

Effect of Xanthan Gum and pH on Pasting Properties and Freeze-Thaw Stability of Tapioca Starch

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ABSTRACT

Effect of xanthan gum on the viscosity and thermal stability of tapioca starch (TS) at different mixing ratios of TS and xanthan gum under different pH values was investigated using a Rapid Visco-Analyzer (RVA) and repeated freeze-thaw treatment. At a total polysaccharide concentration of 5% (w/w) tapioca starch (TS) and TS/xanthan gum mixtures, the RVA peak and final viscosity values increased with xanthan gum concentration. Final viscosity of gelatinized TS alone under pH 3 exhibited the lowest value compared with those of TS at pH 5 and 7 but the extent of difference between those of pH 3 and pH 5 or 7 was lower with increasing gum content. Freeze-thaw stability of TS pastes containing xanthan gum exhibited lower water separation (<10%) compared with that of TS pastes alone (>10%) after 3 cycles of repeated freeze-thaw treatment. This study shows that the substitution of a part of tapioca starch with xanthan gum can improve pasting properties and the freeze-thaw stability of tapioca starch under acidic systems which could be applied to food industry.

Key words: tapioca starch, xanthan gum, pasting properties, pH, freeze-thaw stability

INTRODUCTION

Tapioca starch or cassava starch is a favorable thickener used in food industries especially in Thailand due to its high viscosity, clear appearance, and low production cost, compared to other starches. In food production, the starch-based products may suffer from low stability against shear, or other mechanical stimuli (Temsiripong *et al.*, 2005). Starch stability at different pH values is another parameter to be considered for food preparation. Incorporation of a proper amount of hydrocolloids may improve textural properties and stability of tapioca starch in food products. Blending of starches with other biopolymers is a well-known technique to modify

texture or maintain stability during a long storage period (Yoshimura *et al.*, 1996; Tester and Sommerville, 2003; Pongsawatmanit *et al.*, 2006). However, there are a few reports related to the stability of tapioca starch and hydrocolloids such as xyloglucan (Temsiripong *et al.*, 2005; Pongsawatmanit *et al.*, 2006) in terms of temperature, shear and freeze-thaw stability.

Xanthan gum is a heteropolysaccharide produced by fermentation using *Xanthomonas campestris*. Xanthan gum has a backbone of 1, 4-linked β -D-glucose (like cellulose) with side chains consisting of two mannose and one glucuronic acid. The mannose residue attached to the cellulosic backbone is acetylated, and half of the terminal mannose units contain a pyruvic acid

residue (Urlacher and Noble, 1999). The gum is reported to provide an excellent stability in heat and acid systems (Sahin and Ozdemir, 2004). Therefore, the objectives of this study were to investigate the influence of xanthan gum (Xan) on the viscosity and thermal stability of tapioca starch (TS) at different mixing ratios and pH values using a Rapid Visco-Analyser (RVA) and repeated freeze-thaw treatment.

MATERIALS AND METHODS

Materials

Tapioca starch (TS) was purchased from a manufacturer located in the area of Chonburi province, Thailand. The moisture contents of TS and commercial xanthan gum (Xan) (Thai food and chemical Co., Ltd, Thailand) were 12.1 and 11.9% w/w determined by the hot air oven method at 105°C (AOAC, 1995) for 6 h. Amylose content of TS was 22.0% determined by HPSEC (modified method of Govindasamy, Oates and Wong, 1992). The samples were used without any further purification. HCl was analytical grade for adjusting required pH of the mixture suspensions.

Sample preparations

TS and Xan were prepared at different mixing ratios (TS/Xan = 10/0, 9.5/0.5 and 9/1) of 5% total polysaccharide concentration for all measured samples in distilled water adjusted to be at various pH values (3, 5 and 7) using 0.1 N HCl or NaOH. Xanthan gum dispersions were first prepared at room temperature, stirred using magnetic stirrer at least 2 h and kept at 5°C at least 6 h to ensure complete hydration. Then TS powder was added into the gum dispersion, and continuously mixed for 1 h before RVA measurement and freeze-thaw stability test. All samples were prepared in the closed system for preventing moisture loss during preparation.

