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Preliminary Economic Feasibility Analysis of High Fructose Corn Syrup Processing in the United States with Emphasis on North Dakota

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Preface

This prefeasibility analysis directed at the HFCS industry was carried out under a short-term turnaround basis with the intent of accomplishing two objectives. First, provide a current economic overview of the United States HFCS industry; secondly, to develop some major HFCS processing plant operating benchmarks in an effort to provide a timely informational base for state economic development interests.

The authors are indebted to numerous private businesses and agribusiness associations who provided information and data for this study. Appreciation is given to the Corn Refiners Association, Inc., Washington, D.C., who provided both background information and current statistics on the HFCS industry.

The authors wish to express their appreciation to Dr. Gordon Erlandson, Professor Timothy A. Petry, and Dr. Lawrence Mack for their timely manuscript reviews and helpful comments. Special thanks are extended to Ms. Darla Christensen and Ms. Shelly Swandal for their secreterial expertise. Any errors or omissions are the sole responsibility of the authors.

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Highlights

A pre-feasibility analysis of high fructose corn syrup (HFCS) processing was carried out. Specific areas covered were consumption trends for noncaloric and caloric sweeteners, markets for HFCS and by-products, product pricing, existing processors and their capacities, estimated processing costs and returns, potential for industry growth, and locational advantages-disadvantages for a North Dakota-based HFCS processing plant.

Second generation HFCS products are now commonplace in the industry. HFCS concentrations above 42 percent have been made possible by the development of the fractionation process which allows for HFCS products of 55 and 90 percent concentrations. HFCS-42 is used primarily in the baking, cereal, dairy, and processed food industries. HFCS-55 is used primarily in soft drinks, ice cream, and frozen desserts while HFCS-90 is used in natural and "light" foods, where less sweetener contributes to lower caloric ratings.

Since 1976, the consumption of caloric sweeteners has remained relatively stable, while the source has changed dramatically. Refined sugar has been consistently displaced by HFCS. Refined sugar peaked at 94 pounds on a per capita basis in 1977, falling to 64 pounds in 1986, a 35 percent decrease. Per capita consumption of HFCS, dry basis, increased from 5 pounds in 1975 to over 45 pounds in 1986, an increase of 800 percent.

HFCS is at or near existing product market potential. Additional opportunities for sucrose (sugar) displacement is limited. The HFCS industry accounts for over 96 percent of the combined HFCS and sucrose consumption in the beverage industry. Some potential exists for increased use of HFCS-42 in the processed food industry with very limited displacement potential of sucrose in the confectionery market. By-products, basically corn gluten feed and meal are very dependent on the feed protein markets. Historically, 70 to 75 percent of the domestic HFCS meal by-products have been exported. The European Economic Community (EEC) accounts for 95 percent of the HFCS meal exports.

HFCS product prices are very dependent upon sucrose market prices and have consistently been discounted from the price of sucrose. While this discount has narrowed, sucrose will remain as a ceiling price for HFCS as long as sucrose remains substitutable in the HFCS market. Some potential still exists for HFCS prices to move independently (while remaining discounted to sugar) as the industry reaches maturity and firms begin to compete with each other.

Six firms control the HFCS processing coming from 18 United States plants. This is a capital intensive industry with major capital investments occurring during two time periods. Heavy investment came in the mid 1970s with the introduction of HFCS-42 plants followed in the early 1980s with expansion of HFCS-55 capacity. Expansion of HFCS-55 was due to both construction of new plant capacity and the updating of existing HFCS-42 facilities.

Economy of operation is definitely related to plant size and operating plants close to their designed capacity levels. Estimated historical returns on average plant investment (1981-1986) has been very competitive with other alternative investment opportunities, ranging from 16 to 45 percent.

Potential market for a HFCS plant in North Dakota would primarily be limited to the Pacific Northwest, the northern tier of midwest states, and Minnesota. When compared to an Iowa based operation, a North Dakota HFCS plant would have a slight price advantage for the base raw material (corn) and labor and a disadvantage in terms of energy costs from coal, natural gas, and electric power. A localized market for meal by-products would also be important in evaluating the competitive stance of a North Dakota based plant.

Preliminary Economic Feasibility Analysis of High Fructose Corn Syrup Processing in the United States with Emphasis on North Dakota

Scott M. Wulff and Delmer L. Helgeson[1]

The following report is a preliminary study on the feasibility of high fructose corn syrup (HFCS) production with emphasis on the merit of a North Dakota based plant. Background information is provided on the technological aspects of HFCS processing; HFCS market size, growth and pricing; by-products; existing processors and capacities; processing costs; and locational considerations of a North Dakota based plant.

Technological Background

Wet Corn Milling Process

The raw material for all corn-derived sweeteners is the starch portion of the corn endosperm. The starch portion of the corn endosperm is separated from other fractions in the corn wet milling process. The corn wet milling process is presented in Figure 1. Cleaned shelled corn is soaked and steeped in a series of tanks (steep) in warm water containing sulphur dioxide. The steeping process swells and softens the grain which facilitates the separation of the seed. The steeped corn is then degerminated in a water slurry by a shearing mill which releases the germ. A continuous liquid cyclone then separates the germ, which then becomes ready for oil extraction. The remaining endosperm and hull, after additional fine grinding, are screened, removing the hull and fibers. The remaining slurry is then centrifuged for separation of starch and gluten. The separated starch fraction is then filtered and washed to reduce solubles. The starch, in a water suspension, is now ready for drying to produce dry starches or for conversion into syrups.

Syrup Conversion Process

In the conversion process, the suspended starch is liquified in the presence of acid and/or enzymes which convert the starch to a low-dextrose solution. Treatment with another enzyme continues the conversion process. Refiners can halt acid or enzyme action at key points to produce differing concentrations of sugars, such as dextrose and maltose, to produce syrups with different characteristics for different needs. In production of low-to-medium sweetness syrups, the conversion of starch to sugars is halted at an early stage. In others, the conversion is continued until the syrup is nearly all dextrose. The syrup is refined in filters, centrifuges and ion-exchange columns, and excess water is evaporated. Syrups are then sold directly, crystallized into pure dextrose, processed further to create high fructose corn syrups, or used as a feedstock in the production of alcohol (Corn Refiners Association, Inc. 1986).

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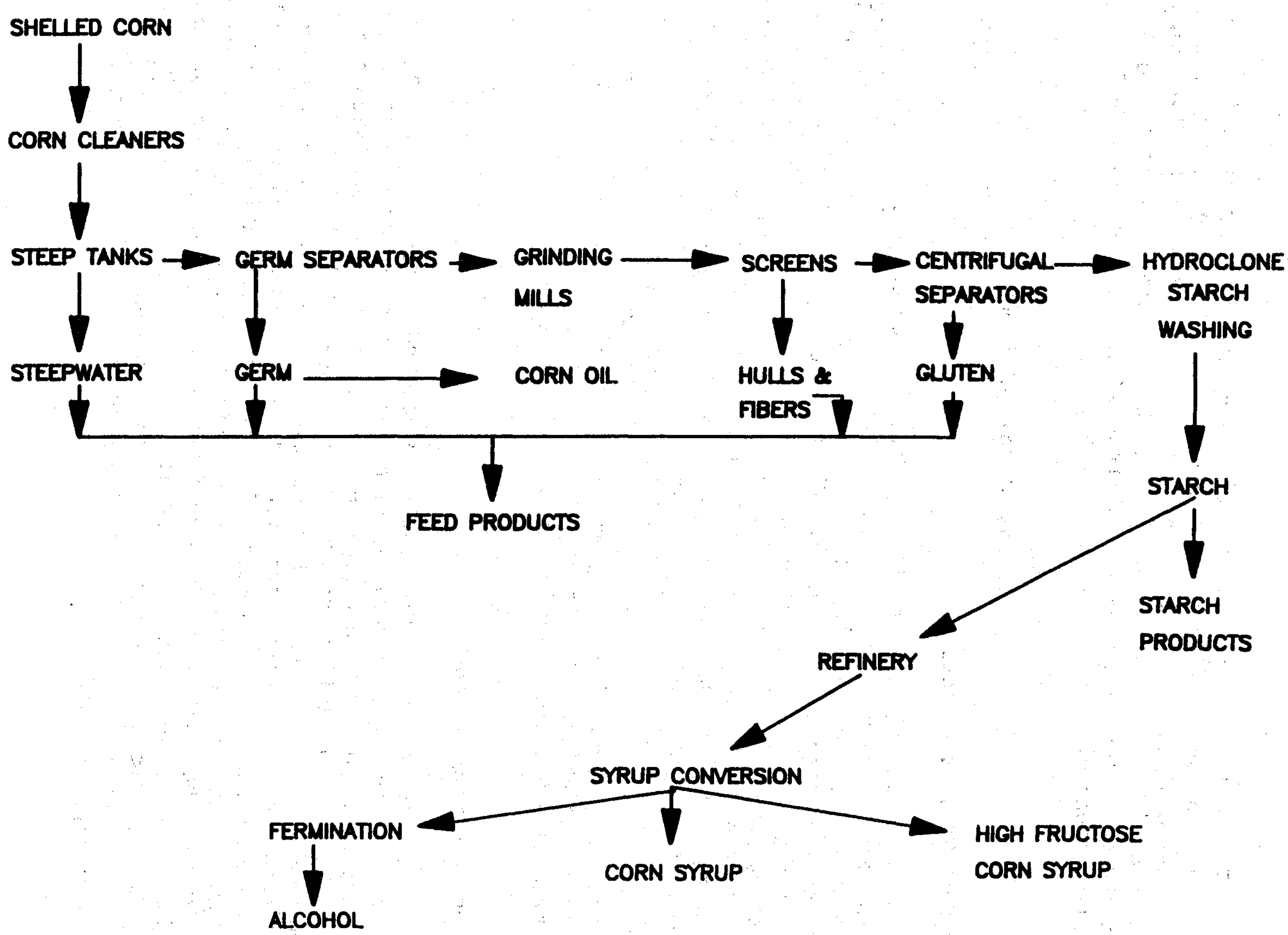

