

The Role of Xanthan Gum in White Layer Cakes¹

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ABSTRACT

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Xanthan gum is widely used in cake formulations. However, its precise role and the mechanism for improving cake systems are unclear. The purpose of this study was to gain a better understanding of the role of xanthan gum in white layer cakes. Cake batters containing 1% (fwb) xanthan gum were prepared by a two-stage mixing procedure. Dried egg white level could be decreased without altering cake properties when xanthan gum was added. The effect of xanthan gum on the rheology of cake batter during heating was followed using an oscillatory probe viscometer in conjunction with electric resistance oven heating. During heating, batter viscosity decreased to a minimum and then increased

sharply to a maximum. Batter viscosity of the xanthan-containing batters at the minimum and maximum points was higher than that of the control batters. For all formulations, batter viscosity at ambient temperature and the onset temperature of rapid increase in viscosity were not significantly different. Cakes containing xanthan gum continued to increase in height for a longer period than that of the control cakes, resulting in a larger volume. Incorporation of xanthan gum did not affect the degree of shrink (difference in cake height at its maximum and final heights). In addition, xanthan did not affect the amount of carbon dioxide gas lost during baking.

Hydrocolloids, or gums, are high molecular weight, water-soluble polysaccharides used for viscosity control in many food systems. Gums are obtained from a variety of sources and exhibit a wide range of properties.

In the past, food technologists used random selection and experience to select a gum that would provide the desired viscosity and texture (Farkas and Glicksman 1967). New technology in the field of rheology is making the selection of hydrocolloids for use in a specific application scientifically possible (Farkas and Glicksman 1967).

Compared to other food manufacturers in the United States, the baking industry uses relatively small amounts of gums. However, gums perform an indispensable function in bakery-related applications (Stauffer 1990). Gums were originally added to cake batters to increase moisture retention during baking and to prevent staling. Other advantages included volume increases and texture changes (Roberts 1973).

Xanthan gum is a microbial polysaccharide produced by aerobic fermentation of *Xanthomonas campestris*. It is commonly added to commercial cakes and cake mixes and has been reported to

increase moisture retention and shelf life and to improve volume and crumb structure (Anonymous 1986). Spies (1981) and Lee et al (1982) showed that the addition of small amounts of xanthan gum increased cake volume.

It is generally believed that xanthan gum improves cake volume by increasing batter viscosity and slowing the rate of gas diffusion. However, Spies (1981) showed that carboxymethylcellulose gum increased batter viscosity but did not increase cake volume. This indicates that the volume-improving effect of xanthan gum is the result of other factors.

Christianson et al (1981) suggested that xanthan gum complexes with starch, but Miller (1981) found no evidence of a gum-starch complex in angel food cakes containing xanthan gum. Differential scanning calorimetry studies of cakes, with and without xanthan gum, showed no detectable differences in starch gelatinization temperature (Spies 1981).

Xanthan's properties in solution and in some food systems have been described in the literature; however, information describing its action in cake systems was not found. The purpose of this study was to gain a better understanding of the role of xanthan gum in the white layer cake system.

MATERIALS AND METHODS

Materials

The flour used in this study was a commercial chlorinated cake flour obtained from the Mennel Milling Company in Fostoria,

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OH. It contained 8.2% protein, 0.35% ash, and 13.2% moisture. Domino superfine pure cane sugar was obtained from Amstar Sugar Corp. in New York, NY. Cake and icing shortening (PS 858), a partially hydrogenated shortening with mono- and diglycerides, was acquired from Kraft Food Ingredients Corp., Jacksonville, IL.

High-heat, nonfat dry milk and double-acting baking powder were provided by ADM Arkady, Olathe, KS. Dried egg white (DEW) was obtained from Monark Egg Corp., Kansas City, KS. Salt was obtained by Fisher Scientific Co., St. Louis, MO. Xanthan gum was provided by Kelco, San Diego, CA.

Cake Method

White layer cakes were baked using three methods: AACC method 10-90 (1983), Kissell method (1959), and Sundberg two-stage method (Sundberg et al 1953). Control cakes contained no xanthan gum. In all methods, xanthan gum was added with the dry ingredients. Xanthan levels (fwb) were 0.48% for the AACC and Kissell methods and 1% for the Sundberg two-stage method. Absorption was optimized in each method for both the control and cakes containing xanthan.

