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NANOENCAPSULATION OF ESSENTIAL OIL: APPLICATION AS THERAPEUTICS AND ANTIMICROBIALS

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ABSTRACT

The demand for safe, wholesome food with few synthetic preservatives is increasing exponentially on the international market. Natural food antimicrobials, particularly essential oils (EOs), have potent antimicrobial properties and might serve as a unique source of food preservatives. Due to numerous inherent limitations, such as limited water solubility, bioavailability, volatility, and stability in food systems, EOs have not been utilized significantly in the food business despite their excellent performance. To employ EOs as preservatives in food systems at low levels, recent developments in nanotechnology have the potential to remove these obstacles. Thus, we looked at the most recent advances in employing natural active ingredients as antimicrobial agents and the various nanoencapsulation techniques adopted for this purpose. The most recent uses of nanoencapsulation antimicrobial agents in food systems will be discussed, along with the current knowledge on the antibacterial capabilities of EOs.

INTRODUCTION

Nanotechnology is a recent field of science that deals with creating, fabricating, and using materials with dimensions smaller than 1000 nm. According to the British Standards Institution, nanotechnology involves designing, characterization, manufacturing, and using structures, electronics, and systems by regulating form and size at the nanoscale, or 10^{9} μ. The encapsulation technology has many possible uses, including in the food and pharmaceutical sectors. Nanoencapsulation is encapsulating bioactive compounds at the nanoscale (10^{9} μ). It primarily protects bioactive substances, including polyphenols, micronutrients, enzymes, antioxidants, and nutraceuticals, against severe environmental conditions during handling and processing and for controlled release at the intended site (Gupta and Variyar, 2016).

Food antimicrobial agents are chemical compounds that can stop or slow the development of microorganisms. They are frequently used in conjunction with other preservation techniques to increase the shelf life of foods. At this time, chemically manufactured preservatives are the most widely utilized in the food business. The possible carcinogenic and mutagenic dangers of chemical preservatives like nitrites and parabens are increasingly becoming a concern among consumers. Food that is "fresher," "more natural," and "slightly processed" is in demand. In this regard, much effort has been given to developing alternative natural and low-toxic antimicrobial agents to replace conventional synthetic antimicrobial compounds (Liao et al., 2021).

Essential oils (EOs) are secondary metabolites of plants that are volatile and aromatic and are primarily used for their taste, fragrances, and biological properties. The effectiveness of EOs and their biologically active components against infections that cause foodborne illness has recently been extensively studied (bacteria, molds, and related toxins). However, the use of EOs in food preservation is frequently constrained due to their high processing costs and other drawbacks, including their inferior antibacterial efficiency versus synthetic antimicrobial agents, their potent aroma, and their instability or insolubility in water. As a result, maintaining the activity of natural food antimicrobials while employing them in the food sector requires an efficient intervention mechanism. Nanotechnology has shown to be an efficient technique to protect natural antimicrobial agents from deterioration and increase their bioavailability and target application. As a result, fewer antimicrobials will be needed for optimal food preservation. As a result, the use of nanotechnology in the food sector has been one of the fastest-growing fields in recent years.

