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Application of Essential Oils in Food Packaging: A Concise Review

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Review Article

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ABSTRACT

Essential oils are concentrated extracts that capture the natural fragrance, beneficial properties of various plants including flowers, leaves, stems, bark, and roots, by extracting it can be used for properties like antimicrobial and antioxidant to extend the shelf life and possessing various bioactive components with potential benefits for food. Application of essential oils to packaging materials can be a challenge, as improper methods might lead to uneven distribution, poor adhesion, or loss of effectiveness and relatively limited due to several factors. There are some experimental or niche uses, also significant challenges and considerations when using essential oils in food packaging. Packaging intended extend the shelf-life and maintaining the properties of the processed food. Active Packaging is packaging system that "deliberately incorporates components that would release or absorb substances into or from the packaged or the environment surrounding the food". Incorporation of essential oil in packaging material develop great aftermath pursuivant.

Keywords: Essential oil; food; packaging; shelf life.

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1. INTRODUCTION

Food is the sustenance of life, providing essential nutrients and energy to the living beings. Beyond mere survival, food is deeply intertwined with socio-cultural and emotional aspects of human existence. With millions worldwide suffering from hunger and malnutrition, minimizing food wastage is imperative. Food spoilage and wastage not only squanders precious resources such as water, land, and energy used in its production but also contributes to environmental decay through greenhouse gas emissions from decomposing food in landfills. "Annually, around 100 million tons of foods are wasted globally, contributing to nearly 30% of the agri-food supply chain" [1]. Such a huge waste of organic matter leads to massive environmental impacts like high carbon footprint, blue water footprint, vain land use, etc. Food waste is projected to rise over 200 million tons by 2050, with 50% increase in food supplies. Moreover, reducing food waste can alleviate pressure on food systems, promote food security, and mitigate the adverse impacts of climate change, making it a critical endeavour for both human well-being and environmental sustainability.

Processing and packaging are the ways for minimizing the wastage and thereby increase availability of food. Packaging is intended to extend the shelf-life and maintaining the properties of the processed food. Active Packaging is a packaging system that "deliberately incorporates components that would release or absorb substances into or from the packaged food or the environment surrounding the food". There are various similar terms like active packaging, intelligent packaging and smart packaging being used with foods, pharmaceuticals, and several other types of products [2]. Such packaging systems help to have convenience, to extend the shelf-life and improve product safety, to display real time product quality information and to maintain and monitor product freshness. The packaging materials used in these systems can be incorporated with components intended to be released into the food or absorb targeted substances released from the food during its storage. The polymeric matrices like polyethylene, Polystyrene, Poly Ethylene Terephthalate, polypropylene, or bio-based materials such as chitosan, starch-based films, Polylactic acid are used as base materials with incorporation of active ingredients/compounds to formulate the active packaging system. A large variety of Essential Oils (EOs) from different plants such as basil, (*Ocimum basilicum* L.), chamomile flowers (*Matricaria chamomilla L.*), and cardamom seeds (*Elettaria cardamomum (L.) Maton*) and rosemary (*Rosmarinus officinalis L.*) have been incorporated to food packaging system to develop the properties like antimicrobial, antioxidant, etc. [3,4].

2. ESSENTIAL OILS

EOs are the concentrated hydrophobic oily liquid compounds, extracted from different plant organs. They are defined as "extract procured from raw material of natural origin i.e. plant by steam distillation, by processes that involve mechanical extraction from the epicarp of citrus fruits or by physical extraction such as dry distillation following elution of the aqueous phase and may also have post extraction physical analysis provided that no changes in its composition takes place. The most common source of EOs are clove, lavender, cinnamon, lemon grass, coriander, rosewood, cumin, ginger, oregano etc [5,6]. EOs are a good source of several bioactive compounds providing the antimicrobial, antioxidant and several other therapeutic properties [7]. Aromatic plants, are known for their potential benefits to human health because of their anti-cancer, anti-inflammatory, anti-diabetic, antiulcerogenic, antidepressant, antianxiety, including antioxidant and antimicrobial properties such products also improve the organoleptic properties [8,9]. In addition, EOs have been used as natural preservatives, replacing the synthetic ones, for the shelf- life extension of foods. Furthermore, EOs can be incorporated into packaging materials to prevent unavoidable microbial spoilage, and to extend shelf-life of the product. FDA approves EO based products for safety and effectiveness before they go on the market [10].

3. APPLICATION OF EOs TO FOOD PACKAGING

Looking to the properties and functionalities of the EOs, they are very well being incorporated into different active packaging systems to reap their benefits [11]. The schematic representation of the preparation of packaging material incorporated with EO is shown in Fig. 1.

