Food Chemistry 229 (2017) 542–552

Contents lists available at ScienceDirect

Food Chemistry

journal homepage: www.elsevier.com/locate/foodchem

Review

Encapsulation and delivery of food ingredients using starch based systems

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ARTICLE INFO

Article history:
Received 28 November 2016
Accepted 20 February 2017
Available online 22 February 2017

Keywords:
Starch modification
Encapsulation
Controlled release
Bioactive
Emulsion
Bioavailability

ABSTRACT

Functional ingredients can be encapsulated by various wall materials for controlled release in food and digestion systems. Starch, as one of the most abundant natural carbohydrate polymers, is non-allergenic, GRAS, and cheap. There has been increasing interest of using starch in native and modified forms to encapsulate food ingredients such as flavours, lipids, polyphenols, carotenoids, vitamins, enzymes, and probiotics. Starches from various botanical sources in granular or amorphous forms are modified by chemical, physical, and/or enzymatic means to obtain the desired properties for targeted encapsulation. Other wall materials are also employed in combination with starch to facilitate some types of encapsulation. Various methods of crafting the starch-based encapsulation such as electrospinning, spray drying, antisolvent, amylose inclusion complexation, and nano-emulsification are introduced in this mini-review. The physicochemical and structural properties of the particles are described. The encapsulation systems can positively influence the controlled release of food ingredients in food and nutritional applications.

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http://dx.doi.org/10.1016/j.foodchem.2017.02.101
0308-8146/

1. Introduction

Targeted delivery of food ingredients by encapsulation is commonly used in a variety of food and nutritional applications (McClements & Li, 2010). Encapsulation of functional ingredients protects them from harsh processing conditions during food production, improves the food safety by better inhibiting microbial growth, and enhances sensory quality by masking unpleasant flavour (e.g., bitterness of polyphenols) (Gökmen et al., 2011; Hasanvand, Fathi, Bassiri, Javanmard, & Abbaszadeh, 2015; Nielsen et al., 2016). For example, encapsulation of isoeugenol in emulsion enhanced the antibacterial activity against *Escherichia coli* K12 and *Listeria monocytogenes* in carrot juice by 2.5 times (Nielsen et al., 2016). Encapsulation of unsaturated fatty acids of flax seed oil in amylose inclusion complexes greatly reduced the lipid oxidation during bread production (Gökmen et al., 2011). Encapsulation of bioactive ingredients can improve the bioavailability of bioactive molecules during human digestion. The encapsulation enhances the water solubility of bioactive ingredients, protects them against unfavourable conditions in certain part of the digestive tract (e.g., stomach) and releases them in targeted area (e.g., intestine) for better absorption by human (Cohen, Schwartz, Peri, & Shimoni, 2011; Wang et al., 2015). For example, encapsulation of genistein (a type of isoflavones) by amylose inclusion complexes increased the *in vivo* bioavailability in a rat model (Cohen et al., 2011).

A range of food ingredients can be encapsulated for targeted delivery. They can be both hydrophilic and hydrophobic and include polyphenols, vitamins, oils, carotenoids, enzymes, flavours, living cells (e.g., probiotics), and so on (Chin, Yazid, & Pang, 2014; Li, de Vries et al., 2009; Mun, Kim, & McClements, 2015a; Wang, Li, Chen, Xin, & Yuan, 2013). These food ingredients tend to have a rather low stability during processing and a low bioaccessibility upon ingestion, which can be significantly improved by encapsulation. Diverse wall materials have been used for the encapsulation, including proteins, carbohydrates, lipids, and so on (Fathi, Martín, & McClements, 2014; Joye & McClements, 2016; McClements & Li, 2010). They are used individually or in combination, depending on the type of the food ingredients and the encapsulation methods. Various encapsulation methods include electrospinning, gelation, layer-by-layer deposition, extrusion, co-precipitation, coacervation, spray/freeze drying, emulsion formation, and so on (Fathi et al., 2014; Joye & McClements, 2016; McClements & Li, 2010). Different encapsulation methods result in different nanostructures or microstructures with different physicochemical and delivery properties.

Starch is a major component of our diet and is widely used in food and other industries. It consists of two major types of biopolymers including amylose and amylopectin. Amylose is linear while amylopectin is branched. These two starch components are assembled in the form of granules with the size ranging from 1 to 100 μm (Pérez & Bertoft, 2010). Native starch is commonly modified by physical, chemical, and/or enzymatic methods to have the desired properties (e.g., increased hydrophobicity as in octenyl succinic anhydride-modified starch) for different applications including encapsulation and controlled release (Fathi et al., 2014; Wurzburg, 1986). Compared with lipid based delivery systems, polysaccharide (e.g., starch) based systems can encapsulate a range of hydrophilic and hydrophobic food ingredients through modifications. Compared with lipid and protein based systems, polysaccharide based systems are more suitable wall materials under high temperature conditions as lipid/protein may melt/denature (Fathi et al., 2014). There has been increasing interest of using starch based delivery systems to encapsulate various food ingredients as reflected by the increasing number of publications during the last few years (Chin et al., 2014; Gökmen et al., 2011; Hasanvand et al., 2015; Li, de Vries et al., 2009; Mun et al., 2015a; Nielsen et al., 2016; Wang et al., 2013). Starch is GRAS, low in cost, non-allergenic, and bland in taste. Some comparative studies showed that starch based systems gave a higher encapsulation efficiency and provided better protection of food ingredients (e.g., flaxseed oil and flavours) against unfavourable environment than protein and gum arabic based systems (Charve & Reineccius, 2009; Tonon, Pedro, Grosso, & Hubinger, 2012). There is a tremendous amount of knowledge on composition, structure, properties, and modifications of starches from diverse sources (Pérez & Bertoft, 2010; Wurzburg, 1986). This provides a solid background of using starches to encapsulate food ingredients for controlled release applications. This min-review summarises the encapsulation of different food ingredients using various starch based systems (Tables 1 and 2). The preparation and characteristics of the encapsulation systems as well as the controlled release of the ingredients are reviewed with a focus on the role of starch in the encapsulation process. There is a very large amount of literatures published in the recent years and it's impossible to list all of them in the present review. Therefore, some papers are selected to represent different types of starch systems for encapsulation.