Food Hydrocolloids 60 (2016) 509–515

Contents lists available at ScienceDirect

Food Hydrocolloids

journal homepage: www.elsevier.com/locate/foodhyd

Effect of starch source on gel properties of kappa-carrageenan-starch dispersions

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ARTICLE INFO

Article history:
Received 3 February 2016
Received in revised form
14 April 2016
Accepted 18 April 2016
Available online 22 April 2016

Keywords:
Kappa-carrageenan
Starch
Dispersion
Gel
Syneresis
Swelling

ABSTRACT

Eight different starches (2%, w/w) were incorporated into dispersions containing various amount of kappa-carrageenan (0.2%, 0.6% and 1.0%, w/w), and the properties including morphology, rheology, texture and syneresis of gel from carrageenan and carrageenan-starch dispersions were examined and compared for elucidating the effect of starch source on gel properties of the dispersions. Results showed that the swelling of starch granules in carrageenan dispersions decreased with increasing concentration of carrageenan. Carrageenan dispersions incorporated with starch possessed high granule rigidity or low swelling power had high values of storage modulus and gel firmness. The presence of starch reduced the syneresis of carrageenan gels, and this was more profound for dispersions containing starch with high amylose content. At each concentration of carrageenan, swelling power of starch showed significant correlations with the storage modulus ($r^2 \geq 0.590$, $p < 0.05$) and firmness ($r^2 \geq 0.890$, $p < 0.05$) of carrageenan-starch dispersions. Results indicate that the presence of starch in carrageenan dispersion improves the gel strength and reduces the syneresis of carrageenan. Moreover, the amylose content of starch and the rigidity of gelatinized starch granules play important roles on gel properties of carrageenan-starch dispersions.

1. Introduction

Polysaccharides, such as starches and gums, are used individually or together in food system for controlling moisture content and water mobility as well as for providing proper texture, which further improves product quality, stability and cost reduction (Shi & BeMiller, 2002). It is important to understand interactions between starches and gums, since that are critical to the functionalities of food products. Previous studies were focused on the influences of polysaccharide gums on starchy system and effects of starch on gel properties of polysaccharide gums. The rheological properties of mixture of starch and hydrocolloids, such as locust bean gum, guar gum, xanthan gum, konjac flour, and carrageenan, have been examined. From the point of starch properties, generally the addition of hydrocolloids increases the viscosity of starch solution (Alloncle, Lefebvre, Llamas, & Doublier, 1989; Christianson, Hodge, Osborne, & Detroy, 1981; Sajjan & Rao, 1987) and reduces the retrogradation rate of starch (Ferrero, Martino, & Zaritzky, 1994; Lee, Baek, Cha, Park, & Lim, 2002; Pongsawatmanit, Chantaro, & Nishinari, 2013; Youshimura, Takaya, & Nishinari, 1996).

The addition of starch in polysaccharide gums has been widely applied for improving gelling, thickening, stabilizing and texture of gel. At low starch concentration (<5%), the gelatinized starch provided soluble materials in continuous matrices and swollen granules acted as "fillers" in the composite system of polysaccharide gums and starch (Eliasson, 1986; Mohammed, Hember, Richardson, & Morris, 1998a, 1998b). Shi and BeMiller (2002) observed the pasting curves of starch in gum solutions (CMC, gellan, xanthan, guar gum, and sodium alginate) at starch concentration of 3.6%, and indicated that the pasting behaviors of starch-gum dispersions varied with the source of gum and starch. The interactions between certain leached molecules, essentially amylose, and certain gums were responsible for the viscosity increase occurred before pasting of starch. Lai, Huang, and Lii (1999) observed rheological properties of agarose and carrageenan gels (1.0–2.0%) in the presence of starch (0–3.0%), and indicated that phenomena including the interference of soluble starch, the exclusion effect of swollen granules, the molecular incompatibility and the coupling interactions in the matrices appeared in the polysaccharide-starch gel systems. This

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http://dx.doi.org/10.1016/j.foodhyd.2016.04.024
0268-005X/

suggests that the effect of starch on gel properties of polysaccharide gums is complicated, and is dependent on amylose content, swelling properties, and particle size of starch.

Carrageenan is water-soluble, linear, sulfated polysaccharides extracted from certain species of red seaweeds (*Rhodophyta*). Kappa-carrageenan is one type of carrageenan, which can form strong, brittle and opaque gel (Piculell, Nillson, & Muhrbeck, 1992), and is widely used in various food products as a bulking agent, carrier, emulsifier, gelling agent, glazing agent, humectant, stabilizer, or thickener (Codex alimentarius commission, 2010). Carrageenan is also used in pharmaceutical pills and tablets and immobilization biocatalysts (Prajapati, Maheriya, Jani, & Solanki, 2014). Gel properties of kappa-carrageenan can be changed by incorporating with other hydrocolloids. Haug, Draget, and Smidsrod (2003) indicated that the strength and turbidity of gels composed of gelatin and kappa-carrageenan could be controlled by varying the hydrocolloids concentration, pH or ionic strength of the dispersions. Starch is wildly presented in food systems, while studies on effect of starch on texture and rheological properties of kappa-carrageenan dispersions are still limited. In this study, carrageenan dispersions composed of 0.2–1% (w/w) carrageenan and 2% (w/w) of starch, from eight different botanical sources, were prepared and studied. Physicochemical properties of starches, as well as, morphology, rheological, texture and syneresis properties of carrageenan-starch dispersions were examined and compared for elucidating the effect of starch incorporation on the properties of carrageenan-starch composite dispersions.

