

HIGH FRUCTOSE CORN SYRUP; A REPLACEMENT FOR
SUCROSE IN CAKES MADE WITH ALL PURPOSE
FLOUR AND CAKE FLOUR

by

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(ABSTRACT)

Cakes were prepared with high fructose corn syrup (HFCS) at 0, 50, 75, and 100% levels for replacement of sucrose by weight of sugar. The water was adjusted to allow for the moisture content of the syrup. All purpose flour and cake flour were used with each level of sweetener.

There was no significant differences of specific gravity of the batters, but the addition of HFCS decreased the linespread which was an indication of increased viscosity of the batter.

The crust color of the cakes was not significantly different, but the cakes prepared with cake flour were significantly lighter than those prepared with all-purpose flour.

The sweetener used had a significant effect on the moistness and deformation of the baked cakes. Increased amounts of HFCS increased the moistness and decreased the deformation on tenderness of cakes. Cakes prepared with cake flour were significantly greater as measured by the index to volume.

There were no flour x sweetener interaction in the objective data ($p < .05$).

The taste panel rated the cakes prepared with 75 and 100% HFCS replacement for sucrose as more moist but less tender than 0 or 50% HFCS replacement.

The crust color of cakes made with all purpose flour was rated darker. However, the crumb color of the cakes prepared with cake flour was rated lighter.

The cakes prepared with 0, 75 and 100% HFCS replacement for sucrose and cake flour were significantly different in overall acceptability. The panel rated the cakes prepared with 0, 50, 75 and 100% HFCS replacement for sucrose with cake flour as the most acceptable.

A satisfactory cake was made using 100% HFCS replacement for sucrose and cake flour.

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INTRODUCTION

Corn syrups are defined as "purified concentrated solutions of nutritive saccharides obtained from corn starch and having a dextrose equivalent of 20 or more" (Wardrip, 1971). Products made from starches other than corn starch are called glucose syrups.

Initially all corn syrups were produced by acid hydrolysis of corn starch. Sweetener syrups made possible by a secondary hydrolysis using saccharifying enzymes were available during World War II. As technology advanced, starch was liquified by one enzyme then saccharified by another to produce corn syrups with a very unique carbohydrate composition (Volpe et al. 1976).

The enzymatic conversion was expanded to a treatment which involved an enzyme that is capable of converting glucose corn syrups that contain over 10% fructose. These are called high fructose corn syrup (HFCS). Thus, by using a combination of enzymes of corn or glucose syrups of varying mono, di, and polysaccharides content of HFCS may be produced. The production of a palatable, nutritious HFCS is definitely a technological breakthrough (Wardrip, 1971). A simplified production process of the making of HFCS by the food industry is shown in Figure 1.

High fructose corn syrups with one treatment of the conversion enzyme contain 42% fructose and are excellent sources of fermentable sugars. HFCS has a built in protection against fermentation during storage (Crocco 1976b).

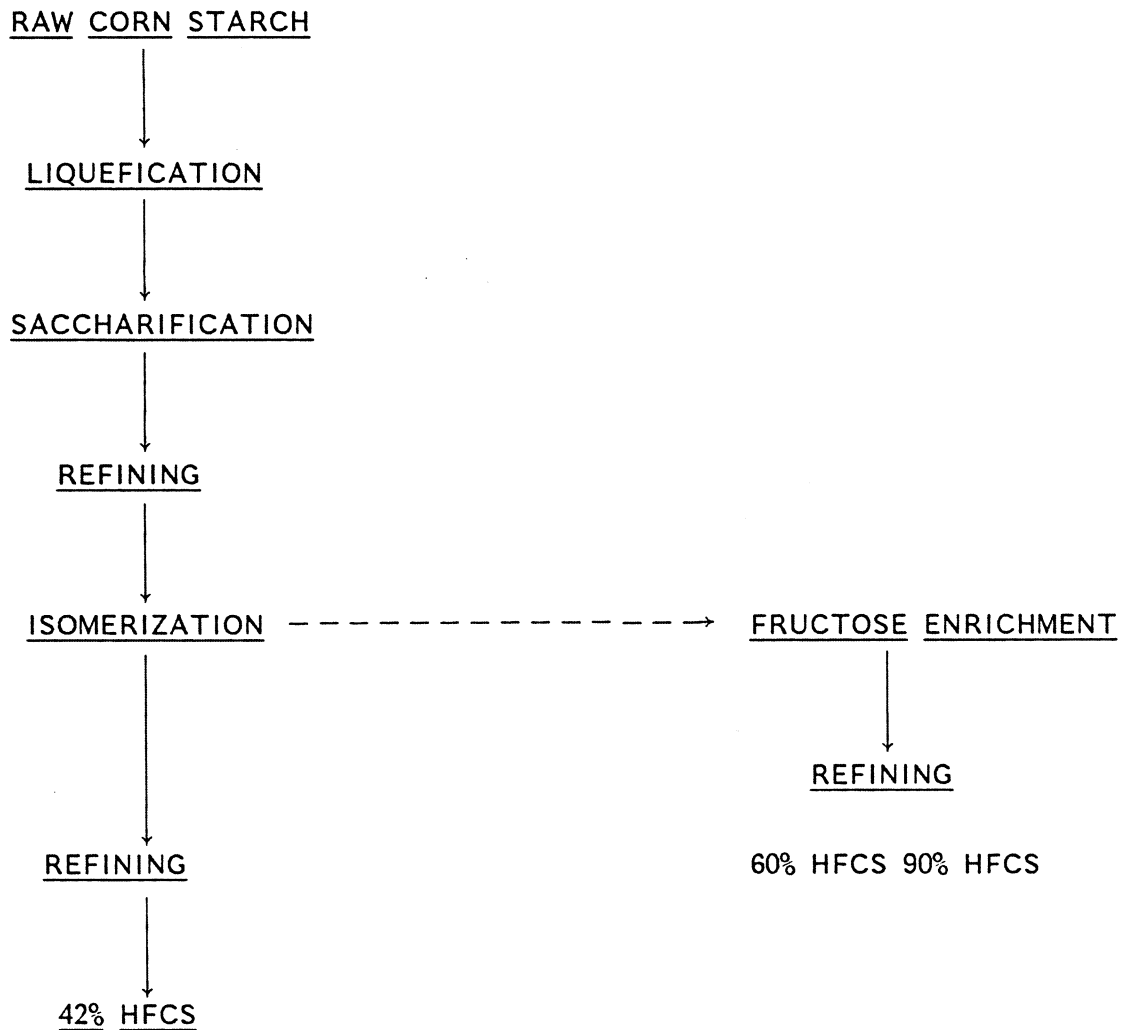


Fig. 1: Manufacturing Process for High Fructose Corn Syrups reprinted from "Immobilized Enzyme Technology Produces High-Fructose Corn Syrup" in Food Technology, 1977, p. 56

Crocco (1976b) states other advantages of HFCS. The sweetness value of HFCS is an important characteristic. HFCS has an excellent color stability when stored at 30°C (Crocco, 1976b). Crystallization of HFCS is minimized or eliminated at optimum storage temperature of 30°C (Crocco, 1976b). Also, cost of HFCS is an advantage for the food industry (Crocco, 1976b).

With advantages there will always be some disadvantages. When attempts were made to replace sucrose in small cakes with HFCS, a number of problems were encountered. The major problem encountered was excessive browning in baked products when HFCS was substituted for sucrose. Henry (1976) stated there was a decrease in volume of the final product due to the delaying effect of sugars on starch gelatinization.

The purpose of this study was to evaluate cakes prepared with cake flour and all purpose flour and with different levels of HFCS as a replacement for sucrose. The data will be utilized to produce a cake using 100% HFCS as a replacement for sucrose.

REVIEW OF LITERATURE

HFCS Uses and Advantages

High fructose corn syrup can be used in practically every food in which a liquid sucrose, medium invert, or total invert syrup is now employed. HFCS is now being commercially utilized in confectionery, baking, still and carbonated beverages, pickles, salad dressings, fountain syrups and toppings, table syrups, ice cream, and catsup - to name just a few items.

The monosaccharide fructose is a very sweet sugar and has been given a relative sweetness value of 120 to 125, compared with sucrose at a sweetness value of 100 (Crocco 1976a). This sweetness quality of fructose is one of the valuable qualities of these fructose products in the food industry. Fructose is known as "fruit sugar" because it is found naturally in fruits such as bananas, oranges, grapes, pears, and apples. Approximately 40% of the edible portion of bees' honey is fructose. It has been called super sweet because of the sweetness value when compared to sucrose (Henry 1976).

Wardrip (1971) conducted a study with an expert panel using sweeteners made into a syrup of known concentrations and ranked them against a series of sucrose solutions. The results indicated that at 11-17% solids, HFCS is sweeter than glucose, approximately as sweet as sucrose, and slightly less sweet than a mixture of glucose and fructose known as medium invert sugar (Wardrip, 1971).

