Effects of Corn Syrups in Layer Cakes[1]

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ABSTRACT

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Four corn syrups and glucose were used to replace sucrose in high-ratio white layer cakes. At 100% replacement of sucrose, only the high maltose corn syrup gave a cake with acceptable volume. The amylograph was used to study the effect of corn syrups on starch pasting characteristics. Swelling temperature was related to the amount of sugars present. Low molecular weight sugars in syrups gave lower swelling temperatures than did equal quantities of high molecular weight sugars. Water activity and gelatinization temperature were apparently related. Corn starch lipids, extracted with methanol, were added to the sucrose-flour mixture in the amylograph. The resulting amylogram was similar in appearance (but not in swelling temperature) to that produced when corn syrups were used. High maltose corn syrup extracted with chloroform gave an amylogram similar to that with sucrose. However, cakes baked from the extracted syrup, although equal to sucrose cakes in appearance, volume, and grain, were sticky and definitely inferior in mouthfeel.

Large quantities of syrups are produced from starch, and manufacture can be controlled to produce a wide variety of sugar combinations in the syrups (Peterson 1974). Presently, corn syrups are used to replace sucrose in many bakery products, but use of corn syrups to replace sucrose in cakes has not been as successful as in other products. Saussele et al (1976) replaced sucrose in a high-ratio white layer cake with various amounts of high fructose corn syrup. At 15 and 25% replacement, the crumb and crust color were darker and the texture good. Henry (1976) also recommended 10–30% replacement of sucrose with high fructose corn syrup.

Volpe and Meres (1976) increased the replacement of sucrose with high fructose corn syrup to 60%, using leavening agents that retarded the browing reaction by decreasing the pH. Sugars delay the gelatinization of starch (Bean and Osman 1959, Bean and Yamazaki 1978, Savage and Osman 1978). On an equal weight basis, different sugars delay gelatinization to different degrees (Bean and Osman 1959, Bean et al 1978). Based on that work, Bean and Yamazaki (1978) and Bean et al (1978) found that reducing the water content by 10–20% gives optimum grain and contour with high fructose corn syrup.

Most of the work to date has attempted to solve the problem of using corn syrup in cakes by changing the formulations. The goal of this work was to uncover the nature of the problem in replacing sucrose with corn syrups.

MATERIALS AND METHODS

The flour was commercially milled from soft wheat and treated with chlorine. It contained 8.8% protein, 11.4% moisture, 0.39% ash, 1.8% starch damage (Farrand 1964) and had a pH of 4.72. The four corn syrups and solid glucose, furnished by A. E. Staley, and the manufacturer's stated composition of each are given in Table I. Other sugars used were maltose (Hayashibara Biochemical Laboratories, Inc.), D-sorbitol, and D-fructose (Fisher Scientific).

Cake Baking Method

The Kissell lean formula (1959), with the level optimized, was used to bake cakes. Cake volumes were determined by rapeseed displacement. Whenever corn syrups or other sugars were used to replace sucrose, the replacement was on a solids basis. All reported cake volumes are the average of at least duplicate cakes. Standard deviation for cake volume was 12.5 cc.

Amylograph Procedure

A mixture of 40 g of flour, 350 ml of carboxymethyl cellulose solution (1.5%), and 162 g of sucrose or other sweetener was used. This empirical formulation gave a lower sugar-to-water ratio than that used in the cake formula. Amylograms, at least duplicates, were determined with a Brabender amylograph at 75 rpm and with the 700 sensitivity cartridge.

Chloroform Extraction

Syrup was diluted with an equal volume of distilled water and stirred overnight with an equal volume of chloroform. The aqueous fraction was twice more extracted with an equal volume of fresh chloroform, stirring 2 hr for each extraction. The resultant aqueous syrup fraction was rotary evaporated at 40° C to remove residual chloroform and reduce the water content.

