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Emulsifying behaviors and interfacial properties of different protein/gum arabic complexes: Effect of pH

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ABSTRACT

Emulsifying behaviors and interfacial properties were two key properties related to microencapsulation processes. This study mainly focused on the above characters of soy proteins/gum arabic (SP/GA) complexes and gelatin/GA complexes. The complexes were prepared at different forming stages (i.e., at $pH_{\varphi 1}$, pH_{opt} and pH_{pd}) with 1:1 protein/GA ratio. The results revealed the emulsifying activity (EA) for SP/GA systems was higher than that for gelatin/GA systems, indicating its better combining capacity with oil droplets. While SP/GA systems showed lower interfacial tensions (21–25 mN/m) than gelatin/GA systems. Through analysis of interfacial tensions and EA data, negative correlations between them were found: the higher the interfacial tensions of complexes with oil droplet, the lower the EA was. Compositional analysis indicated different yield and polymer recovery were obtained at different systems due to ζ potential differences. These findings suggested SP/GA complexes could be used as effective microencapsulated materials in terms of oil combining.

1. Introduction

Proteins and polysaccharides are two important components in daily food. In food processing, complex formation between proteins and polysaccharides is a common phenomenon (Turgeon, Beaulieu, Schmitt, & Sanchez, 2003). Complex formation, arising from electrostatic interaction, occurs when two oppositely charged polymers are coexisted in aqueous media, leading to the formation of soluble or insoluble complexes. Controlling protein/polysaccharide interactions through complex formation may offer a means for improving their functional role as ingredients without chemical or enzymatic modification. In recent years, protein/polysaccharide complexing attracted considerable interest since its potential applications in food industry, such as fat replacement (Le Révérend, Norton, Cox, & Spyropoulos, 2010), microencapsulation of food ingredient (Gharsallaoui, Roudaut, Chambin, Voilley, & Saurel, 2007), protein separation and purification (Xu, Mazzawi, Chen, Sun, & Dubin, 2011), emulsification and foam stabilization (Dickinson, 2009; Miquelim, Lannes, & Mezzenga, 2010), food products stabilization (Laurent & Boulenguer, 2003), and enzyme immobilization and recovery (Xia, Mattison, Romano, Dubin, & Muhoberac, 1997).

Generally, the electrostatic complexes formed between proteins and polysaccharides via the synergistic combination of the two polymers possessed many different functional properties (Hosseini, Emam-Djomeh, Sabatino, & Van der Meeren, 2009). Previous studies showed that the change in protein conformation caused by polysaccharides and pH allowed the complexes having varied surface properties. As a result, new functional properties were formed (Chourpa, Ducel, Richard, Dubois, & Boury, 2006; Turgeon et al., 2003). In this case, many researchers paid attention to functional properties study of protein/polysaccharide complexes, such as emulsifying behaviors (Girard, Turgeon, & Paquin, 2002), foaming properties (Liu, Elmer, Low, & Nickerson, 2010), interfacial properties (Ducel, Richard, Popineau, & Boury, 2005), rheological properties (Ru, Wang, Lee, Ding, & Huang, 2012) and so on.

Emulsifying behaviors and interfacial properties of the complexes were two key factors influencing the preparation of microcapsules, which was treated as the most important industrial use of protein/polysaccharide complexes (Ducel, Richard, Popineau, & Boury, 2005). For emulsifying behaviors, Li, Fang, Al-Assaf, Phillips, and Jiang (2012) found that at low pHs and low bovine serum albumin/sugar beet pectin ratios, the formation of bovine serum albumin/sugar beet pectin complexes obviously improved the

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stability of emulsions. They proposed that the stabilization was controlled by the cooperative adsorption of the two components at the oil-water interface. Through electrostatic complexation bovine serum albumin promoted the adsorption of sugar beet pectin to interfaces to form a thick steric layer around emulsion droplets and thus provided better stability. Liu, Elmer, Low, and Nickerson (2010) reported that pea protein isolate/gum arabic complexes emulsion stability and foam stability were improved for the mixed system between pH 3.10 and 4.00, where complexes could be formed. The improved stability of emulsions using biopolymer admixtures were also reported for canola protein/hydrocolloids (Uruakpa & Arntfield, 2005) and carboxymethylcellulose/potato protein isolates (Vikelouda & Kiosseoglou, 2004) systems. For interfacial properties, Ducel, Richard, Popineau, and Boury (2005) studied the interfacial properties of two plant proteins themselves and the complexes with gum arabic. In their study, they concluded that the increased adsorption of the complexes at the oil/water interface compared to that of the protein alone could be related to the higher hydrophobicity of the complexes. In that case, hydrophobic residues of the protein could be exposed toward the oil phase, with the hydrophilic groups of arabic gum remaining masked inside the complexes. Miquelim et al. (2010) also demonstrated that ovalbumin/polysaccharides complexes significantly reduced the interfacial tension of the mixed system with the similar method.

