Encapsulated bioactive food compounds using double emulsions

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Abstract— Encapsulation is one of the methods to protect bioactive food compounds. Various systems can use for encapsulation of bioactive compounds. One of these systems is double emulsions, because their structural characteristics are suitable for this purpose. Properties of these emulsions are caused that they are used for encapsulating different varieties of bioactive compounds, such as vitamins, enzymes, poly unsaturated fatty acids, etc., nevertheless properties of this type of emulsions such as stability and release control must be considered.

Keywords- encapsulation; double emulsion; bioactive food compounds; W/O/W; O/W/O.

I. INTRODUCTION

Encapsulation, developed in 1950s, is defined as a technology of packaging materials in small, sealed capsules that can release their contents at controlled rates under specific conditions [1]. The use of encapsulated food ingredients for controlled-release applications is a way to solve the major problem of food ingredients. The general challenges about encapsulation, is selection of technique and material used [2]. One of the encapsulation techniques is using emulsion systems such as double emulsions.

Double emulsions are very complex dispersion systems which have low thermodynamic stability. They are classified into two groups water-in-oil-in-water (W/O/W) and oil-in-water-in-oil (O/W/O). These systems have very potential application including controlled release of substances in medicine, pharmaceutics, cosmetics and industrial applications. They also have a high potential for encapsulation of bioactive food compounds from the environment such as antioxidants and to control the aroma and flavor release. The main problem with food related applications, selection of suitable emulsifiers and stabilizers and in preparing such emulsions, especially of the W/O/W type, with acceptable stability and release properties [3].

II. PREPARING OF DOUBLE EMULSIONS

Double emulsions are often prepared by two-step procedure. In the first step, the primary emulsion is prepared. The primary emulsion in the case of an O/W/O double emulsion is a simple O/W (oil-in-water) emulsion with high HLB (hydrophilic–lipophilic balance) surfactant. In the case of a W/O/W double emulsion, the primary emulsion is a simple W/O (water-in-oil) emulsion which is prepared using water and a low HLB surfactant solution in oil [4]. In the food industry this process is usually carried out using mechanical devices such as high speed blenders, high-pressure homogenisers and colloid mills [5]. In the second step, the primary emulsion (O/W or W/O) is re-emulsified in either an oil solution with a low HLB surfactant that produce an O/W/O double emulsion or an aqueous solution with a high HLB surfactant that produce a W/O/W double emulsion. The second emulsification step is carried out in a low shear device in order to avoid expulsion of internal droplets to the external continuous phase [4]. Using membranes for the secondary step can cause (i) good control over droplet size and droplet size distributions, (ii) low energy consumption and (iii) creation a gentle process [5].

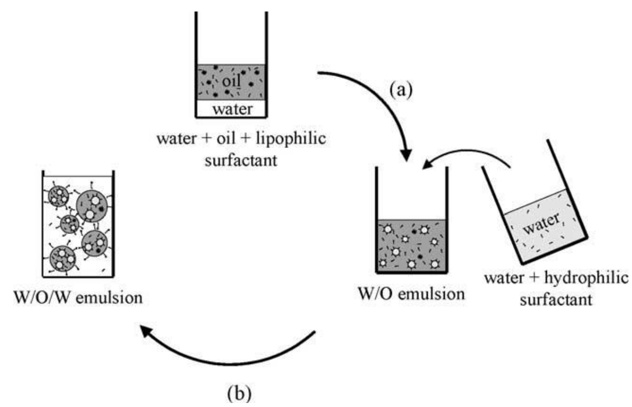

Figure 1. Preparing water-in-oil-in-water double emulsions

III. ENCAPSULATION IN FOOD

A. Applications of encapsulation

Encapsulation is a rapidly expanding technology with high potential applications in food industries and sciences [6]. Many of food compounds are sensitive to the environmental conditions, so they cover up to capsular structures for protect them. Encapsulation is one of the methods to protect bioactive food compounds. These structures have a wide application in the food industry.

Encapsulation increases the effectiveness of essential oils (EOs) and to decrease their sensitivity in foods. Microencapsulation (ME) of EOs is generally achieved in two steps. In first step, an emulsion of the volatile compound is made in an aqueous dispersion of a wall material which also functions as the emulsifier. In second step, the microencapsulated emulsion must be dried under controlled conditions so as to diminish the loss of the encapsulated material by volatilization [7]. Cell microencapsulation plays important role in biotechnology and medicine and is considered an important tool for tissue engineering. Encapsulated cells also provide an important source of materials required for these sciences [8]. In food biotechnology, ME can be also used to entrap or enclose microorganisms by segregating them from the external environment in order to use them in appropriate conditions and requirements. The main purpose of probiotic encapsulation is to protect cells against unfavourable conditions, and to allow their release in a viable and metabolically active state [7]. The use of encapsulated polyphenols instead of free compounds can overcome the drawbacks of their instability, decrease unpleasant tastes or flavors as well as improve the bioavailability and half-life of the compound in vivo and in vitro [1].