Solids Determination

Commercial grade Celite 545 (Fisher Scientific) was washed with HCl and then water, after which it was dried at 120° C. Aluminum dishes containing 20 g of the washed Celite and a glass stirring rod were dried to a constant weight. Corn syrups (10 g) were weighed into disposable weighing dishes, and 10 ml of hot water was added with stirring. The solution was added to the tared dishes, and three

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4-ml portions of water were used to wash the weighing dish. The glass stirring rod was used to incorporate the solution and the Celite into a damp mass. The stirring rod was left in the dish, and the dishes were dried at 120° C to a constant weight.

RESULTS AND DISCUSSION

Baking Properties of Syrups

Cakes were baked using corn syrups and glucose to replace all or part of the sucrose. When glucose was made into a syrup and used to replace 50% of the sucrose (on a solids basis), the cakes had lower volumes, darker exterior colors, and lighter brown grain than the 100% sucrose control (Table II). Characteristically, the cakes containing glucose had flat tops and extremely poor grain. These results indicated that 50% of the sucrose could not be replaced by glucose without a major adjustment in the formula. The low dextrose equivalent (LDE) and high maltose (HM) syrups at 50% replacement (Table II) produced cakes of better quality than did the other syrups.

A series of cakes were baked using some corn syrups at 100% replacement (Table III). The HM syrup produced an acceptable cake. It was slightly lower in volume, evenly browned on the outside, and had a very fine grain but a chewy (sticky) texture. Two other corn syrups, the high dextrose equivalent (HDE) and the LDE, gave cakes of lower volume and poorer grain. The high fructose (HF) syrup gave cakes with much lower volumes, open grain, and dark brown exterior.

TABLE I
Corn Syrup Used and Manufacturers' Stated Compositions

Syrup	Glucose (%)	Maltose (%)	Triose (%)	Oligo-saccharides (%)
High fructose	50[a]	1.5	···	5
High maltose	10	46	24	20
Low dextrose equivalent	20	14	12	54
High dextrose equivalent	39	33	12	16

[a]In addition, this syrup contained 42% fructose.

TABLE II
Cakes Baked with Corn Syrups Replacing 50% of the Sucrose

Sweetener	Volume (cc)	Grain
Sucrose	540	Fine
High maltose	530	Fine
Low dextrose equivalent	500	Fine
High dextrose equivalent	470	Open
High fructose	420	Open
Glucose	410	Open

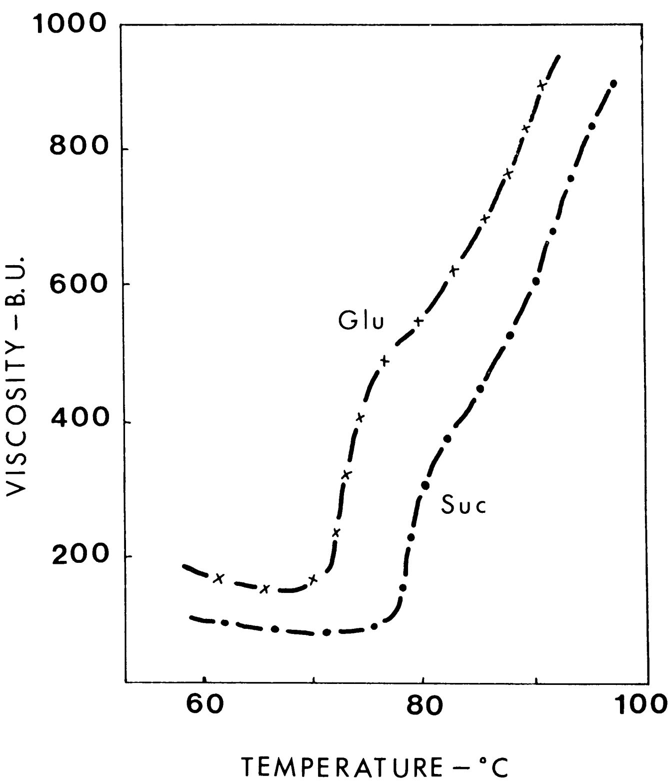

Fig. 1. Amylograms for sucrose (**Suc**) and glucose (**Glu**).

Amylograph Properties of Corn Syrups

The cake-baking results showed that substitution with corn syrups or crystalline glucose would not produce good quality cakes. The amylograph was used to study the effect of each syrup, at 100 and 50% sucrose replacement, on the gelatinization and pasting properties of cake flour.