Wardrip (1971) also compared the sweetness of 42% fructose corn syrup and that of sucrose by triangle testing, using expert panelists. They were able to detect a sweetness intensity difference of $\pm 0.5\%$ sucrose solids in the 15% solids area at the 95% level of confidence. Water solutions of HFCS tend to be slightly less sweet than sucrose at solids levels below 15%, equal at 15%, and sweeter at levels greater than 15% (Wardrip, 1971).

When fructose and glucose are combined in proportions found in HFCS the over-all sweetness level is equal to that of sucrose (Henry, 1976). Thus, HFCS is a suitable replacement for sucrose as far as sweetness is concerned.

Another important and practical factor to consider is the storage stability of HFCS, which is a big plus for the sweetener system. Solutions containing fructose tend to discolor more rapidly at elevated temperatures, compared to glucose or sucrose solutions. Temperatures between 32-38°C accelerated color development for fructose syrups. Thus, storage below 32°C provides excellent color stability for HFCS (Wardrip, 1971).

Crystallization is an important factor. Dextrose is less soluble than fructose and sucrose and redissolving glucose crystals in liquid glucose or standard high glucose corn syrups is very difficult. To dissolve the crystals, it requires a temperature between 49-71°C. However, the glucose crystals formed in syrups contain 42% fructose and can be redissolved in 30 minutes at 38°C. Thus, for a high fructose syrup containing approximately 71% solids, both color development and

crystallization are minimized or eliminated at an optimum storage temperature of 26-32°C (Wardrip, 1971).

High fructose corn syrup has a higher osmotic pressure than sucrose since it contains about 56% higher total solids than liquid sucrose. This gives HFCS greater built-in protection against fermentation during storage.

Methods in the production of HFCS involve controlled refining which give the products an "exceptional" purity (Crocco, 1976ab). Some sources claim that the ash content of HFCS is lower than that of sucrose, thus making HFCS the purest sweetener system available (Crocco, 1976ab). The products meet microbiological specifications of the National Soft Drink Association and are used as the main sweetening agent in Coca-Cola and Pepsi Colas (Food Processing, 1984). The products have been successfully tested in both still and carbonated products. In the past year, Pepsi-Cola and Coca-Cola companies have changed the formulation of both the bottled beverages and fountain syrups to contain 100% HFCS. This decision by Pepsi and Coke will account for an increased need of 500 thousand tons of HFCS a year (Food Processing, 1984), which is the major market for HFCS.

The products containing HFCS have been reported to have increased hygroscopic (water holding capability) properties which might be an advantage in products that require retained moisture for functional and performance properties. The most hygroscopic of the sugars commonly used in baking are glucose and fructose, the principal sugars in HFCS.

High fructose corn syrup also has a synergistic effect on synthetic sweeteners such as saccharin. HFCS is sweeter than a comparable solution of sucrose, when both contain the same amount of sodium saccharin. A series of samples was evaluated, to establish the extent of this synergistic effect. The samples were prepared within the range of 1.78-8.75 parts of sodium saccharin per 1,000 parts of natural sweetener (corn syrup or sucrose). The solids concentration required to equal a 100% sucrose solution was determined (Wardrip, 1971). This information is useful in establishing the calorie and/or cost savings that can result from formulating dietetic food products with HFCS in place of sucrose.

The overall flavor of this product is also important. HFCS was compared to bottlers' grades of sucrose and medium invert syrups. A consulting firm described the HFCS as having fewer inappropriate notes (such as sour, green, metallic, burnt, etc.) than the other two sweeteners. The medium invert was described as having more inappropriate notes than the others (Wardrip, 1971).

The finest sweetener in the world is of little use if its cost is prohibitive. The cost of HFCS is another advantage of this sweetener system. Although prices of all sweeteners have varied considerably in the last few years, HFCS on an equal solid basis, has always been priced 10-20% lower than sucrose (Henry, 1976).

The majority of corn wet milling companies are either now producing a HFCS or have plants under construction to produce the sweetener. Therefore, Coleman and Harbers 1983, predicts the HFCS will maintain or even widen the competitive advantage of cost with sucrose.

A commercially available HFCS containing 42% fructose is the most often used in the food industry. There is a consistent duplication used in manufacturing HFCS with a ratio of 50-51% glucose to 41-43% fructose. The higher the glucose content of the syrup before enzyme treatment, the higher the fructose content of the final syrup (Coleman et al. 1983).

A. E. Staley, Manufacture Company (Decatur, Illinois), producers of another new HFCS, Isosweet 500 (a 50-60% fructose syrup) has tested this product in both the beverage and preserving industries. Researchers at Staley found that another obvious application, besides in beverages, is in the production of jams, jellies, and preserves. One advantage of these 50-60% fructose syrups in the sweet spread system hinges on the fact that the spreads "are almost exclusively fruit based, require a high level of sweetness and a high solids content - but without crystallization - a danger ever present with any sweeteners that are high in sucrose or dextrose," says a Staley spokesman (Crocco, 1976b). When the fructose content increases, the glucose content decreases; as this glucose level of the syrup is lowered, the possibility of crystallization is reduced.

Problems With the Use of HFCS

It has become increasingly evident that HFCS is also an ideal sweetener for the baking industry. However, there have been problems when attempts were made to replace the sucrose in small cakes and layer cakes with HFCS. The syrups, because of their greater humectancy will tend to increase the shelf-life, but may present problems in warmer

weather. Another problem that has arisen is the browning of products containing fructose corn syrup. Fructose and glucose are reducing sugars which participate readily in aldoseamine nonenzymatic browning reaction. Volpe and Meres (1972) minimized this browning in white layer cakes having 60% of sucrose replaced with HFCS by adding a high-acid leavening system that acidified the cake batter to below pH 6.0. This lowered pH reduced crust browning and crumb yellowing to an acceptable level. The Wooster research formula showed that in addition to adding the high-acid leavening system, that a lower protein solids content was quite successful (Bean, Yamazaki and Donelson, 1978).

Coleman and Harbers (1983) did a study using HFCS to replace 25, 50, 75 and 100% of sucrose in angel cakes. They concluded in their study that excessive browning, off flavor, firm texture, and lower volume were all characteristic of the angel cakes. Coleman et al. also stated that cakes made with 25% replacement of HFCS did not greatly affect the physical measurements or sensory characteristics. In another study, by Saussele, Ziegler, and Weideman (1976), HFCS was used in angel food and sponge cakes. They concluded that specific gravity of batter and sweetness of cake did not change with replacement of 25% of sucrose with HFCS, but the crumb color was not satisfactory. Saussele et al. conclude that only dark colored cakes and spice cakes might be suitable for HFCS as a replacement for sucrose and the levels of the HFCS should be limited in yellow cakes and even more so in white cakes.

There were no textural changes found when Saussele et al. (1976) made cakes with 25% replacement of sucrose and the volume changes were attributed to the mixing variable instead of the type of sweetener used.

Stickler (1981) reported that when using HFCS in both white and yellow cakes the crust was thick and crumb color was uneven; the crust also was very brown. To alleviate the color problem HFCS was acidified with lactic acid in small and layer cakes with up to 80% HFCS replacement for sucrose and were successfully made. Stickler (1981) also found that with the use of HFCS there was a significant decrease in cake volume. The cake crumb was overly moist and dense and the cakes required further baking time. The exact amount of HFCS used was not stated.

Curley and Hosney (1984) studied the effects of corn syrups on sugar-snap cookie dough rheology, baking performance, and physical characteristics of cookies after baking. The replacement of the water, for the cookie dough, added to the formula was reduced due to the water content of the HFCS when the syrup was substituted for sucrose. For hard cookies the addition of water caused the cookies to become soft.

Cookies produced with HFCS substituted for sucrose were more tender than sucrose cookies (Curley and Hosney, 1984). The monosaccharides in HFCS, fructose and glucose are the most hygroscopic sugars used in baking. They attributed the increase tenderness to the hygroscopic sugars in the syrup in combination with other ingredients in the cookie dough. The humectant property of HFCS limited the use in hard, crisp cookies. There was also a change in the surface characteristics of the baked cookie with the replacement of small amounts of sucrose with HFCS. The surface cracking commonly associated with certain types of cookies did not occur in cookies containing corn syrup. They also found that the time required for the snap in the cookie to

develop increased with increasing levels of HFCS. This delay in snap appeared to coincide with sugar recrystallization and the type of flour used.

