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# Effect of xanthan and guar gums on the formation and stability of soy soluble polysaccharide oil-in-water emulsions

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ABSTRACT

The incorporation of relevant amounts of non-adsorbing hydrocolloids to oil-in-water (O/W) emulsions is a suitable alternative to reduce creaming. The effect of incorporating xanthan gum (XG) or guar gum (GG) in soy soluble polysaccharide (SSPS) stabilized oil-in-water (O/W) emulsions was studied. The emulsions contained 6 wt.% of SSPS, 20 wt.% Perilla seed oil (PSO), an omega-3 vegetable oil, and variable amounts of XG or GG ranging from 0.03 to 0.3 wt.%. The presence of minute amounts of XG or GG in fresh emulsions significantly decreased the emulsion droplet size (EDS) although such low concentrations did not provide enough continuous phase viscosity to arrest creaming. Emulsion microstructure indicated the presence of flocculation even at high concentrations of XG or GG caused by a depletion mechanism. All emulsions with XG or GG exhibited pseudoplastic behavior while the control emulsions showed an almost Newtonian behavior. Emulsion droplet polydispersion generally decreased with increase in the continuous phase viscosity indicating the importance of continuous phase viscosity in the dissipation of shear energy throughout the emulsion during homogenization. The characteristics of the emulsions were closely related to the rheological changes of the continuous phase.


## 1. Introduction

Food hydrocolloids have been exploited for a number of years in many food systems (Viebke et al., 2014). Food hydrocolloids are high molecular weight hydrophilic biopolymers used as functional ingredients in the food industry to manipulate microstructure, texture, flavor and shelf-life of products (Dickinson, 2003). Most hydrocolloids do not possess surface-active strength with the exception of mainly gum Arabic, modified starch or cellulose derivatives, naturally occurring galactomannan polymers, and others. Surface-active hydrocolloids are used primarily as emulsifiers, just in the same manner as most proteins are used to stabilize food dispersions and emulsions through their interfacial activity.

Obtaining a stable oil-in-water (O/W) emulsion remains to be a great challenge for the food industry and it is here that the non-adsorbing hydrocolloids find their role. Various researchers including Quintana et al. (2002) and Dickinson (2008) have reported the use of non-adsorbing hydrocolloids as stabilizers in food emulsions so as to improve creaming stability. Substantial increase in the aqueous phase viscosity is the primary key to arrest emulsion droplet movement, thereby improving creaming stability. The efficiency of a polymer in this regard depends on the concentration of the polymer in the aqueous phase of the emulsion as well as on the structural features of the aqueous polymer system. For instance, McClements (1999) reports that polymers that form weak-gel-like network in the continuous phase would result in very high viscosities in the low stress range and imparts additional elastic properties to the whole system so that emulsion creaming is strongly inhibited.

Numerous studies have been reported on the interactions of hydrocolloids and proteins, both in aqueous solutions and at the surface of adsorbed protein in an emulsion (Dickinson, 2011). It has been established that in solution, a mixture of proteins and hydrocolloids may exhibit miscibility, thermodynamic incompatibility, or complex coacervation. Whereas, at the interface, when protein is adsorbed, associative interactions could occur due to hydrogen bonding or electrostatic interactions resulting in the so called double-stabilizing layer at the surface of the oil droplet (Dickinson, 2003) given that the added polysaccharide is at sufficient concentration, otherwise bridging flocculation occurs. However there has been few studies to evaluate the effect of adding non-adsorbing hydrocolloids to an emulsion employing a surface active hydrocolloid as the system's sole emulsifier. In this work, we produced emulsions with soy soluble polysaccharide (SSPS) as a sole emulsifier and investigated the effect of adding xanthan (XG) or guar gum (GG).