The amylograph curves for sucrose and glucose (both at 0.46 g/ml) were essentially parallel. Both sugars delayed gelatinization, but sucrose had a larger effect than did glucose (Fig. 1). The amylogram for the HM syrup (0.46 g/ml) showed that a higher temperature was required for gelatinization and that swelling proceeded at a slower rate than with sucrose (Fig. 2). After a pronounced delay, a second swelling stage appeared. The LDE

TABLE III
Cakes Baked with Corn Syrup Replacing 100% of the Sucrose

Sweetener	Volume (cc)	Grain
Sucrose	580	Fine
High maltose	550	Fine
Low dextrose equivalent	520	Semifine
High dextrose equivalent	530	Semifine
High fructose	420	Coarse

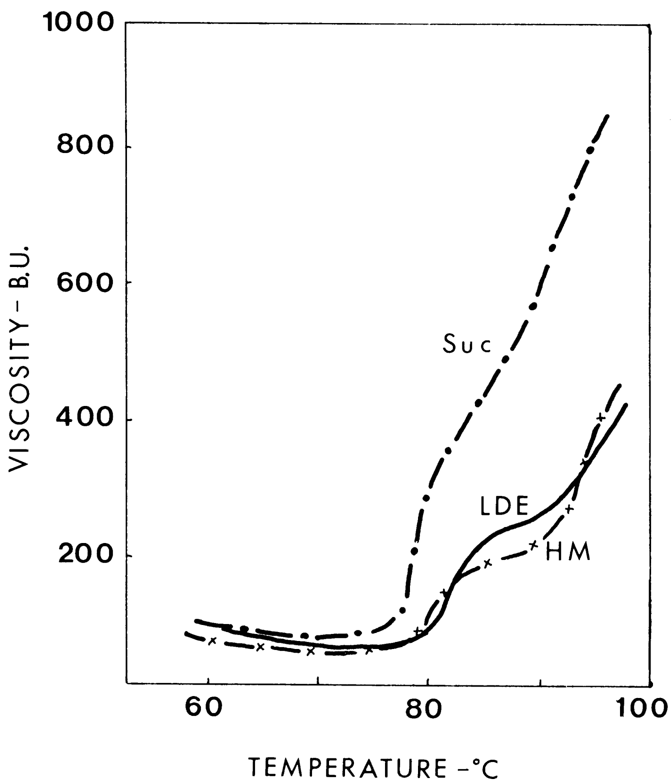

Fig. 2. Amylograms for sucrose (**Suc**), low dextrose equivalent corn syrups (**LDE**), and high maltose corn syrup (**HM**).

syrup (0.46 g/ml) had an amylogram similar to that of the HM syrup.

The HDE syrup (0.46 g/ml) and the HF syrup (0.46 g/ml) both had lower gelatinization temperatures than sucrose did (Fig. 3). Those two syrups also showed a delayed second-stage swelling similar to that noted for the HM and LDE syrups. Amylograms for 50:50 mixtures of the corn syrups and sucrose gave curves between those for 100% sucrose and 100% of the corn syrup in question.

The amylograms showed that the corn syrups and glucose affected the gelatinization of the cake flours differently than did sucrose. None of the curves obtained for the corn syrups and glucose approximated the curve for sucrose. The gelatinization temperature appeared to depend on the composition of the sugars in the corn syrup. The LDE and HM corn syrups, which contained larger amounts of high molecular weight sugars (oligosaccharides), had higher gelatinization temperatures. The HF and HDE corn syrups, which contained larger amounts of low molecular weight sugars (mono and disaccharides), had lower gelatinization temperatures. The delayed second-stage swelling appeared to be associated with the syrups; all syrups gave a delayed second stage, but the purified sugars did not.

Addition of glucose to the HM and LDE syrups, with a constant sugar to water ratio maintained, lowered the gelatinization temperature. As the amount of added glucose was increased, the gelatinization temperature progressively decreased. The overall shape of the amylogram was relatively unchanged by the addition of glucose.