A decrease in volume of cakes has been a problem with the use of HFCS as a replacement of sucrose. Bean et al. (1978) linked this with the delaying effect of sugars on starch gelatinization. Solutions of the monosaccharides, glucose and fructose raised the initial gelatinization temperature on wheat starch, but to a lesser extent than did sucrose. Comparing the temperature loss of birefringence at several solution concentrations showed that the gelatinization temperature of sucrose was greater than glucose which was greater than fructose. These differences among the three sugars increased with concentrations. Monosaccharides or disaccharides were accommodated in the formula if the water level was adjusted to allow starch to gelatinize at an optimum temperature. This was approximated by consideration of the starch gelatinization temperature in the sucrose-water system prevailing in the cake batter. In the study successful cakes were obtained when the sugar/water ratio in the batter permitted a starch gelatinization temperature of approximately 90°C.

Koepsel and Hosney (1980) did a similar study using four corn syrups and glucose to replace sucrose in high ratio white layer cakes. They found that the swelling temperatures of the starch in the cookie dough were related to the amount of sugars present and that the lower molecular weight sugars in syrups gave lower swelling temperatures than did equal quantities of high molecular weight sugars. They concluded that water activity and gelatinization temperature were apparently related.

Koepsel and Hosney (1980) also concluded that the lipids present in corn syrups affect the gelatinization of starch by lowering the volume and causing excessive tenderness of the cakes.

Ingredients of Cakes and Their Function

Lawson (1970) stated that there are five basic ingredients of cakes which contributed to the appearance, taste and overall quality of the product. These include flour, sugar, eggs, milk, and shortening. Lawson classifies flour as a structure builder and toughener as well as a drying agent. Eggs are thought to be structure builders and moisteners. The protein in the egg white and some in the yolk contribute to the structure of the cake. The tenderizing effect seems to be contributed by the fat in the yolk, which also adds a yellow color to the cake.

Milk and milk solids classified as tougheners, add structure and also act as dryers and flavors (Lawson, 1970). The carbonyl-amine reactions in the crust browning are thought to be due to the milk or milk solids (Campbell et al., 1979).

Tenderness and flavor of the cake are attributed to the sugar (Hunter Briant, and Personius 1950). Meiske, Jones, and Jones (1960) attributed this tenderizing effect of the sugar to a peptizing action on flour proteins, but gave no other supporting references.

Sugar also appears to be a major factor in determining cake volume and contour. Bean et al. (1978) concluded that the volume and contour of the cake is related to the delaying effect of sugar on such gelatinization. The temperature at which starch gelatinizes is due to the

type of sugar used. Monosaccharides and disaccharides can be accommodated for optimum temperature of starch gelatinization, if the water level is adjusted for the formula. As stated before, successful layer cakes were obtained when the sugar/water ratio in the batter permitted a starch gelatinization temperature of about 90°C (Bean et al. 1979).

Shortening is also classified as a tenderizer and also helps to improve keeping quality, fineness of grain and moistness (Lawson, 1970). The addition of surfactants to shortenings facilitate emulsification in batters (Campbell, Penfield, and Griswold 1979).

Lawson (1970) states that cakes made with a higher level of sugar, shortening and liquids increase the shelf life, moistness, tenderness and consumer acceptability. These formulas reduce the amount of chemical leavening needed since air was more readily incorporated in mixing (Matz, 1960).

Campbell et al., (1979) found that baking of the cake depended on several factors other than ingredients to produce the best cake. The size and shape of pan, the material of the pan, how much batter used and the oven temperature affected the final product. A dark colored, shallow pan made of metal, correctly filled and placed in a moderate oven seems to produce a cake of higher volume, fewer peaks, and of an even golden brown color (Campbell al., 1979). Heat penetration should occur rapidly to produce a more acceptable cake (Charley, 1952).

The major component of flour, starch, plays a very important role in the physical properties and quality of baked products. Gelatinization

and pasting are the most important changes that starch undergoes in the baking process. The gelatinization and pasting of starch during baking is controlled not only by temperature, but also by the availability of water. Most baked products are made from limited water systems which also contain ingredients that may react with starch or compete with starch for water. The changes that starch undergoes during the baking process are not clearly understood. Starch is a very complex system and it is difficult to evaluate all the factors that influence the final condition of starch in baked products. The nature of starch in the final product is a function of baking temperature and time, water content of the dough or batter, and the effect of other ingredients such as sugar and shortening (Lineback and Wongsrikasem, 1980).

The function of starch in baked products, especially bread, has been investigated extensively, but very little information is available on the extent of the starch gelatinization during baking and in baked products (Schoch, 1965). In one study by Yasumaga, Bushuk, and Irvine (1968) the gelatinization of starch in bread was found to be dependent on the location in the loaf. The starch in the outer layers of the crumb was gelatinized to a greater extent than the starch in the center (Yasunaga et al. 1968). Lineback et al. (1980) came to the conclusion that the main factors controlling the extent of starch gelatinization were baking absorption, temperature and time.

MATERIALS AND METHODS

Experimental Design and Pilot Study

The experimental design for testing different flours in cakes prepared with different amounts of high fructose corn syrup (HFCS) are shown in Table 1.

Four levels of HFCS 0, 50, 75, and 100% by weight of sugar were used as a replacement for sucrose. Two types of flour, cake flour (CF) with a protein content of approximately 7.5% and all purpose (AP), protein content of approximately 10.5%, were tested with the four amounts of HFCS as a replacement for sucrose. Three replications of each variation were made.

A pilot study was conducted during the fall of 1985 in which the cake formulations for this study was established. The formulas, mixing and baking procedures are shown in Appendix A for each variation.

Procurement and Storage of Ingredients

Two 25-gallon drums of Iso Sweet 100 HFCS, Lot 4H1X4 were obtained from A.E. Staley Manufacturing Company, (Decatur Illinois). By high performance liquid chromatography (HPLC) analysis, the syrup contained 43.7% fructose, 51.1% glucose, and 5.2% higher saccharides. Other cake ingredients were obtained from a local grocery in Blacksburg, Virginia.

The HFCS was stored in the original drums. The flour was stored in original boxes inside air-tight plastic containers with close fitting lids.

TABLE 1

Experimental Design for the Replacement of
High Fructose Corn Syrup for Sucrose with
Two Types of Flour in Cakes

Flour	HFCS Replacement for Sucrose			
	0%	50%	75%	100%
All Purpose (AP)	AP	AP	AP	AP
Cake Flour (CF)	CF	CF	CF	CF

All ingredients, with the exception of eggs, were stored at ambient temperatures in a laboratory out of direct light. Eggs were stored in a refrigerator compartment of a Frigidaire Frost Proof refrigerator (Model FP CI-170T, Dayton, Ohio). The dry ingredients and shortening were purchased in three lots during the study. Eggs were purchased as needed, approximately two days prior to use.

Objective Measures

Linespread of the batter for each variation was determined by using an 8" glass pie plate, a brass ring with an inside 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 the batter and leveled off at the top of the ring. The ring was then lifted up to allow the batter to flow for 30 seconds. At the end of 30 seconds, the four values at the edge of the batter flow were read from the grid. The means of the values were used for statistical analysis.

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 five locations of the cake. The standing height was measured with a vernier caliper at the four corners, one centimeter from each edge, and the geometric center.

The moisture was determined by a Barbender Moisture Tester, (Model SAS-692 S. Hackensack, New Jersey). Duplicate 10 gram samples from the midsection containing crust and crumb were dried in metal pans to a constant weight at 110°C. The readings were then taken and each duplicate averaged to give one value. Duplicate readings differed by no more than 1% and were considered in the acceptable range.

The deformation was determined by using a Penetrometer Timer (Labline Instruments, Melrose Park, Illinois) according to the method of Bourne (1984). A sample of cake taken from the mid-section, measuring 3.5 cm x 3.5 cm was compressed with the aluminum disk attachment (3.0 in diameter). A 50 gram weight was added to the bar and the cake sample was compressed a second time. The instrument measured the amount the cake was compressed in millimeters. The deformation was determined by the subtraction of millimeters of compression when the additional weight was added from the millimeters of compression obtained when the weight was not used.

Color differences were determined on both crust and crumb color using a Hunter Lab Color Difference Meter (Model D25, Reston, Virginia). The instrument was standardized using a white tile, standard number 20-1651 where $L = 91.97$, $a = -0.8$, $b = -1.0$. Crust and crumb samples were pressed separately into the bottom of Actron sample cups (American Scientific Products) to help minimize surface variations. Three readings of the crust and crumb color of each variation were recorded, by using the ΔE formula where: $\sqrt{\Delta E = (\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2}$. Photographs were used for overall appearance and are shown in Figures 2-9.

