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Effect of dry heating with ionic gums on physicochemical properties of starch

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ABSTRACT

Corn starch, potato starch, pea starch were impregnated with ionic gums (sodium alginate, CMC, and xanthan, 1% based on starch solids) and heat-treated in a dry state for 0, 2, or 4 h at 130 °C. Effects of the dry heating on paste viscosity (RVA), microstructure and thermal properties were examined. Dry heat treatment with ionic gums reduced the pasting temperature of the three starches. Heating with xanthan increased the paste viscosity of corn and potato starch. With heat treatment, the paste viscosity of all the starch-sodium alginate mixtures decreased. Heating with CMC increased the paste viscosity of potato starch, but decreased that of corn and pea starch. After dry-heating, To, Tp and Tc of potato starch with ionic gums decreased significantly. SEM of potato starch with CMC showed that the gel structure got compacter after drying-heating. Heat treatment obviously improved the functional properties of the three starches.

1. Introduction

Starch is widely used in the food industry, either as a main raw material or as a food additive. As an additive, starch contributes to the thickening and stabilising effects and texture modification in food (Eliasson & Gudmundsson, 2006). However, utilisation of granular starch in its native form is limited, due to its undesirable defects such as poor solubility, low heat and shear resistance, uncontrolled paste consistency, high tendency toward retrogradation and gelling, and low freeze–thaw stability of pastes (BeMiller, 1997; Lawal, 2009; Singh, Kaur, & McCarthy, 2007). To overcome these shortcomings, modification of starch is widely used to improve and enhance its inherent properties in accordance with the intended purposes (BeMiller, 1997; Singh et al., 2007). Modified (by a physical or chemical treatment) starches and cereal flours have become important in processed food because the functional properties of the starches and flours are improved over those of native starches and cereal flours. Heat treatment is a method of physical modified starch. Heating dry starch or flour at >100 °C, preferably for several hours, provides functionality equivalent to chemical cross-linking (Chiu, Schiermeyer, Thomas, & Shah, 1998; Chiu et al., 1999).

Reactive compounds can be added to produce chemical modifications during the heat treatment. For example, a small amount of levoglucosan added to starch before heating gave rise to enzyme-resistant glycosidic linkages through heat-induced reaction with the hydroxyl groups of starch (Siljestrom, Bjorck, & Westerlund, 1989; Theander & Westerlund 1987).

Gums are often used together with starch in various food products, can modify the characteristics of the end products (James N., 2011). Lim, Han, and Lim (2002) found that anionic food gums reacted with starch during dry heat treatment, producing significant changes in pasting properties of the starch, with the pasting properties of the heated products depending on the specific combination of gum and starch (Lim et al. 2002). The properties of waxy maize starch were more affected by heating with an anionic gum than were those of potato starch, and xanthan produced greater changes in paste viscosity than did sodium alginate or sodium carboxymethylcellulose (Lim et al. 2002).

To sum up, effect of dry heating with ionic gums on pasting properties of starch had been studied, but structural change and thermal properties of starch with polysaccharide before and after dry heating had been studied only rarely. In this study, corn, potato and pea starches were heat-treated in a dry state after being impregnated with a gum (sodium alginate, sodium carboxymethylcellulose, or xanthan). The effect of the heat treatment on the pasting behaviour and structural change properties of the starches were examined.

2. Materials and methods

2.1. Materials

Corn starch was from Shandong Zhucheng starch company, China. Potato starch (amylose content 19.24%) was from Neimenggu starch company, China. Pea starch (amylose content

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35.80%) was from Shandong Longkou silk noodles company, China. Food-grade sodium alginate, low-viscosity CMC and xanthan were purchased from Zhengzhou Shun Da Chemical Co. Ltd., China. All other reagents were of analytical grade.

2.2. Methods

2.2.1. Starch modification by dry heat treatment with gums

The starches were modified by dry heating with gums according to Lim et al. (2002). Sodium alginate, CMC, xanthan, and their mixtures (0.4 g, db) were slowly added to distilled water (70 mL) with vigorous stirring. After the gum was completely dissolved, granular starch (39.6 g, db) was dispersed into the gum solution. The dispersion was stirred for 30 min at room temperature. The dispersion was transferred to a glass dish and dried at 45 °C in a convection oven until the moisture content reached <10%. The dried starch-gum mixture was ground to a powder and passed through a 100-mesh sieve.

2.2.2. Heat treatment

The starch-gum mixture was heated in an aluminium dish in an electric oven at 130 °C for 2 or 4 h. The starch itself was concurrently heat treated without gum under identical conditions.