Figure 1. The Corn Wet Milling and Starch Conversion Process

HFCS Conversion Process

Dextrose solutions or high dextrose equivalent (D.E.) substrates are refined by carbon and ion-exchange systems and further treated enzymatically with a purified isomerase. Isomerization is generally carried to a point where the substrate contains 42 percent fructose. This product is refined again through carbon and ion-exchange systems and is evaporated to a dry substance level of 71 percent. The product is consequently named HFCS-42.

Isomerization is the transformation of one chemical into another chemical compound in which both compounds have the same empirical formula. In the production of high fructose corn syrup, HFCS, dextrose is isomerized into fructose. Both sugars have the same formula ($C_6H_{12}O_6$) but different configurations (Figure 2).

Dextrose, a D-glucose, and fructose, a D-fructose, are members of the hexose[2] series. All sugars in the hexose series have the formula $C_6H_{12}O_6$, therefore all members of the group are isomers of one another. The main difference between hexose isomers and isomers of other groups is in the nature of the reducing group (whether aldose or ketose) and in the spatial arrangement (stereo-chemical configuration) of the atoms (Figure 2).

Sweetness is directly related to the structural differences among hexoses. D-fructose, a ketohexose, has a relative sweetness in the range of 120 to 160 as compared to 100 for sucrose (table sugar). Dextrose, D-glucose, an aldohexose, has a relative sweetness of 70 to 80. The increased sweetness of fructose created the interest in an isomerization process where D-glucose can be converted to D-fructose. HFCS-42 is about as sweet as sucrose and is popular in canned fruits, condiments, and other processed foods which need mild sweeteners that will not mask natural flavors.

Second generation high fructose corn syrups, those with fructose concentrations above 42 percent, have been made possible by the development of a fractionation process which allows separation of fructose from dextrose. A 42 percent fructose feedstock is passed through separation columns which retains fructose. The fructose fraction is recovered at an 80-90 percent concentration. This product is blended with 42 percent fructose to produce a syrup with a fructose content of 55 percent. The syrup is refined again with both carbon and ion-exchange systems and evaporated to a dry substance level of 77 percent. This syrup, HFCS-55, is used primarily in soft-drinks, ice cream, and frozen desserts. The high fructose fraction, 90 percent fructose, may also be refined and evaporated to produce HFCS-90 for users who desire a sweeter product. HFCS-90 is one and one half times as sweet as sugar and is used in natural and "light" foods because less sweetener, and thus fewer calories, are needed to provide the sweetness level (Corn Refiners Association 1986).

The yield of HFCS-42 and HFCS-55 is 47 and 45 pounds per bushel, respectively. HFCS-42 has a dry solid content of 71 percent yielding 33.37 lbs. dry solids per bushel of corn. HFCS-55 has a higher dry solids content of

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[2] "ose" is the suffix which identifies a sugar.

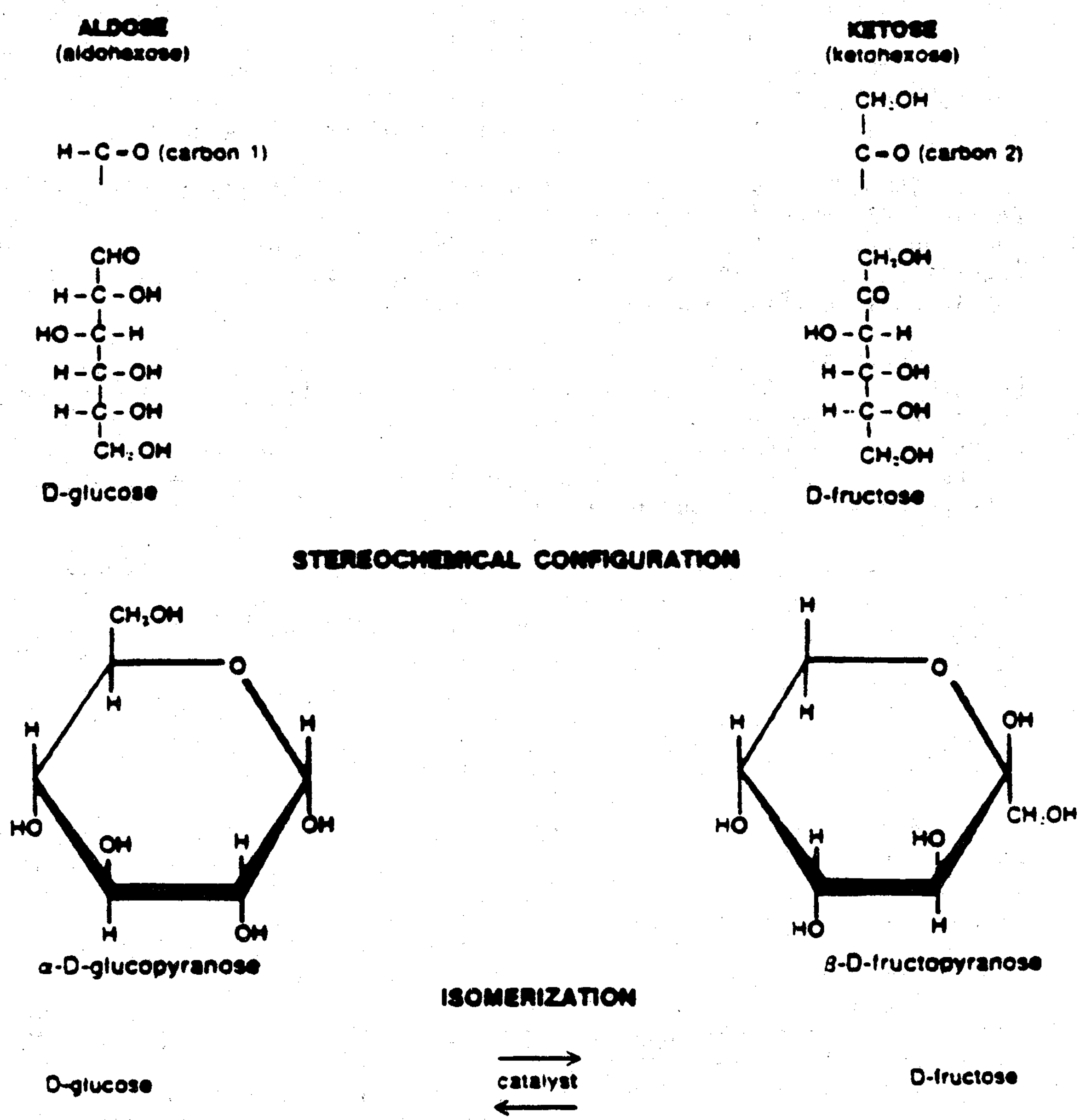

Figure 2. Stereochemical Configuration of Dextrose and Fructose

SOURCE: Corn Refiners Association, 1986

77 percent thus yielding 34.65 lbs. dry solids per bushel of corn (Vuilleumier 1985).