Sensory Evaluation

Sensory evaluation was done by a semi-trained taste panel which consisted of 6 students from the Department of Human Nutrition and Foods at Virginia Polytechnic Institute and State University. Three cakes of randomly selected treatments were baked on Tuesday and Thursday for four weeks. Each variation was replicated three times per taster. The schedule is shown in Appendix B. Three samples were presented to a panelist at a tasting session. The sessions were held at 3:00 p.m. Panelists were instructed to refrain from eating, drinking, smoking or chewing gum for 30 minutes before each tasting session. Panelists were given a tray with 3 4cm x 4cm x 4cm samples of fresh 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, tenderness, and overall acceptability. A sample score sheet is shown in Appendix C.

Statistical Analysis

The statistical analysis consisted of an incomplete block design which tested for main effects such as flour effect, sweetener effect, and flour x sweetener interaction effect for both the objective and sensory data. PROC GLM in SAS (SAS Institute, Cary, North Carolina) was used for the objective data as well as for the sensory data. Statistical tests were performed for the flour and sweetness main effects and the flour x

sweetener interaction for each variable using Type III sums of squares. Sources of the variation such as day effect and person effect were removed but were not tested for significance.

There was a significant flour x sweetener interaction effect on the sensory scores for crust, moistness, tenderness and overall acceptability at $\alpha = .05$. Over and above these significant interactions there are significant main effects, i.e., flour and sweetener ($p < .05$). Because of the significant interactions a general statement cannot be made saying which flour or sweetener to use. It is more useful to look at each level of sweetener individually and compare flours.

There were no significant flour x sweetener interactions for crumb and flavor. Crumb did have significant main effects in both flour and sweetener, but there were not significant main effects with flavor at $\alpha = .05$.

For pairwise comparisons, the T-test was used and adjusted for the overall Type I error using the Bonferroni technique.

The model used for the statistical analysis of the objective and sensory data is found in Appendix D.

RESULTS AND DISCUSSION

The purpose of this study was to evaluate cakes prepared with cake flour (CF) and all purpose flour (AP) and with different levels of HFCS as a replacement for sucrose. The data will be utilized to produce a cake using 100% HFCS as a replacement for sucrose.

This project is the second part of a two year study (McCullough, 1985). At the end of the first year a baked product was prepared using up to 75% HFCS as a replacement for sucrose. This was done at satisfactory levels. The shelf-life and freeze-thaw stability of cakes with HFCS was also studied, which, when compared with sucrose cakes, were not significantly different (McCullough 1985).

As reported in the literature, cakes with 50-75% HFCS were not satisfactory. The first year project contradicted this with the addition of cream of tartar to the formula.

Objective Measurements

The results of the objective measurements on batters and cakes are shown in Tables 2-8.

There were no significant differences found in the interaction of flour x sweetener in the objective data ($p < .05$). Therefore, the significant differences were attributed to the flour or sweetener alone.

The amount of HFCS used had a significant effect ($p < .05$) on the linespread of the batter as shown in Table 2. The batter containing 75 and 100% HFCS as a replacement for sucrose was decreased in linespread, indicating the batter became more viscous.

TABLE 2

Mean¹ Linespread Values Of Cake Batter Prepared
 With All Purpose And Cake Flour With 0, 50, 75,
 And 100% HFCS Replacement For Sucrose

Flour	HFCS Replacement for Sucrose			
	0%	50%	75%	100%
All Purpose (AP)	9.6a ²	7.2	6.9	4.1b
Cake Flour (CF)	9.4a	7.0	6.2b	6.9c

¹Mean value from 3 replications

²Means followed by different letters in the same row are significantly different.

The mean values for the specific gravity of the batter are shown in Table 3. There were no significant differences ($p < .05$) recorded on the specific gravity of the batter, thus the same amount of air was incorporated in all variations.

The values for the index to volume are shown in Table 4. The flour had a significant effect on the index to volume of the cakes ($p < .05$) containing all purpose flour, when the sucrose was replaced 100% with HFCS. This can be attributed to the effect of the starch content of the two different flours, with cake flour having a higher starch content (Lineback, et al. 1980). Therefore at the 100% replacement level of HFCS for sucrose a lower protein flour, such as cake flour, yields a more fluffy product.

The decreased volume of the cakes prepared with all purpose and 100% HFCS as a replacement for sucrose was not attributed to a decrease in air incorporation during the mixing process as shown by the specific gravity measurement of the batter. The decrease in volume did not appear to be related to the viscosity of the batter, since treatments including the 75% HFCS replacement for sucrose were also significantly more viscous. Also, there were no differences in index to volume with the addition of HFCS as a replacement for sucrose when using cake flour.

As shown in Table 5, HFCS had a significant effect ($p < .05$) on moisture content of the baked cakes. As the amount of the HFCS replacement for sucrose was increased, 75 and 100% with all purpose flour and 100% with cake flour the moisture content was significantly greater. The cakes with HFCS were more hygroscopic because of the humectant

TABLE 3

Mean¹ Specific Gravity Values of Cake Batter
 Prepared With All Purpose and Cake Flour With
 0, 50, 75, and 100% HFCS Replacement For Sucrose

Flour	HFCS Replacement for Sucrose			
	0	50	75	100
All Purpose (AP)	.88	.89	.88	.82
Cake Flour (CF)	.88	.83	.84	.86

¹Mean value from 3 replications

TABLE 4

Mean¹ Index to Volume Values of Cakes Prepared
 With All Purpose and Cake Flour With 0, 50, 75,
 and 100% HFCS Replacement for Sucrose

Flour	HFCS Replacement for Sucrose			
	0	50	75	100
All Purpose (AP)	4.1	4.3	4.1	3.4a ²
Cake Flour (CF)	4.8b	4.3	4.4	4.5

¹Mean value from 3 replications

²Means followed by different letters in the same column are significantly different.

nature of the syrup. The cakes made with 100% HFCS as a replacement for sucrose had the highest moisture content.

The deformation values for the cakes are found in Table 6. The amount of HFCS replacement for sucrose had a significant effect ($p < .05$) in the deformation values of the cakes. The cakes prepared with all purpose flour and 100% HFCS replacement for sucrose were deformed less by the penetrometer than the cakes prepared with all sucrose. The deformation value was reported by Bourne (1984) to be an indicator of tenderness. The cakes made with all purpose flour were less tender when the HFCS replacement was 100% than with other levels of replacement. This is in agreement with the findings of Coleman and Harbers (1983). However, cakes prepared with cake flour were not significantly different in tenderness when sucrose was replaced with HFCS.

Hunter Color Meter ΔE values are shown in Table 7 and 8. For the crust values there were no significant differences ($p < .05$). There was a significant effect ($p < .05$) in the crumb color with the use of cake flour shown in Table 8. Cakes made with cake flour were significantly lighter in crumb color than cakes made with all purpose flour. Again cakes made with 75 and 100% HFCS replacement for sucrose with cake flour are significantly lighter in crumb than those made with all purpose flour.

The stable crust color of the cakes support the work of McCullough (1985) that the increased browning of the 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 differences in the color of the flour.

TABLE 5

Mean¹ Moisture Content Values of Cakes Prepared
 With All Purpose and Cake Flour With 0, 50, 75,
 and 100% HFCS Replacement for Sucrose

Flour	HFCS Replacement for Sucrose			
	0	50	75	100
All Purpose (AP)	30.9a ²	32.3	33.6b	34.1c
Cake Flour (CF)	30.4a	32.8	33.2	34.0c

¹Mean value from 3 replications

²Means followed by different letters in the same row are significantly different.

TABLE 6

Mean¹ Deformation Values of Cakes Prepared With
All Purpose and Cake Flour With 0, 50, 75, and
100% HFCS Replacement for Sucrose

Flour	HFCS Replacement for Sucrose			
	0	50	75	100
All Purpose (AP)	81.7a ²	38.2	21.1	5.7b
Cake Flour (CF)	57.0	42.9	31.6	15.5

¹Mean value from 3 replications

²Means followed by different letters in the same row are significantly different.

TABLE 7

Mean¹ ΔE Values² as Determined by the Hunter Color
 Meter of Crust Color for Baked Cakes Prepared With 0, 50, 75
 and 100% HFCS Replacement for Sucrose

Flour	HFCS Replacement for Sucrose			
	0	50	75	100
All Purpose (AP)	36.1	37.6	36.4	39.1
Cake Flour (CF)	41.9	34.3	38.8	37.2

¹Mean values from 3 replications.

² ΔE is calculated by 3 replication readings as follows:

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

TABLE 8

Mean¹ ΔE Values² as Determined by the Hunter Color
 Meter of Crumb Color for Baked Cakes Prepared With 0, 50, 75
 and 100% HFCS Replacement for Sucrose

Flour	HFCS Replacement for Sucrose			
	0	50	75	100
All Purpose (AP)	75.6	75.7	73.0a ²	70.8a
Cake Flour (CF)	79.5b	77.2b	77.0b	78.1b

¹Mean values from 3 replications

² ΔE is calculated by 3 replication readings as follows:

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

³Means followed by different letters are significantly different.