In microencapsulation processes, it was very interesting to find that microcapsules prepared by different protein/polysaccharide complexes presented varied properties and morphological structures. These phenomena were considered to be related to the properties of the complexes. Ducel, Richard, Popineau, and Boury (2005) reported that the morphological structures and the microencapsulation efficiency for different plant protein/gum arabic complexes showed significant variation because of the differences in the interfacial rheological properties of different complexes film. However, few studies were conducted on the relationship between the properties of complexes and microencapsulation. In this paper, the emulsifying behaviors and interfacial properties of soy proteins/gum arabic complexes were investigated and compared with those of heat-treated soy proteins/gum arabic complexes and gelatin/gum arabic complexes, which was beneficial to clarify the properties of different raw food material complexes which directly influenced microencapsulation formation.

2. Materials and methods

2.1. Materials

Hexane defatted and flush desolventized soy flake, provided by Shandong Wonderful Industrial & Commercial Co. Ltd. (Dongying, Shandong, China), had a protein content of 52.4% (dry basis) and nitrogen solubility index (NSI) of 85%. Soy proteins (SP) were prepared as reported previously (Dong et al., 2013). The analysis showed that the dried powder had protein contents of 92.8% as determined by the Kjeldahl method (AOAC, 2000) with a nitrogen conversion factor of 6.25 on a dry basis.

Powder gum arabic (Instant gum AA, GA) was a gift from the Tianjin Jebsen Specialty Chemicals Co. Ltd. (Tianjin, China), and the composition was 2.2% protein, 10.7% moisture and 3.3% ash, and nearly lipid-free. Chemical analysis was conducted according to AOAC methods (2000). Carbohydrate content was calculated on the basis of percent differential from 100%.

Gelatin (G) was purchased from Sinopharm Co., Ltd..

2.2. Stock solution preparation

SP and GA stock solutions were prepared as reported previously (Dong et al., 2013). Certain volume of SP solution was heated for 30 min at 85 °C and 95 °C in the condition of seal, getting 85-SP and 95-SP solutions, respectively. Gelatin stock solution was prepared by dissolving gelatin powders in distilled water under gentle stirring at 45 °C for 2 h. Then, the stock solutions were centrifuged at 3000g for 30 min at room temperature to remove insoluble matter or air bubbles.

2.3. Turbidity titration

Stock solutions were diluted to 0.1% (w/v) with distilled water. Then, protein/GA mixtures at 1:1 mixing ratio were prepared by adding protein solution to GA solution. Turbidity titration curves were measured using a UV-2450 spectrophotometer (Shimadzu, Kyoto, Japan) at 600 nm with glass cuvettes (1 cm path length).

2.4. ζ potential measurement

Stock solutions were diluted to 0.05% (w/v) with distilled water. ζ potential of the solutions were determined at different pH values (25.0 ± 0.1 °C), using Zetasizer Nano ZS instrument (Malvern, British). Each sample repeated three times.

2.5. Emulsifying behaviors

The SP/GA, 85-SP/GA, 95-SP/GA, and G/GA solutions were used to measure emulsifying behaviors by the method of Xie and Hettiarachchy (1997) with some modifications. In this section, the polymer total concentration was set at 1% (w/v), and the protein/GA ratio was 1:1. First, the solutions were adjusted to certain pH values. Then, pure soybean oil (1%, w/v) were added and homogenized in a mechanical homogenizer (Virtishear Tempest, The VirTis Co., Gardiner, NY) at 10000 rpm for 2 min. Emulsion was taken from the bottom of the container at 0 and 10 min and mixed with 0.1% sodium dodecyl sulfate (SDS) to dilute for 10-folds. Absorbance of the emulsions was measured at 500 nm using UV-2450 spectrophotometer (Shimadzu, Kyoto, Japan). Absorbance measured immediately after emulsion formation (0 min) was expressed as emulsifying activity (EA). The emulsifying stability (ES) was determined according to Eq. (1):

$$ES = T/T_0 \quad (1)$$

where T_0 and T were turbidities at 0 and 10 min, respectively.

2.6. Measurement of the interfacial tension

The interfacial tension was determined by means of a drop method (Tracker, IT Concept, Longessaigne, France) as reported by Ducel, Richard, Popineau, and Boury (2005). In the present study, a pendant drop of complexes preparation was formed in pure soybean oil, since the turbidity of the preparation was too high to form an oil drop. The temperature was always maintained at room temperature during interfacial tension measurements.

2.7. Protein/GA complexes preparation

The protein/GA solutions with protein/GA ratio of 1:1 and total concentration of 1% (w/v) were prepared. The mixtures were held at room temperature under stirring rate of ~400 rpm. HCl (1 mol/L) was used for acidification to desired pH values. Then, the mixtures were stirred for 30 min continuously. After that, the mixtures were centrifuged under 2200 g at room temperature for 30 min. Protein/GA complexes were separated by decanting the upper layer of the equilibrium fluid. The obtained protein/GA complexes were