with a relatively short shelf life, such as cookies and crackers, can also use that system to distribute other snack products.

Firms may also apply their marketing expertise to a wider variety of products distributed through grocery stores. A leading soup company, for example, manufactures and distributes a variety of grocery store food products—frozen entrees, specialty baked goods, pickles, cookies, and fresh vegetables—in addition to its canned goods lines. In so doing the company uses its experience in developing and introducing new brand name food products, and its system for high volume production, distribution, and monitoring of such products.

Several food manufacturing companies have also diversified narrowly into processing of such bulk agricultural commodities as wheat, soybeans, and corn into products usually sold to other food processors rather than directly to consumers. However, the skills required to distribute these products are quite different from those required for branded products. Therefore, a group of firms may produce in a variety of commodity food industries and another group in consumer foods industries, but few firms will have major interests in both groups.

Many commodity food producers have diversified into the bulk storage and transportation of grains and oilseeds. With expansion of U.S. agricultural exports since 1969, many large commodity food firms have applied their large storage, transportation, and marketing networks not only to processing but also to domestic and international trade in corn and wheat.

Food firms have increased their diversification into manufacturing industries outside of food. Firms making foods for consumers have generally diversified into other consumer goods industries, such as apparel, toiletries, and games. Some have invested in chemical industries, which use process techniques similar to those of food manufacturing. Other investments have been largely directed to the manufacture of containers and food products machinery—products auxiliary to food manufacturing.

The directions of food firm diversification may change with demand for an industry's products and with technological developments in production and distribution. For example, after 1950 income growth, increasing urbanization and mobility of the population, and the development of television advertising combined to expand national markets for branded consumer food products. Required skills in product development and nationwide distribution systems gave firms with existing large-scale grocery manufacture and distribution systems an advantage. More recently, the expansion of agricultural commodity trade has created opportunities for diversification among existing commodity processors.

Implications

What are the effects of diversification by food manufacturers? If basic economic principles hold true, several developments are likely:

- Diversifying firms may provide new competition in industries where only a few sellers exist. If such firms transfer efficiencies in production, distribution, and product development to their new product lines, they may reduce production costs and, in turn, consumers' costs if competition among firms encourages offering lower prices to attract customers.
- If diversification occurs because of tax incentives, firms with high profits but low depreciation may shelter profits through mergers with low-profit firms possessing high depreciation. Small, rapidly expanding firms and large, capital-intensive firms in depressed industries may be acquired. Such diversification can benefit stockholders, but will not necessarily result in reduced prices or improved products in the firm's new industry.
- In some cases, salaries for a firm's management may be closely tied to company size and growth, rather than profits. Diversification may then be pursued solely to increase the size and growth rate of the firm, and thus managerial rewards, and not because of any skills that the firm may bring to its new industries. □

HFCS: A Sweetener Revolution

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The development of high fructose corn syrup (HFCS) over the last 10 years has radically altered the conventional process of producing and distributing sweeteners, caused the reformulation of many food and beverage products, and reshaped the sugar industry.

HFCS, a liquid caloric sweetener made from ordinary corn starch, has been substituted for beet and cane sugar in a wide range of processed food products such as beverages, baked goods, dairy products, and jams and jellies since its commercial introduction in 1972. By 1982, HFCS accounted for 55 percent of the caloric sweetener market in beverages, 61 percent in canning, 48 percent in processed foods, 31 percent in dairy products, and 24 percent in baking.