3.1 Methods to Incorporate EOs in the Packaging Systems

3.1.1 Solvent casting

In this technique, polymer materials, singly or in combination, are dissolved in a selected organic solvent. In this solution, the selected EOs, singly or combination, in specific concentration ratio are blended well. The mixture is then shaped into its final geometry by casting it on a plate followed by thermal evaporation of the solvent. When the solvent evaporates, it creates a structure of composite film consisting of the EOs embedded with the polymer. For making PLA-PBAT blend film using solvent casting technique, 4 g of PLA/PBAT (ratio 3.96/0.04) resins were dissolved into 100 mL of chloroform with stirring for 6 h [12].

3.1.2 Polymer extrusion with Eos

In this method, the EOs are blended with a virgin polymer resin followed by grinding them to fine fragments. Such resin-EO preparation is then extruded and blown to form a film containing the embedded EOs.

In a method for preparation of LDPE film with GARLIC EO, the master batch is prepared first and then extruded with virgin polymer in a desired ration. For master batch, LDPE resin (250 g) is added to 40 ml of EO at 110 °C and blended at 50 rpm for 30 mina Brabender Instrument. It is then ground in a knife mill to produce 2.0 mm fragments. This master oil resin is incorporated in virgin resin pellets at desired level and extruded through a single screw extruder and formed to film. Such films contained 1.0 to 4.0 % w/w of EOs.

3.1.3 Surface application

The EOs are incorporated in a packaging material by deposition on the modified (ionized) surface of the film.

The surface of the polymer film is modified using ionizing electronic radiation. The wire electrode is passed back and forth approximately 2.5 cm above each film surface for 2 min at high frequency of 4–5 MHz. After the film surface is ionized by electronic radiation, the change in surface hydrophilicity of the films are characterized with a sessile drop contact angle measurement. Further, the treated films are applied with EOs solution of desired strength prepared in a solvent followed by evaporation of the solvent in an incubator at 30°C.

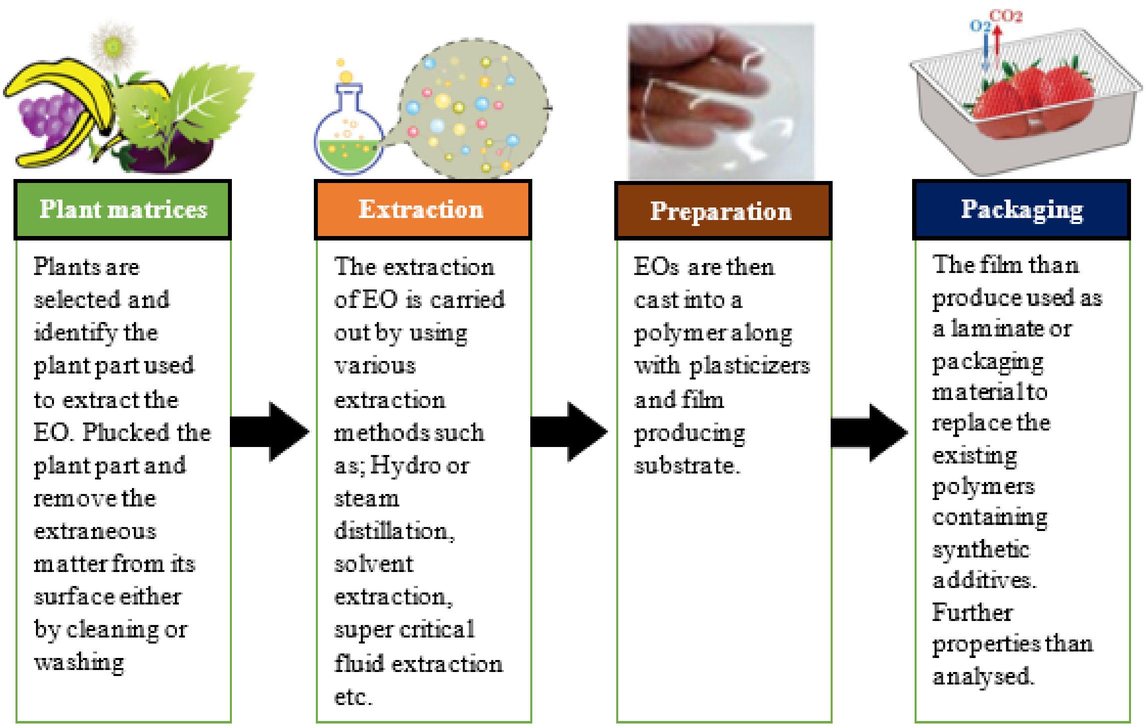

Fig. 1. Schematic representation of the preparation of packaging material incorporated with EO

3.1.4 Polymer lamination

Lamination is the technique/process of manufacturing a material in multiple layers, so that the composite material achieves improved strength, stability, sound insulation, appearance, or other properties from the use of the differing materials, such as plastic.