United States Per Capita Consumption of Caloric Sweeteners

Per capita consumption of caloric sweeteners has increased from 118.1 pounds per capita in 1975 to 129.7 in 1986. Consumption was stable from 1976 to 1983 before increasing in 1985 to 131.2 pounds. Consumption is expected to decrease to 128.9 pounds in 1987 (Figure 3).

The source of caloric sweeteners has changed drastically. Refined sugar has been consistently displaced by the use of high fructose corn syrup. Refined sugar consumption decreased from a peak of 94 pounds per capita in 1977 to 61 pounds in 1986, a 35 percent reduction. HFCS per capita consumption, dry basis, increased from 5 pounds in 1975 to over 45 pounds in 1986. Dextrose and glucose consumption have remained relatively stable (Figure 4).

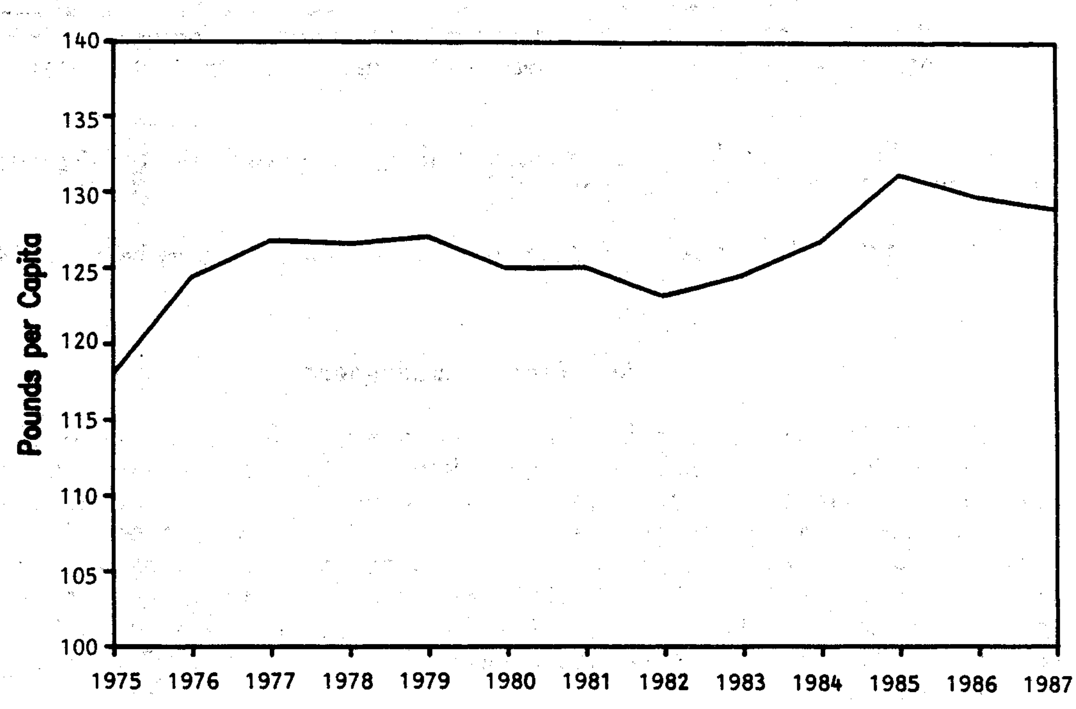

Figure 3. Per Capita Consumption of Caloric Sweeteners, United States, 1975 Through 1986 and Forecast for 1987

SOURCE: Sugar and Sweetener Situation and Outlook Report, March, 1987.

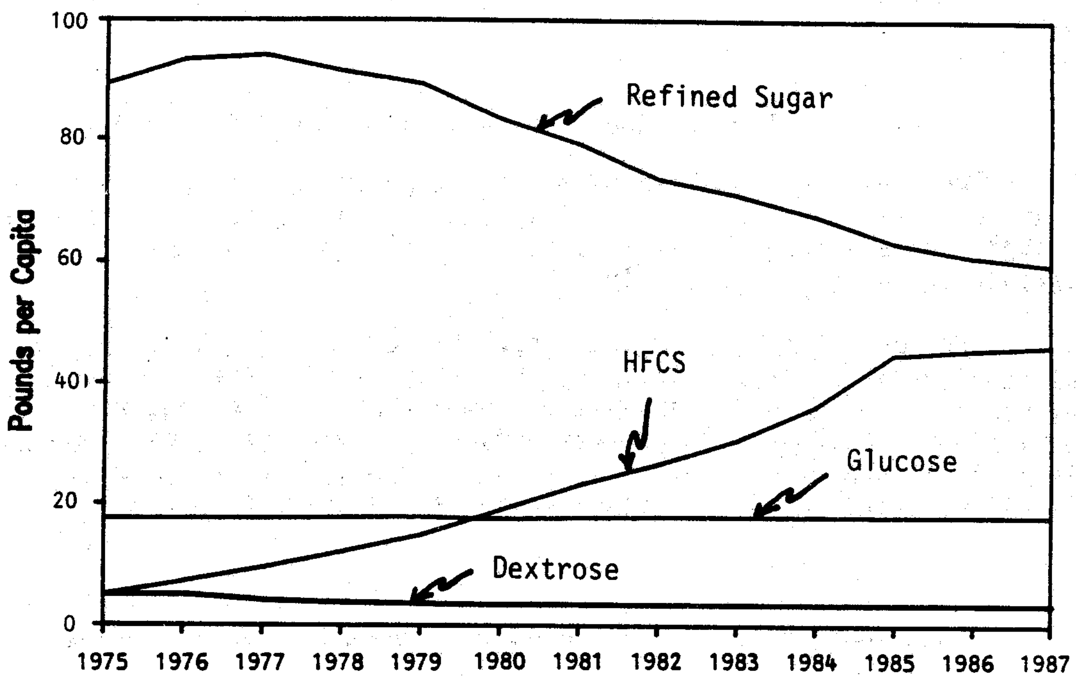

Figure 4. Per Capita Caloric Sweetener Usage by Type, United States, 1975 Through 1986, and Forecast for 1987

SOURCE: **Sugar and Sweetener Situation and Outlook Report, March, 1987.**

Artificial Sweeteners

Artificial sweeteners have been responsible for over one-half of the growth in the sweetener industry since 1975. Total per capita sweetener usage (including noncaloric and low calorie sweeteners on a sugar sweetness equivalent basis) increased by 24 pounds, 124.2 to 148.2, from 1975 to 1986. Artificial sweeteners accounted for 12.4 pounds of the increase (sugar equivalent basis) (Figure 5). Growth, measured both in annual percentage and absolute consumption, has been greater for artificial sweeteners than caloric sweeteners. Much of the increased growth (Table 1) has come from increased use of aspartame.

Aspartame's recent growth has come partially at the expense of saccharin as manufacturers switched from a mixture of aspartame and saccharin to exclusively aspartame. Aspartame and saccharin now account for over 12 percent of the sweetener market.

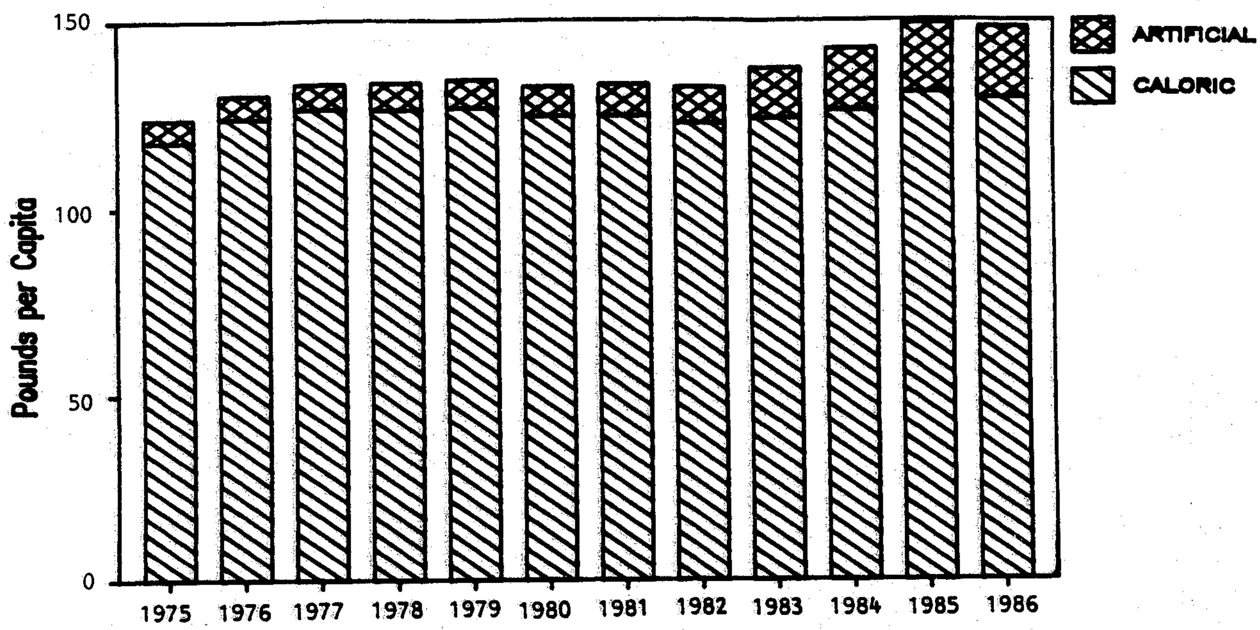

Figure 5. Per Capita Sweetener Usage, Including Artificial Sweeteners[1]

[1]Sugar equivalent basis, assumes saccharin is 300 times as sweet as sugar, and aspartane 200 times as sweet as sugar.

