High-Fructose Corn Syrup Cakes Made with All-Purpose Flour or Cake Flour

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ABSTRACT

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Cakes were prepared containing 0, 50, 75, or 100% high-fructose corn syrup as a replacement for sucrose. All-purpose flour and cake flour were used at each level of sweetener. The physical and chemical measurements of the batter included specific gravity and linespread. Moisture content, deformation, volume, and crust and crumb color physical and chemical measurements were made on the baked cakes. A sensory panel also evaluated crust and crumb color, flavor, moistness, and tenderness. The data suggested no significant flour × sweetener interactions in the physical and chemical variables. Sweetener had a significant main effect on the linespread of the batter, and the moisture content, deformation, and crumb color of the baked cakes. Flour type had a significant main effect on volume and crumb color of the baked cakes. Sensory scores did indicate an interaction between level of sweetener and flour type for crust color, moistness, and tenderness variables. There was no significant flour × sweetener interaction for crumb color sensory scores.

Research interest is on the rise to produce a satisfactory cake product using high-fructose corn syrup (HFCS) as a replacement for sucrose. HFCS is economically stable and is a syrup easily incorporated into formulations. Problems with HFCS in baked goods, such as excessive browning, lower volume, loss of tenderness, and bitter taste, are discussed in Koepsel and Hoseney (1980) and Coleman and Harbers (1983). Nonetheless, the low cost, price stability, and availability of the corn-based sweetener sustains our interest in research. Johnson and Harris (1989) considered effects of acidulants in controlling browning of cakes with 100% HFCS. Johnson et al (1989) considered effects of HFCS on browning, starch gelatinization, and sensory characteristics of cakes. The objective of this study was to monitor seven physical and chemical measures of cakes such as linespread, specific gravity, volume, moisture, deformation, and color differences for each of eight cake treatments. The cake treatments consisted of varied levels of HFCS (0, 50, 75, and 100%) as a replacement for sucrose in combination with 100% cake flour or all-purpose flour. A variety of sensory measures was integrated into the study. Statistical analyses took into account the interacting effects of level of HFCS and flour type on the variables of interest. A comparison is made with the 100% sucrose control noting the strength of the interaction.

MATERIALS AND METHODS

Preparation of Cakes

Based on a variation of Volpe and Meres (1976) cakes were prepared with 0, 50, 75, and 100% HFCS as a sucrose replacement (Table I). The HFCS was first-generation syrup (Isosweet 100, A. E. Staley Manufacturing Co.) and by high-performance liquid chromatographic (HPLC) analysis was determined to be 43.7% fructose, 51.1% glucose, and 5.2% oligosaccharides. Water was adjusted to allow for moisture content of the syrup. Ingredients had a common lot number except for eggs, which were purchased fresh daily.

Cakes were prepared by a two-stage mixing procedure: eggs were separated by hand, and the whites were beaten for 4 min and set aside until the last step. Ingredients were combined in a Kitchen-Aid mixer (model K5SS, Hobart Co.) connected to an automatic timer through a power source. Batter (870 g) was poured into a 20 × 20 × 5 cm stainless steel pan, sprayed with Pam (Boyle Midway Household Products, Inc.), and baked in a household-type oven for 30 min at 177°C.

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Physical and Chemical Measures

Linespread (Campbell et al 1979) of the batter for each variation was determined by using a 20.5-cm glass pie plate, a brass ring with an inner diameter of 3.8 cm and an outer diameter of 5.1 cm, and a linespread grid. The grid was centered under the pie plate with the brass ring in the center of the plate. The ring was filled with batter and leveled at the top. The ring was then lifted up to allow the batter to flow for 30 sec. At the end of 30 sec, four values at the edge of the batter flow were read from the grid. The mean of the values was used for statistical analysis. For every cake made, one mean linespread value was computed. Specific gravity of each batter variation was determined using the following formula:

$$\text{Specific gravity} = \frac{\text{wt of 50 ml of cake batter}}{\text{wt of 50 ml of water}}$$

An index to volume of each baked cake was determined by averaging the standing height (in centimeters) of five points on the cake, measured with a vernier caliper: at the four corners 1 cm from each edge, and the geometric center.

Moisture was determined by a Brabender moisture tester (model SAS-692, S. Hackensack, NJ). Duplicate 10-g samples from the midsection containing crust and crumb were dried in metal pans to a constant weight at 110°C. Readings were taken and averaged to give one value. Duplicate readings differed by no more than 1%.