In above two techniques (3.1.2 and 3.1.3) the complete packaging material contains the EOs, which are migrating to both the surfaces (inside and outside) of the package. The migration in the environment is a loss, which can be prevented by laminating the Polymer-EOs film with another film without Eos [13].

3.1.5 Sachet in tray

A new generation of packaging materials that can release active compounds at desirable rates to extend the shelf life of a wide variety of foods. Small pouches of active compounds such as EOs having antimicrobial or antioxidant properties are incorporated into the package and then released to the food/head space in a controlled manner to inhibit microbial growth, lipid oxidation or other food deteriorations.

The use of sachets having EOs blended with filler materials (such as pyrogallic acid, sodium chloride) can provide controlled and extended release of the active compounds. Similarly, absorbent pads have been recently developed to combine the antimicrobial activity of active compounds including nanoparticles with the convenience of an absorbent material inside the packaging [14,15].

The upcoming concept of intra-mix pack (pouch in pouch) containing a EO based food ingredient, which can be ruptured to mix it with the packaged food when desired. It can release the EOs inside the food to achieve the specific functionalities.

4. CASE STUDIES

4.1 Cassava Starch Composite Films Incorporated with Cinnamon EO [16]

Native cassava starch was used as a film-forming component to provide a continuous matrix of films. Glycerol and Cinnamaldehyde of Cinnamon EO and Clove EO were used as antimicrobial agents. Sucrose ester of fatty acids was used as emulsifier and natural -Na montmorillonite clay was used as reinforcement filler. The films were produced by casting technique in which, the film genic solution was prepared by following method: 0.1 g of clay nanoparticles were suspended in 25 g of distilled water for 1 h, under stirring (500 rpm), and, after rest for 24 h, they were blended with a suspension of 5.0 g of starch and 70 g of distilled water then cinnamon EO(0.4 g) was mixed with emulsifier correspondent to 0.025 for emulsifier content/EO content proportion; and glycerol at 38°C, correspondent to 1.88 for glycerol content/EO content proportion, using a magnetic stirrer (200 rpm). Both mixtures prepared were then homogenized and heated in a domestic microwave oven until starch gelatinization, which occurs at 69°C [17].

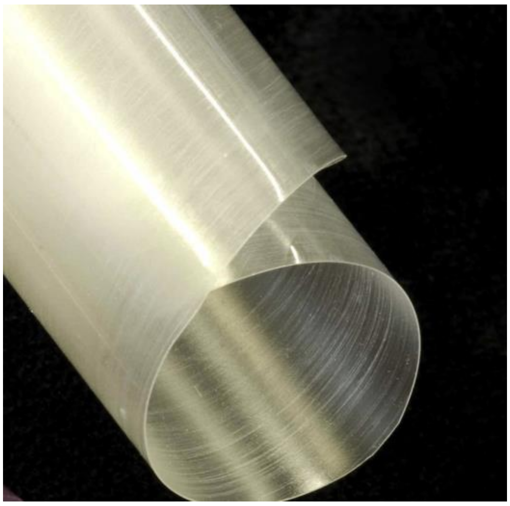

Fig. 2. Cassava starch film incorporated with 0.4 g of cinnamon essential oil/100 g of filmogenic solution

After cooling, the filmogenic solution was diluted with 14.25 g of ethanol. The filmogenic solution poured into rectangular plates to maintain uniform thickness (100 μm) followed by drying for 18 to 24 h. after drying films were placed in a controlled relative humidity and stored. This Cassava Starch Composite Films Incorporated with Cinnamon EO showed effective antimicrobial activity against Penicillium commune and *Eurotiumam stelodami*, fungi commonly found in bread products and found that *E. amstelodami* is more sensitive for cinnamon EO because approximately 91%inhibition was observed.