SOURCE: Sugar and Sweetener Situation and Outlook Report, March, 1987.

Total United States Consumption of Caloric Sweeteners

Total United States consumption of caloric sweeteners has increased from 12.75 million short tons in 1975 to 15.66 in 1986 (Table 2). Glucose consumption has increased slightly from 1.89 million short tons in 1975 to 2.17 in 1986. Dextrose has decreased from .54 million short tons to .42 since 1975. HFCS consumption has grown tremendously, from .54 million short tons in 1975 to 5.5 in 1986. Refined sugar has decreased from 9.6 million short tons in 1975 to 7.37 in 1986. This decrease is primarily due to the increased use of HFCS in the beverage industry and, to a lesser extent, the canning, baking, and cereal industries.

HFCS Growth Potential

Growth potential for HFCS through additional displacement of sucrose (sugar) is limited. Actual usage of HFCS in the market is at or near the theoretical or expected technical level of penetration (Table 3). HFCS has nearly displaced the entire usage of sugar in the beverage industry. Prior to

TABLE 1. UNITED STATES PER CAPITA CONSUMPTION OF NONCALORIC, LOW-CALORIC, AND CALORIC SWEETENERS, 1975-1986

Year	Artificial Sweeteners[a]				
	Saccharin	Aspartame	Subtotal	Caloric[b]	Total
	pounds				
1975	6.1		6.1	118.1	124.2
1976	6.1		6.1	124.4	130.5
1977	6.6		6.6	126.8	133.4
1978	7.1		7.1	126.6	133.7
1979	7.4	.0	7.4	127.1	134.5
1980	7.7	.0	7.7	125.0	132.7
1981	8.0	.2	8.2	125.1	133.3
1982	8.4	1.0	9.4	123.2	132.6
1983	9.5	3.5	13.0	124.6	137.6
1984	10.0	5.8	15.8	126.8	142.6
1985	6.0	12.0	18.0	131.2	149.2
1986	5.5	13.0	18.5	129.7	148.2

[a]Data is on a sugar equivalent basis, and assumes saccharin (noncaloric) is 300 times as sweet as sugar and aspartame (low caloric) is 200 times as sweet as sugar.
[b]Includes sugar, all corn sweeteners, honey, and edible syrups.

SOURCE: Sugar and Sweetener Situation and Outlook Report, March, 1987.

November 1984, major soft drink bottlers limited the use of HFCS to a 50 percent replacement level. In November 1984 the bottlers approved a 100 percent replacement level of sucrose by HFCS in cola drinks. Due to the lower costs of HFCS relative to sucrose, HFCS accounts for over 96 percent of the combined HFCS and sugar consumption in the beverage industry.

The use of HFCS in the baking, cereal, and dairy industries is also near or at its potential technical penetration levels. Some potential increases in the use of HFCS-42 exists in the processed food industry as some manufacturers have not approved its use. Displacement of sugar in the confectionery market is expected to be low since the use of a hygroscopic product is incompatible in many confectionery uses (Vuilleumier 1985).

The rapid market growth of HFCS due to sucrose displacement is rapidly slowing, however there is some limited growth potential in the processed food sectorr. Further market growth will be dependent on population growth and changes in consumption by consumers.

TABLE 2. TOTAL UNITED STATES CONSUMPTION OF CALORIC SWEETENERS, 1975, 1980-1987

Year	Refined Sugar	Corn Sweeteners[a]				Total[b]
		HFCS	Glucose	Dextrose	Subtotal	
	million tons					
1975	9.63	.54	1.89	.54	2.97	12.75
1980	9.52	2.18	2.00	.40	4.58	14.24
1981	9.13	2.67	2.05	.40	5.12	14.39
1982	8.56	3.10	2.09	.41	5.60	14.31
1983	8.33	3.60	2.11	.41	6.12	14.61
1984	8.01	4.30	2.13	.41	6.84	15.01
1985	7.58	5.39	2.16	.42	7.96	15.70
1986	7.37	5.53	2.17	.43	8.12	15.66
1987[c]	7.27	5.65	2.19	.43	8.29	15.72

[a]Dry basis.
[b]Includes honey and edible syrups.
[c]Forecast.

SOURCE: Sugar and Sweetener Situation and Outlook Report, March, 1986.

TABLE 3. ESTIMATED INDUSTRIAL SUGAR AND HFCS DELIVERIES BY MARKET CATEGORY, HFCS MARKET SHARES, AND THEORETICAL LEVEL OF HFCS PENETRATION, UNITED STATES, 1984-1985.

Item	Deliveries				HFCS Market Shares		Estimated Long-Term[a] Penetration Levels	
	Sugar		HFCS					
	1984	1985	1984	1985	1984	1985	Vuilleumier	Carmen
	million pounds				percent			
Beverage	1550	250	5400	6730	77.7	96.4	100	100
Baking, cereal	2829	2885	970	1010	25.5	25.9	25	25
Canned and processed foods	925	945	1350	1400	59.3	59.7	60-75	75
Dairy products	784	800	420	430	34.9	35.0	35	30
Confections	2217	2260	40	50	1.8	2.2	5	10
Other food and nonfood uses	1145	1170	320	330	21.8	22.0		25
Total	9450	8310	8500	9950	47.4	54.5		

[a]These percentages represent the estimated penetration levels of HFCS in the respective sucrose markets based on current technology.

SOURCE: Vuilleumier, 1985, and Carmen, 1983.

Soft Drink Industry

The soft drink industry is the primary consumer of HFCS. The beverage industry accounts for over two-thirds of all HFCS sales and for over 95 percent of all HFCS-55 consumption (Vuilleumier 1985). HFCS, as previously stated, currently accounts for over 96 percent of the combined sucrose and HFCS sweetener usage in the soft drink industry.

The conversion to HFCS from sugar is documented in Table 4. Data are from a survey completed by the National Soft Drink Association (NSDA) of bottlers during 1985. This conversion was significantly related to the approval of 100 percent usage of HFCS by major soft drink companies in November 1984. Excluding noncaloric sweeteners, HFCS was used exclusively in 95 percent of soft drinks in 1985 compared to 55 percent in 1984. The use of a HFCS/sugar combination decreased from 42 percent in 1984 to less than 3 percent in 1985.

Trends in Consumption. Per capita consumption of soft drinks has increased from 289 twelve-ounce cans in 1975 to 486 cans in 1985 (Figure 6). This represents an annual growth rate of 5.3 percent. Total United States consumption has increased from 2.6 million cases (24 twelve-ounce cans) in 1975 to 4.8 million cases in 1985, an annual growth rate of 6 percent. Total growth is greater than per capita growth due to an annual population growth of 1 percent during the period. The market share of diet soft drinks has been increasing over time from 10 percent in 1975 to over 21 percent in 1985 (Figure 7). The annual shift in market share from regular to diet soft drinks is increasing. From 1975 to 1980 the average annual shift was 3.8 percent compared to 7.3 during 1980-1985.

In spite of the shift in market share from regular to diet soft drinks, total United States and per capita consumption of regularly sweetened soft drinks is increasing. This is possible because the annual growth in beverage consumption exceeds the shift from regular to diet soda. However, if the present trend continues, a decrease in per capita consumption of regular soft drinks may result.

TABLE 4. THE METHOD BY WHICH REGULAR SOFT DRINKS ARE SWEETENED

	1984	1985
	------- percent	--------
Beet/cane sugar	3.8	1.8
HFCS	54.6	95.5
Sugar and HFCS	41.5	2.7

SOURCE: Adapted from National Soft Drink Association, 1986.

