Recent advances in designing delivery systems for marine bioactive compounds

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Introduction

The concept of delivery systems is gaining significant attention in various fields such as pharmaceuticals, nutraceuticals, cosmetic industry etc. Delivery systems are mainly being used to encapsulate, protect or to impart controlled/sustained release of the active ingredients. Nutrient based delivery systems is an emerging research sector globally owing to the increased consumer demands for tailor made functional foods. The development of functional foods often involves the process of identifying, isolating, purifying, characterizing biomolecules and their subsequent incorporation in food systems. However, the development of functional foods is not an easier task; it involves several challenges such as loss of physico-chemical stability, solubility, bioavailability, melting point etc. Realising the major scientific and technological challenges associated with the formulation of functional foods, various efforts have been taken by researchers and nutritionists to battle the issue. Development of suitable delivery systems can be a promising solution for designing nutraceuticals by playing a major role in the encapsulation, protection and sustained release of biomolecules (Lekshmi et al., 2018).

Designing delivery systems for bioactive nutrients is an arduous task as several factors need to be taken into consideration. Some of the aspects that need to be considered are given below:

1.Delivery system intended for food application should be fabricated only from biomaterials which are of food-grade quality, safe and biodegradable in nature. It should also have Generally Recognized As Safe (GRAS) status (Augustin and Hemar 2009).

2. The material used for the development of delivery systems should be easy available, economically feasible and the benefits gained out of the encapsulation should outweigh the additional cost incurred in the process (McClements et al. 2007; Gutiérrez 2018).

3. The incorporation of the delivery systems should not adversely affect the physical, chemical, textural and sensory quality of the final product. That is, it should be compatible with other ingredients of the food matrix (Joye et al. 2014).

4. The delivery system developed should be robust. It should be physically and chemically stable and can offer the biomolecule considerable protection from any sort of degradation processes.

5. Ideally, the delivery system should have high loading capacity and retention of the biomolecule. Loading capacity refers to the amount of bioactive substance present per unit mass of the encapsulation material (McClements 2015).

6. Delivery system developed should ensure the sustained and targeted release of the biomolecule in response to a specific environmental stimulus such as pH, enzymatic action, temperature or ionic strength (Shegokar and Müller 2010).

Types of Delivery Systems

Delivery systems for functional food formulation can be developed from a variety of food-grade biopolymers such as proteins, lipids or carbohydrates etc. The biopolymers will be

used either singly or in combination to increase the functionality. The properties of biomolecule to be encapsulated and the nature of the surrounding food matrix has to be taken into account while selecting biopolymers. Adequate knowledge about the molecular structure of the biopolymer is also essential as it in turn determines the functionality of food systems. The different types of delivery systems used in food industry are discussed below:

Protein based delivery systems

Proteins are generally preferred for the development of delivery systems owing to their high nutritional value, biodegradability, economical and GRAS nature. They are also reported to have excellent functional properties including emulsification, gelation, water binding capacity, foaming etc. (Elzoghby et al. 2012). Its structural diversity attributed due to the multiple functional groups present in the primary sequence of polypeptides makes it an excellent candidate for the delivery of bioactives over a wide range of platforms such as hydrogels, micro and nano particles, molecular coacervates, emulsion droplet stabilization, films etc. (Chen et al. 2006). Protein based delivery systems are relatively simple to prepare, economical and deliver both hydrophobic and hydrophilic bioactives. Proteins can be obtained from various sources such as bacterial, fungal, plant and animals and among this, the latter two are commonly employed for food applications (Elzoghby et al. 2012). Gelatin, collagen, elastin casein, albumin and whey proteins are some of the commonly used proteins of animal origin for functional food applications.

Carbohydrate Based Delivery Systems

Carbohydrates which account for calorific value, sensory and textural properties form a significant component of many food systems. It is considered as suitable carrier for many nutraceuticals owing to its biocompatibility, biodegradability, structural versatility, site digestion properties. The presence of functional groups makes it an excellent candidate for the development of delivery systems as it can interact with a wide range of bioactive compounds of both hydrophobic and hydrophilic nature. Carbohydrate based delivery systems can be categorized into four main groups based on their source such as plant origin (e.g., starch, gum Arabic, guar gum, pectin), animal origin (chitin, chitosan), algal (agar, carrageenan, alginate) and microbial origin (xanthan gum, dextran, cyclodextrin etc.) (Kosaraju 2005). Polysaccharides can be further categorized based on their charges such as neutral, anionic and cationic.

Lipid Based Delivery Systems

Lipid based delivery systems are reported to have better encapsulation efficiency and low toxicity than other delivery systems. In general, four major lipid-based delivery systems are being used, namely, nano emulsions, nanoliposomes, solid lipid nanoparticles (SLN) and nanostructure lipid carriers (NLC). Among the various types of lipid-based delivery system, liposomes are widely being used in the food research industry. They are reported to possess wide range of benefits such as (1) can be produced from materials of natural origin (2) used for production, entrapment, release of compounds having wide range of solubility such as water-soluble, lipid-soluble, and amphiphilic materials (3) deliver and release their load in the target site inside and outside the body. They are widely used in food industry for making formulations of antimicrobials, enzymes, lipophilic vitamins, oils and minerals.

Mixed Delivery Systems

Of late, there is an increasing trend in application of mixtures of polymers instead of individual ones with a view to improve and broaden the application range and functionality. Among the various biopolymer mixture studied so far, protein–polysaccharide complex is considered more advantageous, because of their higher chemical and colloidal protection. The formation and stability of protein–polysaccharide complex is found to be affected by a number of factors such as pH, ionic strength, and biopolymer concentration, charge distribution, molecular weight, temperature, pressure, etc. In such cases, the sequence of biopolymers adsorption onto the interface determines the structure and stabilizing properties of the mixed protein- polysaccharide complex. Two phenomena can occur during the mixing of proteins and polysaccharides in a liquid medium depending on the pH and isoelectric point (1) the attractive interactions can lead to the formation of soluble and insoluble complexes and (2) the repulsive interactions can separation of the two biopolymers from each other (Weinbreck et al. 2004).

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