Determination of RVA pasting properties and freeze-thaw stability

Pasting properties of TS/Xan mixtures were determined using a Rapid Visco-Analyser (RVA-4, Newport Scientific, Narrabeen, Australia), interfaced with a personal computer equipped with Thermocline software (Newport Scientific) according to the method and temperature profile of Pongsawatmanit *et al.* (2006). Pasting profiles were determined in triplicate and the evaluated parameters were averaged.

For the determination of freeze-thaw stability, dispersions of TS or TS/Xan were heated to 95°C, held at the temperature 95-98°C for 30 min, and cooled down to 40°C in ice-water bath. The gelatinized TS/Xan pastes (5% w/w total polysaccharide concentration) with three mixing ratios (10/0, 9.5/0.5 and 9/1) and different pH values (3, 5 and 7) were investigated by storing the pastes in the freezer (-25°C) for 20 h, and then thawing at 40°C for 2 h repeatedly from 1 to 3 cycles according to the method of Pongsawatmanit *et al.* (2006). Sodium azide (0.04% w/w) was added to prevent microbial spoilage. The percentage of water separation using centrifugation at 2100 g for 10 min was calculated from the following equation:

$$\text{Water separation (\%)} = (W_1 - W_2) \times 100 / (W_1 - W_0) \quad (1)$$

When : W_0 = weight of syringes without paste samples after centrifugation at 2100 g for 10 min

W_1 = weight of syringes with paste samples before centrifugation

W_2 = weight of syringes with paste samples after centrifugation at 2100 g for 10 min

Statistical analysis

All experiments described above were carried out using at least two freshly prepared samples. The data presented were the means and standard deviation of each experiment.

RESULTS AND DISCUSSION

Influence of xanthan gum and pH on RVA pasting properties of TS

The Rapid Visco-Analyser (RVA) was used to investigate the pasting properties of TS and TS/Xan mixtures during heating and cooling processes. Typical RVA pasting profiles of selected TS/Xan mixtures at pH 7 were shown in Figure 1.

When starch granules are heated above the gelatinization temperature in a sufficient amount of water, the granules absorb a large amount of water and swell to many times their original size and the viscosity increases. When most of the tapioca starch granules became swollen, a rapid increase in viscosity occurred. As the temperature increased further, the starch granules began to rupture and the amylose molecules leached out into the continuous phase until reaching a viscosity called the peak viscosity. The peak viscosity is considered to represent the equilibrium point between swelling and rupture of starch granules (Newport Scientific, 1995). Swelling of granules, accompanied by leaching

of starch biopolymers, increased the viscosity and during further heating, granules would rupture further which resulted in a decrease in the viscosity. When the system was at the holding temperature (95°C), the sample was subjected to mechanical shear stress, which led to further disruption of the starch granules and amylose leaching, followed at a slower rate by leaching of the amylopectin fraction. The leached-out polymer molecules were more or less aligned in the direction of flow, which contributes to a breakdown in viscosity at a constant temperature. Therefore, the reduction in the viscosity after appearance of the peak was likely to be caused by mechanical rupture of starch granules. As the sample was subsequently cooled down to 50°C, the viscosity increased to a final viscosity at the end of RVA experiments, which was attributed to reassociation of amylose molecules or short-term retrogradation. Peak viscosity increased with xanthan gum concentration and showed no difference in the mixtures containing different pH (Figure 2a). However, final viscosity of gelatinized TS (Figure 2b) under higher acidic conditions (pH = 3)