2.2.3. Paste viscosity

Flour (3.0 g, 14 g/100 g moisture basis) was weighed directly in the RVA canister and distilled water was added to obtain a sample weight of 28.0 g. The sample was held at 50 °C for 1 min, heated to 95 °C in 7.5 min, and then held at 95 °C for 5 min. Afterwards, it was cooled to 50 °C in 7.5 min, and then held at 50 °C for 2 min. The rotating speed was maintained at 160 rpm along the process. Parameters including peak viscosity (PV), viscosity at the end of hold time at 95 °Cor trough viscosity (TV), final viscosity (FV) at the end of cooling, breakdown (BD = PV − TV), setback (SB = FV − TV) and pasting temperature were recorded. All tests were replicated three times.

2.2.4. Differential scanning calorimeter (DSC)

The thermal properties of products produced via heat treatment described above were investigated using a differential scanning calorimeter (DSC, 204F1, GER) as described by Chanvrier et al. (2007) with minor modifications. Indium was used as the calibration standard. Each product sample (approx. 4 mg) was placed in a stainless-steel pan, excess water was added (8 μl), and the container hermetically sealed. The scan was carried out immediately to minimise retrogradation. Samples were heated at 5 °C/min from 30 to 120 °C to observe the presence of any residual enthalpy gelatinisation peak.

2.2.5. Scanning electron microscopy (SEM)

The pastes of potato starch with CMC before and after drying-heating immediately after gelatinisation should be quickly put into ultra-low temperature freezer. The microstructure of samples after freeze drying for 48 h was observed by scanning electron microscopy (SEM). The surface topography of product samples was observed by SEM using the method of Kim et al. (2008). A dry, finely ground sample was placed on double-sided Scotch tape, mounted on an aluminium specimen holder, and coated with a thin film of gola under vacuum. Samples were observed under a Jeol scanning electron microscope (JSM 840, Jeol, Japan).

2.3. Statistical analysis

All experiments were conducted at least in triplicate, for which mean values and standard errors were determined. Also, experimental data were analysed using Analysis of Variance (ANOVA), and expressed as mean values ± standard deviations. Differences were considered at significant level of 95% ($p < 0.05$). Pearson's correlation coefficients among parameters were calculated using SPSS v17.0 software.

3. Results and discussion

3.1. Heat treatment without gums

Lim et al. (2002), Lim, Bemiller, and Lim (2003) also reported effect of dry heating with ionic gums on starch paste viscosity. Both the two works used waxy maize starch, which this paper did not, and potato starch, which the current and the other 2 papers have in common. The Lim et al. (2003) paper reports effects of pH adjustment, which this and the other paper did not use. Paste viscogram data of isolated native starches before and after dry heating are presented in Table 1. It was found that the corn starch and potato starch displayed a trend in which the pasting temperature decreased after dry heating. This might result from a minor disintegration of granular structure by dry heating. The peak viscosity, final viscosity breakdown and setback of pea starch decreased after dry heat treatment. Lim et al. (2002) reported that the waxy maize starch displayed similar results after heat treatment. It might be that dry heat treatment restricted granular swelling.

3.2. Heat treatment with xanthan gum

Paste viscogram data of starches before and after dry heat treatment with 1% xanthan are shown in Table 2. From Table 2, we could see that pasting temperatures of all three heat-treated starches decreased after dry heat treatment. Similar results have been reported (Lim et al. 2002). A possible explanation might be that under the conditions of dry heating, the hydrogen bonds in or among starch molecules are disrupted, the water molecule is more easily to enter starch granule, so the pasting temperatures decreased.

The paste viscosity was substantially changed by dry heat treatment when xanthan was present in or on granules. Heat treatment with xanthan gum raised the peak and final viscosities of corn starch (Table 2), compared with native corn starch without modification (Table 1). Dry heating (130 °C, 2 or 4 h) raised the viscosity throughout the RVA analysis. Lim et al. (2002) reported that potato starch was relatively susceptible to dry heat treatment. So we could see that potato starch behaviour was substantially influenced by incorporating xanthan gum. After 4 h at 130 °C, the peak and final viscosity values of potato starch increased by ≈150 and 60 RVU, respectively. The paste viscosity of pea starch-xanthan mixture had no significant difference. But heat treatment of modified pea starch produced a paste more resistant to breakdown and setback. As commonly reported by others (Lim et al., 2002), waxy maize starch became resistant to breakdown when heat-treated with xanthan. Lim et al. (2003) reported that use of xanthan in the treatment produced products with restricted granular swelling and increased shear stability of the pastes.

3.3. Heat treatment with sodium alginate

Table 3 Shows paste properties of corn starch, potato starch and pea starch heat treated at 130 °C for 2 or 4 h with sodium alginate. Upon dry heating with sodium alginate, the pasting temperatures of corn starch and potato starch displayed a trend similar to that of heated starch-xanthan mixtures. Dry heating decreased paste viscosity of the potato starch-alginate mixture, which was consistent with previous reports (Lim et al., 2002, 2003). In addition, due