Fig. 2 Photograph of cake variation 1, made with 0% HFCS and replacement for sucrose and all purpose flour.



Fig. 3 Photograph of cake variation 2, made with 0% HFCS replacement for sucrose and cake flour.



Fig. 4 Photograph of cake variation 3, made with 50% HFCS replacement for sucrose and all purpose flour.



Fig. 5 Photograph of cake variation 4, made with 50% HFCS replacement for sucrose and cake flour.



Fig. 6 Photograph of cake variation 5, made with 75% HFCS replacement for sucrose and all purpose flour.

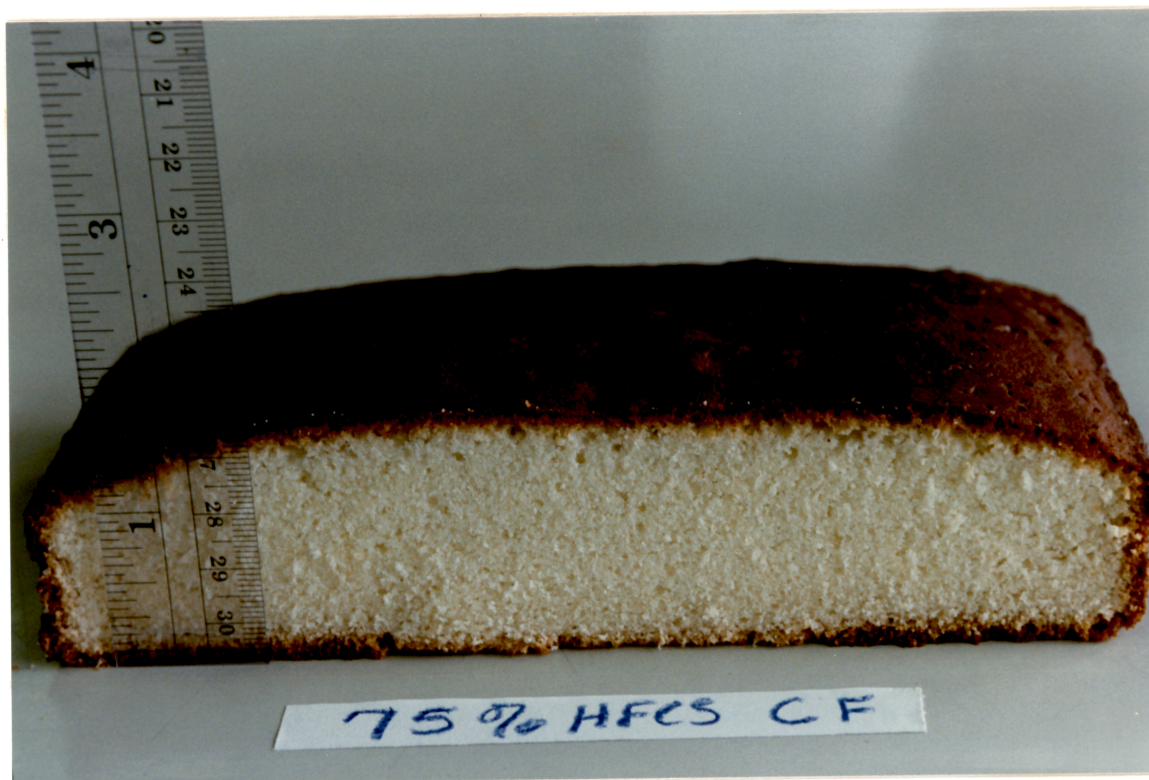


Fig. 7 Photograph of cake variation 6, made with 75% HFCS replacement for sucrose and cake flour.



Fig. 8 Photograph of cake variation 7, made with 100% HFCS replacement for sucrose and all purpose flour.

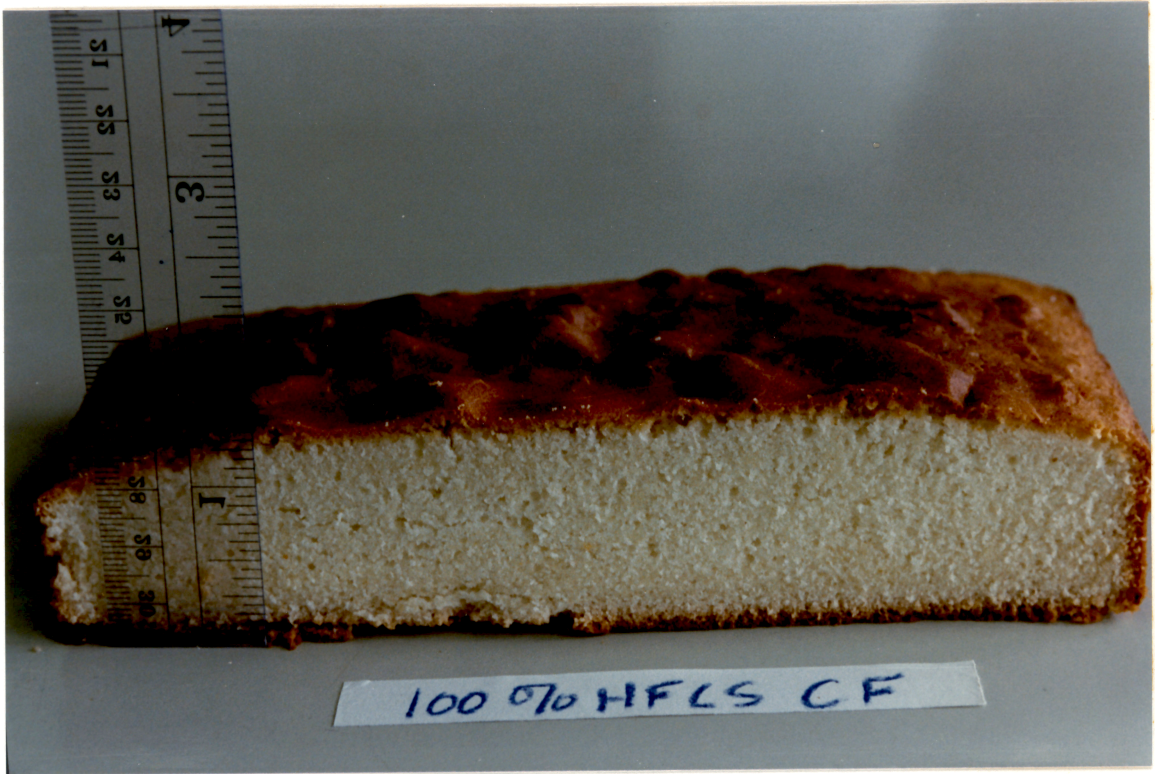


Fig. 9 Photograph of cake variation 8, made with 100% HFCS replacement for sucrose and cake flour.

Sensory Scores

The results of sensory analysis are shown in Tables 9-14. Plots of least square means for sensory variables with significant flour x sweetener interaction are shown in Figures 10-13.

The sensory evaluation scores for crust color are shown in Table 9. There was a significant difference ($p < .0125$) in crust color between cakes prepared with 50 and 100% HFCS replacement for sucrose made with either all purpose flour or cake flour. The cakes prepared with all purpose flour were darker in color.

The greater concentration of crust color as a result of collapsed structure of the cakes prepared with all purpose flour may have accounted for the significant difference noted by the taste panel but not measured by the Hunter Color Difference Meter. The cakes prepared with all purpose flour did not have an adequate starch content to support the structure. This was true with cakes with 50 and 100% HFCS replacement for sucrose but not with the 75% replacement. There was no explanation for this.

The mean values for sensory evaluation of crumb color are shown in Table 10. There was a significant difference ($p < .0125$) in the paired comparisons when comparing cakes made with all purpose flour and cake flour with 75% HFCS replacement for sucrose.

The panelists found that the cakes prepared with all purpose flour had a darker crumb color than cakes prepared with cake flour. The crumb of cakes prepared with 75 and 100% HFCS replacement for sucrose of both all purpose and cake flour were significantly darker than the cakes prepared with all sucrose.

