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A Trend Projection of High Fructose Corn  
Sweetener Substitution for Sugar

by

Hoy F. Carman and Peter K. Thor

Presented at the Annual Meeting of the American Agricultural Economics  
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Abstract

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High fructose corn syrup (HFCS) substitutes directly for sugar in many manufactured food products. Its continued rapid substitution for sugar has economic implications to sweetener industry participants and others. A nonlinear trend projection indicates that per capita and total U.S. sugar consumption will likely decrease during the next decade as HFCS consumption increases.

A TREND PROJECTION OF HIGH FRUCTOSE CORN  
SWEETENER SUBSTITUTION FOR SUGAR

by

Hoy F. Carman\* and Peter K. Thor\*\*

High fructose corn syrup (HFCS) is a recent product innovation which has gained rapid commercial acceptance. It is a caloric sweetener, made from ordinary corn starch, which substitutes for sugar in a wide range of manufactured products. Growth of processing capacity and market acceptance of HFCS have been dramatic since its commercial introduction in 1967. Production has approximately doubled every two years and 1978 output was estimated at 2.40 billion pounds. Estimated U.S. per capita consumption increased from .14 pounds in 1967 to 11.5 pounds in 1978. Continued acceptance and market penetration of HFCS has economic implications to domestic beet and cane sugar producers and processors, sweetener users, consumers, corn producers, and trading partners.

The purpose of this paper is to (1) briefly describe HFCS uses and pricing, (2) summarize published HFCS forecasts and projections, and (3) present a trend model projection of total sweetener and HFCS sales and the substitution of HFCS for sugar.

Uses and Pricing

The first generation high fructose corn syrups (42 percent fructose, 50 percent dextrose and 8 percent higher saccharides) are currently being

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used in soft drinks, ice cream, jelly, sweet pickles, confections, canned fruit and baked goods. In most products it is used as a partial rather than as a total replacement for sucrose. Typical formulations range from 50 percent HFCS/50 percent sucrose in soft drinks to 100 percent HFCS in jams and jellies (Fruin and Scallet).

The higher the fructose content, the greater is the substitutability of HFCS for sucrose. New second generation higher fructose syrups designed as total replacements for sucrose are now being produced. These syrups, with 55 to 60 percent fructose, will increase the range of uses for HFCS and should be especially attractive to the soft drink industry.<sup>1/</sup> A 90 percent fructose product, which may have applications in diet foods and beverages, is also available.

No detailed cost studies for producing HFCS have been published and firms in the industry are reluctant to provide cost information for their operations. All available information indicates, however, that production costs for HFCS are lower than comparable costs for domestic beet or cane sugar.<sup>2/</sup>

The pricing of HFCS relative to sugar has been an important factor in the growth in use of HFCS since its introduction. HFCS has been priced below sugar with the amount of differential being a direct function of

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<sup>1/</sup> These products and some of their applications are described in the two articles by Crocco. Abrams discusses the use of the 55-60 percent syrups in soft drinks.

<sup>2/</sup> Corn wet-milling has the advantage of year-around operation and valuable by-products to offset the cost of corn. The value of corn gluten feed and meal, steepwater, and corn oil from a bushel of corn may be as much as 70 percent of the cost of corn.

the price of sugar. In late 1974, when sugar prices reached record highs, the price differential between sugar and HFCS was as large as \$.30 per pound. For the 1975-1977 period, HFCS prices (dry basis) were 71 percent of sugar prices. During calendar 1978, monthly prices of HFCS were 53 to 62 percent of sugar prices with the annual average equal to 57 percent. The very competitive pricing can be attributed to a favorable price situation for wet-milling by-products and the existence of excess HFCS processing capacity.<sup>3/</sup>

#### Industry Projections of HFCS Use

There have been a number of projections of HFCS production, consumption and market share to 1980, 1985, and beyond. These projections demonstrate considerable variation, both in magnitude and in quality of supporting data and analysis. Those made during the period 1973-1975, when sugar prices were high and HFCS producers were rationing supplies to eager buyers, tend to be much more optimistic than are more recent projections.

Published speeches and interviews provide several projections without supporting data. Robinson estimated annual HFCS output of near four billion pounds by the end of 1978. He stated, "some experts predict that high fructose corn syrups may eventually account for up to 40 percent of industrial sugar consumption." Donald Francis, President of Clinton Corn Processing Company, spoke of annual HFSC capacity of four to six billion pounds

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<sup>3/</sup> Industry processing capacity was estimated at 4.71 billion pounds in 1978 while production was estimated at 2.4 billion pounds (Carman and Thor, p. 14).

by 1980 from firms that had announced production plans in 1975. He speculated that "this could easily increase to as much as nine to 10 billion pounds of HFCS yearly by 1990." Fred Gray, at a World Bank seminar in early 1976, said that "the corn sweetener industry expects that U.S. high fructose corn syrup consumption will likely total about three million tons (dry basis) in 1980." Charles Burck projected market share rather than total consumption. He stated, "in theory, better than 50 percent of the total sugar market is susceptible to the substitution of high fructose syrups. Few in the industry expect anything like that in the foreseeable future, but conservative estimates project 20 percent by 1980, and at least a 25 percent share over the long run."