Sweets from Starch

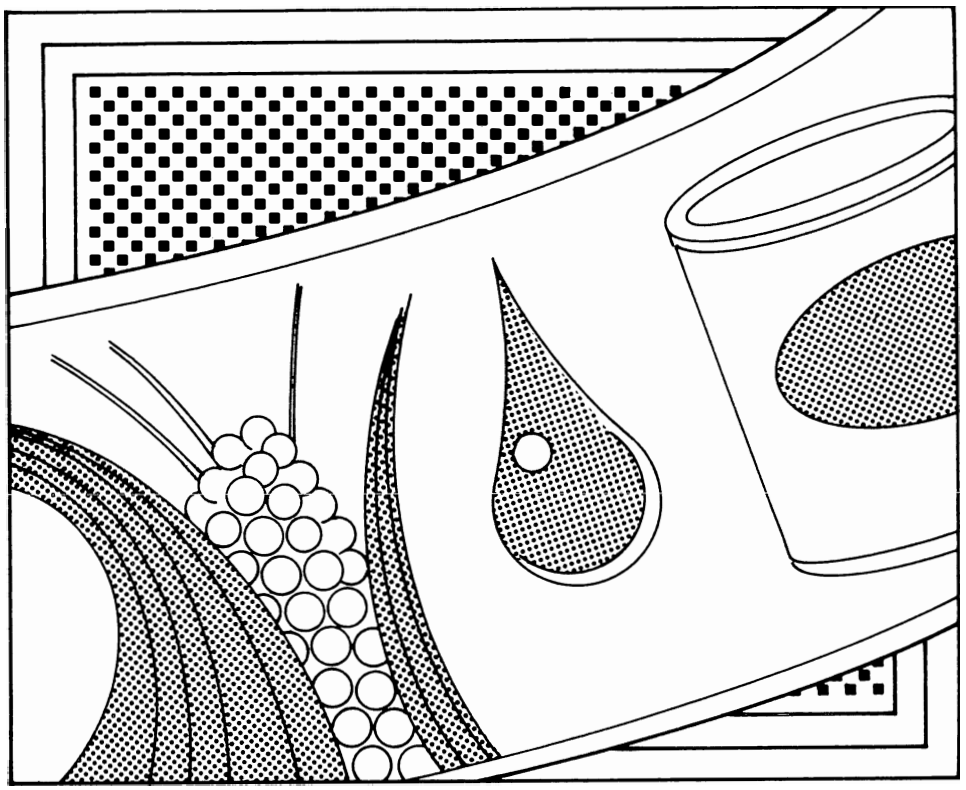
Converting corn starch into sweet substances was discovered as early as 1811. Sweeteners such as glucose corn syrup and dextrose were produced in corn wet milling before 1900. These products, however, were only about 70 percent as sweet as sugar, so they were typically combined with sucrose to derive the desired sweetness.

Initial attempts to convert glucose to fructose, a substance 110 to 170 percent sweeter than sucrose, date back to 1865. By the 1960's, scientists had discovered an effective method for obtaining fructose from glucose, but the high cost discouraged commercial prospects.

A commercially successful HFCS product of 42 percent fructose, about 50 per-

Table 1. HFCS use as percent of total caloric sweeteners use

	1982	Long-term theoretical penetration
Beverages	55	90
Baking	24	25
Canning	61	70-75
Processed foods	48	60-65
Dairy products	31	35
Confections	1	5



cent dextrose, and about 8 percent other saccharides was discovered in the early 1970's. HFCS-42 was approximately 90 percent as sweet as sugar and had other characteristics comparable or superior to sucrose syrups for use in processed food and beverages.

In 1978, a second generation HFCS product of 55 percent fructose, about 40 percent dextrose, and about 5 percent other saccharides was introduced. Compared with HFCS-42, HFCS-55, with its superior sweetness (100 to 110 percent as sweet as sugar) and only slightly higher production cost, had far greater commercial potential. HFCS-55 was especially suitable as a sweetener for soft drinks. Soft drink firms raised their approved rates of substitution of sugar by HFCS from 25 to 50 percent of sweetener content in cola drinks, and up to 100 percent for other soft drinks. In 1979, soft drink use of HFCS rose 34 percent to 680,000 tons, and by 1982 had jumped to 1.8 million tons, 58 percent of all HFCS consumption.

HFCS's main limitation is that it is available only in liquid form, and therefore confined to certain industrial uses. In addition, HFCS-42, with a water content of 29 percent of product weight, costs more to transport than an equivalent quantity of sugar. Further, HFCS is more difficult to handle, since it must be maintained at 80°-100° F temperature when stored or transported.

Influences on HFCS Growth

The success of HFCS was immediate. It was able to do sugar's job in a wide number of applications more cheaply because of a lower cost of production. Production costs vary with size of plant, operating rates, net costs of corn, and other inputs. A 1977 World Bank study placed HFCS-42 cost, including plant and equipment, at a range of 12 to 17 cents a pound. USDA estimated the cost to produce refined beet sugar at 17.8 cents a pound in 1977-78. Depending on the area, raw cane sugar was estimated at 13.7 to 15.9 cents a pound prior to refining. In a 1979 Purdue University study, the cost of producing HFCS-42 (not including plant and equipment costs) in a plant with the capacity to produce 36,000 bushels a day was estimated at 8.7 cents a pound, dry-basis, assuming corn prices of $2.26 a bushel and byproducts at 1977-78 average prices.

The rapid adoption of HFCS for commercial use was further encouraged by occurrences in the sugar market. In 1974, the bill to renew the Sugar Act of 1948 was defeated, ending 40 years of Government regulation of domestic sugar production, imports, and prices. Its defeat at a time of world sugar shortages threw the U.S. sugar trade into chaos. Raw sugar prices climbed above 60 cents a pound. HFCS prices also rose, but producers held them to less than 40 cents a pound in order to build a long-term market. HFCS production grew 68 percent in 1975, 44 percent in 1976, and 35 percent in 1977.

The price advantage of HFCS was further enhanced by Federal legislation that assured minimum sugar prices for producers. During the decade of 1972-82, HFCS production costs were below these Federal support prices for sugar, assuring a competitive advantage for HFCS.

