Food Chemistry 52 (1995) 281–284

0308-8146/95/$9.50

ELSEVIER

Effect of sucrose on starch–hydrocolloid interactions

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(Received 27 October 1993; revised version received and accepted 27 May 1994)

Starch–gum interactions have a wide application in the food industry, such as in bakery products and low-calorie food formulations. In the present work, an attempt was made to study the effect of sugar (sucrose) on corn starch–xanthan and corn starch–guar interactions, using a Brabender Amylograph. Corn starch (5% w/v) was mixed individually with xanthan (0–0·25% w/v) and guar (0–0·2% w/v) in sugar solution (0–30% w/v) and heated in a Brabender Amylograph; the resulting changes were interpreted with respect to the gelatinisation temperature and cold paste viscosity. These results may find applications in starch-based sugar-containing products such as puddings where gums are used as stabilisers and syneresis inhibitors.

INTRODUCTION

Corn starch is a basic ingredient of many baked and cooked products. Hydrocolloids such as xanthan, guar and CMC modify the pasting properties of starch and also improve moisture retention, texture and overall product quality (Christianson *et al.*, 1981).

Studies on starch–gum systems have indicated a synergistic effect resulting in a much higher viscosity of the mixtures compared with starch or gum alone (Crossland & Favor, 1948; Sandstedt & Abbott, 1964; Sudhakar *et al.*, 1992).

Among other ingredients usually present in baked, cooked systems, sugar is known to impede starch granule swelling by competing for water, thus altering the gelatinisation temperature (Christianson, 1982). But its effect on starch–gum combinations is not established. Therefore, in order to access the interaction of hydrocolloids such as xanthan and guar gum with corn starch in the presence of sugar, the present work was undertaken.

MATERIALS AND METHODS

Corn starch was procured from M/s. Laxmi Starch Pvt. Ltd, Bombay. Food-grade xanthan gum was procured from Kelco Ltd, USA, and food-grade guar gum from Indian Gum Industries Ltd, Bombay.

Corn starch (moisture content of 10%) at 5% (w/v) level was mixed individually with 0–0·25% w/v xanthan (having a moisture content of 8%) and 0–0·2% w/v guar gum (having a moisture content of 9%) in sucrose solution (0–30% w/v). The mixture was then heated in a Brabender Viskograph (Model PT 100) from 35°C to 95°C at a rate of 1·5°C/min at 75 rpm, held for 10 min at 95°C and then cooled back to 40°C. The change in behaviour was interpreted with respect to gelatinisation (pasting) temperature and cold paste viscosity.

RESULTS AND DISCUSSION

The effect of sugar on gelatinisation temperature and cold paste viscosity of corn starch — xanthan and corn starch — guar combinations at different concentrations was studied. Initially, as shown in Table 1, in the presence of sucrose an increase in the cold paste viscosity of 5% corn starch was observed. This viscosity increased from 450 BU at 10% sugar concentration to 520 BU at 30% sugar concentration, whereas it decreased to 480 BU at 50% sugar concentration. This observation is in agreement with an earlier report (D'Appolonia, 1972) according to which an increase in viscosity was observed as the sucrose concentration increased up to 30%.

The reason for the increase in cold paste viscosity with increase in sucrose concentration might be due to the crosslinking (sugar bridges) between the sugar molecules and the starch chains in amorphous regions of the granule (Spies & Hoseney, 1982) which restricts the starch swelling. The tightened granule structure therefore becomes less rigid and less susceptible to disintegration, and fewer solubles are leached from the granules (Hester *et al.*, 1956). Therefore the resulting paste would be less subject to shear thinning and hence more

Table 1. Effect of sugar on the cold paste viscosity (CPV) and gelatinisation temperature of corn starch (5%)

Ingredients	Cold paste viscosity (BU)	Gelatinisation temperature (°C)
5% corn starch	300	86·6
5% corn starch + 10% sugar	450	87·0
5% corn starch + 20% sugar	480	87·2
5% corn starch + 30% sugar	520	88·0
5% corn starch + 50% sugar	480	88·5

viscous after stirring, probably with continued granule swelling. However, no clear evidence has been found to explain how high concentrations of sugar solutions keep starch pastes from breaking down. Since several possible reactions are involved in pasting, a simple explanation is not possible (Kim & Walker, 1992). At high concentrations of sugar, due to the high molecular weight of sugar compared to water, there is a probable decrease in free volume of co-solvent, leading to decreased mobility (Slade & Levine, 1989), which seems to be manifested as a decrease in viscosity. It is also known that at higher concentrations of sugar, the rate of consistency increase is slower than at low concentrations and the maximum value attained is lower. However, the details for the change in trend on increasing the sugar concentration to 50% have yet to be worked out and need further study (Olkku & Rha, 1978).