TABLE 9

Means¹ Sensory Scores² for Crust Color of Baked Cakes
 Prepared With All Purpose and Cake Flour With 0, 50, 75,
 and 100% HFCS Replacement for Sucrose

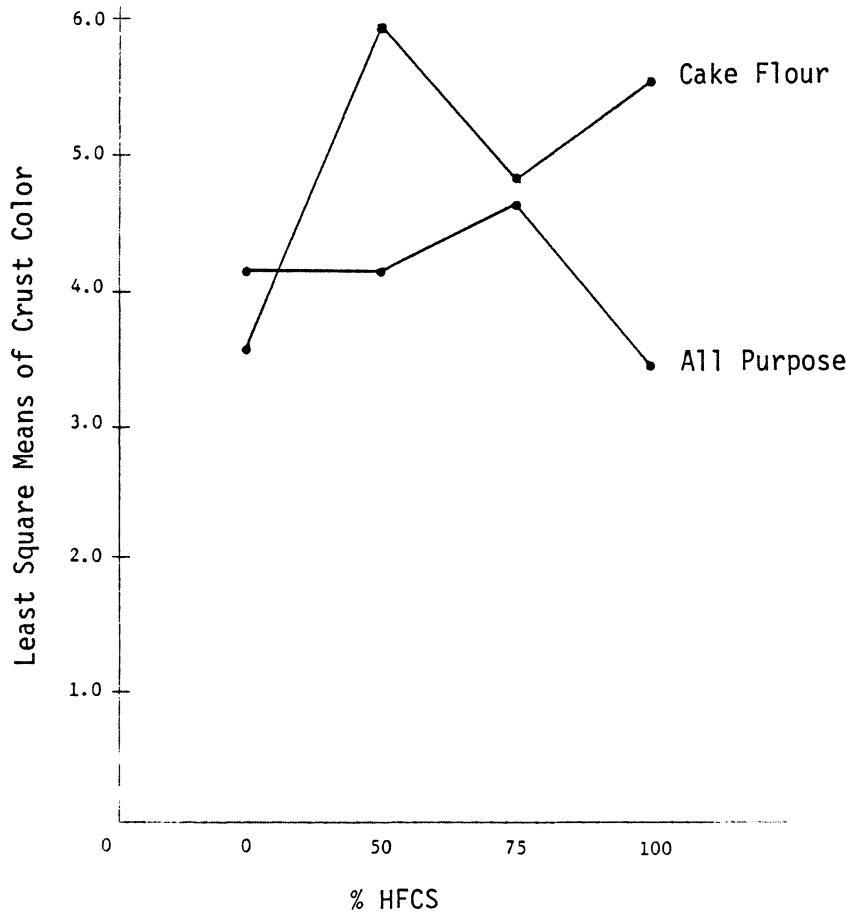
Flour	HFCS Replacement for Sucrose			
	0	50	75	100
All Purpose (AP)	4.1	4.2a ³	4.7	3.4a
Cake Flour (CF)	3.5	6.0b	4.8	5.5b

¹Least square means from 3 replications.

²Scores derived from an unstructured scale of 0-7.5 with 0=light brown and 7.5=dark brown.

³Means followed by different letters in the same column are significantly different.

FIGURE 10



Interaction Sensory Scores for Crust Color of Baked
Cakes Prepared With All Purpose and Cake Flour
With 0, 50, 75, and 100% HFCS Replacement For Sucrose

TABLE 10

Mean¹ Sensory Scores² for Crumb Color of Baked Cakes
 Prepared With All Purpose and Cake Flour With 0, 50, 75,
 and 100% HFCS Replacement for Sucrose

Flour	HFCS Replacement for Sucrose			
	0	50	75	100
All Purpose (AP)	1.4a ³	1.7	2.7b	2.8b
Cake Flour (CF)	.50a	1.9	1.5c	1.8b

¹Mean values from 3 replications.

²Scores derived from an unstructured scale of 0-7.5 with 0=light brown and 7.5=dark brown.

³Means followed by different letters in the same column are significantly different.

This was not supported by the Hunter Color readings in that by objective measurements the flour used made a significant difference with all purpose cakes being darker. The sensory evaluation indicate that HFCS replacement for sucrose as darker. One explanation is that the color differences were small and may have been masked by the shadows of the crumb structure to the eye of the panel members.

The mean values for sensory flavor scores are shown in Table 11. The panelists found no significant differences ($p < .0125$) in flavor among all treatments of cakes. Flavor was defined as the degree of sweetness of the cakes. Thus, the taste panel could not detect any differences in sweetness.

The mean values for moisture content are shown in Table 12. The panel evaluated all cakes prepared with 0, 75, and 100% HFCS replacement for sucrose as significantly more moist ($p < .0125$) when prepared with all purpose flour rather than cake flour. As the HFCS replacement for sucrose increased, the moistness rating increased with the exception of the cakes prepared with 50% replacement by HFCS.

The increased moistness evaluation of the cakes prepared with all purpose flour by the taste panel was not supported by the objective data. There were no differences between flours as measured by the Barbendy Moisture Tester. This may be attributed to the compact structure of the cake prepared with all purpose which contributed to a moist mouthful.

The mean values of tenderness as measured by the panelists are shown in Table 13. As the amount of HFCS replacement for sucrose was increased to 75 and 100% replacement in cakes prepared with all purpose

TABLE 11

Mean¹ Sensory Scores² for Flavor of Baked Cakes
 Prepared With All Purpose and Cake Flour With 0, 50, 75,
 and 100% HFCS Replacement for Sucrose

Flour	HFCS Replacement for Sucrose			
	0	50	75	100
All Purpose (AP)	3.8	3.5	3.3	2.7
Cake Flour (CF)	3.2	4.0	2.9	3.1

¹Mean values from 3 replications.

²Scores derived from an unstructured scale of 0-7.5 with 0=Sweet (Bland) and 7.5=Sweet (Sickly).

TABLE 12

Mean¹ Sensory Scores² for Moistness of Baked Cakes
Prepared With All Purpose and Cake Flour With 0, 50, 75,
and 100% HFCS Replacement for Sucrose

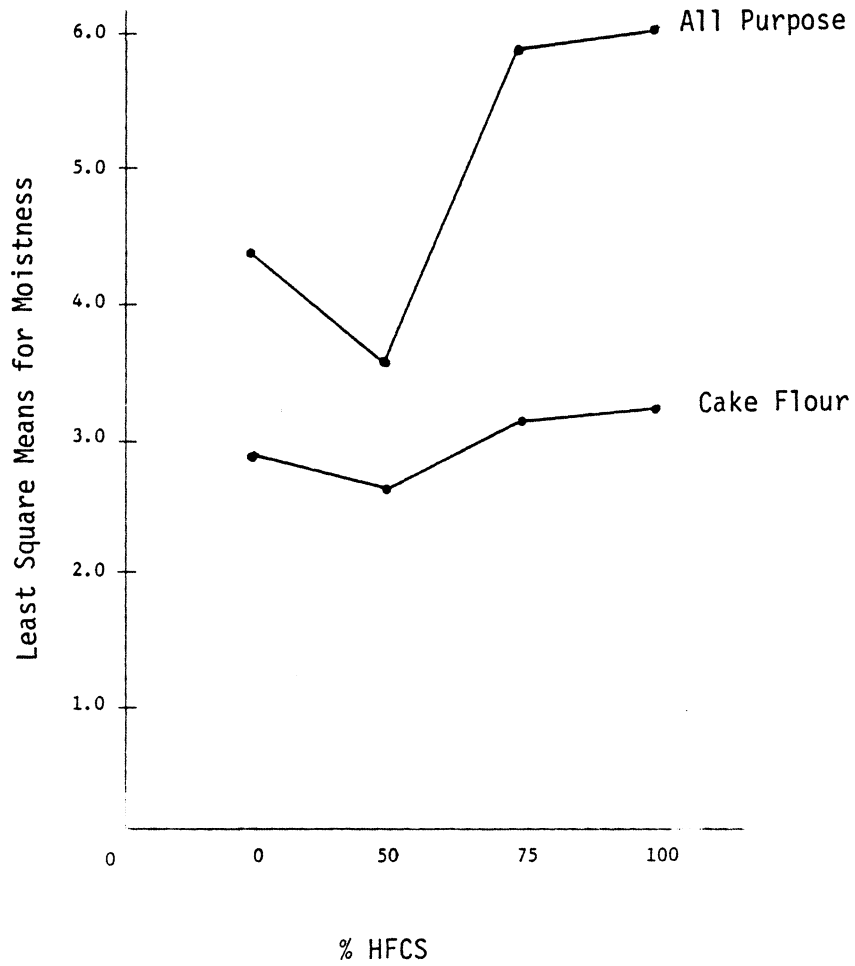
Flour	HFCS Replacement for Sucrose			
	0	50	75	100
All Purpose (AP)	4.3a ³	3.4a	5.8a	6.0
Cake Flour (CF)	2.9b	2.5a	3.2b	3.1b

¹Mean values from 3 replications.

²Scores derived from an unstructured scale of 0-7.5 with 0=Moist (Dry) and 7.5=Moist (Wet).

³Means followed by different letters in the same column are significantly different.

FIGURE 11



Interaction Sensory Scores for Moistness of Baked
Cakes Prepared With All Purpose and Cake Flour
With 0, 50, 75, and 100% HFCS Replacement for Sucrose

flour, there was a significant decrease in tenderness. The difference in tenderness between flours was not supported by the deformation data. This may be attributed to the compact nature of the cakes prepared with all purpose flour. The taste panel perceived the more compact cakes as less tender.