Deformation was determined by using a penetrometer timer (Labline Instruments, Melrose Park, IL) according to the method of Bourne (1982). A 3.5 × 3.5 cm sample of cake, taken from the midsection, was compressed with the aluminum disk attachment (7.7 cm diameter). A 50-g weight was added to the bar and the cake sample was compressed a second time. The

TABLE I
Formula for Cakes Prepared with High-Fructose Corn Syrup or Sucrose[a]

	% High-Fructose Corn Syrup			
Ingredient	**0**	**50**	**75**	**100**
Flour[b]	200.0	200.0	200.0	200.0
Shortening	108.0	108.0	108.0	108.0
Egg white	82.8	82.8	82.8	82.8
Egg yolk	57.2	57.2	57.2	57.2
Baking powder	10.0	10.0	10.0	10.0
Cream of tarter	3.0	3.0	3.0	3.0
Nonfat dry milk	20.0	20.0	20.0	20.0
Sucrose	240.0	120.0	60.0	0.0
High-fructose corn syrup	0.0	169.0	253.0	338.0
Water[c]	149.0	99.0	74.0	50.0

[a] Ingredient amounts in grams.
[b] All-purpose or cake flour.
[c] Water was adjusted to allow for the moisture content of the syrup.

TABLE II
Summary of Physical Chemical Variables[a] Based on Analysis of Variance for All-Purpose and Cake Flours and for High-Fructose Corn Syrup

	Marginal Means[b]					
	Flour		% High-Fructose Corn Syrup			
Variables	All-Purpose	Cake	0	50	75	100
Linespread	6.95	7.38	9.50	7.10	6.55*	5.50*
Specific gravity	0.87	0.85	0.88	0.85	0.86	0.84
Index to volume	3.98	4.50*	4.45	4.30	4.25	3.95*
Moisture	32.73	32.60	30.65	32.50*	33.40*	34.05*
Deformation	36.68	36.75	69.35	40.55	26.35*	10.60*
Crust color	37.30	38.05	39.00	35.95	37.50	38.15
Crumb color	73.78	77.95*	77.55	76.45	75.00	74.45

[a] Levels of sweetener and type of flour did not have significant interaction for any physical chemical variables.
[b] Marginal means for flour type were based on 4 × 3 repetitions = 12 observations; those for high-fructose corn syrup were based on 2 × 3 repetitions = 6 observations. Significant difference from control indicated by (*).

instrument measured the amount the cake was compressed in millimeters. Deformation was determined by the difference in millimeters of compression due to the additional weight.

Color differences were determined on both crust and crumb color using a Hunter Lab color difference meter (model D25, Reston, VA). The instrument was standardized using a white tile (standard number 20-1651 with parameters $L = 91.97$, $a = -0.8$, and $b = -1.0$). Crust and crumb samples were pressed separately into the bottom of Agtron sample cups (American Scientific Products) to help minimize surface variations. Three readings of the crust and crumb color of each variation were recorded, and differences from the calibrated standard were calculated by using the ΔE formula where:

$$\sqrt{\Delta E} = \sqrt{(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2}$$

Sensory Evaluation

Sensory evaluation was done by six trained panelists who were students from the Department of Human Nutrition and Foods at Virginia Polytechnic Institute and State University. Training of students required two 1-hr sessions to acquaint them with the descriptors used for the anchors. Three cakes of randomly selected treatment combinations were baked on Tuesdays and Thursdays for four weeks. Over the course of the study, each variation was replicated three times per panelist. Three samples (one of each of the selected treatment combinations) were presented to a panelist at a session. The sessions were held in the late afternoon, and panelists were instructed to refrain from eating, drinking, smoking, or chewing gum for 30 min prior to each tasting session. Panelists were given a tray with three 4 × 4 × 4 cm samples of freshly cut cake from the midsection and a glass of water for rinsing between each sample. They were asked not to talk during tasting of cakes. The testing was conducted in a room with partitions between each seat and tables with fluorescent lights and neutral gray walls. Cakes were evaluated for crust and crumb color, flavor, moistness, and tenderness. Sensory scoring was done on a 7.5-cm line with anchor words on each end. The panelists were asked to make a mark on the line in relationship to the anchors.

Statistical Analysis

The statistical analysis consisted of an incomplete block design that tested for main effects (flour effect and sweetener effect) and flour × sweetener interaction effect for both the physical chemistry and sensory variables. PROC GLM of the SAS program (SAS Institute 1985) was used for the objective data as well as for the sensory data. Statistical tests were performed for the flour and sweetener main effects and the flour × sweetener interaction for each variable using the partial Type III sums of squares. Sources of the variation such as day effect and person effect were removed via blocking but were not tested for significance. Due to the unbalanced nature of the incomplete block design, standard pairwise comparison tests, such as Duncan's multiple range or Tukey's honest significant difference, could not be used.

