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Relationship of rheological and microstructural properties with physical stability of potato protein-based emulsions stabilized by guar gum

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ABSTRACT

Despite potato protein is a great potential ingredient in food products due to its nutritional quality, it is not useful for the formation of sufficiently stable emulsions. For this reason, a widely used polysaccharide in the food industry, Guar gum, was added. The addition of guar gum to potato protein-based emulsions results in enhanced stability as demonstrated by the cooperative information provided by the combination of different techniques (rheology, optical microscopy and multiple light scattering). We established a relationship between a critical time for the onset of creaming and two rheological functions, namely the zero shear viscosity and the storage modulus. In addition, we propose a fast rheological method consisting of non-linear creep tests to detect shear-induced microstructural transitions.

1. Introduction

Emulsions are complex systems comprised of an oil-dispersed phase and an aqueous continuous phase that may contain a variety of ingredients (sugars, salts, acids, surfactants, polysaccharides, etc.) (McClements, 2005). Emulsions tend to destabilize due to some physicochemical mechanisms such as creaming, flocculation, coalescence, phase inversion or Ostwald ripening. The shelf-life of these dispersed systems is principally determined by their physical stability (McClements, 2005; Walstra, 1996). The interfacial region between the two phases may contain a mixture of various surface-active components including proteins, surfactants and phospholipids (Dickinson, 2003). Proteins reduce interfacial tension and form viscoelastic films; therefore it can be effective at producing and stabilizing dispersed systems such as emulsions and foams (Prins, Bos, Boerboom, & van Kalsbeek, 1998). Polysaccharides increase the long-term stability against creaming.

Potato protein is a potential ingredient in food products because it possesses a nutritional quality higher than most major plant proteins and close to that of egg proteins (Van Gelder & Vonk, 1980). About 1–2% of the human population has food-related allergies, with egg, gluten, soy, fish and nuts being among the most common. These are all important food protein sources, and many are being used as emulsifiers, gelling and foaming agents in food systems. Allergy towards potato protein is much less common (Castells, Pascual, Esteban, & Ojeda, 1986), and potato protein concentrates can therefore be an interesting replacement for the aforementioned proteins as food hydrocolloids. Furthermore, there is an increasing interest in the application of vegetable proteins in food products because they help to prevent some gastrointestinal diseases, some types of cancer, and cardiovascular diseases (Serra & Aranceta, 2005). In this sense, potato may be regarded as a potential source to produce plant protein-based food products with high valorisation standard (Calero, Muñoz, Cox, Heuer, & Guerrero, 2013), whose ability in the stabilization of O/W interfacial layers has been already put forward (Romero et al., 2011).

Polysaccharides are used to increase the viscosity of the continuous aqueous phase of the emulsion and to control their rheological properties. For this reason, polysaccharides are widely used in the food industry in many sauces. However, the majority of these polysaccharides show little surface activity. (Erçelebi & Ibanoğlu, 2009; Neirynck, Dewettinck, & Van Der Meeren, 2007; Tuinier, Ten Grotenhuis, & DeKruif, 2000).

Today, xanthan gum, guar gum, modified starch as well as carboxymetyl cellulose are the most common polysaccharides being used in concentrated emulsion products such as mayonnaises and salad dressings. Such polysaccharides impart important product characteristics including creaming mouthfeel, thickeness and, to

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certain extent, long-term stability (Erçelebi & Ibanoğlu, 2009; Nor Hayati, Che Man, Tan, & Nor Aini, 2009).

Proteins tend to be better than polysaccharides at producing small emulsion droplets, whereas polysaccharides tend to be better than proteins at producing emulsions that are stable to a wider range of conditions (McClements, 2005). The use of polysaccharides to enhance the stability of emulsions that contain proteins has been previously reported in many studies (Dickinson, 2011; Murray, 2011; Schmitt & Turgeon, 2011).

In addition, there is an increase of social awareness about health problems due to obesity. For this reason, an increase in consumption of low-fat food is occurring nowadays (Vázquez, De Cos, & López, 2005). High-oleic sunflower oil is very important for the diet because it contains a high percentage of mono-unsaturated fatty acids (MUFA) like oleic acid (at least 82%). These acids, in contrast with the saturated acid, have health benefits and positively influence many digestive functions (Serra & Aranceta, 2005).

This study focuses on emulsions formulated with a) high-oleic sunflower oil, with dietary benefits supported above, b) vegetable protein (potato protein isolate which may provide many health benefits) and c) Guar gum which is a well-known stabilizer and thickener in the food industry. To be more precise, the specific goal of this project was to study the effect of guar gum concentration on the stability, microstructural and rheological properties of O/W potato protein-stabilised emulsions.