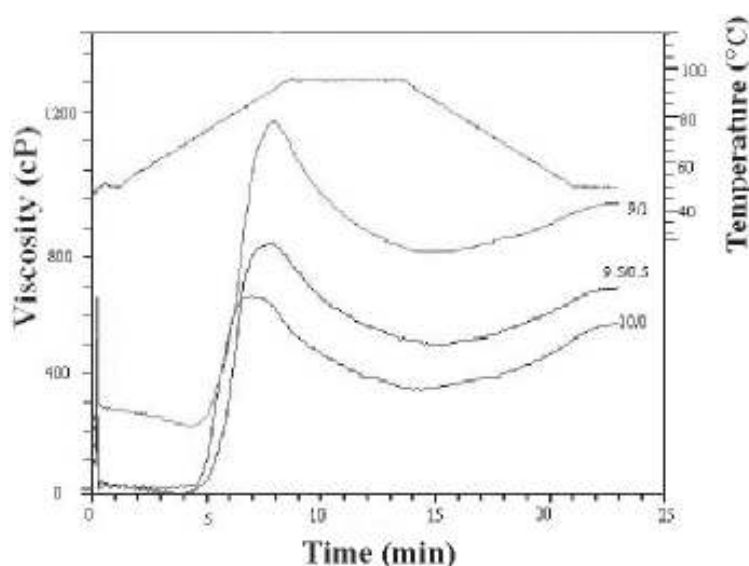


Figure 1 Typical RVA pasting profiles of tapioca starch/xanthan gum mixtures at pH 7 with mixing ratios of 10/0, 9.5/0.5 and 9/1 (a total polysaccharide concentration of 5%).

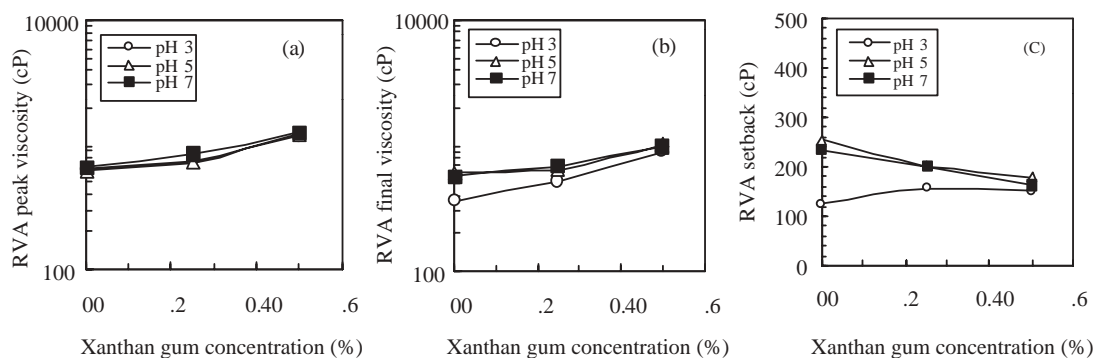


Figure 2 RVA peak (a), final (b) viscosities and setback (c) of 5% w/w tapioca starch/xanthan gum mixtures as a function of gum concentration for different pH.

exhibited the lowest final viscosity ($p \leq 0.05$) compared with those at with pH 5 and 7 probably related to a more damaged granule structure at low pH. The final viscosity values of TS pastes at pH 3 increased with gum concentration and showed a lower extent of difference from those at pH 5 and 7 with increasing gum concentration. The results suggest that xanthan gum provides a good stability of TS in acidic systems. Setback values, referred to short-term retrogradation, of TS and TS/Xan pastes at pH 3 were lower than those at pH 5 and 7 ($p \leq 0.05$). Considering the pastes at pH 5 and 7, setback values of TS pastes were lower with increasing xanthan concentration, indicating that xanthan gum decreases the retrogradation of TS pastes at these pH.