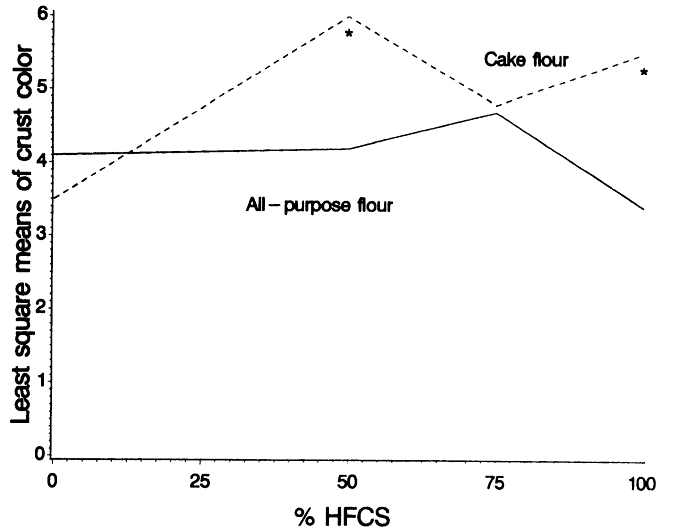

Fig. 1. Sensory scores for crust color of baked cakes prepared with all-purpose and cake flour with 0, 50, 75, and 100% high-fructose corn syrup (HFCS) replacement for sucrose indicating interactive effects. Significant flour effect at specified HFCS level is indicated by asterisks. Response anchors are 0 = light brown and 7.5 = dark brown.

Accordingly, pairwise t tests were used and adjusted for the overall Type I error using the Bonferroni technique (overall $\alpha = 0.05$).

Results of Physical and Chemical Measurements

The level of sweetener and flour type did not interact for any of the physical and chemical measurements ($P > 0.05$). Consequently, any significant differences were attributed to the sweetener or flour main effects alone. Table II provides a summary of the seven analyses of means as well as a summary of pairwise comparisons.

Linespread and Specific Gravity

The amount of HFCS had a significant effect on linespread ($P < 0.05$). Batter with 75 and 100% HFCS was more viscous and exhibited decreased linespread. No differences in mean specific gravity were found in the eight variations of cakes.

Index to Volume and Moisture

For 0 and 100% HFCS levels, the cakes made with all-purpose flour (APF) had a significantly lower (by an average of 0.9 cm) index to volume than cake flour (CF) cakes. Hence, a more aerated product was found using CF rather than APF at the 0 and 100% HFCS level. HFCS also had a significant effect ($P < 0.05$) on moisture content of the baked cakes. As the amount of the HFCS replacement for sucrose was increased (75 and 100% with APF and 100% with CF), the moisture content was significantly greater. The cakes with HFCS were more hygroscopic because of the humectant nature of the syrup. The cakes made with 100% HFCS as a replacement for sucrose had the highest moisture content.

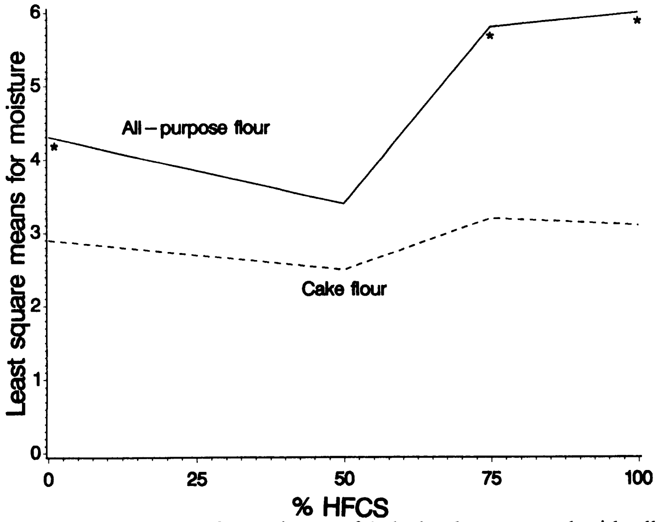

Fig. 2. Sensory scores for moisture of baked cakes prepared with all-purpose and cake flour with 0, 50, 75, and 100% high-fructose corn syrup (HFCS) replacement for sucrose showing interactive effects. Significant flour effect at specified HFCS level is indicated by asterisks. Response anchors are 0 = dry and 7.5 = wet.