2. Materials and methods

2.1. Materials

Kappa-carrageenan (Sigma–Aldrich Company, St. Louis, MO), waxy corn and Hylon V starches (National Starch and Chemical Co., Bridgewater, NJ), normal corn starch (Roquett Co., France), potato starch (Ting Hsin Co., Taiwan) and tapioca starch (Vedan Co., Taiwan) were commercial products. Rice starches from local variety of TCW70 (waxy rice), TNG71 (japonica rice) and KSS7 (indica rice) were isolated according to the method proposed by Lu, Duh, Lin, and Chang (2008). All reagents used were of analytical grade.

2.2. Methods

2.2.1. Physicochemical properties of starch

Amylose content of starch was determined by iodine potentiometric titration method, while before titration starch was defatted by Soxhlet extraction for 48 h with 85% methanol (Lu, Chen, Lin, & Chang, 2005).

Average granule size of starch was determined by using of a laser-light scattering-based particle-size analyzer (Mastersizer Micro, Malvern Instruments, Malvern, U.K.). Swelling power and solubility of starch at 90 °C was measured according to the method proposed by Lu et al. (2008).

2.2.2. Preparation of dispersions

Carrageenan dispersion of 0.2%, 0.6% or 1% (w/w) concentration was respectively heated in 90 °C water bath with continuously shaking for 30 min to prepare dispersions composed of carrageenan only. While dispersions composed of both carrageenan and starch were prepared by incorporating equal volume of carrageenan solution and starch suspension, then heating in 90 °C water bath with continuously shaking for 30 min. The final concentration of component in carrageenan-starch dispersions was 0.2%, 0.6% or 1.0% for carrageenan and 2% for the starch, respectively.

2.2.3. Light microscopic observation

Carrageenan-starch dispersion was stained by iodine solution (containing 2 mg I_2 and 2 mg KI per mL) and was observed in a light microscope (BH-2, Olympus, Tokyo, Japan) at room temperature for observing the distribution of starch in dispersion. Photomicrogram of a calibration slide at the same magnification was taken and used as reference of size determination.

2.2.4. Rheological properties

Small-deformation rheological behaviors of carrageenan-starch dispersion were measured using a dynamic rheometer (Carri-Med CSL2-100, TA Instruments Ltd., Surrey, UK) equipped with parallel plate system (4 cm diameter) according to the method proposed by Lu et al. (2008). The gap size was set at 1 mm, and the strain and frequency were set at 1% and 1 Hz, respectively. All measurements were conducted in at least triplicate. Dispersions were loaded on the ram of the rheometer, which was pre-heated to 90 °C, and covered with a thin layer of silicon oil. After equilibrated for 1 min and quenched to 20 °C, the rheological properties, such as G′ (storage modulus), G″ (loss modulus) and tan δ (phase angle), of dispersion were determined.

2.2.5. Gel firmness

Dispersion was poured into a plastic container with 28 mm inner-diameter and 16 mm height, the container was sealed and stored at 4 °C for 24 h to form gel. After standing the stored gels for half an hour at room temperature, the firmness of sample was measured by using of a Texture Analyzer (TA-XT2, TA Instruments, UK). Gel was penetrated (two penetration cycles) at a speed of 1.0 mm/s using a standard probe having a diameter of 10 mm (P/10). The penetration strain was 50% height of gel. The firmness was taken as peak height of curve of the first penetration cycle.

2.2.6. Gel syneresis

Method proposed by Funami et al. (2005) with some modification was used for syneresis measurement of samples. Twenty-five grams of dispersion was poured into tube and stored at 4 °C for 24 h. After storage, the sample was centrifuged at 4000 × *g* for 10 min. The supernatant was descanted and the remained gel in centritube was weighted. The syneresis (%), as percentage of water leached out during storage, of gel was calculated. All measurements were conducted in at least triplicate.

2.2.7. Statistics analysis

All measurements were performed in triplicate. Statistical analysis was conducted using Statistical Analysis System (SAS Institute Inc., Cary, NC, USA). The data were analyzed by ANOVA and Duncan's new multiple range test to determine the statistical significance of differences among the values ($p < 0.05$).

3. Results and discussion

3.1. Physicochemical properties of starches

Table 1 summarizes the physicochemical properties of starches. The amylose content of starches ranged from 0.3 to 49.5% with waxy starches (TCW70 and waxy corn) had less than 1% amylose content, while Hylon V starch had the highest amylose content (49.5%) among starches used in this study. Granule size of starch ranged from 6.7 to 40.7 μm, and rice starches had the smallest granule size (6.7–7.4 μm), while potato starch showed the largest granules size (40.7 μm), among the starches from different botanical sources. Swelling power and solubility of starches at 90 °C ranged from 6.5 to 44.7 g/g and 6.2–12.7%, respectively. The swelling power and solubility of the 3 rice starches decreased with