Three modifications were made to the Sundberg two-stage method: 1) the DEW level was decreased to 6.3% (fwb); 2) the dry ingredients were added to the creamed mixture, followed by slow addition of water during the first 10 sec of mixing; and 3) 425 g of batter were scaled into 8-in. pans.

Adjustment of DEW Level

Batters made with the original formula (12.5% DEW) were firm and became rubbery when xanthan was added. A 50% reduction of DEW level (to 6.3%) minimized firmness but maintained good cake volume. To determine whether xanthan gum was acting in the same role as DEW, three batters were baked containing: 1) 0% xanthan gum and 0% DEW, 2) 0% xanthan gum and 12.5% DEW, or 3) 1% xanthan gum and 0% DEW. Height increase and batter viscosity during baking were measured.

Height Increase

An aluminum ruler was suspended from a detachable frame that clipped to the sides of a cake pan. The ruler was centered 8 mm above the base of the pan. This prevented heat transfer from the pan to the ruler to minimize premature setting of the cake around the ruler. Increase in cake height during baking was monitored with a camera mounted on the oven door taking photographs at 1-min intervals. Batter temperature at the center of the cake during baking was monitored with a thermocouple. A lead wire to the thermocouple was inserted through a hole in the top of the oven. Shrink during baking was measured as the difference in cake height at the maximum and final points.

Carbon Dioxide Loss

A Beckman infrared analyzer (model 865) in range 1 was used to quantify carbon dioxide gas loss during baking. The procedure

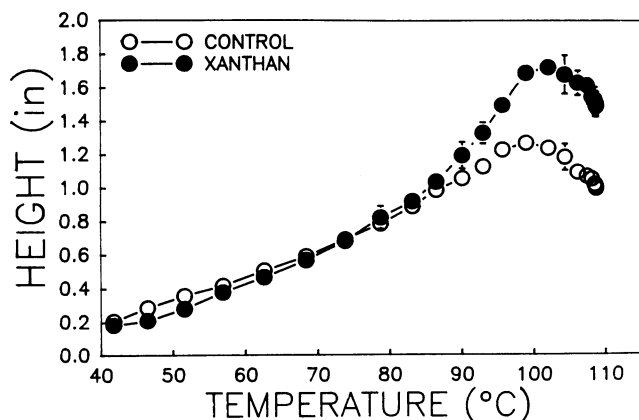


Fig. 1. Cake height increase during conventional oven baking.

for carbon dioxide quantification was as described by He and Hosney (1991). Gas flow rates into the electrical resistance oven (ERO) and infrared detector were 6,100 cm³/min and 660 cm³/min, respectively. At these flow rates, each unit on the chart represented 0.898 μmol of CO₂/min.

A modified ERO was made to accommodate cake batter. A 1-cm wide-lip containing eight threaded holes was added around the top of the ERO similar to that described by Shelke et al (1990). The gas outlets were moved from the bottom of the oven to opposite corners in the lid of the ERO (He and Hosney 1991). The thermocouple was inserted into the batter through the lid by a hole 25 mm from the gas inlet.

The rate at which carbon dioxide gas was lost from the cake during baking was monitored until the cake temperature reached 100°C. The total amount of carbon dioxide gas released during baking was determined by heating the cake until the detector returned to zero, indicating that all of the carbon dioxide gas had been released. The total amount of carbon dioxide gas released was obtained from the area under the curve.

Batter Viscosity

Batter viscosity was determined using an oscillating rod viscometer (model 710, Nametre Co., Metuchen, NJ) according to the ERO baking technique described by Shelke et al (1990).

RESULTS AND DISCUSSION

Cake Method

Cakes containing xanthan gum that were baked using the AACC and Kissell methods showed slight volume increases over the control cakes, which contained no gum. This slight increase in volume was not large enough to effectively study the effect of xanthan gum. The Sundberg two-stage method showed a 28% volume increase with the addition of 1% xanthan gum and was selected as the cake preparation method.

