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The Needs and Applications of Delivery Systems to Fortify Food with Active Ingredients

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Abstract

Fortifying food products with bioactive agents is a major initiative within the food industry for human health. However, many agents are water insoluble with low bioavailability; some are unstable and easily degrade during storage. Thus, it is necessary to overcome these obstacles before adding them to the final food products. Entrapping bioactive agents into suitable delivery systems such as liposomes, emulsions, etc., has been proven to be a useful method. This review simply describes the reasons for bioactive agents needed to be entrapped in delivery systems, the common formulations used, and their applications. This would provide a general understanding of how active ingredients generally enrich food.

Keywords: Active ingredients; Delivery systems; Emulsion; Liposome

Introduction

Consumers are increasingly demanding a healthy diet rich in active ingredients such as flavors, vitamins, minerals, antioxidants, lipids and so on [1-3]. However, on the one hand, the compositions of active ingredients in natural food are usually limited; on the other hand, some agents may be high in raw food, but their bioavailability is very low [4-6]. For example, β-carotene has received increasing attention during the past 30 years due to its beneficial health effects such as antioxidant and anticancer activities as well as its ability to reduce the risk of heart disease and certain chronic disease [7]. However, humans cannot synthesize β-carotene in their bodies, and they must obtain it from the foods they consume. Many vegetables and fruits (peppers, tomatoes, carrots, mangoes, and kale) are rich in β-carotene, but literatures show that only a minor part (<10%) of the carotenoids in these raw foods is absorbed [8,9]. In addition, many active ingredients including β-carotene also have many other disadvantages such as low water-solubility, physical or chemical instability, undesirable flavor, and so on [10-12]. All of them make active ingredients difficult to directly incorporate into final food products. Therefore, development of strategies to incorporate active ingredients is necessary if such foods are to keep successful and initiative in the marketplace.

Luckily, these challenges can be overcome by entrapping active ingredients into suitable delivery systems. During the past decades, delivery systems (such as liposomes, emulsions, lipid particles, microcapsules, beads, etc.) have been effectively designed and utilized in food industry to encapsulate, protect, and deliver functional components before introduced into final food products [13-16].

Among of them, emulsions especially for oil-in-water emulsion have attracted the interest of many research groups in food and pharmaceutical fields due to their favorable properties such as good biocompatibility, easy design and preparation [3,17]. To obtain uniform emulsion, the oil phase dissolved with bioactive agents is mixed with emulsifier water solution, blended and then passed through a homogenizer. In this system, emulsifiers play an important role in the formation of emulsion and its stability thereafter. To be an effective emulsifier, ingredients should exhibit perfect emulsifying activity [18]. That means it should quickly adsorb to the surfaces of small oil droplet form an interfacial coating and appreciably decrease the interfacial tension during homogenization [3]. Synthetic emulsifiers such as Tween 20, tween 80 are the traditional emulsifiers for many products. With the increasing demand for food and beverage with natural ingredients in recent years, many food manufacturers are trying to replace synthetic emulsifiers with natural and sustainable alternatives. To date, researchers have found a lot of natural emulsifiers (such as protein, polysaccharides, phospholipids, and bio surfactants), which are able to form and stabilize oil droplets [18-21]. Chung et al., [18] found that emulsion prepared by using quillaja saponin as a natural emulsifier could produce whitish milk similar to a commercial liquid creamer. Lin et al., [22] have prepared β-carotene loaded emulsion by using modified starch. He et al., [4] have fabricated curcumin emulsions containing Konjac glucomannan stabilized with whey protein isolate and achieved a controlled and sustainable release of bioactive compounds from emulsions. Lv et al., [20] have compared the effectiveness of a number of natural emulsifiers (whey protein, gum arabic and quillaja saponin) on the production and stability of vitamin E fortified emulsions and found that whey protein isolate and quillaja saponin were more effective at forming emulsions containing fine droplets than gum arabic, while quillaja saponin based and gum arabic based emulsions exhibited better resistance to pH change. Due to the above-mentioned advantages, emulsions are already widely utilized in the food industry, e.g., in dressings, sauces, soups, beverages, dips, creams, and desserts [6,19,22].

Liposome, as one of the most common used formulations, also has great potential to embed bioactive agents. A liposome is a self-assembling and cell-resembling delivery system with concentric bilayer structure. The size of liposome is typically about 10 to 1000nm with the structure varying from a balloon-like unilamellar to an onion-like multiple structures [3,12]. There are different hydrophilic and hydrophobic regions in liposomes separated by surfactant substances (such as phospholipids) [3]. Therefore, both hydrophilic and lipophilic molecules and even amphiphilic molecules can all be entrapped in the special bilayer. Since liposomes were first described in the 1960s by Alec Bangham, they have been beneficial in medical, cosmetic, and agricultural fields, and have become integral to food research. More recently, liposomes have been widely used to encapsulate proteins/peptides/enzymes, polyphenols/flavones, essential oils/fatty acids, vitamins, energetic substrates, and minerals [3,23-25]. Active agents in the form of liposomes could then be effectively added into different food products: dairy products (milk, cheese, and yogurt), drinks (juices and milk drinks), meat (pork, beef, and rabbit), and other products (chocolate, tofu, etc.) [12,27-32].

Delivery systems containing bioactive agents could be directly added into food material with simple blending or homogenization and bring a number of benefits to food industry: supplying good protection for bioactive agents against environment stress, masking off-flavor (bitterness, astringency), improving storage and handling characteristics, extending shelf life, besides increasing bioavailability. However, the food system microenvironment (pH, intrinsic component, and ionic strength etc.) and emulsifier properties used are critical factors needed to take into account if appropriate final food is wanted [3,6]. For example, whey protein-based emulsion could effectively inhibit oxidation of fish oil in milk, but is less stable in yoghurt and dressing [18].

Conclusion

A number of challenges associated with active ingredient need to be addressed when incorporated into food. Suitable delivery systems such as emulsions, liposomes, etc. could be designed to encapsulate active agents followed by simple blending or homogenization. However, whether appropriate final food could be obtained is dependent on food and emulsifier properties.

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