

Mini Review

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Essential Oil Nanoemulsions and Food Applications

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ABBREVIATIONS: EIP: Emulsion Inversion Point; PIC: Phase Inversion Composition; PIT: Phase Inversion Temperature; EOs: Essential Oils; SE: Spontaneous Emulsification.

INTRODUCTION

Food quality, food preservation, and food safety are the most significant concerns in the food industry currently.¹ Moreover, consumers demand for minimally processed foods and ready-to-eat fruits and vegetables because of its convenience since they do not need to process the product later.² However, minimally processed foods are known for high chances of microbial contamination and high enzymatic activity. When the product is cut, the nutrients inside the fruits and vegetables are exposed to enzymes and microorganisms that will provide decrease of the shelf life.³ Therefore, microbial and enzymatic activity is a leading concern in the food industry in regards to proving food safety and convenience for the consumers. Due to this challenge, food industries have been using chemical substances to inactivate some of the enzymes, and specially, to reduce the microbial population. Nevertheless, these kinds of chemicals are most of the time corrosive, ineffective in the presence of high organic loads, may form organochlorides and may have long-term toxicological implications.³⁻⁵ Because of this issue, new technologies are being developed in order to find out new alternatives for replacement of chemical treatments.⁶

Currently, there is a growing interest in the utilization of new preservative methods that are from natural origin. Essential Oils (EOs) are natural compounds that have been shown promising treatment for food application because of its strong antifungal, antiviral, and antibacterial activities.⁷⁻⁹ EOs present photo-chemicals, such as 1,8-cineole, carvacrol, eugenol, cinnamaldehyde, carvone, citral, estragole, geraniol, perillaldehyde, terpineol, thymol, and vanillin which are able to extend shelf life of processed food products by preventing lipid oxidation and antimicrobial properties.^{7,10,11} Moreover, EOs also have been proved to have other diverse beneficial functions, such as antidiabetic,^{12,13} antiradical, and antioxidant effects.¹⁴ The antimicrobial properties of EOs is associated with the dissolving of the cytoplasmic membrane of bacterial cells in the hydrophobic domain.¹⁵ Previous studies have shown that EOs were able to inhibit *Bacillus cereus*,¹⁵ *Zygosaccharomycesbailli*,¹⁶ *Listeria monocytogenes*, and *Staphylococcus aureus*.¹⁷ Pandit and Shelef have applied rosemary oil in pork liver sausage and verified that it was effective against *Listeria monocytogenes*.¹⁸ Another study evaluated the use of carvacrol and cinnamaldehyde in kiwifruit and melon by dipping the food products in solution. The study showed that the natural flora of the product was reduced significantly after the EOs application.³

Although essential oils have been shown to be promising alternative to chemical preservatives against foodborne pathogens, they present special limitations that preclude its use in food products. Low water solubility, high volatility, and strong odor of EOs are the main properties that make it difficult for food application.¹⁷ It is also a big challenge to incorporate

oil-based compounds in aqueous food products because it shows physical and chemical instability when it is applied in food systems.¹⁹ However, several studies have shown that the use of nanoemulsions can be a great choice for application of EOs in food matrix.²⁰

NANOEMULSIONS AS ANTIMICROBIAL DELIVERY SYSTEM

Nanoemulsion presents differences in their physical properties and structures. They are stable colloidal systems within nanometric size (≤ 100 nm) that usually consist of oil, surfactant and water, presenting as transparent or slightly turbid.²¹ Nanoemulsions differ appreciably from conventional emulsions in their functional activity due to the decreased size.¹⁹ For example, these emulsions may not scatter light strongly in the visible region and can thus be transparent. Nanoemulsion has the advantages of high surface area and kinetic stability against coalescence or creaming. As a result, nanoemulsions are important vehicles for hydrophobic bioactive substances through the formation of nano-dispersions. Hence, these systems permit the application of essential oils in food since they present solubilization in the water phase through molecular dispersion.²⁰

Nanoemulsions can be formulated using low-energy methods or high-energy emulsification methods. High-energy methods include high-pressure homogenization, microfluidization and sonication. In this case, energy is necessary to provide intense disruptive forces and minimized droplet size. Low-energy methods include Spontaneous Emulsification (SE) method, Emulsion Inversion Point (EIP) method, Phase Inversion Composition (PIC) method and Phase Inversion Temperature (PIT) method. In these methods, emulsion is formed spontaneously by mixing the ingredients together. The droplet size can be reduced by varying the composition and altering the environmental factors.¹⁵ Ultrasonic emulsification is one of the methods, which has been showing promising properties for application of EOs in foods. It is a high-energy method of formulation nanoemulsions that is able to decrease the size of droplets in the emulsion, which

can promote very small droplet diameter, high physical stability, high bioavailability, and optical transparency.^{22,23} Because of the small size of the droplets, gravitational separation, flocculation, and coalescence often occur at a reduced rate in nanoemulsions. Nanoemulsion presents a very interesting application in certain food and beverage since the small droplet size promotes transparency or only slightly turbid in the food product.²⁴

