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Effect of gum Arabic on stability of oil-in-water emulsion stabilized by flaxseed and soybean protein

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ABSTRACT

The effects of gum Arabic (GA) addition (0–4%, w/w) on stability of oil-in-water emulsion stabilized by flaxseed protein concentrate (FPC) and soybean protein concentrate (SPC) were studied. The result shows that emulsions stabilized by both proteins in the presence of the 2% gum Arabic (w/w) have better stability than its absence, by increasing the emulsion viscosity of the FPC stabilized emulsion and causing competitive adsorption between the GA and SPC layer to give a steric repulsion for the SPC stabilized emulsion, respectively. Then, the influences of ionic strength (0–200 mM NaCl) and temperature (25–95 °C for 20 min) on these emulsions in presence of GA were determined. The GA adsorbed at SPC-stabilized oil–water interface provided stability against NaCl concentration. In presence of GA, the SPC-stabilized emulsions also showed better stability at higher temperatures compared to the FPC-stabilized emulsions due to the denaturation of SPC and competitive adsorption between GA and SPC at higher temperatures.

1. Introduction

Many food products are in the form of oil-in-water (O/W) emulsions consisting small lipid droplets dispersed in an aqueous phase, such as salad, milk, cream, beverages and desserts (Grigoriev & Miller, 2009; Leal-Calderon, Thivilliers, & Schmitt, 2007; Sikora, Badrie, Deisingh, & Kowalski, 2008). These emulsions are thermodynamically unstable and are prone to destabilization (Dickinson, 1992; Guzey, Kim, & McClements, 2004; McClements, 1999). Destabilization of these emulsions can occur through variety of physicochemical processes such as gravitational separation, flocculation, coalescence, and Ostwald ripening (McClements, 1999). One of the most commonly used methods to improve the stability of O/W emulsions is to utilize emulsifiers (Stauffer, 1999). Emulsifiers are surface-active compounds which adsorb at oil–water interface and facilitate the droplet formation and stabilization by lowering the surface tension. They also prevent droplet aggregation by generating repulsive forces between droplets (Walstra, 1993). In food and pharmaceutical applications, there is an increasing trend of using 'green' emulsifiers such as protein and polysaccharides to produce and stabilize emulsions (Dickinson, 1993; Gariti, 1999; Mirhosseini, Tan, Hamid, & Yosuf, 2008; Wang, Li, Wang, & Özkan, 2010; Wang, Li, Wang, Adhikari, & Shi, 2010; White et al., 2008). Generally, proteins are the main emulsifiers and the polysaccharides contribute to the stability of emulsions through their thickening and steric stabilizing characteristics. The interactions between proteins and the carbohydrates can also help stabilizing the emulsions. Several polysaccharides have been used together with proteins to enhance the emulsion stability. The combinations such as whey protein isolate/gum Arabic (Klein, Aserin, Svitov, & Garti, 2010), β-lactoglobulin/pectin (Guzey & McClements, 2007), β-lactoglobulin/ι-carrageenan (Gu, Regnier, & McClements, 2005), whey protein/chitosan/gum Arabic (Moschakis, Murray, & Biliaderis, 2010) and milk protein products/xanthan (Hemar, Tamehana, Munto, & Singh, 2001) are most frequently used.

Gum Arabic is a complex blend of natural polysaccharides composed of three components differing in molecular size and protein content (Mahendran, Williams, Phillips, & Al-Assaf, 2008; Randall, Phillips, & Williams, 1989). These are commonly referred to as the arabinogalactan–protein (AGP, about 10 wt% of total), arabinogalactan (AG, about 90–99 wt% of total) and glycoprotein (GP, about 1 wt% of total) (Phillips & Williams, 2000). In the gum Arabic obtained from *Acacia senegal* (L.), the molecular weight of AGP and AG are 286 kDa and 1860 kDa, respectively. The three populations of GP have molecular weight of 2670 kDa, 776 kDa and 295 kDa (Renard, Lavenant-Gourgeon, Ralet, & Sanchez, 2006). It has been shown that the protein-containing faction of this gum adsorbs on

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Nomenclature

η	apparent viscosity, Pa s
η_∞	infinite shear rate limiting viscosity, Pa s
$\dot{\gamma}$	shear rate, s^{-1}
K	consistency coefficient in Sisko model, Pa s^n
n	flow behavior index of Sisko model, dimensionless
A	absorbance of 500 nm wavelength light of emulsions
T	turbidity of emulsions, m^{-1}
V	dilution factor, dimensionless
l	path length of the cuvette, m
ESI	emulsifying stability index of emulsion, h

the oil–water interface. Therefore, gum Arabic can be used not only as a stabilizer for increasing emulsion viscosity, but it also contributes as emulsifier to create surface active layer at water–oil interface.

