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Encapsulation of Essential Oils - A Booster to Enhance their Bio-efficacy as Botanical Preservatives

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Abstract: **Essential oils (EOs) and their bioactive components are safer and novel formulations used as green preservative in food industries but their rapid volatility and high instability in varying environmental conditions pose a major hurdle for large scale practical application. Recently, different encapsulation technologies have been recommended as the booster for improvement of EOs bio-efficacy. The present article deals with some major encapsulation techniques and their role in enhancing bio-efficacy of EOs being used as botanical preservatives.**

Index Terms: **Essential oils (EOs), Bio-efficacy, Botanical preservative, Nanoencapsulation.**

I. INTRODUCTION

Since antiquity, different formulations of plant essential oils (EOs) and volatile extracts have been used in traditional medicine for the prevention of different health disorders. Presently, plant products including EOs and its bioactive compounds are gaining cumulative interest as safer and novel preservatives for the food commodities and are regarded as safer alternatives to synthetic preservatives due to their eco-friendly GRAS (Generally Recognized as Safe) category (Hu et al., 2019). Essential oils (EOs) are secondary metabolites of different aromatic plants biosynthesized in different plant parts such as epidermal cells, glandular trichomes and in secretary cavities or canals. EOs are mixture of different bioactive volatiles such as terpines, phenols, ketones, aldehydes, alcohols, esters and phenylpropanoid (Bakkali et al., 2008).They have wide spectrum of antifungal, antibacterial, antiparasitic and larvicidal activities due to presence of multiple bioactive compounds. Synergistic action between different components of EOs is reported to enhance its bio-efficacy and prevention of resistance development in microorganisms (Basak& Guha, 2018). Approximately, 300 EOs belonging to families Zingiberaceae, Asteraceae, Apiaceae, Lamiaceae, Myrtaceae, Lauraceae, Piperaceae and Cyperaceae are commercially being used in fragrance and essence industries (Burt, 2004).

Recently, the nanoencapsulation technology has added a new dimension to food industries as it enhances the bio-efficacy of essential oils by increasing the bioavailability of nano-sized products which are readily able to concentrate the bioactive compounds in solid-liquid interface and liquid- rich phases where microorganisms are more favorably located (Hosseini et al., 2013).

Although EOs exhibit excellent antimicrobial, fungicidal, bactericidal, insecticidal, antioxidant and medicinal properties but practical applicability of most of them as green preservative is still challenging as the EOs are highly volatile and get easily degraded upon oxidation through direct exposure to light, heat, oxygen and humidity (Bilia et al., 2014). Besides, low water solubility of EO, inconsistent bio-efficacy in relation to varying geographical conditions, age of plant, threat of biodiversity loss, requirement of specialist for collection and negative impact of EOs on organoleptic properties in fumigated food systems restrict their commercial application as food preservative (Prakash & Kiran, 2016; Noori et al., 2018). Nanoencapsulation as an efficient and hurdle technology offers a new dimension for enhancement in stability of EOs and bioactive components by protecting them from direct exposure to natural environmental conditions. Furthermore, encapsulation also reduces volatility and toxicity of EOs, improves its water solubility and also enhances its bioavailability and bio-efficacy due to increased surface to volume ratio, controlled and site specific delivery as well as deep tissue penetration ability (Gupta &Variyar, 2016).

II. ENCAPSULATION TECHNIQUES

Encapsulation of botanicals refers to entrapment of plant products i.e. EOs or its bioactive components inside polymeric protective covering, while nanoencapsulation deals with plant products encapsulation in nano range i.e.10-1000 nm (Ezhilarasi