The U.S. Department of Agriculture, in a recent issue of the Sugar and Sweetener Report (May 1978, p. 20), stated that:

People close to the sweetener market report that 'first generation' 42 percent (fructose) HFCS has nearly reached its U.S. market potential with sales of around a million tons in calendar 1977. Over half of the prospective 250,000-ton increase in HFCS sales in 1978 is now expected to come from the 'second generation' 55 percent product. It was originally thought by some in the industry that the 42 percent product market would eventually total 1.5 to 2 million tons.

HFCS sales are reportedly slow in the first quarter this year. The apparent failure of the 42 percent product to capture as large a market as originally thought suggests the possibility the eventual size of the 55 percent fructose product market could fall short of current expectations.

But there are signs that economic conditions could improve over the next few years. HFCS sales are expected to continue to grow at a minimum rate of 200,000 to 250,000 tons per year for the next few years.

Continued growth in HFCS sales of 250,000 tons per year would result in 1985 sales of 3.0 million tons. This is below the industry estimates just summarized but is in the range of study projections which follow.

Three studies of the HFCS industry, done by Arthur D. Little, Inc., Westway Trading Corporation, and Brook, present fairly detailed projections with some discussion of their underlying assumptions. Following is a brief summary of the projections in these three studies.

A.D.L. Study: The Arthur D. Little study of the domestic sweetener industry contains a rather detailed examination of potential use of HFCS by manufacturing product category. Projections of HFCS use to 1980, 1985 and 1990, given three alternative price levels for sugar, were made. The "most likely" projections were based on a sugar price of \$.20 per pound (bulk refined, Chicago-West). Total HFCS consumption was projected at 6 billion pounds in 1980, 7 billion pounds in 1985 and 7.6 billion pounds in 1990. The HFCS total sweetener market share was 19.8 percent in 1980, 21.2 percent in 1985 and 21.3 percent in 1990. A projection based on sugar prices of \$.30 per pound had substantially higher consumption of HFCS and lower total sweetener consumption.

Westway Study: Westway projected a total long-run potential for HFCS of 3.3 million tons (dry basis). Projected total 1985 HFCS consumption of 2.825 million tons (25 pounds per capita) is 19.2 percent of total sweetener consumption.

Brook Study: Ezriel Brook, in his study for the World Bank, estimated market potential for HFCS as being limited by liquid sweetener handling facilities and equipment. More specifically, he multiplied sucrose use by manufacturing category by the percentage which was liquid sugar in 1973. These were summed to obtain a weighted percentage of total sugar use which he uses as the market potential for HFCS. Brook's estimated market potential for HFCS is 2.6 million metric tons in 1980 and 3.9 million



metric tons in 1985. This is a projected market share of 25.3 percent of total caloric sweeteners.

#### A Trend Model Projection

Future consumption of HFCS depends on a number of factors. Technical considerations such as handling equipment and product suitability in various applications serve to establish market share potential. The rate of which sales approach that potential (the rate of adoption of HFCS) depends on the profitability of HFCS production and use, the ratio of HFCS and sugar prices, and U.S. sugar policy. Total sweetener demand will change through time in response to changes in prices, incomes, tastes and populations.

Projection of 1985 and 1990 HFCS and sugar consumption proceeds in a series of steps. First, we specify and estimate a trend equation for total sweetener consumption. This equation is then used to project total sweetener consumption. Next, we estimate a trend equation of HFCS market share. Combination of estimated market shares with total sweetener consumption yields estimates of HFCS and sugar consumption.