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Xanthan is an anionic extracellular polysaccharide produced by *Xanthomonas Campestris* bacteria (Desplanques et al., 2012). The composition of XG is of glucose, mannose, and glucuronic, pyruvic and acetic acids. The structure and properties of XG are relatively well documented (Gordon, 1990). XG is resistant to pH variations. Due to stability in both alkaline and acidic conditions, XG is being used in a wide range of products. Kobori et al. (2009) found that XG was stable in pH ranging from 5.5–3 and Poojaa et al. (2014) also found that XG stabilized gold nanoparticles were stable to pH changes in the range of 5–9. Several industries employ XG as a thickening (Sopade et al., 2008) or stabilizing agent (García-Ochoa et al., 2000). Aqueous dispersions of XG contain highly ordered networks such that the solutions are highly viscous at low shear rates, and exhibit low viscosity at high shear rates, due to the disruption of the network and the alignment of the individual macromolecules in the direction of shear (Hemar et al., 2001). GG is a neutral galactomannan, which is produced from the endosperm of the guar plant *Cyamopsis teragonoloba*. GG solutions are stable over a wide pH range and the non-ionic nature of the molecule is responsible for the almost constant viscosity of its solutions in the pH range of 1.0–10.5. The molecular weight is more than $10^3$ kDa (Narchi et al., 2009). The specific polysaccharide component of guar gum is guaran, a galactomannan where about one-half of the β-D-mannopyranosyl main-chain units, joined by (1 → 4) bonds, contain an α-D-galactopyranosyl side chain attached at the C6-position (Long et al., 2012). One of the major advantages of GG is that it could swell and dissolve readily in cold water due to the higher galactose content. Therefore, GG is widely used in the food industry as thickening, water holding or stabilizing agents (Long et al., 2012).

SSPS is an acidic polysaccharide extracted from soybean cotyledons. SSPS is composed of a main rhamnogalacturonan backbone branched by β-1,4-galactan and α-1,3- or α-1,5-arabinan chains, and homogalacturonan (Nakamura et al., 2001). Changing the extraction conditions of SSPS results in the production of SSPS with different molecular weight, composition and functionality. In the present study, three types of SSPS, code named SSPS-L, SSPS-M and SSPS-H, have been used. These three were chosen because they have been characterized in previous studies in terms of their emulsifying ability and physical properties of their O/W emulsions (Chivero, Gohtani, Yoshii & Nakamura, 2014 and Nakamura et al., 2004). Variable absolute molecular weight values for the different types of SSPS have been published in several literature (Chivero, Gohtani, Ikeda & Nakamura, 2014; Nakamura et al., 2012; Nakauma et al., 2008; and Wang et al., 2005). In general, size exclusion chromatography showed that SSPS-L had the least amount of high molecular weight fraction compared to SSPS-M and SSPS-H (Nakamura et al., 2004). According to Nakamura et al. (2004), SSPS possesses emulsifying activity and it was established that lower amounts of SSPS are required to stabilize emulsions compared to those reported for gum Arabic and modified starch. The emulsifying properties of SSPS were found to be dependent on the fine structure and molecular weight of SSPS. Enzymatic degradation of SSPS to remove the side chains resulted in oil droplet aggregation, indicating that oil droplet stabilization occurred mainly via steric repulsion (Nakamura et al., 2004). It was also reported that emulsifying properties of SSPS were compromised after hydrolysis with trypsin (Nakamura et al., 2006). The protein fraction associated with the high molecular weight fraction of SSPS was seen to be fundamental to the adsorption at oil–water interfaces.

SSPS could serve as both an emulsifier and a stabilizer if high concentrations of the polymer are used in emulsion preparation. Unadsorbed SSPS aggregates would remain in the continuous phase of the emulsion and restrict the movement of emulsion droplets. However, high concentration solutions of SSPS are very difficult to prepare due to high viscosity. In order to fully stabilize SSPS emulsions, non-adsorbing stabilizers are necessary. Therefore, the aim of this study was (i) to investigate the interactions that could occur between adsorbed SSPS and XG or GG dispersions and (ii) to study the effect of XG or GG concentration on emulsion droplet size (EDS), droplet size distribution (DSD), stability and rheology of SSPS O/W emulsions.