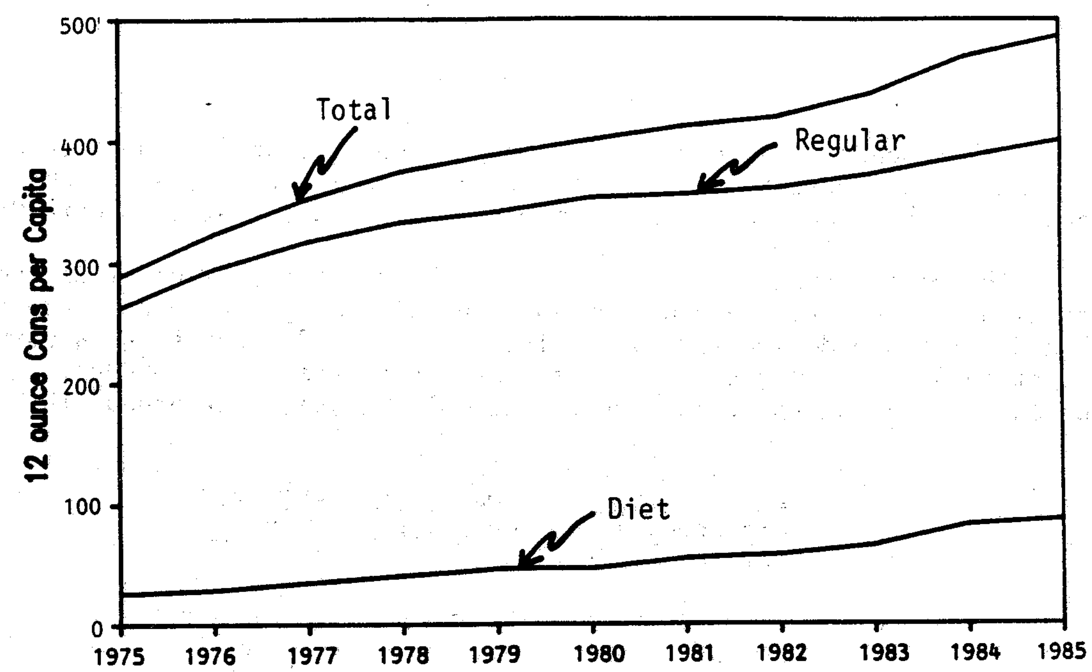

Figure 6. Per Capita Consumption of Soft Drinks, United States, 1975 Through 1985

SOURCE: Adapted from National Soft Drink Association, 1986.

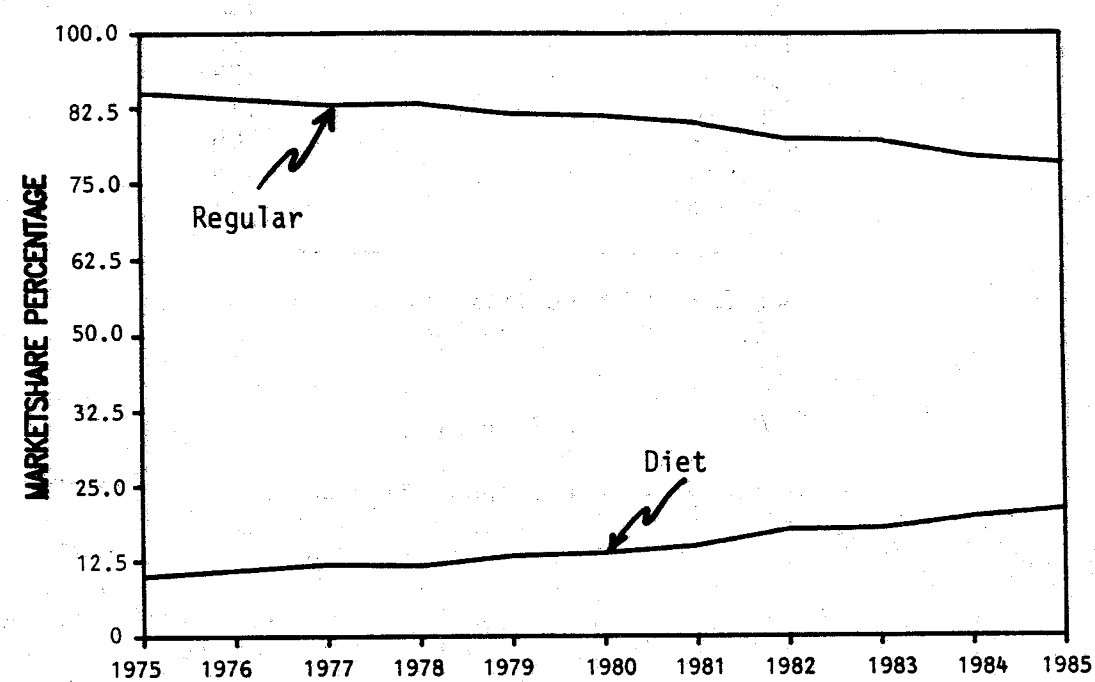

Figure 7. Market Shares of Soft Drinks by Type, Diet Versus Regular, 1975 Through 1985

SOURCE: Personal communications, National Soft Drink Association, 1987.

Other Concerns. There is industry concern regarding the future usage of aspartame as the patent for aspartame expires in 1992. There is some speculation that generic aspartame may become price competitive with HFCS.

The consumption of soft drinks is very seasonal. Monthly deliveries of soft drinks as a percentage of the 1985 annual average are presented in Table 5. Monthly deliveries ranged from a low of 72 percent in January to 134 percent in July and August. This seasonality increases the production costs of HFCS as the plants cannot be operated at full capacity throughout the year.

TABLE 5. MONTHLY SOFT DRINK DELIVERIES AS PERCENT OF ANNUAL AVERAGE, UNITED STATES, 1985

Month	Percent
January	72
February	80
March	95
April	109
May	108
June	108
July	123
August	123
September	115
October	105
November	86
December	77

SOURCE: Adapted from National Soft Drink Association, 1986.

HFCS Pricing

HFCS prices are very dependent upon sugar prices. Both HFCS-42 and HFCS-55 are discounted to the price of sugar (Figure 8). However, this discount has decreased and stabilized over time. HFCS-42 was initially discounted to sugar prices to gain market entry. The discount has narrowed for the period from 1984 to 1986. The discount for HFCS-42 has been between 22 and 23 percent (Figure 8). HFCS-55 is discounted 12 to 15 percent less than the price of sugar. As the industry matures, plant capacity will equal or exceed market demand. The potential for HFCS prices to move independently (as long as HFCS remains discounted to sugar) exists as HFCS manufacturers begin to compete with each other and with the sugar market. The price of sugar would still be the ceiling price for HFCS as long as sugar remains substitutable in the HFCS market.

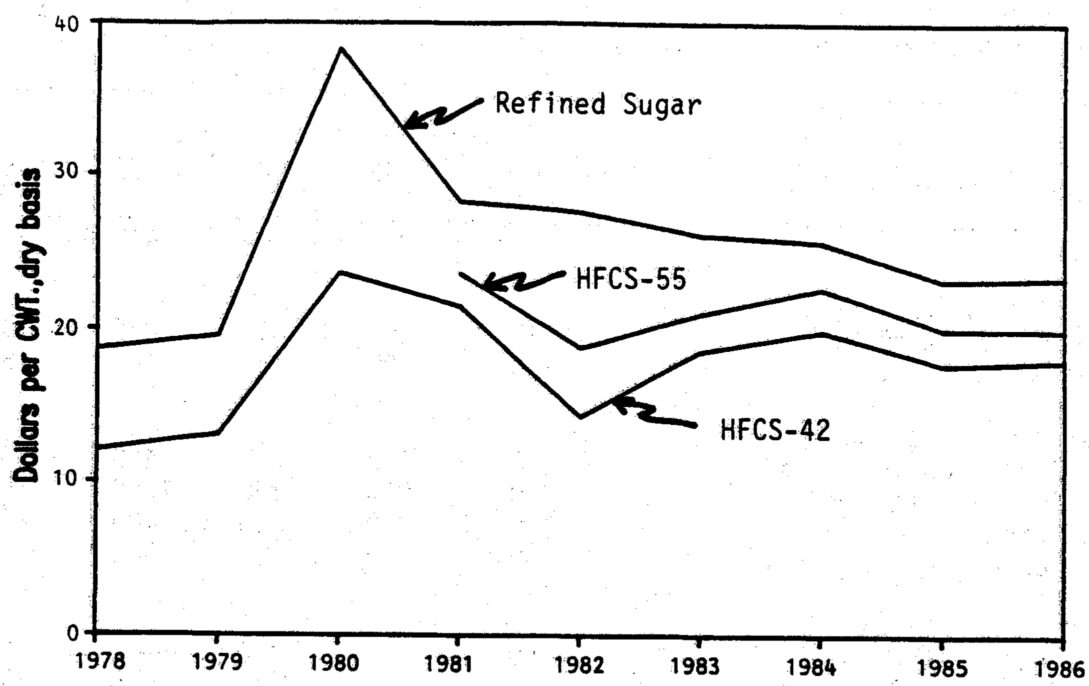

Figure 8. Prices, Refined Sugar, HFCS-55, and HFCS-42, 1978 Through 1986

SOURCE: **Sugar and Sweetener Situation and Outlook Report, March, 1987.**

HFCS Industry Capacity

Capital investment in HFCS facilities came during two periods, the mid-1970s with the introduction of HFCS-42 and the early 1980s with the use of HFCS-55 in the beverage industry. Expansion in the 1980s of HFCS-55 capacity was due to both construction of new facilities and the updating of existing HFCS-42 facilities.