2. Materials and methods

2.1. Materials

Potato Protein Isolate (PPI) was supplied by Protastar (Reus, Barcelona, Spain). The chemical composition of potato protein isolate was determined in a previous study (Romero et al., 2011): 80 ± 2% wt% protein; 3.1 ± 0.4% lipids; 5.9 ± 0.6 wt% carbohydrates; 0.8 ± 0.1 wt% ashes; 10 ± 2 wt% moisture. Guar Gum (GG) was purchased from Sigma Chemical Company.

2.2. Preparation of oil-in-water (O/W) emulsions

Oil-in-water emulsions were prepared following the procedure described by Calero et al. (2013). Potato protein stock dispersion was prepared by dispersing 5 wt% potato protein isolate powder in water. Then it was adjusted to pH 11.5 with 1 M NaOH in order to improve protein solubility.

Guar Gum stock solution was prepared by dissolving 2.5 wt% Guar powder in water containing 0.2 wt% NaN_3. GG solution was stirred for at least 3 h at 700 rpm to ensure complete dissolution. The stock solution was diluted to prepare the rest of guar gum solutions (0.1 wt%, 0.2 wt%, 0.3 wt% and 0.5 wt %). The system was left to stand for 48 h at 7 °C for complete hydration of the polymer and the removal of bubbles.

Concentrated high-oleic sunflower oil-in-water emulsions (50 wt% oil, 5 wt% PPI as emulsifier) was prepared by gradually blending 50 wt% high-oleic sunflower oil with 50 wt% aqueous potato protein dispersion (pH 11.5) using a high-shear mixer (Silverson L 5 M). The mixture was stirred for 3 min at 8600 rpm (pre-emulsion 1). The mixture was passed through a high-pressure valve homogenizer once at 105 KPa.

Subsequently diluted emulsions were prepared by diluting concentrated emulsions with guar gum solutions. The concentrated emulsion and guar gum solutions were mixed manually using a spatula (final emulsion).

Final emulsion contained 40 wt% high-oleic sunflower oil, 40 wt % aqueous potato protein dispersion (2 wt% potato protein) and 20 wt% GG solution (0 wt%, 0.1 wt%, 0.2 wt%, 0.3 wt%, 0.5 wt%). The pH of final emulsions is 8.

2.3. Rheological characterization

The Thermo Haake MARS rheometer was used for all rheological measurements. Oscillatory, step-wise flow curves and stress jumps were carried out for final emulsions with different concentrations of guar gum at 20 °C, using a plate-and-plate geometry with a rough surface (60 mm diameter).

Stress sweeps at a frequency of 0.62, 6.20 and 12.52 rad/s were performed for all systems studied to estimate the dynamic linear viscoelastic range. Frequency sweep tests (from 0.1 to 100 rad/s) were performed selecting a stress well within the linear range. Shear flow tests were carried out from 0.05 to 100 Pa. Creep experiments were performed for constant shear stresses for all emulsions in the range of 10–60 Pa.

2.4. Microstructural observation

The microstructure of emulsions was observed at room temperature using an optical microscope Axio Scope A1 (Carl Zeiss) equipped with an AxioCam camera. Microphotographs were taken of all emulsions before and after stress jump tests with a 63× objective. To improve the view of the flocs, all samples were diluted to 1:20 in distilled water.

2.5. Physical stability

Backscattered light measurements with Turbiscan Expert Lab-Measuring were used in order to study the destabilization of the emulsions. Measurements were carried out for 15 days to study the influence of the concentration of GG on the stability of the emulsions and to determine the predominant mechanism of destabilization in each case as well as the kinetics of the destabilization process.

3. Results and discussion

3.1. Oscillatory measurements

Dynamic frequency sweep tests were performed in the linear viscoelastic range (LVR) to determine the frequency dependence of

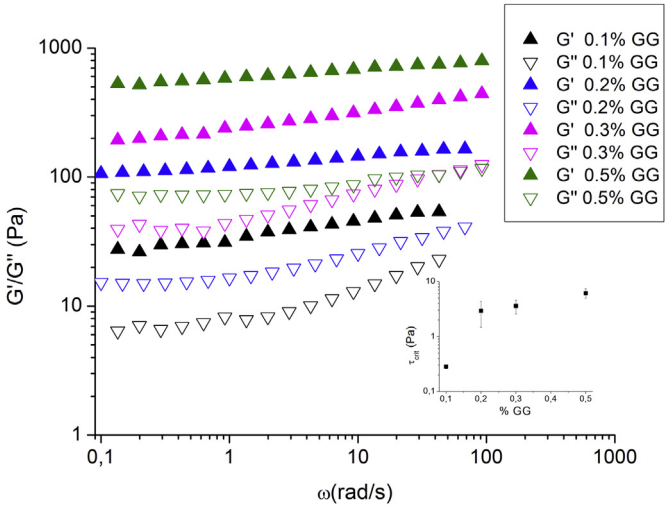

Fig. 1. Influence of Guar gum concentration on the mechanical spectra for the studied emulsions. Inset: evolution of the critical shear over gum concentration.