Height Increase

Increases in cake height during the early and intermediate stages of baking were similar for both the control and the xanthan formulations (Fig. 1). During the final stage of baking, the height of the xanthan-containing cake began to increase at a faster rate than that of the control. The structure of the control cake may have been setting during this time, decreasing the rate of expansion. The xanthan cake reached a higher maximum height than the control; however, both formulations exhibited the same degree of shrink during baking.

Carbon Dioxide Loss

The rate of carbon dioxide gas lost during baking is shown in Figure 2. Both the control and xanthan formulations retained most of the evolved gas during early and intermediate baking, and gave the same rapid loss of gas during the last few minutes

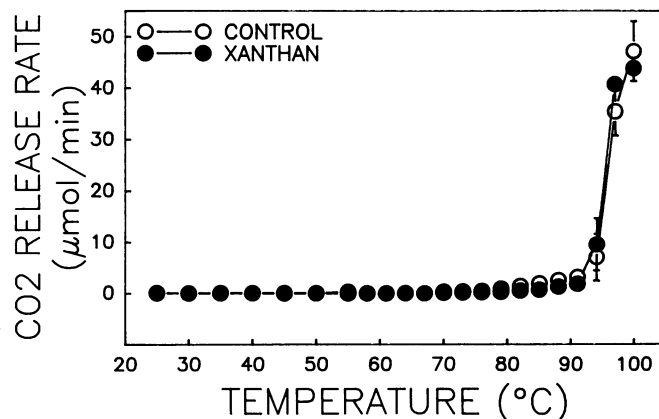


Fig. 2. Effect of xanthan gum on carbon dioxide gas loss during baking in an electrical resistance oven.

of baking as the cake structure became solid. This explains why both formulas exhibited the same degree of shrink during baking. Expanding the graph for the final stages of baking (Fig. 3) shows that the control cake lost significantly more gas at the onset of rapid gas loss (79–91°C). This confirms that the structure of the control cake was setting earlier and, thus, was unable to expand at the faster rate. This is shown by the cake height increase during baking (Fig. 1).

The cakes were heated until all of the carbon dioxide gas was released to determine whether xanthan gum allowed the leavening acid to produce more gas. There was no significant difference between the areas under the two gas loss curves.

Batter Viscosity

Viscosity profiles (Fig. 4) of cake batters during baking shows that the viscosity of the xanthan-containing batter decreased at a slower rate than the control did and was level from 35–45°C. The viscosity may have decreased more slowly because the xanthan gum was not completely solubilized. The viscosity profile of xanthan-containing batters, which were heated to 45°C, cooled to 25°C, and then baked, showed an initial viscosity decrease similar to that of the control (no xanthan) batter. Differential scanning calorimetry analyses of batters containing xanthan gum did not show a peak before starch gelatinization. This indicated that the xanthan gum was not completely solubilized during mixing but dispersed during heating.

Both the control and xanthan formulations exhibited the same viscosity at ambient temperature. However, batters containing xanthan gum maintained a significantly higher minimum viscosity during heating. Moreover, the viscosity increased rapidly at about 91°C to a significantly higher maximum viscosity than that of the control. The viscosity of the control batter reached a maximum at 94°C and then began to decrease, suggesting that the structure had set and the system had become elastic. Batters containing

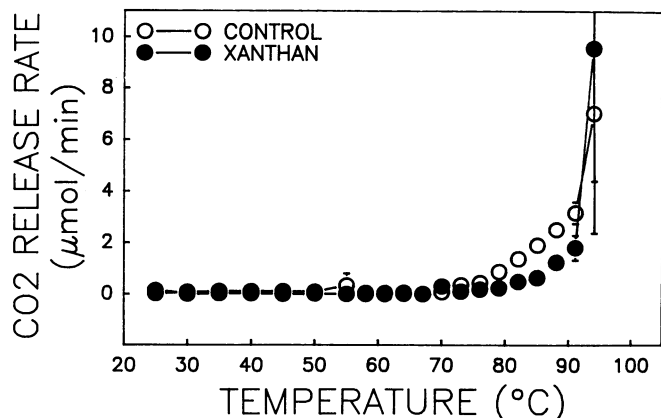


Fig. 3. Carbon dioxide gas loss in the final stages of baking in an electrical resistance oven.