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et al., 2013). Encapsulated material is called as core material, internal phase or active agent, while encapsulating substances are known as wall material, carrier agent, external phase or matrices (Zuidam & Shimoni, 2010; Pandit et al., 2016). Different polysaccharides (cellulose, starch, dextrin, chitosan, alginate), lipids (phospholipids, triglycerides, cholesterol) and proteins (albumin, lectin, casein, lutein, zein) based polymers have been widely utilized for encapsulation with certain qualities of water solubility, biocompatibility andbiodegradability (Khandelwal et al., 2016). Among different nanoencapsulation technologies, spray drying, coacervation emulsification and ionic gelation are the most widely used encapsulation methods to boost up the preservative potential of EOs and its bioactivities. Based on encapsulation methods, different forms of encapsulated EOs/bioactive components are developed such as nanogel, nano-emulsion, nanoparticle, nanofibre, nanoliposome and nanosponge. Amongst them, nanogel, nano-emulsion and nanoparticles have been utilized as efficient delivery system in food and pharmaceutical sectors (Wan et al., 2019). Encapsulation techniques are reported to enhance the antimicrobial efficacy of EOs. For instance, encapsulated Lavender EO displayed threefold enhancement in its antimicrobial potency (Yuan et al., 2019). Besides, encapsulation also enhances the antifungal, antioxidant potency and thermal stability of EOs.Some major advantages of nanoencapsulation techniques are presented in Fig.1.

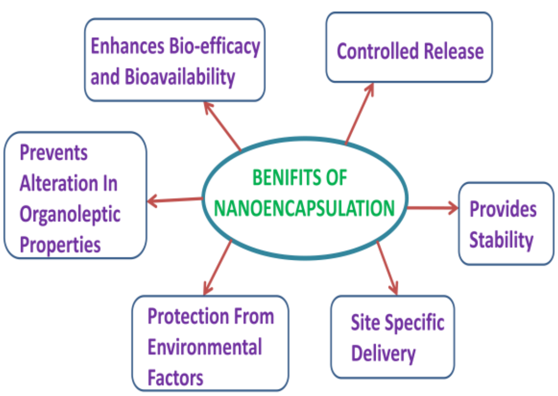

Fig.1. Different advantages of encapsulation technology

Some major encapsulation techniques and their role in enhancing the bio-efficacy of EOs as botanical preservatives are discussed below.

A. Nano-emulsion

Nano-emulsion is stable colloidal system prepared by addition of two immiscible liquids (oil and water) which are stabilized with the help of emulsifiers or surfactants. The method is basically used to encapsulate hydrophobic substances for improving their stability and bioactivity. Satureja khuzestanica EO and pure Carvacrol nano-emulsion is reported to improve its antibacterial activity up to 2-4 times and was recommended for its utilization in food industries as antibacterial preservative (Mazarei & Rafati, 2019).

B. Coacervation

Coacervation technique is based on phase separation of single or mixture of polyelectrolytes from solution and further deposition around EO or bioactive compounds to form coacervates; robustness of coacervate increases by addition of cross linking substances viz. glutaraldehyde and transglutaminase. Encapsulation of Pimenta dioca EO within chitosan/carrageenan by complex coacervation leads to significant enhancement in antioxidant potency and antimicrobial efficacy (Dima et al., 2014).

C. Inclusion Complexation

Inclusion complexation method for nanoencapsulation of EO is based on principle of entrapment of EOs inside polymer cavity through Van der Waals forcesand hydrogen bonding. Cyclodextrins are the most commonly used polymer for encapsulating EO through inclusion complexation. Encapsulation of EO within cyclodextrin biopolymer exhibited significant increment in water solubility up to 16-fold and reduced the photo-degradation rate up to 44-fold leading to physical and chemical stability as well as enhancement in its bio-efficacy (Kfoury et al., 2019). Similarly, hydroxyl propyl β-cyclodextrin encapsulating guava leaf EO through inclusion complexation exhibited increased antimicrobial activity and promising antioxidant stability (up to 26-38%) (Rakmai et al., 2018).

D. Nanoprecipitation

Nanoprecipitation or solvent displacement method relies on precipitation of polymer from organic phase (comprised of organic solvent, polymer and bioactives) on addition of aqueous phase (comprised of mixture of polymer non solvents along with surfactants). Polymers like poly (lactide) (PLA), poly-ε caprolactone (PCL) and poly lactide-co-glycolide (PLGA) are the most commonly used substances for nanoprecipitation (Rosset et al., 2012). Nanoencapsulation of Zanthoxylum riedelianum EO through nanoprecipitation caused improvement in the insecticidal activity against whitefly (Bemisia tabaci) and reduction in its photo-degradation up to 33% (Pereira et al., 2018). Besides, being the fast and economic technique, it is best suited for encapsulating hydrophobic substance (EOs) in comparison to hydrophilic core material (Ladj-Minost, 2012).