Sweetener Consumption: Analyses of the demand for sweeteners indicate that demand is very price and income inelastic. Our results agree with other studies. We estimated the following equation using first differences in logarithms for the period 1950-1977:

$$\Delta \ln QS = .005599 - .0715 \Delta \ln PS - .0341 \Delta \ln Y$$

(2.20)      (-5.57)      (-.44)

where QS is per capita consumption of all caloric sweeteners, PS is the average retail price of sugar deflated by the consumer price index (1967 = 100) and Y is per capita disposable income deflated by the consumer price

index. The t-statistics are shown in parentheses. The income coefficient has an unexpected negative sign but it is not significantly different than zero. The coefficients can be interpreted as elasticities. Thus, we conclude that the estimated price elasticity of demand for all sweeteners is approximately  $-.07$  and that the income elasticity is approximately zero. The constant in the equation indicates that the demand for all sweeteners has been increasing at a rate of  $.56$  percent annually.<sup>4/</sup>

The above equation was used to project sweetener consumption under the following conditions:

1. The base period is 1977. Thus, projected prices, income, etc., are in terms of 1977 conditions.
2. Population will increase in line with the medium growth (Series II) projection of the Census Bureau. Thus, U.S. population will increase from 215,118,000 in 1977 to 230,692,000 in 1985 to 243,513,000 in 1990.
3. Real income will increase 2.5 percent annually.
4. Estimated 1977 total caloric sweetener consumption was 128.1 pounds per capita (13,778,308 tons) and the average retail price of sugar was 21.62 cents per pound.

Our projections of total caloric sweetener consumption for three levels of sugar prices are shown in Table 1. Since the demand for sweeteners is very price inelastic, different price levels have a comparatively small impact on projected consumption. Income and trend factors also have a small impact. Most of the projected growth in sweetener demand is due to population growth.

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<sup>4/</sup> As suggested by Foote (p. 43) and George and King (pp. 44-52), the percentage effect of time in each year can be obtained by taking the anti-logarithm of the constant term if all variables in the first-difference analysis are converted to logarithms and if the constant term is significantly different from zero.

TABLE 1

Projected Per Capita and Total Caloric Sweetener Consumption  
for Three Alternative Retail Sugar Price Levels, 1985 and 1990

Average retail price of sugar	1985		1990	
	lb/capita	1,000 tons	lb/capita	1,000 tons
\$.20	133.68	15,419	136.73	16,648
.25	131.48	15,166	134.49	16,375
.30	129.28	14,912	132.24	16,101

HFCS Market Share: The literature on the adoption of product innovations supports the concept that market penetration typically follows an S-shaped pattern through time. Sales (and market share) begin slowly, increase at an increasing rate, and then increase at a decreasing rate until the maximum potential market share is achieved. Sales of HFCS since its introduction in 1967 have followed the expected S-shaped pattern. The market potential for HFCS depends on technical considerations, the price of sugar, and costs of HFCS. Technical considerations will probably limit HFCS to a maximum of 35 percent of the total sweetener market (about one-half of industrial sweetener use) but this share will only be achieved with very high sugar prices. The most likely ceiling values are in the range of 20 to 30 percent of total sweetener sales.

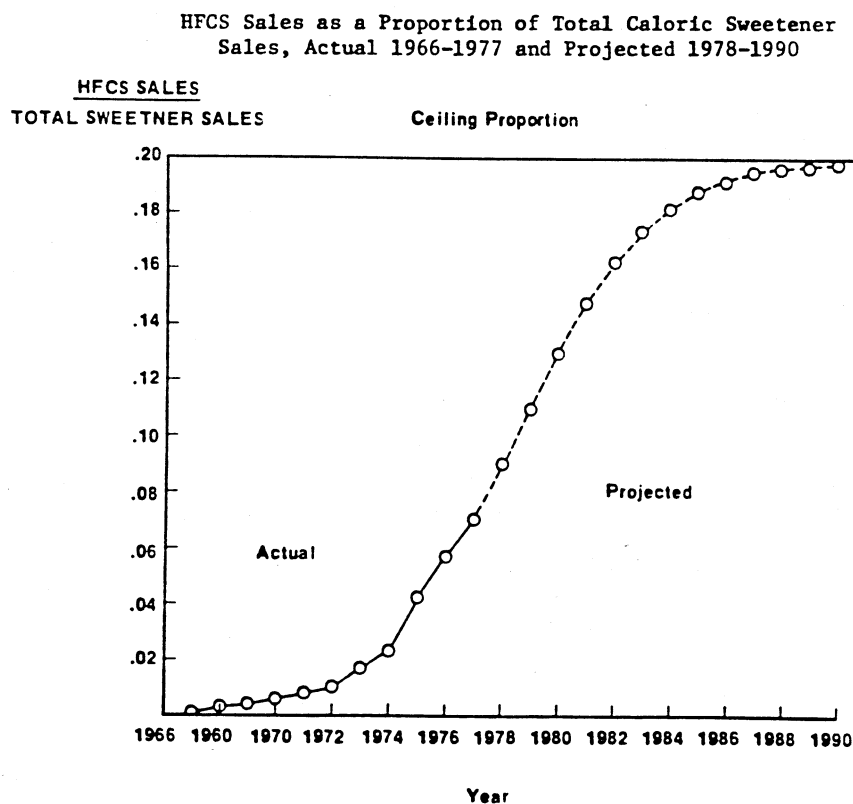
We estimated a simple logistic growth curve from HFCS market share data for the period 1967-1977 using various ceiling values. The trend in sales and market share is consistent with ceiling values between 20 and 35 percent. A ceiling value of .20 was selected for use in making market share projections through 1990. The equation estimated was:

$$\ln (P_t / (.2 - P_t)) = -5.2522 + .4204t \quad R^2 = .986$$

where  $P_t$  is the proportion of total sweetener sales which are HFCS in year  $t$  and  $t$  is time with 1967 = 1, 1968 = 2, . . . , 1977 = 11.

The estimated 1967-1977 HFCS market share data used to estimate the logistic function are shown in Figure 1. The projection of market share to 1990 for a ceiling value of 20 percent is also shown. Using this projection, the HFCS share of the total caloric sweetener market would be .131 in 1980, .188 in 1985 and .198 in 1990. Adoption of HFCS would be very rapid between 1978 and 1984 and would be essentially completed by 1990.

FIGURE 1



HFCS Projections: Combination of the projections of total sweetener demand and market share for HFCS yields a projection of HFCS demand. Some care must be exercised in combining the two projections since the sugar price level and ceiling market share for HFCS interact. We believe that a HFCS ceiling market share of 20 percent is consistent with a low-to-medium level of retail sugar prices. Thus, we project total sweetener consumption based on retail sugar prices of \$.25 per pound. High sugar

prices and a large differential between sugar and HFCS prices would probably be associated with a higher market share for HFCS.

Per capita consumption of glucose corn syrup, dextrose and minor caloric sweeteners is likely to continue at recent levels. While there may be some substitution of HFCS for dextrose, it is likely that this will be offset by growth in glucose consumption. Per capita consumption of glucose and dextrose has recently averaged 22.8 pounds while consumption of minor caloric sweeteners has averaged 1.4 pounds. These values and projections of HFCS demand under the assumption of sugar prices at \$.25 per pound and an HFCS ceiling market share of 20 percent are combined in Table 2 to derive a projection of sugar consumption.

Estimated 1977 sugar consumption was 10.29 million tons or 95.7 pounds per capita. Projected 1985 demand for sugar shows a 13.7 percent decrease in per capita terms and a 7.4 percent decrease in total. Since the projected adoption of HFCS is almost complete by 1985 (Figure 1), there is a slight increase over 1985 in projected 1990 per capita sugar consumption. While projected sugar demand increases between 1985 and 1990, total consumption in 1990 is still slightly below total consumption of 10.29 million tons reported in 1977.

TABLE 2

Projected Per Capita and Total Demand for Caloric Sweeteners by Category, 1985 and 1990

Sweetener	Projected Demand			
	1985		1990	
	lb/capita	1,000 tons	lb/capita	1,000 tons
Glucose and Dextrose	22.8	2,630	22.8	2,776
Minor caloric sweeteners	1.4	161	1.4	170
HFCS	24.7	2,848	26.7	3,251
Sugar	82.6	9,527	83.6	10,179
Total	131.5	15,166	134.5	16,376

### Implications

The future size of the domestic sweetener industry and market penetration by HFCS are a function of the domestic price of sugar. Thus, the future of the domestic HFCS industry will be based on the form taken by U.S. sugar price policies. Government actions which support the price of sugar (quotas, tariffs, duties, fees and loan programs) provide a price umbrella for HFCS and encourage its substitution for sugar. Since domestic sugar production is a function of government target price, HFCS will substitute for imported sugar.

The impact of HFCS on world sugar prices will be small since substitution is a very small portion of world sugar production. Likewise, the use of corn for sweeteners accounts for a minor portion of the U.S. corn crop and its impact on corn prices is small. The estimated total corn grind for sweeteners and starch grew from approximately 154 million bushels in 1960 to some 400 million bushels in 1978 (Sugar and Sweetener Report, Sept. 1977 and Dec. 1978). This was only about six percent of the estimated 1978 corn crop of 6.5 billion bushels. The percentage of the corn crop used for sweeteners was about four percent and, of that amount, an estimated 73.2 million bushels (1.1 percent) was used for HFCS. It is unlikely that HFCS will use more than four percent of the U.S. corn crop by 1990.

The impact of HFCS on sweetener users and U.S. consumers can be substantial. Food manufacturers can reduce costs and prices by utilizing HFCS in their sweetener formulation. Likewise, substitution of HFCS for imported sugar will have an impact on balance of payments accounts and on trading partners. Quantitative estimates of these impacts are beyond the scope of this paper.

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