Six firms, American Maize-Products Co.; ADM/Corn Sweeteners; CPC International, Inc.; Cargill, Inc.; Hubinger; and A.E. Staley Manufacturing Co. produce HFCS. Plant locations and capacities are presented in Table 6. Total United States plant capacity in 1985 is estimated at 3,877 million pounds dry basis of HFCS-42 and 7,033 million pounds dry basis of HFCS-55, for a total combined capacity of 10,901 million pounds. Plant capacity in 1985 exceeded 1985 usage by 10 percent. HFCS plants are generally new or recently updated. The majority of plants are located in the Corn Belt, with a limited number near population centers.

TABLE 6. HFCS FIRMS, PLANT LOCATIONS, AND PLANT CAPACITIES, BY HFCS CONCENTRATION, UNITED STATES (42 AND 55 PERCENT), 1983-1985

Company/Location	1983		1984		1985	
	42	55	42	55	42	55
	-------- million pounds, dry basis ---------					
American Maize-Products						
Decatur, Alabama	142	269	142	269	192	423
Dimmit, Texas	180	120	180	120	180	120
ADM/Corn Sweeteners						
Cedar Rapids, Iowa	700	400	700	450	700	450
Decatur, Illinois	300	850	250	1300	250	1300
Clinton, Iowa	370	300	250	400	250	400
Montezuma, New York	150	150		350		350
CPC International						
Argo, Illinois	450		450		200	250
Stockton, California	215		215	150	215	230
Winston, North Carolina	95	100	120	200	155	270
Canadian Operations						
Port Colborne, Ontario	80	115	80	115	80	115
London, Ontario	115	160	115	160	115	160
Cardinal, Ontario	105		105		105	
Cargill, Inc.						
Dayton, Ohio	200	310	200	310	200	310
Memphis, Tennessee	200	310	200	310	200	310
Eddyville, Iowa					170	310
Hubinger, Division of H.J. Heinz						
Keokuk, Iowa	320	170	200	300	200	300
Johnstown, Colorado[a]	30	70	30	120	30	120
A.E. Staley Manufacturing Co.						
Decatur, Illinois	420		460		460	
Lafayette, Indiana		1000	140	1000	140	1000
Louden, Tennessee	200	200	220	330	335	430
Morrisville, Pennsylvania	275	275		460		460
Total - Excluding Canada	4247	4524	3757	6069	3877	7033
Total - Including Canada	4547	4799	4057	6344	4177	7308

[a]The Johnstown, Colorado, facility is owned by Coors Brewing Co. but the production is marketed by Hubinger.

SOURCE: Vuilleumier, personal communication, 1987.

Product Distribution

HFCS moves either by rail or truck. In general, for shipping distances greater than 300 miles HFCS is shipped by rail, and for distances less than 300 miles HFCS is moved by truck. Truck transportation has an advantage over rail during cold weather if HFCS can be delivered before the syrup cools. This means unloading can be accomplished without incurring warming costs. Truck transport of HFCS is generally more expensive than other commodities because a backhaul is not available.

Sanitation of the shipping vessel is critical as contamination of the vessel can lead to off-quality product and subsequent rejection. The product must then be sold at a discount.

HFCS Processing Costs

There are two major cost components in producing HFCS. They are the raw material cost for corn and the fixed and variable processing costs.

Net Corn Costs

Net corn cost is dependent on the value of by-products: corn gluten feed, corn gluten meal, corn germ meal, and corn oil. The by-products are sometimes called co-products because of their significant value. By-products can reduce corn cost by 40 to 60 percent. Yields are presented in Table 7.

TABLE 7. SALABLE PRODUCT YIELDS FROM A BUSHEL OF CORN (56 LBS.)[a]

Product	Quantity
	(lbs.)
Corn germ meal	2.24
Corn oil	1.58
Corn gluten feed	10.81
Corn gluten meal	2.80
Corn starch (dry basis)	30.60

[a]Number 2 yellow dent corn is the raw product and it contains approximately three to five percent broken corn and foreign matter (BCFM). This is screened out before the corn is processed.

SOURCE: Cubenas, et al., Purdue University, 1979.

Net corn costs for an Illinois based HFCS plant(s) are presented in Table 8. In 1986 and 1987 co-products reduced net corn costs by up to 70 percent. This is a result of low corn prices and a relatively strong market for corn gluten feed and meal. The values of corn gluten feed and meal are very dependent on the protein market, primarily soybean meal, as they are both considered protein feeds. The corn gluten feed and meal market is also very dependent on the export market to the European Economic Community (EEC). Traditionally 70 to 75 percent of domestic production is exported, with the EEC accounting for 95 percent of the volume (Tables 9 and 10). The strength of the market is dependent on the EEC tariff structure.

TABLE 8. CORN PRICES, BY-PRODUCT VALUES, AND NET CORN COSTS, ILLINOIS LOCATIONS, 1982-1986

Year	Corn[a]	By-product Value[b]	Percent Cost Reduction	Net Corn Cost
	($/bu)	($/bu)	(percent)	($/lb.)
1982	2.98	1.57	53	.047
1983	3.46	1.63	47	.061
1984	2.79	1.32	47	.049
1985	2.35	1.36	58	.033
1986	1.75	1.23	70	.017

[a]Corn, No. 2 Yellow, Chicago.
[b]Adapted from Table 7, yields and prices in Appendix Table 11.

SOURCE: Feed Situation and Outlook Yearbook, November, 1986.

Fixed and Variable Processing Costs

HFCS processing is capital intensive. A plant processing 70,000 bushels per day and producing a product mix of 70 percent HFCS-55 and 30 percent HFCS-42 requires an investment of $210 million. This investment and other related fixed costs result in a total fixed cost of $6.96 per cwt. of HFCS dry solids (Table 11). Major processing costs include energy, labor, enzymes, chemicals, interest on working capital, and repairs and maintenance. These costs are delineated in Table 11. Total variable costs are estimated at $5.86 per cwt. of dry solids.

Historical Profitability

Historical corn prices, by-product values, and HFCS prices (see Appendix Table 1 for price series) were incorporated with estimated processing costs to estimate profitability of HFCS processing over the previous five years. Estimated return on average plant investment has been very attractive, ranging

TABLE 9. TOTAL INDUSTRY SHIPMENTS AND EXPORTS OF CORN GLUTEN FEED AND MEAL, 1984-1986

Year	Total Shipments	Exports	Export Market Share
	------- million pounds --------		----- percent -----
1984	10395	7996	76.9
1985	10439	7634	73.2
1986	10328	8924	86.4

SOURCE: Corn Refiners Association, 1986.

from 16 to 45 percent (Table 12). Caution is advised because plant utilization was estimated at 292 days per year. This level of utilization may be considered full utilization when considering the seasonality of HFCS-55 sales. Due to high fixed costs, a less than full plant utilization level will have substantial effects on rate of return on investment.

Locational Considerations

The potential market area for a North Dakota based HFCS plant would primarily be the Pacific Northwest, the northern tier of midwest states, and Minnesota. HFCS would not likely move east of the Mississippi River because of the facilities located in the Corn Belt. Locations of present HFCS plants are presented in Figure 9. The primary competition for a North Dakota based

TABLE 10. EEC MARKET SHARE OF UNITED STATES EXPORTS OF CORN GLUTEN MEAL, GLUTEN FEED, AND OTHER CORN BY-PRODUCTS, 1981-1986

Year	Total Exports	EEC Exports	Market Share
	--------- 1000 metric tons --------		- percent -
1981	3202	3078	96
1982	3155	3084	98
1983	4177	4120	98
1984	4197	4038	96
1985	3902	3715	95
1986	5204	4999	96

SOURCE: Foreign Agricultural Trade of the United States, 1982-1986.