Influence of xanthan gum and pH on freeze–thaw stability of gelatinized TS

Freeze–thaw stability is important in the food industry. In cold chain storage, thermal fluctuations and consequent phase changes of water are the main causes of deterioration in frozen food especially in the gel matrix of starch (Pongsawatmanit *et al.*, 2006). During cold storage, the reorganization of starch molecules may result in the release of water (or syneresis) and this may affect the functional properties in terms of viscosity or gel behavior. Repeated freeze–thaw treatment for one cycle of TS paste

at pH 3 showed the highest water separation (17%) compared with those at pH 5 and 7 (10 to 11%) as shown in Figure 3 due to the damaged granule structure during heating and starch hydrolysis promoted by acidic heat treatment (Rogols, 1986). The damage of starch network resulted in higher water separation after thawing. However, the water separations of gelatinized TS containing xanthan gum (for mixing ratios at 9.5/0.5 and 9/1) were lower than 10% for all studied pH (Figure 3)

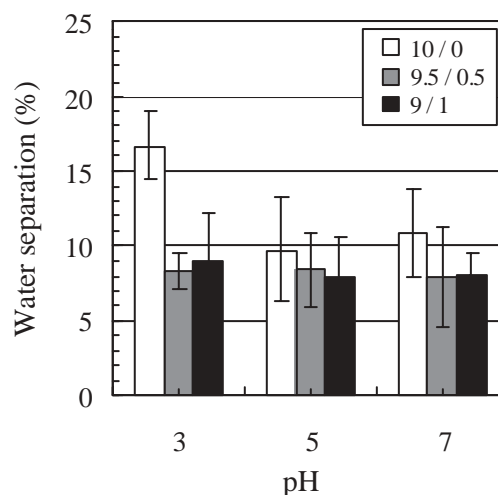


Figure 3 Water separation of 5% w/w gelatinized tapioca starch/xanthan gum mixtures at mixing ratios of 10/0 (a), 9.5/0.5 (b) and 9/1 (c) for different pH values after freezing and thawing.

The thermal stability of gelatinized TS and TS/Xan pastes was investigated further with higher number of freeze–thaw cycles. After the third cycle of repeated freeze–thaw treatment, again the percentages of water separation of TS (pH 3, 5 and 7) containing xanthan gum were almost lower than 10% (Figure 4). Percentages of water separation from TS pastes alone at pH 3 gave the highest value. This results also confirm that the substitution of a part of tapioca starch with xanthan gum improve the freeze–thaw stability of tapioca starch system under acidic condition.

CONCLUSION

At a total polysaccharide concentration of 5% (w/w) TS and TS/Xan mixtures, the peak and final viscosities increased with xanthan gum concentration. Final viscosity of gelatinized TS alone under pH 3 exhibited the lowest value compared with those of pH 5 and 7 but increasing xanthan gum content decreased the extent of such difference. TS pastes containing xanthan gum

showed the lower water separation compared with those of TS pastes alone for both one and three cycles of repeated freeze–thaw treatment especially at pH 3.

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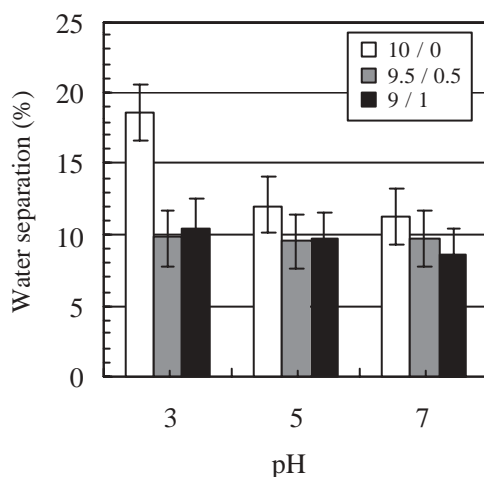


Figure 4 Water separation of 5% w/w gelatinized tapioca starch/xanthan gum mixtures at mixing ratios of 10/0, 9.5/0.5 and 9/1 for different pH values after three cycles of repeated freeze–thaw treatment.

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