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Effect of flaxseed gum on the rheological properties of peanut protein isolate dispersions and gels

Chen Chen [a, 1], Xin Huang [a, 1], Li-jun Wang [a, *], Dong Li [b, **], Benu Adhikari [c]

[a] College of Food Science and Nutritional Engineering, Beijing Key Laboratory of Functional Food from Plant Resources, China Agricultural University, P. O. Box 50, 17 Qinghua Donglu, Beijing, 100083, China
[b] Beijing Advanced Innovation Center for Food Nutrition and Human Health, College of Engineering, National Energy R & D Center for Non-food Biomass, China Agricultural University, Beijing, 100083, China
[c] School of Applied Sciences, RMIT University, City Campus, Melbourne, VIC, 3001, Australia

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ABSTRACT

The effect of addition of flaxseed gum (FG) on the rheological and thermal gelation properties of peanut protein isolate (PPI) was studied. Small quantity (1–5 g/kg) of FG was added to PPI solution (140 g/kg) and the resultant rheological properties were studied using steady shear and small amplitude oscillatory measurements. The apparent viscosity of all samples increased with the increase from 1 to 5 g/kg in the concentration of FG and was fitted well by the Herschel-Bulkley model ($R^2 > 0.99$). The addition of FG reduced the gelling time almost from 1000 to 500 s and increased the strength of FG-PPI mixed gels from 2000 to more than 3000 Pa. These FG-PPI gels showed the behavior of physical gels since their storage modulus (G') was much higher than the loss modulus (G'') and G' was only slightly frequency dependent.

1. Introduction

Proteins and polysaccharides are widely used to control structure, texture and stability in food products as they easily form network structure in food systems (Chen, Xu, & Wang, 2006; Dickinson, 1998). The electrostatic interaction or complex coacervation between proteins and polysaccharides can be important mechanism which can be harnessed to broaden the application of these two biopolymers as functional ingredients without chemical or enzymatic modification (Liu, Elmer, Low, & Nickerson, 2010; Wang, Adhikari, & Barrow, 2014). The gelation of mixtures generally shows three characteristic patterns: formation of covalent bonds between two polymers, polyanion-polycation electrostatic interactions, and formation of composite gel due to mutual exclusion of each other (Morris, 1990). The rheology tests provide valuable information regarding the protein-polysaccharide texture characteristics and stability of protein-polysaccharide mixtures.

The protein chosen in this study is peanut protein isolate (PPI) extracted from partially defatted peanut flour (DPF). The extraction of oil from peanut yields DPF as a byproduct. DPF is a protein-rich albeit inexpensive and underutilized by-product of the peanut industry which offers the same health and dietary benefits of peanut with less fat (Ma, Wang, & Wu, 2010). DPF contains 47–55% high quality protein with high essential amino acid content (Basha & Pancholy, 1982). PPI is a novel and high protein food ingredient used for protein fortification and product formulation in food industry (Yu, Ahmedna, & Goktepe, 2007).

Flaxseed gum is a neutral heterogeneous polysaccharide composed of xylose, arabinose, glucose, galactose, galacturonic acid, rhamnose and fucose (Cui, Mazza, & Biliaderis, 1994; Erskine & Jones, 1957; Hunt & Jones, 1962; Muralikrishna, Salimath, & Tharanathan, 1987). It is a water soluble dietary fiber and is found to be beneficial to diabetes mellitus, heart disease and colorectal cancer (Cunnane et al., 1993; Tarpila, Wennberg, & Tarpila, 2005; Thakur, Mitra, Pal, & Rousseau, 2009). Flaxseed gum is functionally similar to gum Arabic and guar gum and possesses good water-holding and emulsifying properties, high viscosity and weak gelling properties (Chen et al., 2006; Fedeniuk & Biliaderis, 1994; Mazza & Biliaderis, 1989; BeMiller, 1973). Thus, it can be preferably used as a thickener, a stabilizer and an emulsifier in food systems.

* Corresponding author.
** Corresponding author.
E-mail addresses: wlj@cau.edu.cn (L.-j. Wang), dongli@cau.edu.cn (D. Li).
[1] These authors contributed equally to this work.

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To the best of our knowledge, there is no published study that characterizes or makes use of the interaction between flaxseed gum (FG) and peanut protein isolate (PPI). Thus, the primary objective of this work was to study the effect of addition of flaxseed gum on the rheological properties of PPI-FG mixtures. Both steady shear and small amplitude oscillatory measurements were carried out in order to determine the effect of addition of FG (at various concentrations) on the shear viscosity and the storage and loss moduli of the PPI-FG dispersions and gels. This study provides better understanding of steady shear and dynamic rheological behavior of PPI-FG mixed dispersions and gels. Such understanding helps broaden the utilization of PPI-FG dispersions and gels in various food products.

2. Materials and methods

2.1. Materials

Flaxseed (65 g/kg moisture) was purchased from Xianghe County, Hebei province of China. Defatted peanut flour (70 g/kg moisture) was obtained from Tianshen Ltd. (Tancheng County, Shandong province, China). All reagents used in this study were of analytical grade and were used as received.