TABLE 11. HFCS PROCESSING COSTS, UNITED STATES, 1987

Item	Annual Cost
Fixed Costs	
Total plant investment[a]	$210,000,000
(Capital recovery factor, 15 yr life and 12 percent interest)	0.1468
Annualized capital charge	30,832,477
Plant insurance $10/$1000 plant investment	2,100,000
Real estate taxes, 1.755 percent of plant investment	3,685,500
Premise liability insurance, $.29/$100 payroll	19,821
General & administrative overhead and selling exp.[b]	12,000,256
Total Fixed Costs	48,640,367
Variable Costs	
Labor and fringe benefits, 215 plant employees	6,835,136
Power and utilities	
Steam, 180,000#/hr. at $.035/1000#	4,415,040
Electricity, 13,000kw./hr., $.0359/kw.	3,271,545
Fuel, 100 million BTU/hr., natural gas, $.39827/CCF	2,791,076
Enzymes, chemicals, and supplies, $1.50 per cwt. of HFCS dry solids	10,504,116
Repairs and maintenance, 4% of plant investment[c]	8,400,000
Interest on working capital[d]	4,801,027
Total Variable Costs	41,017,941
TOTAL ESTIMATED FIXED AND VARIABLE COSTS[e]	$ 89,658,308

[a]Designed plant capacity is 70,000 bushels per day yielding a product mix of 70 percent HFCS-55 and 30 percent HFCS-42. Daily production is 23,982 cwt. of HFCS, dry solids basis. A total of 292 annual operating days.
[b]Seven and one-half percent of annual sales.
[c]Includes repair and maintenance labor.
[d]Working capital requirement is 25 percent of annual sales, annual interest rate of 12 percent is assumed.
[e]Excludes the cost of corn.

SOURCE: Various HFCS industry sources, 1987.

TABLE 12. ESTIMATED RETURN ON INVESTMENT FOR HFCS PLANTS, MIDWEST, UNITED STATES, 1981-1986

Year	Percent
1982	16
1983	24
1984	41
1985	35
1986	45

facility would be plants located in Iowa. Plants located in Stockton, California, and Johnstown, Colorado, would most likely be serving the more populated Southwest region.

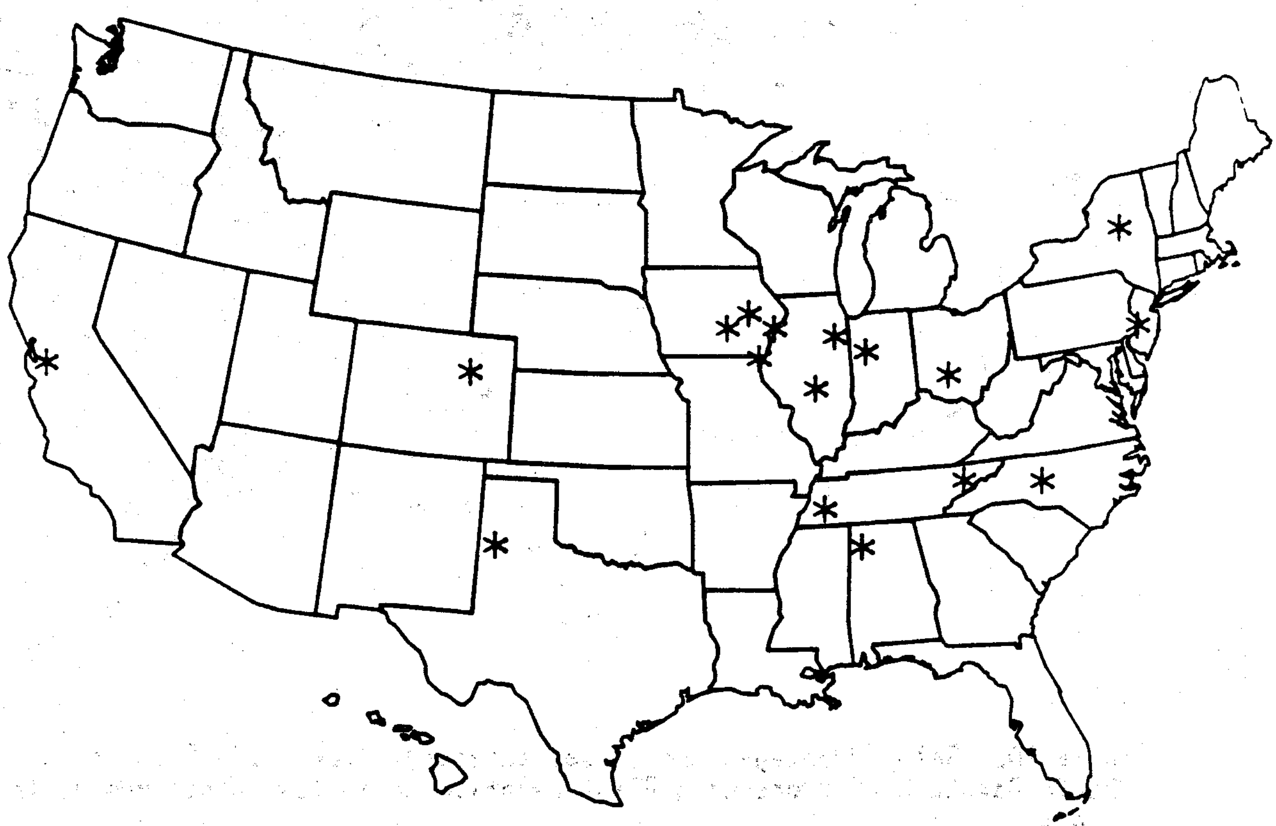

Figure 9. Locations of United States HFCS Processing Plants, 1985

Transportation Costs

North Dakota has a $.60/cwt. transportation cost advantage over Iowa in serving the Pacific Northwest; however, North Dakota is at a slight disadvantage in shipping to the Southwest. An Iowa facility would have a $.19/cwt. advantage in shipping to San Francisco and Los Angeles, California. Rate advantages and disadvantages relative to Iowa are presented in Figure 10. North Dakota would compete on an equal transportation cost basis to the Minneapolis and St. Paul markets.

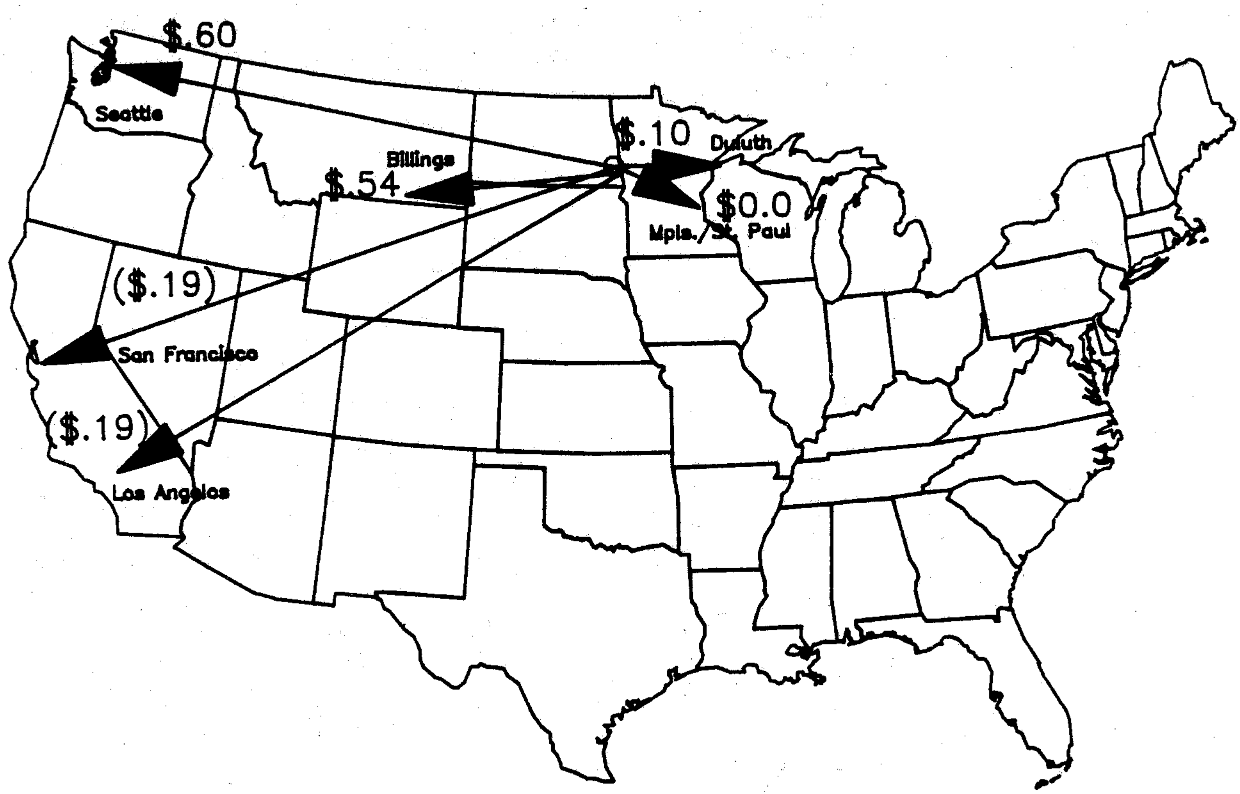

Figure 10. Rate Advantages and (Disadvantages), $/cwt. of HFCS, for a North Dakota HFCS Processing Plant Relative to an Iowa-Based Processing Plant