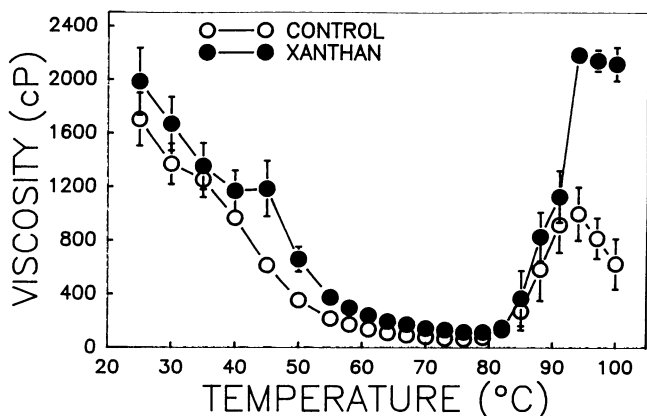


Fig. 4. Effect of xanthan gum on batter viscosity profile during heating.

xanthan gum appear to remain in the viscous state longer, reaching a higher maximum viscosity before the structure sets and expansion is curtailed.

Height Increase with Adjusted DEW

Figure 5 shows the height increase of cakes containing adjusted levels of DEW. The control cake containing 0% xanthan gum with 12.5% DEW exhibited the same height increase and shrink pattern as did the control containing 0% xanthan with 6.3% DEW. The formulations containing 1% xanthan with 0% DEW and 1% xanthan with 6.3% DEW showed the same pattern of height increase to the same maximum point. This indicated that the xanthan gum was not acting like egg white. The xanthan-containing cake without DEW did not have enough egg protein structure to support its weight. It shrank significantly more than any of the other formulations during the last few minutes of baking.

Batter Viscosity with Adjusted DEW

The viscosity profiles of batters containing 0% xanthan with 12.5% DEW and 0% xanthan with 6.5% DEW were similar (Fig. 6). The batter containing the higher level of DEW did not exhibit the rapid viscosity increase seen with the xanthan formula, indicating that the xanthan did not act like egg white.

The viscosity versus temperature plots in Figure 7 show the effect of batters containing no DEW, with and without xanthan gum. The batter containing xanthan gum with no DEW (1% xanthan, 0% DEW) maintained a significantly higher minimum viscosity during heating than did the batter containing no xanthan gum or DEW (0% xanthan, 0% DEW). Both formulations increased to the same viscosity, which was significantly higher than that of the control with DEW (0% xanthan, 6.3% DEW)

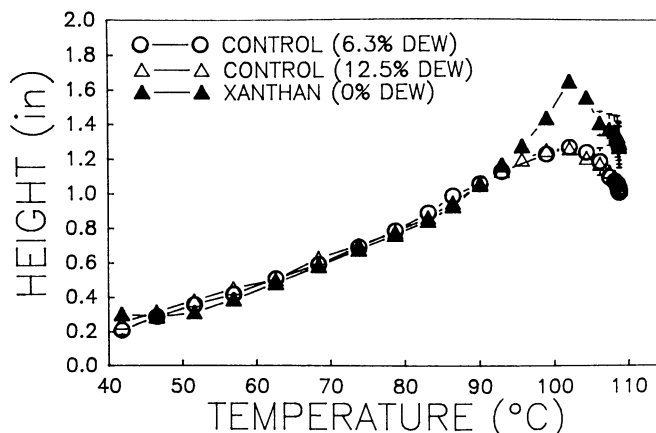


Fig. 5. Effect of xanthan gum and dried egg white (DEW) level on cake height increase during baking. Control (0% xanthan). Xanthan (1% xanthan).

