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# Soybean protein isolate gel particles as foaming and emulsifying agents

Kentaro Matsumiya [a, b, *], Brent S. Murray [a]

[a] Food Colloids Group, School of Food Science and Nutrition, University of Leeds, Leeds LS2 9JT, UK
[b] Laboratory of Quality Analysis and Assessment, Division of Agronomy and Horticultural Science, Graduate School of Agriculture, Kyoto University, Gokasho, Uji, Kyoto 611-0011, Japan

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ABSTRACT

In order to enhance functional properties of commercial soybean protein isolate (SPI), SPI microgel particles as foaming and emulsifying agents were studied. Microparticulation of heat-set SPI macrogels containing no added and various added salts was systematically carried out using a high-speed blender, an ultrasonicator and a high-pressure jet homogenizer. Among the tested conditions, the smallest gel particles were achieved via the high-pressure jet homogenization process under conditions of no added salts. Conversion of ordinary high molecular weight commercial SPI into the counterpart gel particles enhanced foam stabilizing properties of the suspensions and stability against creaming and freeze-thaw triggered instability of the emulsions, while the enhancement was not necessarily achieved for low-molecular-weight partially hydrolysed SPI. This can be attributed to the different steric repulsive effects of the gel particles.



## 1. Introduction

Food products including oils exist as o/w or w/o emulsions where one phase is dispersed as small droplets in the other immiscible phase; for example, fruit cordials, milk beverages and salad dressings (Dickinson, 1992). Even though emulsions differ in their appearance, texture and so on, they are all thermodynamically unstable in principle, and therefore usually subjected to various kinds of periodical destabilization such as creaming, aggregation and coalescence of oil droplets in their shelf life before consumption (McClements, 2004a). In order to slow down the destabilization processes, surface-active food macromolecules like proteins and polysaccharides have been widely and extensively used for emulsion production in the food industry.

Surface-active macromolecules adsorbed at the oil–water interface during emulsification not only lower the interfacial tension and improve emulsification efficiency but also form relatively thick layers around the emulsion oil droplets (McClements, 2004b). These protective layers generate repulsive interactions, *i.e.*, steric and electrostatic forces between oil droplets that lead to improved stability against aggregation and coalescence on the shelf (Dalgleish, 2006). On the other hand, in the last decade, colloidal particle-stabilization known as Pickering stabilization has received increasing attention in the food science field because the even thicker particle layers at the oil–water interface produce even more effective barriers to droplet aggregation and coalescence (Dickinson, 2010).

Common mature examples of Pickering stabilization in foods include protein granules from egg yolk, casein micelles particularly in homogenized milk and ice creams (Dalgleish, 2003) and triglycerides crystals in margarines/spreads (Dickinson, 2010; Rousseau, 2013). Recently, growing numbers of colloidal particles suitable for making Pickering emulsions have been reported; *e.g.*, glyceryl stearyl citrate solid particles (Gupta & Rousseau, 2012), cellulose micro crystals (Wege, Kim, Paunov, Zhong, & Velev, 2008), chitin nanoparticles (Tzoumaki, Moschakis, Kiosseoglou, & Biliaderis, 2011), soy protein nanoparticles (Liu & Tang, 2013), zein protein particles (de Folter, van Ruijven, & Velikov, 2012) and flavonoid particles (Yusoff & Murray, 2011). In addition to these reports regarding Pickering stabilization, insoluble egg or milk protein aggregate preparations are well-known to have positive

* Corresponding author. Laboratory of Quality Analysis and Assessment, Division of Agronomy and Horticultural Science, Graduate School of Agriculture, Kyoto University, Gokasho, Uji, Kyoto 611-0011, Japan.
*E-mail address:* matumiya@kais.kyoto-u.ac.jp (K. Matsumiya).

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influences on foam stability (Dickinson, 2010).

In this context, Destribats, Rouvet, Gehin-Delval, Schmitt, and Binks (2014), in their latest work, have reported the utility of another novel class of protein-based particles, whey protein microgel particles. They employed a bottom-up approach in their research to produce the microgel particles by heating whey protein solutions sufficiently diluted to prevent the formation of brittle macrogels, within combination of microfiltration and spray-drying. They demonstrated that this new class of food-grade particles can successfully stabilize a food-grade oil-in-water emulsion for a long time with exceptional resistance to droplet coalescence that shows good promise for application in the food industry.

Soybean proteins, as well as whey proteins, are commercially and extensively used in food products due to their high nutritional value (Friedman, 1996). Since they are originally from plant resources, they need much less energy input for their production than those from animal resources, including milk and egg proteins, which is helpful for energy savings in overall food production (Pimentel & Pimentel, 2003). However, commercially available soybean proteins, denatured due to high-temperature pasteurization or drying processes, although practically easy to manufacture, do not necessarily have enough ability to stabilize oil-in-water emulsions compared to their native counterparts (McSweeney, 2008).

In the current study, in order to enhance the functional properties of soybean proteins, we describe the production of soybean protein gel particles under varied conditions to examine effects of the gel particles on the stability of foams and oil-in-water emulsions prepared with food-grade oils. Two kinds of soybean protein, ordinary commercial soybean protein isolate (SPI) and low-molecular-weight partially hydrolysed SPI (LMW-SPI) were used to estimate the impact of steric repulsive effects of the gel particles. Because the commercial SPIs are not so soluble and disperse into water as suspensions, we employed a top-down approach, different from the latest work on whey proteins by Destribats et al. (2014), to produce the gel particles, whereby a SPI macrogel was first formed and then efficiently broken into microgel particles.