Raw Product, Labor, and Utility Costs

North Dakota has a slight corn cost advantage over Iowa, $.04 per bushel (1981-1985 average), and a significant labor cost advantage of 24 percent (Table 13). Iowa, however, has the benefit of lower energy prices. North Dakota's electric power, natural gas, and coal costs are 7.5, 11.3, and 37.8 percent higher than Iowa's.

TABLE 13. FIVE-YEAR CORN AND ENERGY PRICES FOR IOWA AND NORTH DAKOTA, 1980-1985

Item	Iowa	North Dakota	North Dakota's Percent Advantage (Disadvantage)
Corn $/bu.	$2.66	$2.62	1.5%
Labor, manufacturing $/hr.	$10.05	$7.67	23.7%
Steam coal, industrial sector $/million BTU	$1.72	$2.76	(37.8%)
Natural gas $/million BTU	$3.46	$3.90	(11.3%)
Electric power $/million BTU	$12.58	$13.60	(7.5%)

SOURCE: Agricultural Statistics, USDA, 1984-1986; State Energy Price and Expenditure Report, 1984; and United States Statistical Abstract, 1987.

By-Product Market

The local markets for by-products are also important. A sufficiently sized local livestock and poultry industry is required to support prices for by-products, primarily corn gluten feed and meal. To remain competitive a North Dakota plant must be able to realize the same by-product prices as other midwestern plants. This is crucial as by-products have historically reduced corn cost by between 47 and 70 percent (Table 8). If local demand for corn gluten feed and meal exceeds the plant's production, a North Dakota plant will most likely be able to maintain the same prices as plants located elsewhere. However, if quantity supplied exceeds quantity demanded then a portion of the by-products must be sold in a more distant market, such as Minneapolis, the Pacific Northwest, or an export market. As a result net plant prices will be decreased by the cost of transportation. A corn syrup plant in Marshall, Minnesota, has been successful in merchandising corn gluten feed and meal in its local market to both livestock and poultry enterprises.

Summary and Conclusions

The HFCS industry has progressed to a point where it must now be regarded as an industry nearing maturity with limited future growth expectations. Several major developments within the sucrose (sugar) and HFCS industry leads to this conclusion. First, HFCS has replaced over 96 percent of all sucrose in the soft drink industry, leaving little or no growth potential for increased demand within that industry. Second, the HFCS products have currently reached the long-run technical level of penetration in the baking, cereal, and dairy product industries. Third, there is evidence to suggest that HFCS is nearing the long-term technical penetration levels in the canning, processed food, and confectionery industries.

The primary market for HFCS-55 is the soft drink industry, which accounts for 95 percent of all HFCS-55 sales in the United States. Demand for HFCS-55 may level off or decline in the future. Currently, the diet soft drink market share is increasing and growing at an increasing annual rate. Consumption of "regular" soft drinks [soft drinks sweetened either by sugar (sucrose) or corn sweeteners] continues to increase, but at a decreasing rate. There is also industry concern that generic aspartame may be priced competitively with HFCS-55 when the patent for aspartame (the major artificial sweetener) expires in 1992.

HFCS production in the United States is controlled by six firms. Location of these firms is primarily in the Corn Belt with a limited amount of plant capacity located near population centers. Existing plant capacity is estimated to exceed demand by 10 percent. Recent industry expansion has been for new HFCS-55 processing capacity and for updating existing HFCS-42 plants. HFCS plant capacity is in excellent shape with most of the plant capacity within the industry new or updated with essentially no obsolete plant capacity.

HFCS products were initially priced at a discount to sucrose. Recently HFCS-55 was priced 12 to 15 percent below sucrose and HFCS-42 was priced at 22 to 24 percent below sucrose prices. This pricing strategy enabled the HFCS industry to penetrate the sucrose market. HFCS margins have, since 1980, been relatively stable, following the market stability experienced by the sucrose industry. Marketing margins in the future can be expected to decrease somewhat due to increased competition resulting from an industry that is near maturity with some excess capacity.

The HFCS industry is very capital intensive making entry into the industry a limited and selective process. Estimated rates of return for HFCS processing has ranged between 16 to 44 percent during the 1980s.

North Dakota has a transportation advantage in distributing HFCS to the Pacific Northwest and the northern tier of midwest states. North Dakota would compete with Iowa for the Minnesota markets on an equal transportation cost basis. Population in these markets would not be of sufficient size unless a high level of penetration was achieved. To have a sufficient market area a North Dakota plant must be willing and able to penetrate the Southwest markets where it has a slight, $.19/cwt., transportation rate disadvantage compared to an Iowa-based plant.

APPENDIX

APPENDIX TABLE 1. UNITED STATES PRICES, 1982-1986

Year	Corn[a]	Corn Gluten Feed[b]	Corn Gluten Meal[b]	Corn Oil Crude[c]	HFCS-42	HFCS-55
	$/bu	-----------$/ton-----------		-$/cwt.-	$/cwt.	dry basis[d]
1982	2.63	116.15	241.90	23.80	14.30	18.81
1983	2.98	114.57	269.15	24.70	18.64	21.06
1984	3.46	72.08	203.11	29.80	19.94	22.69
1985	2.35	89.48	209.38	25.58	17.75	20.03
1986	1.75	89.00	210.00	18.50	18.07	19.96

[a]No. 2 Yellow Chicago.
[b]Illinois Points.
[c]Tank cars, f.o.b. Decatur.
[d]Tank cars, delivered prices to Chicago-West. Note, a discount of $1/cwt. was applied to price series when estimating historical profitability to reflect f.o.b. plant prices net of discounts and other delivery costs (various industry sources).

SOURCES: Feed Situation and Outlook Yearbook, November, 1986. Agricultural Statistics, USDA. Sugar and Sweetener Situation and Outlook Report.

References

Carman, Hoy F. November 1982. "A Trend Projection of High Fructose Corn Syrup Substitution for Sugar." American Journal of Agricultural Economics. Volume 64, Number 4. Ames, IA: American Agricultural Economics Association.

Cubenas, G. J.; Schrader, L. F.; and Ford, J. R. D. September 1979. Cost of Producing High-Fructose Corn Syrup: An Economic Engineering Analysis. Station Bulletin, Dept. of Agricultural Economics, Agricultural Experiment Station, Purdue University, West Lafayette, Indiana.

Corn Refiners Association, Inc. 1987. Personal communications.

___________. 1986. Corn Refining. Washington, D.C.

___________. 1986. Industry Statistics.

___________. Nutritive Sweeteners from Corn.

National Soft Drink Association. 1985. NSDA: Sales Survey of the Soft Drink Industry, 1985. Washington, D.C.

___________. 1987. Personal communications, Washington, D.C.

United States Bureau of the Census. 1987. Statistical Abstract of the United States: 1987. 107th Edition. Washington, D.C.

USDA Statistical Reporting Service. 1983-1986. Agricultural Statistics. Washington, D.C.

___________. November 1986. Feed Situation and Outlook Yearbook. Washington, D.C.

___________. March 1987. Sugar and Sweetener Situation and Outlook Report. Washington, D.C.

United States Department of Energy, Energy Information Administration. 1986. State Energy Price and Expenditure Report, 1984. DOE/EIA - 0376(84), Washington, D.C.

Vuilleumier, Stephen. 1987. McKeany-Flavell Company, Oakland, CA. Personal Communication.