E. Liposome Based Method

Liposomes are vesicular self-assembled system comprising of single phospholipid bilayer (unilamellar liposome), single aqueous core or several phospholipid bilayers (multilamellar liposome) and several aqueous core materials. Major advantages of liposome method are suitable carrier for hydrophobic, hydrophilic and amphipathic compounds as well as increased bioavailability, stability and water solubility of encapsulated compound along with enhanced bio-efficacy (Sherry et al., 2013). Liposome loaded Melaleuca alternifolia EO exhibited strong antimicrobial potential against Staphylococcus aureus, E.coli, Candida ablicans and high stability against oxygen, light and temperature in comparison to its unencapsulated form (Ge & Ge, 2016). Moreover, liposomal encapsulation of different EO components such as thymol, carvacrol, p-cymene, γ-terpinene and geraniol showed superior antifungal and antibacterial efficacy as compared to their unencapsulated formulations.

F. Ionic Gelation

In this technique nanoparticles are formed due to cross linking between polyelectrolyte and counter ions of essential oils (Giri et al., 2013). Encapsulation of clove EO within chitosan bio-polymer enhanced antifungal activity against Aspergillus niger along with its controlled release pattern (Hasheminejad et al., 2019). Encapsulation of Schinus molle EO through ionic gelation enhanced its fungicidal activity against Aspergillus parasiticus and also accelerated its antiaflatoxigenic efficacy at lower doses (Lopez-Meneses et al., 2018).

G. Drying Techniques

Although different nanoencapsulation techniques are recognized as efficient booster of EOs or bioactive compounds bio-efficacy, but nanosuspensions formed in these methods have major challenge due to irreversible aggregation and leakage of entrapped active ingredient through polymer hydrolysis. Hence, after preparation of nanosuspension drying of formed particles through spray drying or freeze drying technique enhances the stability of dried nano capsules with controlled release of encapsulated bioactive volatile components (Nakagawa et al., 2011). Moreover, rapid and cost effective property of spray drying technique make it more preferable to be used in food industries for encapsulating food additives and enhancement in their shelf life. Microcapsules of thyme EO obtained by spray drying technique exhibited improved chemical stability and antimicrobial potential against Vibrio alginolyticus and V. parahaemolyticus (Tomazelli et al., 2018).

III. CONSTRAINTS OF ENCAPSULATION TECHNIQUES

Till date, different encapsulation procedures have been utilized, but none of them could be proved equally suitable for majority of the bioactive components. The prime reason of this failure is the specific structure of the bioactive components. Further, nanoencapsulated EOs may aggregate after longer storage period causing decrease in overallbio-efficacy. Application of emulsifiers may lead to the evaporation of alcoholic components of EOs causing effective reduction of antimicrobial activity and induction of some toxicological impacts like allergy and skin irritation in the mammalian system (Das et al., 2019). Impact of such nanoencapsulated EOs on the non-target organisms are also a considerable matter. Moreover, encapsulation processes currently being practiced have still certain hurdles and require skilled man-power as well as excessive time for product formulation.

CONCLUSION AND FUTURE PERSPECTIVES

Encapsulation techniques improve the bio-efficacy of EOs used as botanical preservatives by enhancingtheir stability, antimicrobial activity, antimycotoxigenic potential and antioxidant activity. Nanoencapsulation of EOs within specific biopolymers offers the opportunity for development of novel carrier matrices with controlled release property.Although, nanoencapsulation technology enhances the bio-efficacy of EOs, safety assessment of these botanical preservative and interaction of EOs with different food components needs to be investigated extensively before large scale recommendation in food and agricultural industries as green foodpreservative.

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