## 2. Materials and methods

SPI and LMW-SPI were kindly donated by Fuji Oil Co. (Osaka, Japan). The protein content of the SPI and LMW-SPI was both >90 wt%. LMW-SPI is partially hydrolysed by proteases with an average molecular weight of approximately 60,000 Da. Corn oil (Mazola, ACH Food Companies, Inc., UK) was purchased from a local supermarket in the UK. All other chemicals used were of Analytical grade. Ambient temperature was approximately 25 °C throughout all the experiments.

### 2.1. Sample preparation

#### 2.1.1. Macrogel

SPI and LMW-SPI were mixed with deionized water and then the appropriate amount of salt solution was added to adjust the concentration of salts. The final concentration of SPI and LMW-SPI in the macrogels was 15 wt% and 20 wt%, respectively. The salt concentration in the final macrogels was set at 0 mM (no added salts), 60 mM for NaCl and 30 mM for $CaCl_2$ or $MgCl_2$. The concentrations of the salts were determined according to the gelation method reported by Kohyama, Sano, and Doi (1995). The cationic salts were chosen based upon their use in the creation of *tofu* gels, which are proposed as comparable to the microparticulated SPI gels presented.

The SPI and LMW-SPI mixtures were stored in a water bath at 40 °C for 30 min to allow enough hydration of the protein powders. The mixtures were respectively in paste and liquid forms and thereby required two kinds of equipment with different shearing speeds to ensure complete dispersion of the proteins. The mixtures were then dispersed by a hand blender with a puree masher attachment (HB711M, Kenwood) at Speed 1 (350 rpm) and a hand blender with one of twin steel beaters (HM320, Kenwood) at Speed 2 (1050 rpm) at ambient temperature to prepare SPI and LMW-SPI suspensions, respectively. They were heated in a glass jar at 90 °C for 30 min in a water bath and then cooled down to room temperature in another water bath at ambient temperature. The suspensions were kept in a cold room at 4 °C overnight to fully set the macrogels.

#### 2.1.2. Gel-particle suspensions

The heat-set macrogels were placed in a water bath at 25 °C for

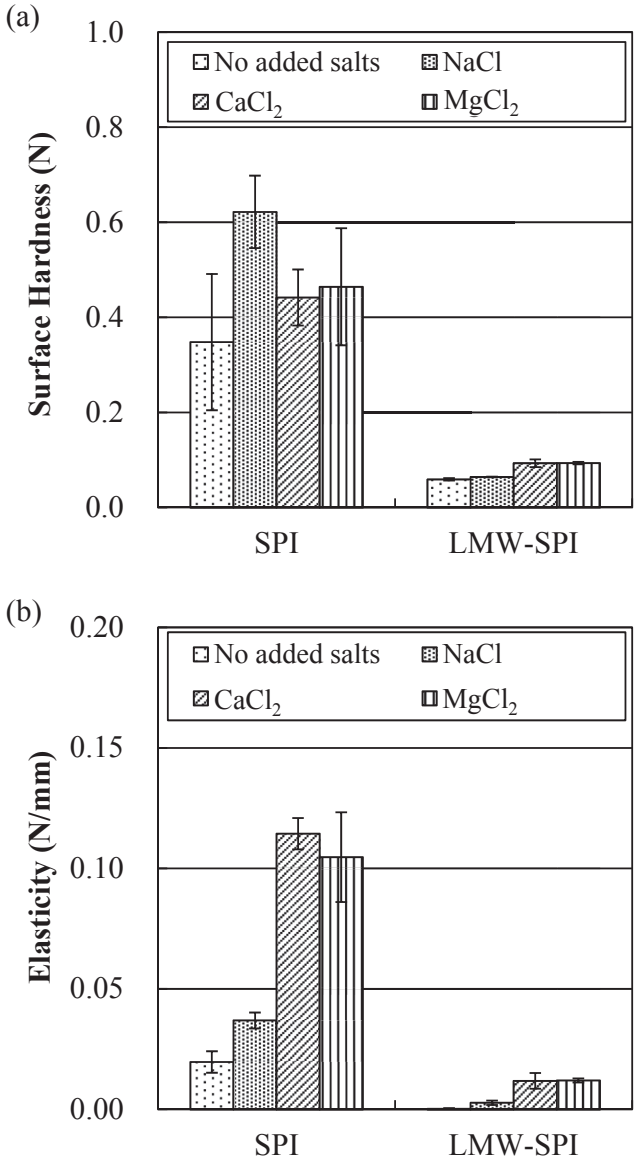


**Fig. 1.** Texture properties of SPI and LMW-SPI macrogels. Texture analysis was conducted at 25 °C using a 1/4 inch spherical stainless steel probe under penetration mode. The fracture force (N) and the proportionality constant of initial linear parts of force (N) vs distance (mm) curves were reported as the surface hardness and elasticity of the macrogels. The salt concentration in macrogels was 0 mM (no added salts), 60 mM for NaCl and 30 mM for $CaCl_2$ or $MgCl_2$.