Soybean protein has been widely used as a source of high quality proteins in many food products because of its excellent functional properties and low cost. It is preferred in stabilizing O/W emulsions because of the surface active properties of its constituent proteins: 7S and 11S globulins (Palazolo, Mitidieri, & Wangner, 2003). It has been shown that soybean protein decreases the interfacial tension at the oil–water interface and stabilizes the emulsions by forming a physical barrier at the oil–water interface (Molina, Papadopoulou, & Ledward, 2001). It is also reported that the soybean protein possesses better emulsifying properties compared to many other plant proteins (Hettiarachchy & Kalapathy, 1998; Tornberg, Olsson, & Persson, 1997; Zayas, 1997). Recent studies on flaxseed have shown that it contains two protein fractions: a salt-soluble protein with high molecular weight (11–12S globulins) and a water-soluble protein with low molecular weight (1.6–2S globulins) (Madhusudhan & Singh, 1983; Madhusudhan & Signh, 1985; Marcone, Kaduda, & Yada, 1998; Youle & Huang, 1981) with molecular weights of 29.4 kDa and 16 kDa, respectively. These flaxseed proteins are also found to be beneficial to various diseases such as coronary heart disease, kidney disease and cancer (Oomah & Mazza, 2000; Wang et al., 2009; Wang, Li, Wang, & Özkan, 2010). It has also been shown that flaxseed protein concentrate has better water and oil absorption, emulsifying activity and emulsion stability compared to soybean protein (Dev & Quensel, 1988, 1989).

The objective of this study was to investigate the effect of gum Arabic (GA) on the stability of O/W emulsions stabilized by flaxseed protein concentrate (FPC) or soybean protein concentrate (SPC). Furthermore, using the best addition concentration of GA, the effect of environmental stresses such as ionic strength and heating on the emulsion stability was also determined. The study will provide further insights regarding the interaction between GA and these two types of proteins, then benefit for using them in food industrial application.

2. Materials and methods

2.1. Materials

Gum Arabic (GA) was purchased from Xilong Chemicals (Shantou, Guangdong province, China). Soybean protein concentrate was donated by Buer Soybean Protein Corporation (Jilin Province, China). Food grade soybean oil (Fortune, Beijing, China) and flaxseed (Henan province of China) were purchased from local market. Flaxseed protein was extracted using Oomah et al.'s method with some modification (Oomah, Mazza, & Cui, 1994). The crushed flaxseed was defatted using hexane at a ratio of 1:6 for 6 h. The hull was separated from the kernel by screening the tailings using a 0.15 mm sieve. The flaxseed kernel powder obtained by this method contained a negligible quantity of the hull. This powder was subsequently soaked in 0.1 M Tris buffer (pH 8.6 with 0.1 M NaCl) at a seed-to-buffer ratio of 1:16 for 24 h. The extract was passed through double layered cheesecloth to remove large residues. Subsequently, it was centrifuged at 9000 rpm for 20 min using an ultracentrifuge (GL-20G-II, Anke Corporation, Shanghai, China). The pH of the supernatant was adjusted to 4.2 (iso-electric point of flaxseed protein) using 0.1 M HCl. The extract was stored at 4 °C for 16 h to allow the protein to precipitate completely. The precipitate was subsequently centrifuged at 12,000 rpm for 20 min. The pH of this protein concentrate was adjusted to 7.0 by using 0.1 M NaOH and finally freeze-dried (LGJ-18 C, Sihuan Corporation, Beijing, China) to obtain the flaxseed concentrate powder.

Table 1
Proximate composition (%) (w/w) of flaxseed protein (FPC) and soybean protein (SPC) concentrates.

Constituent (%) (w/w)	FPC	SPC
Protein	87.25 ± 1.64	88.73 ± 1.36
Fat	2.43 ± 0.44	3.25 ± 0.13
Moisture	5.24 ± 0.10	4.85 ± 0.15
Ash	2.03 ± 0.06	1.78 ± 0.16

These data are the average of the three replicates.

The protein content of the concentrates was determined by Kjeldahl method. The fat content was determined by Soxhlet extraction. The moisture and ash contents of the extract were determined by oven drying (105 °C for 24 h and 550 °C for 12 h, respectively). The main composition of SPC and FPC is provided in Table 1.

2.2. Preparation of protein polysaccharide dispersions

Protein and GA dispersions (w/v) were prepared by dissolving the desired amount of SPC, FPC and GA powder in deionized water containing 0.04% (w/v) sodium azide. The sodium azide was used as a protective agent against the microbial growth. These dispersions were stirred overnight to ensure complete dissolution. The pH of all the protein and polysaccharide solutions was adjusted to 7.0 using 0.1 M HCl or 0.1 M NaOH as required.

2.3. Emulsion preparation

Coarse emulsions containing 10% (v/v) soybean oil and 1% (w/v) protein were produced by blending soybean oil (v/v) with protein solutions (v/v) together using an ultra turrax (T25, IKA, Staufen, Germany) at 15,000 rpm for 2 min. Subsequently, the primary emulsions were prepared by passing these coarse emulsions through a homogenizer (NS1001L-PANDA 2 K, Niro Soavi S. P. A., Parma, Italy) at 300 bar pressure for first pass and subsequently at 500 bar pressure for further three passes. The primary emulsions were neutralized using 0.1 M HCl or NaOH. Secondary emulsions were prepared by diluting the primary emulsions with desired amount of gum Arabic solutions. The pH of these secondary emulsions was also brought to 7.0 with the use of 0.1 M HCl or NaOH as required and finally passed through the homogenizer at 200 bar pressure.

The final emulsions containing 0.8% (w/v) protein, 8% (v/v) soybean oil and 0–4% (w/v) GA were stored at 4 °C. Before further analysis and tests, the stored emulsions were brought to ambient temperature by allowing them to stand for 2 h.

2.4. Droplet size and zeta-potential

When the emulsions were aged for 24 h their droplet size and zeta-potential were determined by dynamic light scattering (DLS)