B. *Encapsulant Materials*

Encapsulated materials can be selected from a wide range of natural or synthetic materials depending on the properties desired in the final microcapsule (Table 1). The encapsulated materials in food are more limited to natural food components such as proteins, sugars, starches, gums, lipids, and other ingredients that have Generally Regarded As Safe (GRAS) status such as cyclodextrin, chitosan, low-molecular weight emulsifiers (e.g. Tweens), mineral salts, etc. They can be used alone or with other compounds to achieve the best functionality. The composition can significantly influence the functional properties of the final microcapsule as can the choice of processing technologies used. In addition, Cost of these materials is important. Neutral taste and odor, low viscosity, good film forming, gelling and barrier properties are some of the desired characteristics of encapsulated materials [9].

IV. Encapsulation by Using Double Emulsion

Double emulsions can be used to deliver both oil and water-soluble bioactive food compounds, and are suited for controlled and sustained release of these bioactive compounds in the encapsulation of internal phase of the double emulsion. Conventionally, double emulsions are made surfactants with low weight which can limit their long time stability. By using natural biopolymers, it can be prevented [10]. Alternatively, the oil phase of double emulsions may be modified to provide control of the release of an encapsulated hydrophilic bioactive. The structure of the double emulsions can be preserved after spray drying. This causes double emulsions to be produced in both liquid and powder forms. Depending on the formulation and conditions of preparation, O/W/O or W/O/W double emulsions may be formed. These have potential for the controlled delivery of a range of bioactive food compounds [9].

TABLE I. Materials Used for Encapsulation of Bioactives for Food Applications.

Material class	*Types of materials*
Proteins	Milk proteins—caseins and whey proteins, Soy proteins Wheat proteins Egg proteins Zein Hydrolyzed proteins
Carbohydrates	Sugars—fructose, galactose, glucose, maltose, sucrose, oligosaccharide, corn syrup solids, dried glucose syrup Starch and starch products—maltodextrins, dextrins, starches, resistant starch, modified starches Gums—agar, alginates, carrageenan, gum acacia, gum arabic, pectin, Carboxymethyl cellulose Chitosan Cyclodextrins
Lipids	Natural fats and oils Fractionated fats Mono- and diglycerides Phospholipids Glycolipids Waxes—beeswax, carnauba wax

A. *Encapsulation bioactive compounds of double emulsions*

Double emulsions for encapsulated many bioactive food compounds are used in the delivery systems. For example, Encapsulation of omega-3 fatty acids, phytosterols, oil-soluble vitamins (e.g. vitamin A, B1), etc. [11].

Yoshida, Sekine, Matsuzaki, Yanaki, and Yamaguchi (1999) made O/W/O emulsions in which the outer oil phase contained an organophilic clay and a non-ionic surfactant. Retinol was Perched into encapsulations that made by different types of emulsions, and stability decreased in the order O/W/O >W/O > O/W [12]. Also Rodríguez-Huezo & et al (2004) explained that water-dispersible microcapsules have been prepared by spray-drying W/O/W emulsions containing carotenoids have these properties. These emulsions were formulated with combinations of low molecular weight emulsifiers and biopolymer blends of various gums [9]. Della Porta & et al (2012) encapsulated L. acidophilus bacteria by using the double emulsions. In this case, they used different combinations to generate these emulsions [8]. Di mattia & et al (2009) showed that encapsulated of catechin caused an interfacial localisation which was reflected in the enhancement of primary oxidation and in the inhibition of secondary oxidation and about quercetin was poorly partitioned in the aqueous phase and had no effect on slowing down the bimolecular phase of auto-oxidation [1].

B. Encapsulation stability & control release of double emulsions

Due to the presence of two aqueous domains separated by an oil layer, the inner aqueous compartment offers great potential for the encapsulation and controlled release of hydrophilic bioactive compounds. However, these emulsions are more difficult to prepare and control than simple emulsions as they typically consist of relatively large droplets that coalesce either standstill or due to commonly-encountered processing regimes such as shear, sterilization, and have a strong tendency to release entrapped compounds in an uncontrolled condition [13]. To enable high encapsulation yields of the internal droplets in the final product requires a slight emulsification step is essential. Even though much work has been done, investigation of the influence of membrane emulsification parameters on the droplet size and droplet size distribution in W/O/W double emulsions, and encapsulation and marker release from these, remains scarcely explored. Okochi and Nakano compared the encapsulation of water-soluble pharmaceutical drugs and food compounds in W/O/W emulsions prepared with the SPG membrane (secondary emulsification step) and a stirring method (both emulsification steps). They found that the encapsulation was higher for membrane emulsification and this was mainly associated with more homogenous particles and reduced surface are a due to the absence of small droplets[5]. Also Fechner & et al (2007) was studied on the effects of adding various compounds such as conjugates of proteins and polysaccharides to the emulsion composition and found that these compounds are, in addition, effective both stability of emulsion and also release control of it [14]

Conclusions

Encapsulation of bioactive food compounds is a method for protection and prevention against adverse environmental conditions. Multiple emulsions are conventional systems for encapsulation of bioactive food compounds that these systems have high performance in food industry. But they are often more complicated to prepare and are sometimes more unstable. Thus, consideration about stability of these emulsion systems and also control release of them in food conditions is essential.

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