Results showing the effect of sugar on starch–guar combinations are as shown in Table 2. It is observed that, at a fixed starch and gum concentration, an increase in cold paste viscosity is observed when the sugar concentration is increased from 10 to 30%. For instance at 5% starch and 0·05% guar, the viscosity increases from 330 BU at 10% sucrose to 490 BU at 30% sucrose. This phenomenon is observed at all levels of guar gum tested. Similarly, at a fixed sugar and starch concentration, there is an increase in cold paste viscosity when the guar gum concentration is varied from 0·05 to 0·2%. This phenomenon is observed at sugar concentrations ranging from 10 to 30% (Table 2).

The behaviour of starch–gum combinations in the presence of sucrose can be explained by categorising the interactions occurring in the system into two types (Elfak *et al.*, 1977): (1) Polymer–polymer interactions and (2) Polymer–solvent interactions.

Table 2. Effect of sugar on the cold paste viscosity (CPV) and gelatinisation temperature of corn starch–guar gum combinations

Ingredients	10% sugar		20% sugar		30% sugar	
	CPV (BU)	Gel. temp. (°C)	CPV (BU)	Gel temp. (°C)	CPV (BU)	Gel. temp. (°C)
5% corn starch +0·05% guar	330	85·0	410	84·3	490	82·5
5% corn starch + 0·1% guar	380	80·0	530	82·3	680	82·5
5% corn starch + 0·2% guar	600	74·7	780	78·0	870	81·0

Table 3. Effect of addition of guar gum on the cold paste viscosity and gelatinisation temperature of 5% corn starch

Ingredients	Cold paste viscosity (BU)	Gelatinisation temperature (°C)
5% corn starch	300	86·6
5% corn starch + 0·05% guar	420	86·0
5% corn starch + 0·1% guar	520	86·0
5% corn starch + 0·2% guar	690	81·0

Table 4. Effect of addition of xanthan gum on the cold paste viscosity and gelatinisation temperature of 5% corn starch

Ingredients	Cold paste viscosity(BU)	Gelatinisation temperature (°C)
5% corn starch	300	86·6
5% corn starch + 0·05% xanthan	630	86·0
5% corn starch + 0·1% xanthan	1000	82·0
5% corn starch + 0·25% xanthan	1570	73·0

In the absence of sugar, it is assumed that both the above interactions take place, giving rise to an increase in cold paste viscosity (Tables 3 and 4). In the presence of sugar, polymer–polymer interactions seem to be favoured, as compared to polymer–solvent interactions, due to the solvent becoming bound by the sugar. As sugar concentration increases, the polymer–polymer interactions also keep on increasing, especially in the case of starch–guar combinations (Table 2). This is supported by the fact that, when the sugar concentration is kept constant and the concentration of guar is increased, an increase in polymer–polymer interaction takes place which is reflected as increased cold paste viscosity. Also, it is reported that sugar protects guar gum against hydrolysis and subsequent loss of viscosity (Carlson & Ziegenfuss, 1965).

Results showing the effect of sugar on starch–xanthan combinations are as shown in Table 5. At a fixed starch and xanthan concentration, there is an increase in cold paste viscosity from 500 BU at 10% sucrose to 600 BU at 30% sucrose. These data are for a starch concentration of 5% and xanthan concentration of 0·05% (Table 5). At higher levels of xanthan (i.e. at 0·1 and 0·25%), such direct behaviour is not seen. In fact, at these concentrations of xanthan, a decrease in viscosity is observed with increase in sugar concentration. This can be explained by considering that for efficient interaction starch and gum must be hydrated completely. It is assumed that, in a sugar free environment, starch and xanthan gum (at all concentrations) are hydrated completely and hence interact effectively to give an increase in viscosity. The difference in behaviour of starch–xanthan combinations with increase in concentrations of sugar can be thought to be due to the insufficient or incomplete hydration at high sugar levels and hence the decrease in cold paste viscosity. Though not much information is available regarding xanthan–sugar interaction, some reports support the observed