Amylogram Properties of Sugars

The effect of certain sugars and sugar alcohols on the gelatinization properties of cake flours has been extensively studied (Bean and Yamazaki 1978, Bean et al 1978, Miller and Trimbo 1965). Sugars delay the gelatinization of starch, and different sugars affect gelatinization to different extents. This phenomenon is not understood, and the factor(s) that control gelatinization of starch in sugar solutions are unknown.

We postulated that sucrose might have a sterostructure that would, at least in part, exclude it from entering a starch granule as freely as glucose or water. This would create an osmotic gradient between the sucrose solution and the interior of the starch granule that might affect the gelatinization temperature. If the hypothesis were true, a slurry of dry starch in a sucrose solution, after centrifugation, should show an increase in sucrose concentration in the supernatant. However, when such slurries were prepared with both sucrose and glucose and the supernatants were examined by high performance liquid chromatography, no difference in the sugar concentration was found. In fact, the sugar concentrations were equal to that of the original sugar solution. Thus, both sucrose and glucose freely enter the starch granule.

Effect of Water Activity on Amylograms and Baking Properties

Sugars are used in the food industry to lower water activity. Sugars decrease water activity as the concentration increases; however, the rate of change of water activity per unit of concentration is different for different sugars (Sloan and Labuza 1968, 1975).

The amylograph data also showed that gelatinization temperature varied with the individual sugars, even though the sugar to water ratio was held constant. Therefore, we plotted the gelatinization temperature vs water activity (calculated from Sloan and Labuza [1968, 1975] at the concentration of sugar used in the amylograph) for several sugars (Fig. 4) and found an apparent relationship between water activity and gelatinization temperature. So, to achieve the same gelatinization temperature with glucose as with sucrose, the amount of glucose must be increased.

On the basis of these results, cakes were baked with increasing glucose concentrations but with the water held constant (Fig. 5). The volume of the cakes increased with increased glucose concentration up to 450 g; above 450 g, the volume decreased rapidly and progressively. The grain of the cakes progressively improved up to 311 g of glucose. Above 311 g, the grain became progressively coarser and darker in color. At the higher concentrations of glucose, the cake would rise to the top of the pan in the oven but would shrink to an unusual extent when cooled. All the glucose cakes had a wet appearance.

For comparison, cakes were baked with increasing concen-

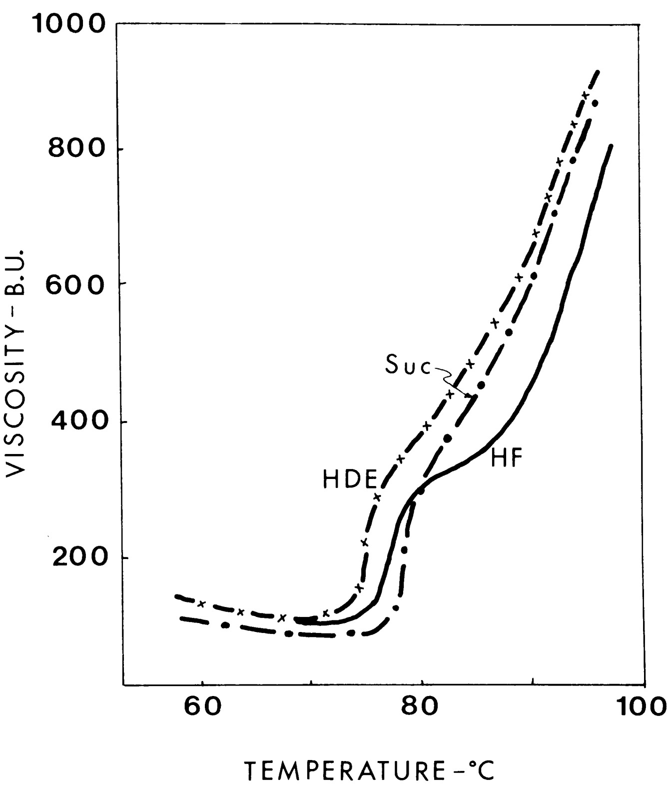

Fig. 3. Amylograms for sucrose (**Suc**), high dextrose equivalent corn syrup (**HDE**), and high fructose corn syrup (**HF**).

