Encapsulation of curcumin into β -cyclodextrins inclusion: A review

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Abstract. Curcumin is an important natural pigment, which has many functions such as anti-oxidation, anti-inflammatory, and the prevention of cardiovascular, cerebrovascular and Alzheimer's disease. However, its poor water-solubility, unstable chemical properties and low bioavailability limit its application in the food industry. The above problems can be effectively solved by using β -cyclodextrins to encapsulate curcumin. Combining with the domestic and foreign research literature, the structure and properties of β -cyclodextrins, preparation method of β -cyclodextrins inclusion, the curcumin-loaded β -cyclodextrins, and their applications in industry were summarized in this paper. Finally, the research status of Curcumin-loaded β -cyclodextrins delivery vector was discussed and its development prospect was prospected.

1 Introduction

Curcumin is a kind of natural polyphenols, which is mainly extracted from the roots of some plants in the Zingiberaceae and Araceae. The appearance of curcumin is an orange-yellow crystalline powder with spicy light and slightly spicy ginger, and it can be widely used as a functional active factor in the food industry. In addition, studies have shown that curcumin has strong antioxidant activity, which can effectively reduce the incidence of chronic diseases such as hyperlipidemia and hypertension [1], preventing Alzheimer's disease [2] and protecting liver [3].

However, curcumin also has some disadvantages. For example, the solubility of curcumin in water is very low (about 11 ng/mL) [4], which makes it difficult to be applied in the water-soluble system, and curcumin is easy to be degraded under light, heat and oxygen conditions. Only a small amount of curcumin ingested orally is digested and absorbed by the human body, and it will combine with glucosidic acid and sulfide in intestinal cells and liver cells, and will be metabolized and excreted out of the body quickly, so it is difficult to exert its physiological effects. [1] The development of delivery carrier is an effective method to solve these problems, a lot of material such as proteins, polysaccharides and lipids are used as base materials to design the delivery carriers, including β -cyclodextrins. β -cyclodextrins, as a source of a wide range of natural materials, has good performance of embedding, digestion and absorption in the body. It is safe and harmless to human body, so it is regarded as an ideal material to prepare the delivery carrier for embedding curcumin, through the inclusion of cyclodextrin, the water solubility and chemical stability of curcumin are greatly improved, and the residence time of curcumin in the gastrointestinal tract is extended, promotes digestion and absorption, as well as the bioavailability of curcumin is

improved. Therefore, in this paper, the fabrication of β -cyclodextrins delivery vector and the latest research progress in the field of curcumin delivery were reviewed in combination with the literature reports at home and abroad in recent years, so as to provide a reference for the development and application of curcumin in food and condiments.

2 Physicochemical properties and structure of β -cyclodextrins

β -cyclodextrins is a cyclic oligosaccharide produced by starch through the action of cyclodextrin glycosyltransferase by bacillus SPP. The β -cyclodextrins molecule contains 7 D-pyroglyucose- α with α -1,4 glycoside connecting end to end in a ring. Each glucose is a chair conformation and its three-dimensional structure is wide at the top and narrow hollow truncated cone cavity at the bottom. The hydroxyl groups of β -cyclodextrins are all clustered at the outer edge of the molecule, so the outside of the molecule has strong hydrophilicity, while the inside of the molecule has hydrophobicity due to the shielding effect of C-H. Due to its unique chemical structure, β -cyclodextrins can be used as a delivery carrier to package curcumin [5], resveratrol [6], lycopene [7], astaxanthin [8], vanillin [9] and other natural active compounds, to protect and control release of natural active compounds [10, 11].

The molecular weight of β -cyclodextrins is about 1135 Da, the cavity height is about 7.9 Å, the cavity diameter is about 6.5 Å, and the solubility in water at room temperature is 1.85 g/100 mL. Generally, the structure of β -cyclodextrins is relatively stable and storage-resistant, and it can maintain certain stability to acids, bases and heat [10]. In terms of chemical reactions, hydroxyl groups at the C2, C3, and C6 positions of β -cyclodextrins can be connected to new chemical

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groups to form cyclodextrin derivatives, such as esterified cyclodextrins or etherified cyclodextrins. In addition, the C2-C3 chemical bonds and C-O-C chemical bonds can also generate cyclodextrin derivatives through chemical bond breaking and grafting polymerization, which enables them to produce cyclodextrin derivatives with different properties according to actual requirements. Thus, having more selectivity and advantages in the construction of delivery vectors [11].

3 Preparation of curcumin-loaded β -cyclodextrins inclusion

Fig. 1. The molecular structure of curcumin

As shown in Figure 1, the molecular structure of curcumin contains two benzene rings and a carbon chain, which makes the molecular polarity of curcumin low and hydrophobic, while β -cyclodextrins is an external hydrophilic and internal hydrophobic cavity structure. Thus, curcumin molecules could migrate into the cavity of the β -cyclodextrins through hydrophobic interaction, and then self-assembly to form a delivery system [12]. It could avoid the direct contact of curcumin with the surrounding environment, so improved its stability to light, heat and oxygen, and facilitated the dispersion of curcumin- β -cyclodextrin in the aqueous phase. Therefore, β -cyclodextrin inclusion complex would expand the application of curcumin in the food industry.