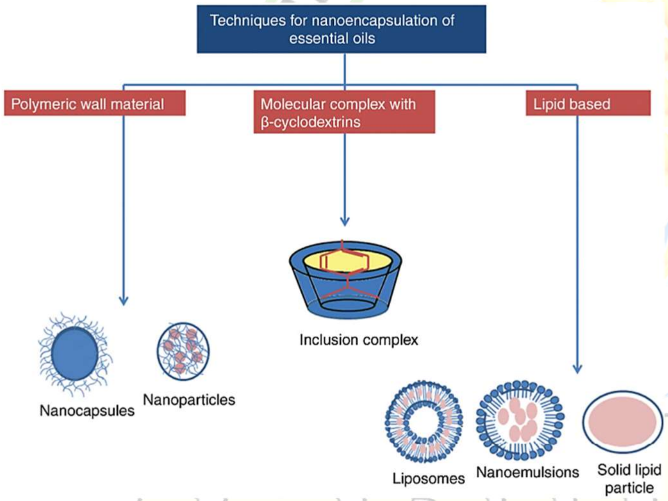
NATURAL ANTIMICROBIAL AGENTS AND THEIR ACTIVITIES

"Natural antimicrobial agent" refers to naturally occurring active ingredients taken from microbes, animals, or plants, such as polyphenols, flavonoids, tannins, alkaloids, terpenoids, isothiocyanates, and polypeptides, as well as their oxidized derivatives. Natural antimicrobial compounds are more palatable to consumers than synthetic antimicrobials, based on safety concerns and the search for healthier and natural products (Liao et al., 2021). Researchers have undertaken numerous studies on active chemicals over the past several years to understand their antibacterial properties. The primary antibacterial pathways include: (i) the rupturing of cell membranes, (ii) the complexation of metal ions, (iii) the alteration of microorganisms' genetic material, (iv) the leaking of cell contents, (v) the inhibition of metabolic enzymes, and (vi) the ATP-based consumption of cellular energy. The target microorganisms (species, strains, and genes), environmental factors (pH, ionic strength, water activity, temperature, and atmospheric composition), food characteristics, and their chemical properties (acid dissociation constant, hydrophobic/hydrophilic ratio, solubility, and volatility) all have an impact on the bacteriostatic effects of these naturally occurring active substances (ingredients and initial bacterial amount)

NANOENCAPSULATION STRATEGIES FOR ESSENTIAL OIL

Due to their high volatility and tendency to decompose when exposed to heat, humidity, light, or oxygen, EOs can experience considerable chemical changes while being stored and handled. Degradation of the components of EOs may result through isomerization, cyclization, dehydrogenation, or oxidation processes induced either enzymatically or chemically (Liao et al., 2021). The handling and storage of the EO after it has been extracted from the plant material, as well as the conditions during distillation and throughout the extraction process, all significantly impact how rapidly reactions degrade it (Gupta and Variyar, 2016). For optimal application, a specific understanding of the chemical composition and characteristics of EO is required (Gupta and Variyar, 2016). Encapsulation makes EOs more physically stable, which shields them from environmental influences.

Additionally, encapsulation leads to higher bioactivity, controlled release, less volatility and toxicity, and greater convenience. Due to its nanometric size and extracellular and intracellular protection, nanoencapsulation of EOs also aids in regulated and sustained release, myofascial penetration, and cellular absorption. A wide range of substances and structures can be used to create nanocapsules (Gupta and Variyar, 2016). Three nano-encapsulated techniques are commonly employed: polymer-based nanocapsules, lipid-based nanocarriers, and molecular inclusion complexes (Fig.1 and 2).



.Fig. 1. Various types of carriers available for nanoencapsulation EOs

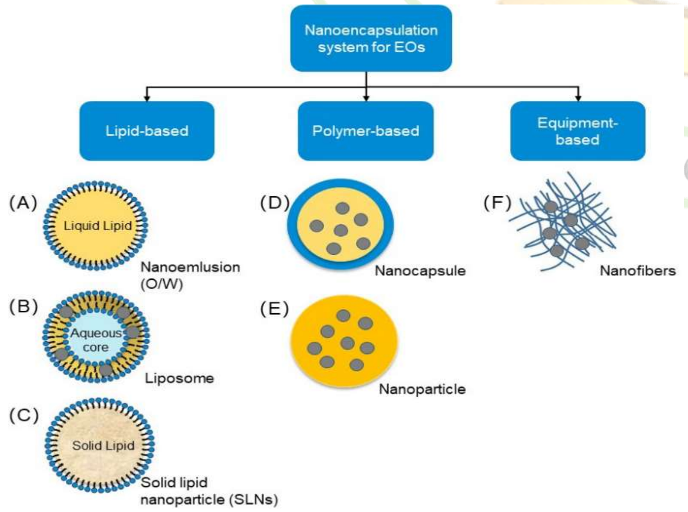


Fig. 2. Different nanoencapsulation techniques available for EOs

ESSENTIAL OILS AS FOOD PRESERVATIVES: CURRENT STATUS AND CHALLENGES

Different plant organs produce essential oils (EOs) as secondary metabolites to offer protection against outside influences. They have potent antibacterial properties and are frequently used in sanitary products, cosmetics, and other items. EOs are naturally occurring compounds that may be extracted using water vapor from various plant tissues, including flowers, leaves, stems, roots, and fruits. EOs have a strong odour, are often lipophilic and volatile, and have a low molecular weight. Additionally, most EOs are transitory in nature and have low mammalian toxicity, making them generally safe for human health and the environment (Gupta and Variyar, 2016).