Table 5. Effect of sugar on the cold paste viscosity (BU) and gelatinisation temperature of corn starch—xanthan combinations

Ingredients	10% sugar		20% sugar		30% sugar	
	CPV (BU)	Gel. temp. (°C)	CPV (BU)	Gel. temp. (°C)	CPV (BU)	Gel. temp. (°C)
5% corn starch + 0·05% xanthan	500	86·0	590	85·0	600	86·5
5% corn starch + 0·1% xanthan	770	84·0	760	84·5	670	85·5
5% corn starch + 0·25% xanthan	1330	78·0	1100	79·6	1150	80·6

results. In studies carried out on the effect of surfactants and sugars on the dispersibility of xanthan gum (Baird *et al.*, 1987), it is reported that a non-uniform solution having many lumps, is observable in xanthan–sugar system not containing surfactant, which implies that the hydration of xanthan is restricted in the presence of sugar. This observation may account for the behaviour of starch–xanthan combinations in the presence of sugar at xanthan levels of 0·1 and 0·25%. Similarly, at a fixed sugar and starch concentration, the cold paste viscosity increases with increasing xanthan concentration (from 0·05 to 0·25%). This phenomenon was observed at all the sugar concentrations tested (i.e from 10 to 30%).

Sugars added to starch pastes are known to delay the gelatinisation temperature (Hester *et al.*, 1956; Bean & Yamazaki, 1978; Slade & Levine, 1989; Eliasson, 1992; Kim & Walker, 1992). However, sugars added at various concentrations to starch–gum combinations influence the pasting or gelatinisation temperature. This delay in gelatinisation temperature is diminished in the presence of gums, and hence the gums bring the gelatinisation temperature of starch–sugar combinations to almost that of starch alone (Tables 2 and 5). This is mainly due to two opposing effects. First is the decrease in the gelatinisation temperature of corn starch with increase in gum concentration, which is much higher with xanthan than with guar gum (Tables 3 and 4), in accordance with an earlier report (Christianson *et al.*, 1981). Second, there is an increase in gelatinisation temperature of starch alone with increase in sugar concentration which has been reported in earlier studies (Hester *et al.*, 1956; Bean & Yamazaki, 1978; Slade & Levine, 1989; Kim & Walker, 1992). Thus, the coupled effect tends to bring the gelatinisation temperature close to that of corn starch alone. The delay in gelatinisation of starch in the presence of sugar has been attributed to decreased water activity of the sugar solution as compared to that of water (Spies & Hoseney, 1982). It is probable that gums may be counteracting this effect. However, this needs experimental verification. The delay in gelatinisation temperature of starch in the presence of sugar has also been demonstrated to result from 'antiplasticisation' by sugar–water cosolvents as compared to water alone (Biliaderis, 1990). The sugar–water cosolvents are less effective in exerting their plasticising effect on starch, relative to water alone. It can be hypothesised that gums counteract the antiplasticizing effect of sugar–water cosolvents, an effect which is manifested as a decreased delay in gelatinisation temperature in the presence of sugars. This again needs to be experimentally confirmed.

The effect of sugars on the gelatinisation and pasting behaviour of modified and native starches is well known to be important to the processing and properties of food products such as baked goods, in that the effect influences the extent of starch gelatinisation, and its retardation, or even inhibition, during the baking of, for example, high-sugar cookie doughs and cake batters.

CONCLUSION

The observations put forward in this paper are important for understanding the changes which take place during the process of baking. These interactions are also important in systems such as starch-based puddings, where syneresis inhibition can be brought about.

The results presented in this study were obtained by using a Brabender amylograph. There is a possibility of co-existing polymer networks in such systems where the resultant viscosity is a composite viscosity obtained under the constant shearing action of the Brabender amylograph. The data obtained in this study should be evaluated and confirmed using other rheological techniques to achieve a deeper understanding of these mixed polymer networks.

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