3.1 Liquid-type curcumin-loaded β -cyclodextrins inclusion

Liquid-type β -cyclodextrins curcumin delivery carrier is one of the most widely used types in the food industry. By β -cyclodextrins embedding, curcumin and other insoluble substances can be dissolved in aqueous phase system, making it more convenient to be used in beverage, oral liquid and other products. The preparation process can be summarized as follows: firstly, prepare the aqueous solution of β -cyclodextrins, then directly add curcumin or organic solvent solution of curcumin in proportion, and fully mix. In order to achieve better embedding and solubilizing effect, appropriate solvent, temperature and pH adjustment and ultrasonic-assisted method are usually selected [13]. A cyclodextrin-curcumin inclusion compound was prepared by the saturated aqueous solution method, and the inclusion compound could be well dispersed in water [5]. The derivative of β -cyclodextrins obtained by the derivatization reaction of β -cyclodextrins can better embed curcumin and improve its solubility. For example, the delivery vector prepared by hydroxypropyl- β -cyclodextrin has better solubilization effect on curcumin than that of β -cyclodextrin. The

delivery carrier of hydroxypropyl β -cyclodextrins curcumin prepared by saturated aqueous solution increased the solubility of curcumin in water by 276 times [14] and the bioavailability of oral curcumin by 3 times [15].

3.2 Solid-type curcumin-loaded β -cyclodextrins inclusion

The solid particle delivery carrier made of β -cyclodextrins can be made into powder, which is convenient for transportation and storage, and has a wider range of applications. There are two technological routes for preparing solid particles. One process is to mix β -cyclodextrins and the buried substance directly, grind and mix with a ball mill or in a mortar, so that the buried substance can fully combine with the β -cyclodextrins [16]. Another process is using β -cyclodextrins and embedded material to form inclusion compound in solution, and use solvent evaporation, low-temperature drying, freeze-drying or spray drying to obtain solid particles [17, 18]. Based on solid type β -cyclodextrins curcumin delivery carrier, the maximum load of curcumin can reach one half of the total weight. β -cyclodextrins prepared by grinding method of curcumin in water solubility is about 100 times higher than free of curcumin, the β -cyclodextrins prepared by solvent evaporation method curcumin solid particles can increase the solubility of curcumin is about 1026 times, the β -cyclodextrins prepared by freeze-drying method curcumin can increase the solubility of curcumin 1052 times [19]. In addition, the solid granule-based β -cyclodextrins curcumin delivery vector has a very good storage stability, and the retention rate of curcumin is still up to 90% after three months of storage at 25°C [19].

3.3 Gel-type curcumin-loaded β -cyclodextrins inclusion

Gel is a kind of semi-solid matrix that liquid filled in a three-dimensional network structure [20]. In different solvent systems, the gel processes of β -cyclodextrins are similar. Briefly, β -cyclodextrins dispersed in the solvent, and then increased the temperature of solution by heating. Meanwhile, β -cyclodextrins would form dimers head on tail to tail, a large number of dimers assemble to form gel fiber clusters, and a lot of fibers clusters bind each other to create a three-dimensional network structure of the gel [21]. β -cyclodextrins gels can be used as a chemical material, as well as a carrier for drugs and fat-soluble natural substances.

Gels can be classed as hydrogels and organogels. The hydrogel is a three-dimensional polymer network structure filled with aqueous solution [22]. β -cyclodextrins can form hydrogels through direct cross-linking, copolymerization with other monomers, fixation in the hydrogel matrix and turbomolecular self-assembly [23]. β -cyclodextrins hydrogels have good development prospects in the delivery of delivery drugs and functional factors due to their responsiveness to

stimuli such as temperature and thixotropism and good biocompatibility [24]. Nanoparticle dispersions of β -cyclodextrins-curcumin was prepared by means of saturated solution method, and then solid particles were obtained by freeze-drying, and then solid particles were evenly mixed into the aqueous solution of acrylic polymer (gel factor), and the mixed solution was gelled by adjusting pH value to obtain hydrogel of β -cyclodextrins curcumin [25]. β -cyclodextrins prepared by grinding method of curcumin solid particles, and then blended with chitosan solution, and then get a heat-sensitive hydrosol by cooling [26], β -cyclodextrins curcumin hydrogel has the very good permeability, can be used as an adjunct to the treatment of arthritis and can also be added in food matrix, with oral intake, a slow-release role in gastrointestinal digestion.

4 Conclusions

Curcumin, as a natural pigment and functional active substance, has a long history in the application of food and flavoring. However, its poor water-solubility, unstable properties and low biological utilization rate have always been the problems that limit its development and utilization. Based on the unique chemical structure and good delivery performance of β -cyclodextrins, it can effectively overcome the shortcomings of curcumin and expand the application range of curcumin in food and flavoring. At present, liquid-type delivery carriers and solid-type based delivery carriers have shown many practical advantages, but gel-type delivery carriers are still worthy of further study. Due to the unique structural characteristics and physicochemical properties of the gel, it can be expected that in the future, the β -cyclodextrins gel will be paid more attention to and studied in the field of food. With the development of new technologies and processes, the curcumin loaded β -cyclodextrins delivery vector can be applied in the food industry more widely.

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