The values for rating the overall acceptability of the cakes are shown in Table 14. There was a significant difference ($p < .0125$) in overall acceptability. Cakes with 75 and 100% HFCS replacement for sucrose made with all purpose flour were significantly less acceptable than with cakes made with cake flour. The panel did not observe a difference with levels 0% and 50% HFCS replacement for sucrose.

TABLE 13

Mean¹ Sensory Scores² for Tenderness of Baked Cakes Prepared With All Purpose and Cake Flour With 0, 50, 75, and 100% HFCS Replacement for Sucrose

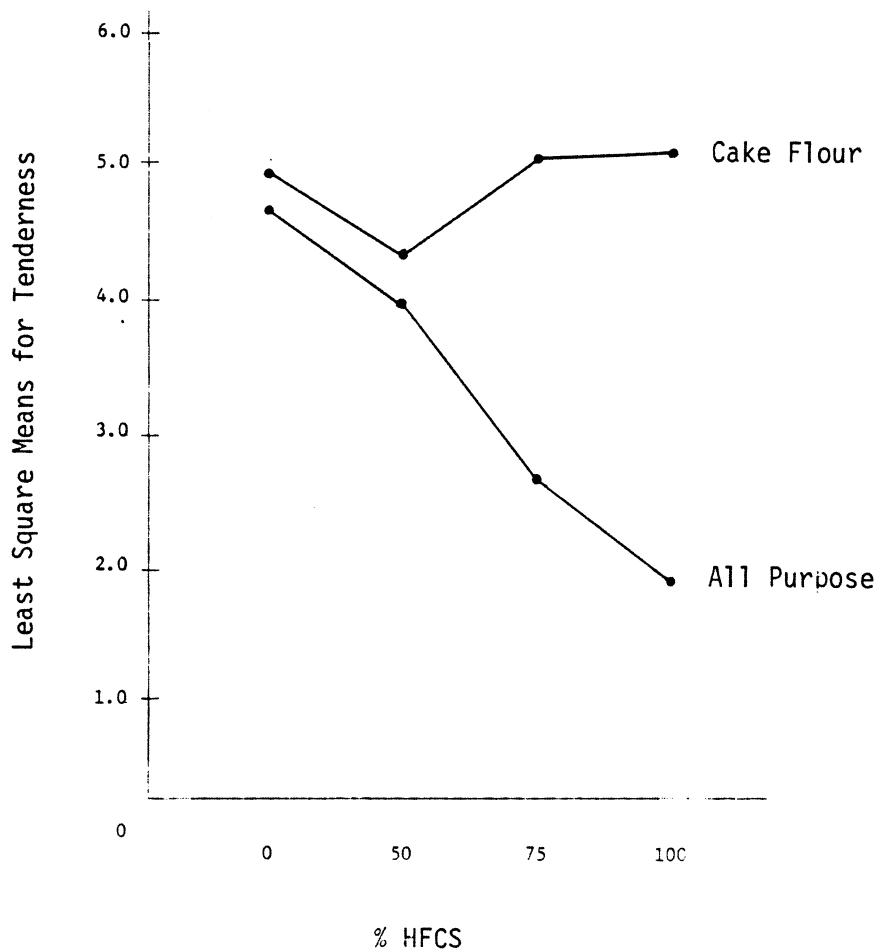
Flour	HFCS Replacement for Sucrose			
	0	50	75	100
All Purpose (AP)	4.6	3.9	2.6a ³	1.9a
Cake Flour (CF)	4.9	4.4	4.9b	5.0b

¹Mean values from 3 replications.

²Scores derived from an unstructured scale of 0-7.5 with 0=Tender (Tough) and 7.5=Tender (crumbly).

³Means followed by different letters in the same column are significantly different.

FIGURE 12



Interaction Sensory Scores for Tenderness of Baked
Cakes Prepared With All Purpose and Cake Flour
With 0, 50, 75, and 100% HFCS Replacement for Sucrose

TABLE 14

Mean¹ Sensory Scores² for Overall Acceptability of
Baked Cakes Prepared With All Purpose and Cake Flour With
0, 50, 75, and 100% HFCS Replacement for Sucrose

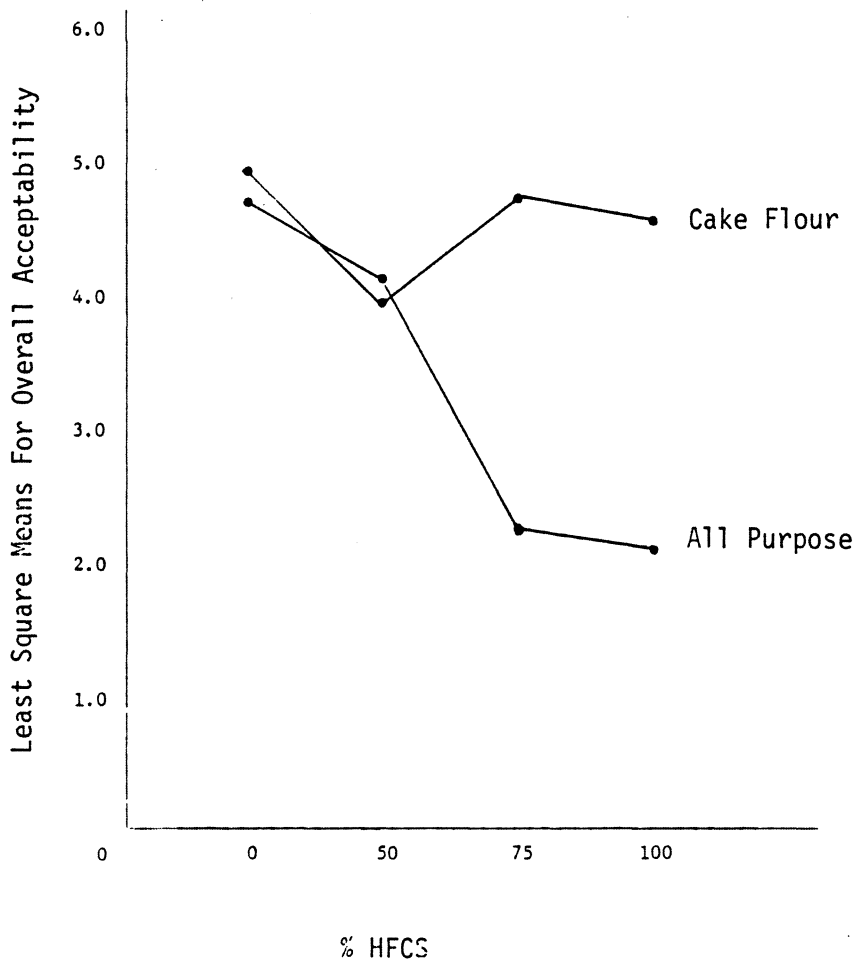
Flour	HFCS Replacement for Sucrose			
	0	50	75	100
All Purpose (AP)	4.7	4.0	2.2a ³	2.1c
Cake Flour (CF)	4.9	3.8	4.8b	4.5d

¹Mean values from 3 replications.

²Scores derived from an unstructured scale of 0-7.5 with 0=Desirable (Least) and 7.5=Desirable (Most).

³Mean values followed by different letters in the same column are significantly different.

FIGURE 13



Interaction Sensory Scores for Overall Acceptability of Baked Cakes Prepared With All Purpose and Cake Flour With 0, 50, 75, and 100% HFCS Replacement for Sucrose

CONCLUSIONS

At levels of 0 and 50% HFCS replacement for sucrose, fewer differences were observed between cakes made with cake flour and with all purpose flours. However, when the level of HFCS replacement was increased to 75 and 100%, the use of cake flour produced a superior cake to that prepared with all purpose flour. Increased browning and lowered volumes were evident in all cakes containing HFCS, but both effects were less when using cake flour. Cakes made with HFCS replacement were more "gummy" than cakes made without HFCS. Cake flour minimized this gummy texture to an acceptable level.

Further research in the utilization of HFCS should include a formula to decrease the browning of the crust, and explore the effect of acidulants on the pH of the batter and the reducing sugars of the sweetening system. Also, the use of HFCS in combination with aspartame (Nutra Searle, Chicago, Illinois) in reduced calorie products may be an area of interest to research.

SUMMARY

Cakes were prepared containing 0, 50, 75, and 100% high fructose corn syrup (HFCS) as a replacement for sucrose. All purpose flour and cake flour were used at each level of sweetener. There were eight different cakes baked, thus having eight treatment combinations. Three replications of each treatment combination were made.