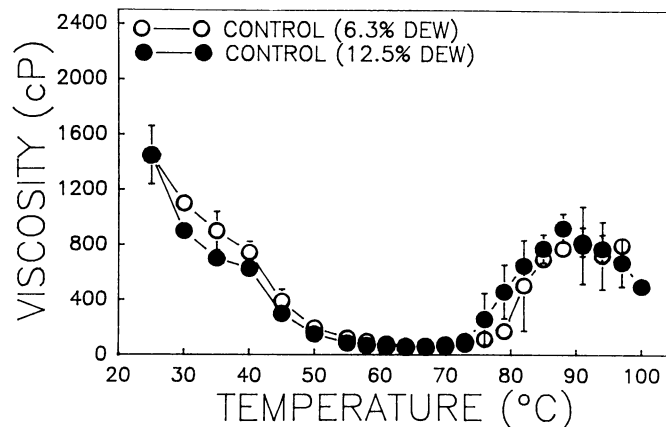


Fig. 6. Effect of dried egg white (DEW) level on cake batter viscosity during electric resistance oven baking. Control (0% xanthan).

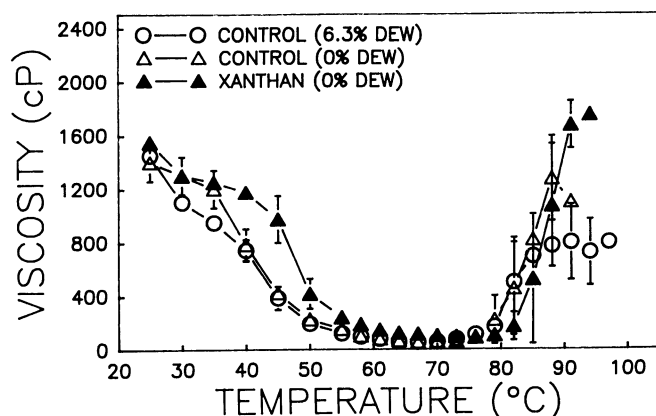


Fig. 7. Effect of xanthan gum and dried egg white on cake batter viscosity profiles during electrical resistance oven heating. Control (0% xanthan). Xanthan (1% xanthan).

formulation. However, the cakes were unable to support their own weight and collapsed during baking. Therefore, no conclusions could be drawn concerning maximum viscosity. The egg proteins curtailed expansion but were necessary to prevent structural collapse.

The addition of xanthan gum had no effect on the onset slope of rapid viscosity increase (starch gelatinization) but did significantly increase the rate of viscosity increase.

CONCLUSION

The addition of xanthan gum significantly improved cake volume. The formulation containing xanthan increased in height at a faster rate than the control. The rapid increase in height started at 79°C and reached a significantly higher maximum point than that of the control.

Cake batters containing 12.5% DEW (0% xanthan) gave the same height increase and viscosity profile as the control (0% xanthan, 6.3% DEW). The formulation containing 1% xanthan with 0% DEW showed a height increase similar to the formulation containing 1% xanthan and 6.3% DEW and increased to the same maximum viscosity as the formulation containing 0% xanthan and 0% DEW before the structure collapsed. These observations show that xanthan gum does not increase cake volume by acting like egg protein.

An interaction of xanthan gum with the gelatinized starch in the system would produce a cake with a firmer crumb that would not collapse. However, the addition of xanthan gum to formulations containing DEW had no effect on cake shrinkage (no collapse) during baking. This suggests that no interaction occurred between xanthan gum and gelatinized starch.

These data do not support the hypothesis that xanthan gum improves cake volume by increasing batter viscosity and slowing the rate of gas diffusion. Both the control and xanthan formula-

tions lost carbon dioxide gas at the same rate during the early stages of baking. In the later stages of baking (79–91°C), the control cake lost significantly more gas. Presumably, this gas loss occurred because the structure became rigid, increasing the pressure in the gas cells and causing more gas to diffuse to the atmosphere. Moreover, the viscosity of the control cake reached its maximum at 94°C and then began to decrease, indicating that the structure had set and that the cake crumb had become elastic. Spies (1981) had similar results in which carboxymethylcellulose gum increased batter viscosity without improving cake volume. Therefore, the volume-improving effect of xanthan gum must be the result of other factors.

The xanthan cake was significantly higher than the control cake at 94°C, which corresponded to the temperature of the rapid increase in batter viscosity of the xanthan cake. This indicates that the batter was still viscous at the high temperature, and that the cake continued to expand. Xanthan gum appeared to keep the batter viscous and less elastic at higher temperatures, allowing the cake to expand more before the structure set. Xanthan gum exhibits the unique property of being pseudoplastic, which may allow the batter to expand longer.

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