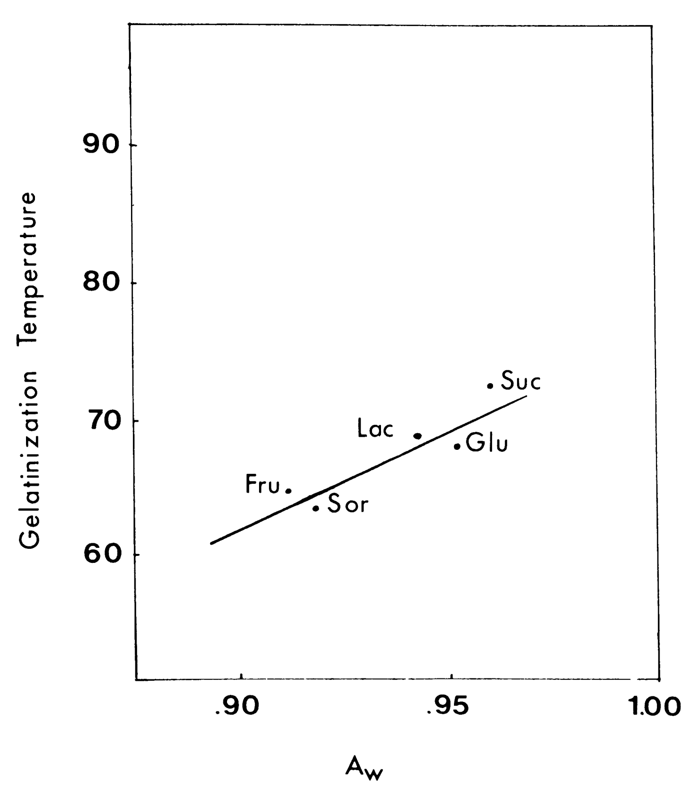

Fig. 4. Gelatinization temperature vs water activity (**A_w**) for sucrose (**Suc**), lactose (**Lac**), glucose (**Glu**), fructose (**Fru**), and sorbitol (**Sor**).

trations of sucrose but with the water level held constant (Fig. 5). The volume of the cakes increased gradually to 195 g (normal concentration) and then rapidly decreased. Cakes with less than 195 g of sucrose had a peaked center, smooth sides, and fine snowy grain. Cakes with more than 195 g of sucrose had a depression in the centers that increased in size as the amount of sugar was increased. At high sucrose concentrations the sides became less smooth and the grain extremely coarse.

The HM corn syrup was also used at different concentrations of solids. Volumes of the cakes were equal to those of cakes baked with the normal concentration (195 g) of sucrose, except that at the highest concentration (239 g) the volume was lower (Table IV). However, cake volume was not as sensitive to the concentration of HM syrup as it was to sucrose concentration. The cakes at the lowest HM concentration were noticeably peaked, with golden crust color, and with an off-white semifine grain. The peak became less apparent as the amount of syrup was increased, until at the highest concentration a dip became apparent in the center of the cake. At the highest concentration, the cakes had coarse grains and a light brown color.

Bean et al (1978) reported that cakes with good contour and grain could be produced with HF syrup if the water was reduced 10–20%. We tried a similar experiment using crystalline glucose as the total sugar. The amount of glucose (311 g/150 g flour) used was higher than the normal amount of sucrose; it was the amount of glucose that gave cakes with the best grain. Water was removed from the formula in 10% increments. The data (Table V) show a slight increase in volume when water was removed up to 30% of the