Further helping HFCS to penetrate the sweetener market was the easing in 1974 of Food and Drug Administration (FDA) rules on the quantities of corn sweeteners allowed in canned and processed foods. In addition, HFCS profited from the continuing trends toward consumption of processed foods and low-sugar products.

By 1982, HFCS made up 21 percent of all caloric sweeteners used. The total corn sweeteners consumed, including glucose corn syrup and dextrose, accounted for 39 percent of U.S. caloric sweetener use. In 1982, per capita consumption of HFCS was 26.7 pounds; glucose, 18 pounds; and dextrose, 3.5 pounds (figure 1). Corn sweeteners' share of industrial sweetener use doubled from 24 percent in 1972 to 48 percent in 1982.

Production of HFCS

By 1982, HFCS production had reached 3.1 million tons, having increased at an average annual rate of almost 25 percent since 1977. Production gains followed considerable investments in building new corn wet milling plants specifically designed to produce HFCS or by expanding existing facilities. The replacement value of capital investment for

HFCS production had reached an estimated $2.4 billion in 1982.

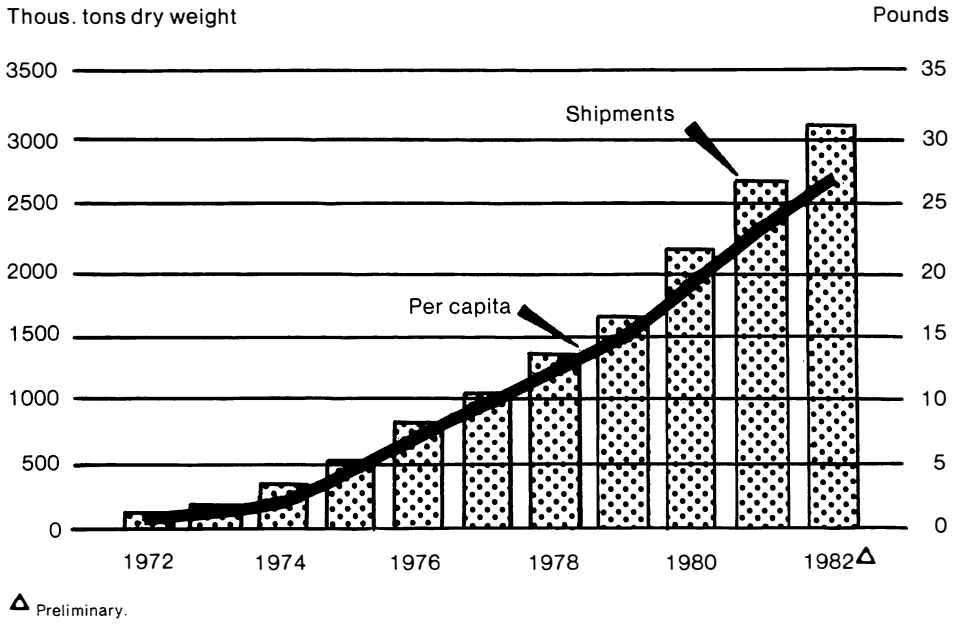
Capital investment in HFCS occurred in two major spurts—in the mid 1970's and between 1980 and 1982. The latter reflected the growth in demand after the decision by beverage companies to increase the use of HFCS in cola soft drinks.

HFCS producers were encouraged to risk expansion by the expectation that Federal sugar support prices would be kept at levels above the cost of producing HFCS. Fluctuations in sugar prices, then, were not expected to eliminate the price advantage of HFCS.

The HFCS industry expanded rapidly in the 1972-82 decade. In 1982, 10 corn wet milling firms produced HFCS in 16 plants, compared with only 2 firms and 2 plants in 1972. Production capacity grew from 250,000 tons of HFCS to 4.2 million tons by the end of the decade. Plant capacities to grind corn increased from a range of 4,000 to 50,000 bushels a day in 1972 to a range of 16,000 to 70,000 bushels a day in 1982.

Expansion of the HFCS industry was also helped by U.S. farm policies that kept farm price supports for corn low enough to encourage exports, and by the farm-held grain reserves designed to serve as a large buffer against a corn crop disaster. Because corn accounts for 50 percent of HFCS production costs, these public policies reduced costs and minimized investment risk.

Figure 1. High Fructose Corn Syrup: U.S. Shipments and Per Capita Consumption



HFCS's Challenge to Sugar

HFCS's gains in many food and beverage uses adversely affected the U.S. sugar industry, including cane mills, beet processing factories, cane refineries, growers, labor, and other suppliers of inputs.

