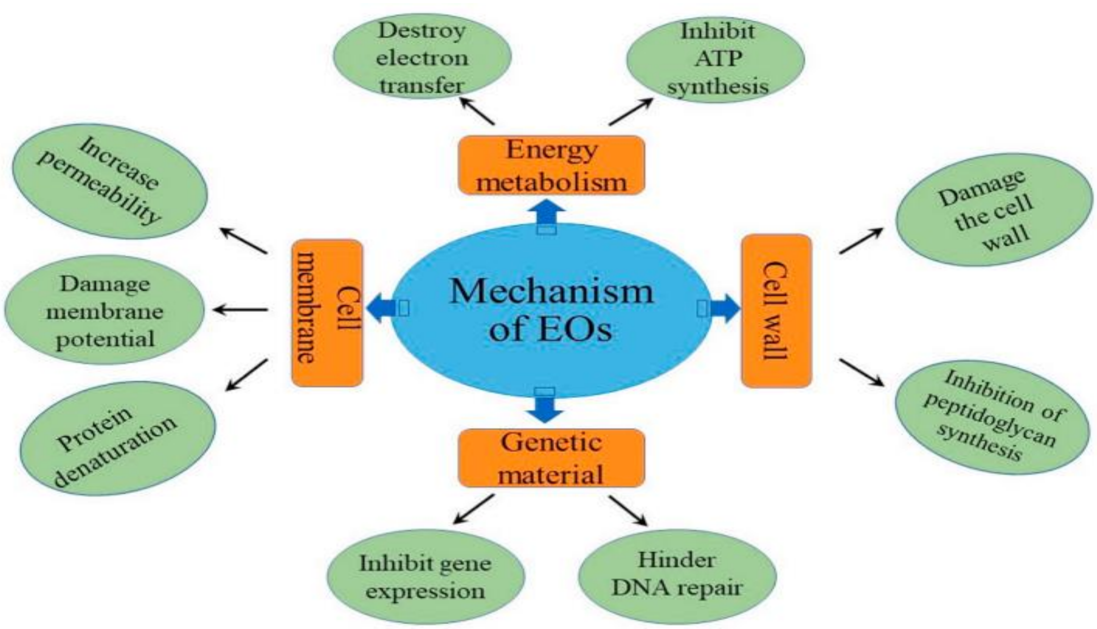

Figure 1 Mechanism of action of EOs on microbial cells

Antioxidant activity of essential oils

The antioxidant potential of EOs mainly depends on their chemical compositions. Phenolic and other secondary metabolites bind with double bonds, which is responsible for the substantial antioxidant activity of EOs. Phenolic compounds, like thymol, eugenol, and carvacrol, are the main potent antioxidant agents in EOs as they can donate hydrogen atoms to free radicals and transform them to more stable products. Mainly, their activities are related to the presence of phenolic compounds that have significant redox properties and play important roles in neutralizing free radicals and in peroxide decomposition [16].

Mode of application of essential oils for fruits and vegetables preservation

Direct application

Dipping: Fruits and vegetables are immersed in emulsions of essential oils made with substances like alcohol, glycerol or natural adjuvants as essential oils do not mix with water easily. The treated horticultural commodities are dipped for a few minutes and then dried.

Vapour emissions: Essential oils are volatile fragrant substances by nature. In order to prevent postharvest infections in fresh fruits and vegetables, essential oils have been used as fumigants. The quality of button mushrooms (*Agaricus bisporus*) was improved by fumigation using essential oil of cinnamaldehyde produced from cinnamon, clove (*Syzygium aromaticum*), and thyme. This approach slowed the browning process and cap opening while lowering microbial counts [17]. Besides the commonly used plant extracts, essential oil of Solidago canadensis L. was also used as fumigant in inhibiting growth of postharvest pathogens [18]. Solidago canadensis is a herbaceous perennial of the family Asteraceae and one of the most destructive invasive weeds in south-eastern China. Since the leaves possess antimicrobial property, it was extracted and used as fumigants during postharvest. It was proven that essential oil vapour of S. canadensis could inhibit B. cinerea growth and preserve postharvest quality of strawberry. [19]

Incorporated with edible coatings

Fruits naturally have waxy protective covering on their exterior. Nevertheless, during postharvest treatment, this soon shrinks or becomes thinner. As a result, thin layers of edible substance are used to provide edible coatings to the fruit's surface in addition to or as a substitute of the fruit's natural protective wax [20]. Edible coatings have demonstrated aesthetic value, the ability to stop moisture and beneficial volatiles from escaping, and the ability to shield items from microbiological and mechanical harm [21]. The use of edible coatings, like chitosan, combined with EOs, allows the synergetic effect of reducing weight loss and maintaining overall quality of fruits. The inhibitory effect is higher for fruit directly dipped into the chitosan-EO emulsions than those exposed to vapour.

Conclusion

- Driven by the growing interest of consumers for natural ingredients and their concern about potentially harmful synthetic additives, the global demand for EOs is increasing nowadays, and more than 250 types of EOs are marketed annually.
- Essential oils exhibit high potential to be used as a natural antimicrobial and antioxidant agents for postharvest perishable products such as fruits and vegetables. Exploring these bioactive mixtures can contribute to increasing the chances of developing potent, ecological, and safer preservative agents that can be good alternatives to synthetic chemicals.
- Nowadays, most EOs are classified as “generally recognized as safe or GRAS” by the United States Food and Drug Administration (FDA) and are therefore permitted as food preservatives.
- However, it must be taken into account that EOs have an intense taste and smell, which can modify the taste and aroma of products. Therefore, studies should focus on the minimum necessary EO amount, which still maintains antimicrobial activity without changing the organoleptic characteristics.

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