4.2 Preparation, Characterization and Antimicrobial Activity of Polyvinyl Alcohol/Gum Arabic/ Chitosan Composite Films Incorporated with Black Pepper EO and Ginger EO [18]

"Essential oils (EOs) such as black pepper essential oil (BPEO) and ginger essential oil (GEO) have extensively been reported for their nutritional and biomedical properties. In this study, bio-composite films based on polyvinyl alcohol (PVA), gum Arabic (GA) and chitosan (CS) incorporated with BPEO and GEO were fabricated by solvent casting method. FTIR, XRD, SEM and DSC were performed with mechanical and antimicrobial properties of PVA/GA/CS films with and without BPEO and GEO. The BPEO-PVA/GA/CS film showed heterogeneous rough surface with cavities containing entrapment of BPEO droplets, whereas, the GEO-PVA/GA/CS film showed heterogeneous rough surface with coarseness due to the incorporation of respective EOs. The BPEO and GEO incorporated PVA/GA/CS films were considerable resistant to breakage and flexible with improved heat stability. The BPEO and GEO incorporated PVA/GA/CS films were significantly inhibited the growth of *Bacillus cereus*, *Staphylococcus aureus*, *Escherichia coli* and *Salmonella typhimurium*. The obtained results have demonstrated that both BPEO and GEO incorporated PVA/GA/CS films are promising alternatives to wound dressing and food packaging materials" [19].

4.3 Chitosan Films Incorporated with Apricot (*Prunus armeniaca*) Kernel EO as an Active Food Packaging Material [19]

"Apricot kernel essential oil (AKEO) is extracted from kernels of bitter apricot which is considered to be a major agricultural seed waste. The chemical composition of AKEO revealed that oleic acid is the major fatty acid present in AKEO. Also, N-methyl-2-pyrrolidone (NMP), which is a strong antioxidant and antimicrobial agent, is present in a significant quantity" [19]. The films were fabricated by casting method in which, chitosan (2% w/v) was dissolved in acetic acid aqueous solution (1% v/v). The solution was magnetically stirred overnight at 70 °C for proper dissolution. The filtration was carried out with the help of an ASTM 100 mesh sieve having a pore size of 150 microns. Thereafter, AKEO was added in appropriate amount so as to obtain the final desired concentration. The filmogenic solution was then homogenized at 10,000 rpm for5 min and the films were casted and stored. The films showed an improved water resistance and 41% enhanced water vapour barrier properties when CS to AKEO ratio was 1:1. A continuous increment in tensile strength value was observed with increasing AKEO concentration and a substantial 94% enhancement was observed for the film with AKEO ratio equal to that of CS. The chitosan-AKEO films displayed not only excellent antioxidant activity but also substantial antibacterial activity against both gram negative *E. coli* and gram positive *B. subtilis*. The films were found to be successful in inhibiting the fungal growth on bread, thereby enhancing its shelf life [20].

5. LIMITATIONS

- Some of the EOs may possess certain undesirable effects like hypo-allergenicity and toxicity in few human beings.
- Information Network of Departments of Dermatology (IVDK), country reported 637 cases of hypersensitivity due to ylang-ylang oil, lemon-grass oil, jasmine oil, sandalwood oil, and clove oil during 2000 and 2008.
- Because of high volatility of EOs, the processing area required to be well ventilated in order to avoid fatigue and suffocation among the workers.
- The storage stability of packaging materials embedded with EOs is limited [21-24].

6. FUTURE PERSPECTIVE

- The growing demand of consumers for safe and natural products, without chemical additives, has resulted in necessity to improve the safety of foods, while maintaining their good nutritional and organoleptic quality.

- The demand is also growing for the minimally processed foods with better product safety, which paves the way for the advanced packaging systems such as EO based active packaging.
- The research on improvement in potentiality and functionality of EO based packaging in various food system is needed.
- In Research and development area ongoing, and scientists are exploring various techniques and formulations to effectively incorporate essential oils into food packaging while ensuring their stability and efficacy [25-28].

7. CONCLUSIONS

The major challenges to the food technocrats in order to prevent the food spoilage are to restrict the microbial proliferation and lipid oxidation. By delicately controlling the above-mentioned parameters, one can easily achieve food with higher quality and shelf-life. Processing is one way of doing this, but the higher the processing, the lower is the nutritional quality of food, which limits the intense processing aids. The packaging is another way of preserving the processed food. The better the packaging performance, the minimal is the requirement of processing. The active packaging system incorporated with EOs having desirable functionalities are opening up the opportunities in food processing sector. Bio-based food packaging has been largely studied by incorporating EOs in order to protect different types of foods for e.g. meat, fish, fruits, raw, processed/fried foods, etc; such studies have shown promising results in food preservation without harmful chemical preservatives and antioxidants. There is a huge future prospect in application of EOs based packaging at the commercial level in the food processing.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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