Numerous studies have demonstrated that EOs have antibacterial activities, making it possible to employ them to preserve a variety of food products. Terpenoids, aromatic chemicals, aliphatic compounds, and sulfur-containing nitrogen compounds are the four primary groups of chemical components in plant EOs. The bacteriostatic mechanism of various components often involves multiple points of action rather than a single mode of action. Plant EOs and their primary constituents have an impact on microorganisms in two ways: first, by altering the cell membrane, cell wall, and organelle composition of microbial cells and mycelia; and second, by decreasing or inhibiting the production and germination of spores, thereby interrupting the spread of pathogens (Liao et al., 2021).

EOs have a variety of internal and external critical challenges hindering their process as food preservatives: (i) EOs typically have low solubility in aqueous mediums and the reached concentrations are not able to exert significant biological activities; (ii) the scarcity of raw materials means that the quantity of EO obtained after extraction is generally insufficient for commercial applications; (iii) the high processing cost are also some of the major challenges; (iv) EOs are unstable due to their volatilization and oxidation, and thus are difficult to store, which may change the functional composition of active compounds (in actual production, it is necessary to rely on suitable carriers or adopt appropriate methods to achieve good antibacterial and fresh-keeping effects); (v) Some EOs have a potent fragrance even at low concentrations (EOs may attach to lipids, proteins, and carbohydrates in food systems, therefore a particular amount may have an adverse influence on the sensory properties of foods in order to accomplish antibacterial effects), as well as the quality of raw materials, requires a more systematic evaluation, especially safety assessment (Gupta and Variyar, 2016).

The primary issues of employing EOs as food-preserving agents can be mitigated by using nanoencapsulation rather than applying the EOs directly to food items as free antimicrobials. Compared to free EOs, the integration of EOs into nanosized encapsulation systems can dramatically enhance their physical characteristics, such as dispersibility, dispersion stability, turbidity, and viscosity, and hence boost their functional activities. Additionally, nanoencapsulation may be used to mask undesirable taste and odor, protect EOs from oxygen, light, pH, moisture, and degradation during processing and storage, enhance the solubility of lipophilic compounds in aqueous media, protect them against oxygen, light, pH, moisture, and degradation during processing and storage, and release them at the correct area at the right rate through effective design of the capsules and suitable selection of wall materials (Liao et al., 2021).

CONCLUSION AND FUTURE PERSPECTIVES

Developing mild food preservatives in recent years has driven consumer desire for safe, natural goods. In this situation, natural antibacterial agents like essential oils have the potential to improve quality and safety. They have less effect on human health but still have certain limitations. In contrast to adding antimicrobial ingredients directly to food items, advances in nanotechnology can protect active compounds against deterioration, increase their solubility, and optimize their release. However, due to a lack of systematic study, most of these are only synthesized on a laboratory scale.

Nanoencapsulation can enhance chemical stability against oxidation, light-induced reactions, moisture, high temperatures, and several other conditions that might hasten the deterioration of the active ingredients. Additionally, nanocarriers improve water solubility, increase bioavailability and bioefficacy, and transform liquid EO into solid powders to ensure their safety and simpler handling. A viable method for overcoming EOs limits, reducing their dosage, and improving the long-term safety of these components is the nanoencapsulation of EOs in liposomes, solid lipid nanoparticles, nano- and microemulsions, and polymeric nanoparticles. Despite developing several alternative delivery system types, the fundamental principles controlling their logical design for specific purposes are still largely unknown. Future research should concentrate on how nanocarriers interact physiochemically with food systems. Analyzing the impact of nanocapsule inclusion on the sensory quality of food items should receive greater attention. The preparation of active packaging materials with nanocapsules requires more investigation.

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