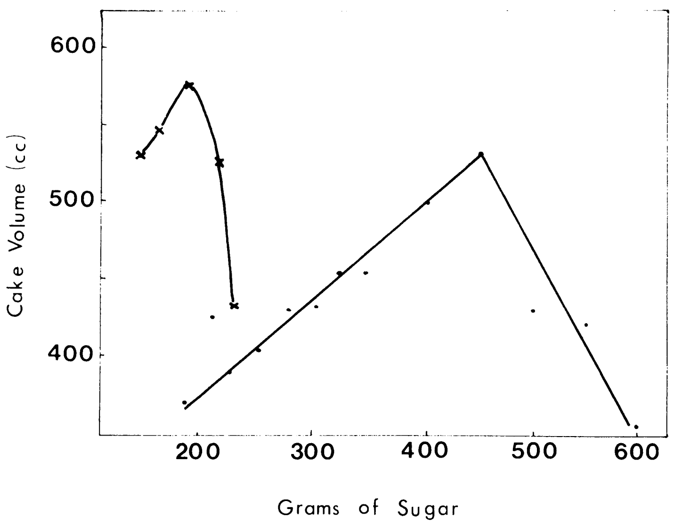

Fig. 5. Cake volume vs grams of sugar used in baking, sucrose (**x**) and glucose (•).

TABLE IV
Cakes Baked with High Maltose Corn Syrup at Various Solids Concentrations

Syrup (g)	Volume (cc)	Grain
195[a]	570	Fine
205	575	Fine
215	570	Fine
239	510	Coarse

[a]Control.

TABLE V
Cakes Baked with Glucose (311 g) and Gradual Decrements of Water

Water Removed (%)	Volume (cc)	Grain
0	430	Slightly fine
10	475	Slightly fine
20	475	Slightly fine
30	550	Fine
40	475	Coarse
50	460	Coarse

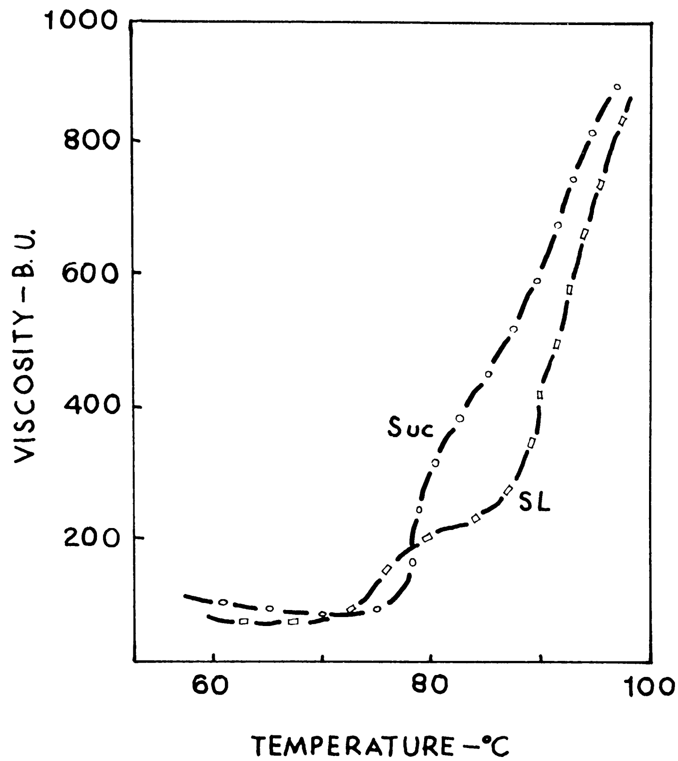

Fig. 6. Amylograms for sucrose (**Suc**) and sucrose plus corn starch lipids (**SL**).