## 2. Experimental

### 2.1. Materials

Samples of SSPS (type SSPS-L, -M and -H) were provided by Fuji Oil Co., Ltd. (Tokyo, Japan). The samples are differentiated by their extraction conditions as outlined in Section 2.2 below and their composition is shown in Table 1. Perilla seed oil (PSO) from genus *Perilla Frutescens* containing 60 g of α-linolenic acid, 13 g of linoleic acid, and 14 g of oleic acid, was purchased from a conventional retail shop. Analytical grade sodium azide ($NaN_3$) antimicrobial was purchased from Nacalai Tesque (Kyoto, Japan). Polysaccharides xanthan gum (XG) and guar gum (GG) were purchased from Sigma (Sigma-Aldrich, St. Louis, MO) and Wako Pure Chemical Industries (Osaka, Japan), respectively. Purified water was prepared using a Barnstead E-pure system (Dubuque, USA).

### 2.2. Preparation of SSPS

SSPS-L and -M were prepared using the method of Nakamura et al. (2004). SSPS-L and -M were extracted from *okara* (soy bean residue after extraction of oil and protein) using hot water by heating at 120 °C, pH 3.0 for 2 h and 120 °C, pH 4.0–5.0 for 2 h, respectively. Insoluble materials were then removed by centrifugation and the extract was desalted by electric dialysis before being spray dried. The sample named SSPS-H in this paper was prepared using the method of Nakamura et al. (2012). Okara was heated at 120 °C at pH 4.0 for 2 h. Insoluble residue was then centrifuged out, desalted and then concentrated by a rotary evaporator to 20% w/w before being freeze-dried.

### 2.3. Preparation of emulsions

PSO was used as the dispersed phase in the preparation of SSPS O/W emulsions. SSPS dispersion (12%) was prepared by dispersing 0.6 g of dried powder in 5 g of distilled water containing 0.02% sodium azide as an antimicrobial. Dried XG or GG (0.003 g–0.03 g) was dispersed in distilled water (2.370 g–2.397 g) using magnetic stirrers for 1 h after which they were refrigerated overnight for complete hydration prior to use in emulsion preparation. The pH of SSPS dispersions were 5.50, 5.10, and 6.57 for SSPS-L, SSPS-M, and SSPS-H, respectively. The pH of the final emulsions was the same as their respective SSPS solution dispersions since the presence of the polysaccharide dispersion and oil had little influence on the solution pH. No pH adjustments were made to the final emulsions. In order to prepare the primary emulsion, PSO (2 g) was added to SSPS solutions and homogenized for 2 min at 15,000 rpm using a rotor-stator homogenizer, Polytron PT3100 (Kinematica AG, Littau, Switzerland). XG or GG dispersions were then added to the formed primary emulsions and homogenized again at 15,000 rpm for 1 min to form the final emulsion. For control emulsions,

**Table 1**
Monosaccharide compositions of different types of soybean polysaccharide (SSPS).

| Type of SSPS | Sugar composition (mol%) | | | | | | | Protein (dry %) |
|---|---|---|---|---|---|---|---|---|
| | Rha | Fuc | Ara | Gal | Xyl | Glc | GalA | |
| SSPS-L[a] | 4.3 | 1.5 | 15.3 | 48.3 | 1.5 | 1.6 | 27.5 | 8.2 |
| SSPS-M[a] | 4.1 | 2.4 | 20.1 | 47.2 | 1.2 | 1.1 | 23.9 | 5.9 |
| SSPS-H[b] | 2.5 | 1.1 | 21.0 | 43.7 | 6.4 | 5.4 | 19.9 | 5.1 |

Rhamnose (Rha), Fucose (Fuc), Arabinose (Ara), Galactose (Gal), Xylose (Xyl), Glucose (Glc), Galacturonic acid (GalA).
[a] Nakamura et al., 2004.
[b] Nakamura et al., 2012. (Reproduced from, Chivero, Gohtani, Yoshii, et al., 2014).