The objective measurements of the batter included specific gravity and linespread. Moisture content, volume and crust and crumb color measurements were made on baked cakes. Photographs were made to determine overall appearance.

A six member, semi-trained, taste panel evaluated fresh cakes for crust and crumb color, flavor, moistness, tenderness, and overall acceptability. An unstructured scale (0 to 7.5) was used.

There were no significant flour x sweetener interactions ($p < .05$) found in the objective data, thus the flour and sweetener main effects are not masked. The sweetener had a significant effect on the linespread of the batter, the moisture content, the deformation and the crumb color of the baked cakes. The addition of the HFCS increased the viscosity of the batters and moistness of the cake. Cakes with HFCS were less tender and darker in crumb. Flour had a significant effect on the volume and crumb color of the baked cakes. The cakes prepared with cake flour were greater in volume and lighter in color than the cakes with all purpose flour at all levels of sweetener. In all cases the flour had little effect on objective measurements of the cakes where 0 or 50% HFCS for

sucrose was used. Significant differences were observed between the cakes of the two flours when HFCS was utilized at 75 and 100% for sucrose. There were no significant differences in specific gravity and crust color between any cakes prepared with HFCS replacement for sucrose.

There was a significant flour x sweetener interaction effect on the sensory scores for crust, moistness, tenderness, and overall acceptability. Over and above these significant interactions there are significant main effects, i.e., flour and sweetener. There were no significant flour x sweetener interactions for crumb and flavor.

The crumb of the cakes prepared with cake flour was evaluated as lighter than those made with all purpose flour and 0 and 50% HFCS replacement. The panel found no differences in flavor among any of the treatments.

The cakes prepared with all purpose flour were darker in crust color than prepared with cake flour. The panel evaluated all cakes prepared with 0, 75 and 100% HFCS replacement for sucrose as significantly more moist than when prepared with all purpose flour rather than cake flour. As the amount of HFCS replacement for sucrose was increased to 75 and 100% replacement for cakes prepared with all purpose flour, there was a significant decrease in tenderness.

The cakes at levels of 75 and 100% HFCS replacement for sucrose and made with cake flour were rated more acceptable than the cakes made with all purpose flour.

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APPENDIX A

Cake Formulations, Mixing and Baking Instructions

Cake Formulations, Mixing and Baking Procedure

<u>Ingredients</u>	0% HFCS __ (g) __	50% HFCS __ (g) __	75% HFCS __ (g) __	100% HFCS __ (g) __
Hydrogenated Vegetable Shortening (Crisco)	108	108	108	108
Sugar System				
Sucrose (Domino)	240	120	60	0
HFCS		169	253	338
Egg White (Kroger)	82.8	82.8	82.8	82.8
Egg Yolk (Kroger)	57.2	57.2	57.2	57.2
All Purpose	200	200	200	200
Double Acting Baking Power (Hearth Club)	10	10	10	10
Cream of Tartar (Kroger)	3	3	3	3
Nonfat Dry Milk (Kroger)	20	20	20	20
Water (deionized, distilled)	149	99	74	50

Method:

All ingredients were mixed in a Hobart Kitchen Aid electric mixer, KSSS, listed 775A), connected to a Universal timer through the power source.

Beat egg white four minutes, speed 4 - set aside. Cream shortening one minute, speed 2.

Add sugar system and cream two minutes at speed 2. Add remaining ingredients, except egg whites, and mix one minute at speed 1.

Scrape bowl with rubber spatula and mix four minutes at speed 4.

Fold in egg whites to batter, beat one minute at speed 1.

Pour 630 grams of batter into a 20.32 cm X 20.32 cm X 5.08 cm Wear Ever metal baking pan that has been sprayed with Mazola No Stick (Mazola Town Co. - Englewood Cliffs, New Jersey) on bottom only.

Bake at 350°F (177°C) oven temperature inside, for 30 minutes in a General Electric oven, (Model J 336B1DC, Louisville, Kentucky).

APPENDIX B
Sensory Evaluation Schedule

Flour	HFCS Replacement for Sucrose			
	0%	50%	75%	100%
All Purpose Flour (AP)	#545* A**	#687 B	#796 C	#834 D
Cake Flour (CF)	#941 E	#273 F	#384 G	#497 H

		Tuesday	Thursday
January	28	A, F, G	
	30		E, B, C
February	4	H, D, A	
	6		G, C, H
	11	F, B, D	
	13		E, A, C
	18	B, F, G	
	20		D, E, G

*Randomized three-letter code.

**Cake identification letter

APPENDIX C
Sample Sensory Score Sheet

The lines below are labeled from left to right, least to most. Place a vertical slash through the line at the point that best describes the sample.

Taster _____
Sample _____

Least Most

- | | | | |
|-----------------------------|----------------|-------|---------------------|
| 1. Crust Color | Lt. Brown | _____ | Dk. Brown |
| 2. Crumb Color | Lt. Brown | _____ | Dk. Brown |
| 3. Flavor | (Bland) Sweet | _____ | Sweet (Sickly) |
| 4. Moistness | (Dry) Moist | _____ | Moist (Wet) |
| 5. Tenderness | (Tough) Tender | _____ | Tender
(Crumbly) |
| 6. Overall
Acceptability | Desirable | _____ | Desirable |

Sample _____

Least Most

- | | | | |
|-----------------------------|----------------|-------|---------------------|
| 1. Crust Color | Lt. Brown | _____ | Dk. Brown |
| 2. Crumb Color | Lt. Brown | _____ | Dk. Brown |
| 3. Flavor | (Bland) Sweet | _____ | Sweet (Sickly) |
| 4. Moistness | (Dry) Moist | _____ | Moist (Wet) |
| 5. Tenderness | (Tough) Tender | _____ | Tender
(Crumbly) |
| 6. Overall
Acceptability | Desirable | _____ | Desirable |

Sample _____

Least Most

- | | | | |
|-----------------------------|----------------|-------|---------------------|
| 1. Crust Color | Lt. Brown | _____ | Dk. Brown |
| 2. Crumb Color | Lt. Brown | _____ | Dr. Brown |
| 3. Flavor | (Bland) Sweet | _____ | Sweet (Sickly) |
| 4. Moistness | (Dry) Moist | _____ | Moist (Wet) |
| 5. Tenderness | (Tough) Tender | _____ | Tender
(Crumbly) |
| 6. Overall
Acceptability | Desirable | _____ | Desirable |

APPENDIX D

Models Used For Statistical Analysis
Of Objective And Sensory Data

Model For Objective Measurements

$${}^{(m)} Y_{ijk} = \mu + \zeta_i + \beta_j + (\zeta\beta)_{ij} + \gamma_k + \varepsilon_{ijk}$$

Model For Sensory Data

$${}^{(p)} Y_{ijkl} = \mu + \zeta_i + \beta_j + (\zeta\beta)_{ij} + \gamma_k + \rho_l + \varepsilon_{ijkl}$$

Where:

- $i = 1, 2$
- $j = 1, 2, 3, 4$
- $k = 1, 2, 3, \dots, 8$
- $l = 1, 2, 3, \dots, 8$
- $m = 1, 2, 3, \dots, 8$ (8 objective variables)
- $p = 1, 2, 3, \dots, 6$ (6 sensory variables)
- μ = overall mean
- ζ = cake effect
- β = sweetener effect
- $\zeta\beta$ = cake x sweetener effect
- γ = day effect
- ρ = person effect

Note: Day effect and person effect are blocks to reduce the variability in the data.

APPENDIX E
Summary of Analysis

TABLE 15
Summary of Objective Data

Choice of Flour: C = Cake Flour, AP = All Purpose Flour, E = Either

<u>Linespread</u>	<u>Specific Gravity</u>	<u>Volume</u>	<u>Moisture</u>	<u>Deformation</u>	<u>Crust</u>	<u>Crumb</u>
E	E	C	E	E	E	C

Levels of HFCS Statistically the same as 0% HFCS (control):

Linespread	50%
Specific Gravity	50%, 75%, 100%
Volume	50%, 75%, 100%
Moisture	None
Deformation	50%
Crust	50%, 75%, 100%
Crumb	50%, 75%, 100%

TABLE 16

Summary of Sensory Scores

Choice of Flour: C = Cake Flour, AP = All Purpose Flour, E = Either

Crumb AP

Flavor E

Levels of HFCS Statistically the same as 0% HFCS (control)

Crumb 50%

Flavor 50%, 75%, 100%

Choice of Flour: C = Cake Flour, AP = All Purpose Flour, E = Either

Variables with Flour X Sweetener Interaction

<u>% HFCS</u>	<u>Crust</u>	<u>Moistness</u>	<u>Tenderness</u>	<u>Overall</u>
0%	E	AP	E	E
50%	C	E	E	E
75%	E	AP	C	C
100%	C	AP	C	C

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