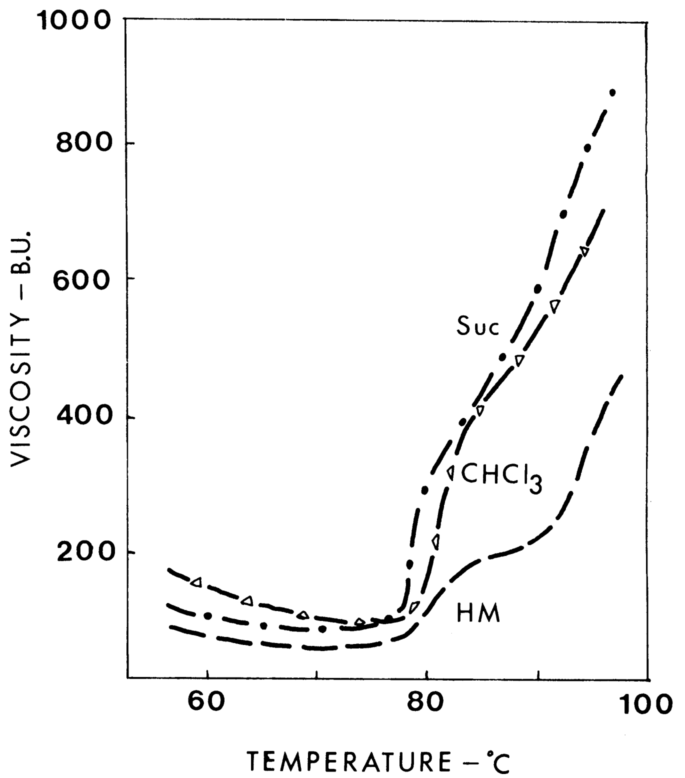

Fig. 7. Amylograms for the high maltose corn syrup (**HM**), high maltose corn syrup treated with chloroform (**$CHCl_3$**), and sucrose (**Suc**).

TABLE VI
Cakes Baked with Chloroform-Treated High Maltose Corn Syrup

Sweetener	Amount (g)	Volume (cc)	Grain
Sucrose	195	620	Fine
High maltose	195	580	Fine
High maltose[a]	190	565	Fine
High maltose[a]	195	630	Fine
High maltose[a]	205	630	Coarse

[a]Chloroform-treated syrup.

total. The cakes with 0, 10, and 20% of the water removed had flat tops, golden brown crust color, a wet-appearing crust, smooth sides, and a semifine snowy white grain. The cakes produced with 30% of the water removed had good volume and grain but still had a flat contour and a wet, golden brown crust. All the cakes tended to rise to the top of the pan during baking but shrank and pulled away from the sides of the pan upon cooling. With 40 and 50% of the water removed, the cakes were collapsed in the center and were golden brown with brown dots throughout the wet crust. The interior was coarse and dry looking and had golden spots throughout.

Effect of Corn Syrup Lipids

The gelatinization of starch is affected by the lipids present (Gray and Schoch 1962, Medcalf et al 1968). Because the syrups we used were derived from corn, the lipid from corn starch was extracted with methanol. The corn starch lipids (0.5% based on the amount of wheat flour used) were then added to a sucrose solution and run on the amylograph (Fig. 6). Corn starch lipids definitely affected the amylograph curve; the gelatinization temperature was lowered and the second-stage swelling temperature was increased. In some respects the effect was similar to that of corn syrups, ie, a delay in the second-stage swelling.

Because corn starch lipids may also be present in syrup and thereby affect the amylograms, the HM syrup was extracted with chloroform. After being concentrated to remove the residual chloroform, the syrup fraction was run on the amylograph. The amylogram (Fig. 7) was radically different; the gelatinization temperature was unchanged, but the second-stage swelling temperature was decreased. The amylogram was similar to that obtained with sucrose.

A series of cakes were then baked with the chloroform-extracted HM corn syrup to see if the removal of the corn starch lipids would affect the cakes as it had the amylogram. The data (Table VI) show that the volumes of the cakes were comparable to that of sucrose cakes. The external appearance of the cakes was quite good. At 190 g of the treated syrup, the cakes had the peaked appearance that occurred in earlier studies when the sugar solids concentration was too low. The cakes had a pale yellow crust and a fine white grain. At 195 g, the cakes were like the sucrose cakes in appearance, with a rounded contour, a slightly golden crust color, and a fine grain. At 205 g the cakes began to show a dip, which is characteristic of cakes with above optimum concentration of sugar; these cakes also had a coarse grain, a golden crust color, and a light brown grain. The cakes with the chloroform-extracted HM syrup were more sensitive to changes in sugar concentraion than were cakes baked with sucrose or glucose. Although the volume and appearance of the cakes made with the chloroform-extracted HM syrup were good, the cakes still felt chewy and sticky in the mouth.

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