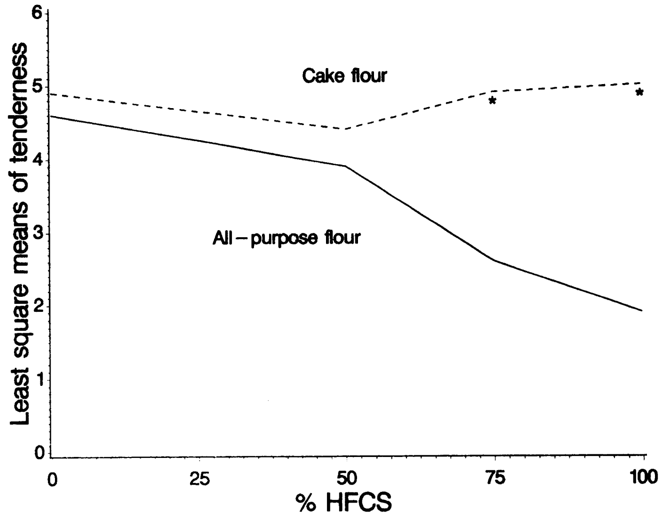

Fig. 3. Sensory scores for tenderness of baked cakes prepared with all-purpose and cake flour with 0, 50, 75, and 100% high-fructose corn syrup (HFCS) replacement for sucrose showing interactions. Significant flour effect at specified HFCS level is indicated by asterisks. Response anchors are 0 = tough and 7.5 = crumbly.

Deformation Crust Color and Crumb Color

The amount of HFCS replacement for sucrose was a significant factor ($P < 0.05$) in the deformation values of the cakes. In fact, the APF cakes prepared with 100% HFCS replacement for sucrose were deformed less (an average of 76 mm by the penetrometer) than the APF cakes prepared with 100% sucrose. The deformation value was reported by Bourne (1982) to be an indicator of tenderness. Sensory evaluations indicated that the APF cakes were less tender with 100% HFCS than with other levels of HFCS replacement. This is in agreement with the findings of Coleman and Harbers (1983). However, statistically significant differences were not found in tenderness for CF cakes when sucrose was replaced with any level of HFCS.

Hunter color meter ΔE values also are given in Table II for the crust values; no significant differences ($P > 0.05$) among flour type or HFCS level were found. CF cakes were significantly (4.175 units on average) lighter in crumb color than APF cakes. Furthermore, CF cakes made with 75 and 100% HFCS replacement for sucrose were significantly lighter in crumb color than APF cakes with 75 and 100% HFCS. The stable crust color of the cakes supports the work of McCullough (1985) that the increased browning of cakes prepared with HFCS replacement for sucrose may be controlled with the addition of cream of tartar. Differences in crumb color may be attributed to the color of the flour or Maillard browning as a result of protein content of the flour.

Sensory Evaluation

The sensory evaluation results and response anchors are given in Figures 1–3. A significant ($P < 0.05$) flour type × sweetener level interaction was found for the variables crust color, moistness, and tenderness. Because of the interactions, a general statement cannot be made on which flour or sweetener to use. Examining the interaction plots in Figures 1–3 can be useful to compare flour types at a specific level of sweetener. Notice the nonparallel lines in these figures. In sensory crust color, the mean lines even cross, indicating strong interaction. At the higher levels of sweetener (75 and 100% HFCS), CF cakes were more tender than APF cakes, whereas APF cakes were more moist.

As for the remaining sensory variables without interaction, a table is not provided. Crumb color was significantly darker brown for 75 and 100% HFCS cakes compared with the control 0% HFCS. Furthermore, APF cakes had significantly darker brown crumb color than CF cakes. Response anchors for crumb color were 0 = light brown and 7.5 = dark brown.

CONCLUSIONS

At the levels of 0 and 50% HFCS replacement for sucrose, fewer differences were observed between cakes made with CF and with APF. However, when the level of HFCS replacement was increased to 75 and 100%, the use of CF produced a cake that was more tender than that prepared with APF. Increased browning and lowered volumes were evident in all cakes containing HFCS, but both effects were less when using CF. These results do not support the work of Beery (1982) who reported that cakes prepared with HFCS require a high-protein flour. The use of CF, a lower protein flour, increased the tenderness and volume of cakes when a higher replacement level of HFCS was used. Thus, this study suggests that CF can be used with HFCS in baked products while minimizing the loss of tenderness and volume. A satisfactory cake was made with HFCS replacement for sucrose and CF as indicated by sensory evaluation.

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