In nanoemulsions, the choice of surfactants is very critical since emulsifiers have to rapidly cover the many new surfaces that are formed. Generally, in food emulsions two classes of surface-active species are used: (1) small-molecule surfactants such as monoglycerides, sucrose esters, and others and (2) macro-molecular emulsifiers such as protein or modified starches.²⁵ EOs have to be associated or combined with surfactants in order to enhance the antimicrobial activities by increasing the solubility of EOs in the aqueous phase. Tween 80 has a high hydrophilic and lipophilic balance. Tween 80 is non-ionic in nature and stabilizes emulsion droplets by stearic stabilization. Moreover, being a low molecular weight surfactant, it is efficient in minimizing droplet size better than polymeric surfactants.²⁶

Nanoemulsion based delivery system could be characterized by dynamic light scattering, zeta potential, thermodynamic stability studies, pH, refractive index and viscosity. Dynamic light scattering is used to determine the size distribution profile of particles in nanoemulsions and zeta potential indicate stability of emulsions. Imaging techniques such as transmission electron microscopy, scanning electron microscopy and atomic force microscopy is used to confirm diameter of particles and understand distribution of nanoparticles.²⁷

APPLICATIONS IN FOOD MODELS

Recently, few studies have applied EOs in food systems, which makes these studies even more exciting and needed. Table 1 summarizes the most recent studies that apply EOs and nanoemulsions in food systems.

Antimicrobial	Target Microorganism	Food System	Reference
Oregano oil	<i>Listeria monocytogenes</i> , <i>Salmonella</i> Typhimurium, <i>E.coli</i> O157:H7	Lettuce	28
Carvacrol	<i>Salmonella enteric Enteritidis</i> <i>E. coli</i>	Broccoli and Radish seed	29
Carvacrol	<i>Salmonella enteric Enteritidis</i> <i>E. coli</i>	Mung bean and Alfalfa seeds	30
Mandarin oil	<i>Listeria innocua</i>	Green beans	31
Mandarin oil	<i>Listeria innocua</i>	Green beans	32
Lemongrass oil	<i>Salmonella</i> Typhimurium <i>E. coli</i>	Plums	33
Cinnamaldehyde	<i>Lactobacillus delbrueckii</i> <i>Saccharomyces cerevisiae</i> <i>Escherichia coli</i>	Apple and Pear Juice	34
Eugenol	<i>Escherichia coli</i> O157:H7 <i>Listeria monocytogenes</i>	Fruit Juice	15

Table 1: Food model research studies on delivery system for natural antimicrobials.

Bhargava, et al. applied oregano oil nanoemulsion to control the foodborne on fresh lettuce.²⁸ The food product was evaluated against *Listeria monocytogenes*, *Salmonella Typhimurium* and *Escherichia coli* O157:H7. The data suggested that applying oregano oil nanoemulsion to fresh produce may be an effective antimicrobial control strategy. Another similar study evaluated the effectiveness of carvacrol nanoemulsion against *Salmonella enterica Enteritidis* and *E. coli* on broccoli, radish seed,²⁹ mung bean, and alfalfa seeds.²⁹ The experiments have shown that the nanoemulsion is effective on radish seed, mung beans, and alfalfa seed but not affective on broccoli seeds. The antibacterial and physical effects of modified chitosan based-coating containing nanoemulsion of mandarin essential oil on green beans is recently being analyzed.^{31,32} The experiments were associated with different non-thermal treatments against *Listeria innocua* and the results have shown promising application of this type of nano-emulsion in food products.

A very interesting food application of EOs nanoemulsion has been observed in plums. Recently, lemongrass oil nanoemulsion was used to evaluate antimicrobial properties, physical, and chemical changes in plums.³³ The nanoemulsion was able to inhibit *Salmonella* and *E. coli* population without changing flavor, fracturability, and glossiness of the product. It was also able to reduce the ethylene production and retard changes in lightness and concentration of phenolic compounds.

Essential oil emulsion based delivery system is emerging as viable solution to control growth of food borne pathogens on food. However, limited studies are performed on food model and there exist several challenges in application of this system in complex food matrices such as meat and meat products. Application of nanoemulsions in food models will also offer challenges to government and industry.³⁵ Food industry has to build consumer confidence on acceptance on nano food ingredients such as antimicrobial essential oil nanoemulsions. On the other side, regulatory agencies such as FDA should ensure safety of these antimicrobial delivery systems.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

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