2.2. Extraction of flaxseed gum

Flaxseed samples weighing 100 g were washed with de-ionized water to remove the surface dust. The flaxseed was then soaked in de-ionized water (900 mL). This flaxseed-water mixture was stirred at 300 rpm for 5 h in a water bath maintained at 60 °C, following a previously reported extraction method (Wang, Wang, Li, Xue, & Mao, 2009). The extracted flaxseed gum solution was filtered through 40-mesh screen, precipitated using two volumes of 95 mL ethanol/100 mL and then collected by using a glass rod with gentle stirring as suggested by Wang, Li, Wang, and Xue (2011). The flaxseed gum extracted in this way was subsequently dried in a hot air oven (Model 101-3, Shanghai Luda Experimental Instrument Co., Shanghai, China) at 80 °C for 8 h. The protein content of flaxseed gum extracted in this way was 144 g/kg as determined by Kjeldahl method using a FOSS Kjeltec 2300 analyzer (FOSS Co., Höganäs, Sweden). The protein content was calculated using a conversion factor of 6.25.

2.3. Extraction of peanut protein isolate

The defatted peanut flour was mixed with de-ionized water at flour-to-water ratio of 1:12 (g:mL), then the pH was adjusted to 10 using 1.0 mol/L NaOH. After stirring and equilibrating in a water bath maintained at 50 °C for 2 h, the suspension was centrifuged at 1370 × g for 20 min. The supernatant was collected and the pH was adjusted to 4.5 with 1.0 mol/L HCl. After allowing it to stand for 1 h, the suspension was centrifuged at 1370 × g for 20 min. The supernatant was discarded and the precipitate was re-suspended and washed in de-ionized at precipitate-to-water ratio of 1:10 (mL:mL) and stirred at room temperature for 1 h in order to remove the acid. The solid content was recovered by centrifuging at 1370 × g for 20 min (Wu, Wang, Ma, & Ren, 2009). The precipitate was collected and freeze dried using a LGJ-18S freeze dryer (Sihuan Science Instrument factory, Beijing, China). The dry PPI powder was stored in a refrigerator at 4 °C until used in further tests. The protein content of the PPI was 901 g/kg as determined by Kjeldahl method (Section 2.2) and using the conversion factor of 6.25.

2.4. Sample preparation for complexation

Stock suspension of PPI (280 g/kg) was prepared by dispersing the PPI powder in 0.1 mol/L phosphate buffer (pH) followed by stirring at room temperature for 2 h. This stock solution was stored overnight at 4 °C for a complete hydration (Wu et al., 2009). Solutions of flaxseed gum (2, 6, 10 g/kg) were prepared in 0.1 mol/L Na_2HPO_4 - NaH_2PO_4 buffer (pH 7) at ambient with continuously stirring for 2 h using a magnetic stirrer and storing overnight at 4 °C to ensure complete dissolution of the gum.

Stock solution of PPI was diluted in de-ionized water at 1:1 ratio (mL:mL) and further stirred for 30 min at room temperature to prepare (140 g/kg) PPI solutions. PPI-FG mixed solutions were also prepared by mixing the PPI and FG stock solutions at 1:1 ratio (mL:mL) followed by stirring for 30 min at ambient temperature. The stirring action was mild or non-vigorous in order to avoid the incorporation of air bubbles into the solutions.

2.5. Rheological testing of PPI-FG mixed solutions

AR2000ex rheometer (TA Instruments Ltd., Crawley, UK) with aluminum parallel plate geometry (40 mm diameter, 1 mm gap) was used to carry out the rheological measurements. The AR2000ex is a stress controlled rheometer equipped with a force rebalance transducer. The temperature of the samples was controlled by using a water bath connected to the bottom plate. The temperature of the water bath was controlled by a Peltier system. Viscoelastic properties of samples were measured within the linear viscoelastic region determined for each sample through strain sweep tests carried out at 1 Hz. The viscoelastic properties (storage modulus G', loss modulus G'', and phase angle δ) of the samples were measured within the linear viscoelastic region. To prevent evaporation of water, a thin layer of silicone oil was used on the edge of the samples. The samples were allowed to equilibrate for 2 min before the tests were carried out.

2.5.1. Measurements of steady shear

The steady shear tests were performed at 25 °C over a shear rate range of 0.1–100 s^{-1} to measure the apparent viscosity. This shear rate range covers the flow of a number of non-Newtonian fluid foods in many food operations (Mazza & Biliaderis, 1989).

2.5.2. Temperature sweep measurements

Solution samples were loaded onto the plate of the rheometer and were equilibrated at 25 °C. The samples were then heated from 25 °C to 85 °C at a rate of 2 °C/min and held at 85 °C for 20 min and then cooled to 25 °C at a rate of 6 °C/min. These cooled samples were equilibrated at 25 °C for 10 min. The storage (G') and loss (G'') moduli and phase angle (δ) were measured continuously during the above mentioned thermal scan at a frequency of 1 Hz. The amplitude of the strain in these tests was selected to be 0.5% according to the strain sweep results (data not shown) in order to be within the linear viscoelastic region.

2.5.3. Frequency sweep tests

The frequency sweep tests were performed at 25 °C over the angular frequency range of 0.1–10 rad/s. The strain amplitude for the frequency sweep tests was selected as 0.5%.

2.6. Statistical analysis

All the rheological measurements were carried out in triplicate. The experimental data sets were directly obtained from TA Rheology Advantage Data Analysis software V 5.4.7 (TA Instruments Ltd., Crawley, UK). The mean value of triplicate runs has