The impact of HFCS can be seen by comparing today's sugar industry with its 1975-76 peak of 7 million tons. Output fell to 5.7 million tons during 1982-1983, with even lower levels likely in the future. Beet sugar production dropped from 4 million tons to 2.8 million and 17 beet factories have shut down. Processing capacity for all sugarbeet plants fell 26 percent between 1975-76 and 1982-83.

Output of cane sugar is about the same as 7 seasons ago, 3 million tons. However, the industry has been restructured, with Hawaii production down 11 percent while production in Florida is up 23 percent. Eighteen cane mills representing 18 percent of processing capacity and four refineries accounting for 16 percent of capacity ceased operations between 1975-76 and 1982-83.

While smaller, the sugar industry is also more efficient as a result of improvements in equipment and energy use. On the farm, sugarbeet yields were up to 20.5 tons an acre for the 1978-82 period from 19.3 tons during the 1968-72 period. Output per manhour in beet factories rose faster between 1974 and 1979, increasing at an average annual rate of 3.7 percent, versus rates of less than 3 percent in prior years. Comparable data for raw and refined sugar combined show productivity per manhour increased at 3.2 percent a year, also higher than in earlier years.

Some sugar companies have also diversified their interests into areas outside sweeteners and foods. In addition, four companies entered into HFCS production either independently or in joint venture with a corn wet milling firm.

To the extent that it has been able to compete with sugar in particular uses, HFCS has dominated because of its modern, automated, and efficient plant facilities and highly advanced custom-oriented technology. Also, HFCS facilities can be operated year-round compared with 3 to 5 months for beet factories and cane mills. HFCS supplies are more reliable and predictable, and prices are less volatile than sugar.

Despite dramatic gains by HFCS, cane and beet sugar continue to be important because HFCS's technological limits prevent it from replacing much more than about a third of sugar's volume of use. Sugar accounted for over 60 percent of U.S. caloric sweetener use in 1982.

Other Impacts

While HFCS has hurt the competing sugar industry, it has provided an additional outlet for the rising output of corn. The 3.1 million tons of HFCS produced in 1982 required about 200 million bushels of corn or 2-1/2 percent of the total crop.

The arrival of HFCS has represented a major boon to processors and ultimately to consumers. HFCS has provided processors a greater diversity of sweeteners and associated ingredients to choose from and reduced production costs for foods and beverages. It has led to the reformulation of old products and the creation of new ones.

Part of the success of HFCS stems from aggressive customer service. HFCS suppliers are working closely with sweetener users, providing technical assistance and adapting products to the special requirements of specific classes of customers. HFCS blender-distributor companies are also providing combinations of HFCS, sugar, and other corn sweeteners for specific client requirements. HFCS, because of its lower cost, has encouraged selective use of various sweeteners, each chosen for its special contribution. This allows processors to obtain effective sweeteners at the lowest cost.

The introduction of the lower priced HFCS may also mean cost savings for consumers of processed foods and beverages. HFCS-42 prices ranged from 17 to 48 percent, or 2.7 cents to 14.7 cents a pound less than sugar between 1975 to 1982. Part of these savings could be reflected in consumer product prices.

HFCS has also influenced the international markets. Sugar imports have customarily provided about 45 percent of U.S. sugar needs. As a sugar substitute, HFCS has reduced some of the U.S. dependence on sugar imports. However, imports continued to provide over 30 percent of U.S. sugar use in 1982. Both domestic and foreign sugar have shared in sugar's market loss to HFCS.

While all the HFCS produced in the United States is marketed here, about 85 percent of the corn gluten feed, a byproduct of the wet milling process, is sold in the European Community (EC). The EC is increasingly concerned about the rising volume of such grain substitute feeds, which enter with little or no duty and undermine the EC policy of high variable levies on grain to protect their high-cost grain producers.

The Future of HFCS

The United States produces about 75 percent of the world's HFCS output of over 4 million tons, and will likely continue to be the leading producer because of low-cost and large corn supplies, vast technical resources, and a large consumer market. World corn sweetener production including HFCS is now estimated at about 9 million tons, or 10 percent of the total output of world sugar and corn sweeteners.

Having carved out a sizable sweetener domain, U.S. producers of HFCS now face problems of industrial maturity as HFCS nears the limit of its technological applicability to various uses. Except for the beverage market, HFCS is near market saturation in most uses (table 1). Without further development of HFCS characteristics or new applications, HFCS will lose momentum and settle into a conventional slow growth due largely to changes in population.

Assuming the two major cola firms will permit 100 percent replacement of sugar, HFCS is expected to reach full market potential over the next 2 to 3 years, and HFCS consumption for all uses including beverages should level off at 36 pounds per person. Sugar consumption is expected to average about 67 pounds, and total caloric sweeteners about 126 pounds per person. Sugar will continue to be the dominant sweetener at 53 percent of total use, while HFCS will take 29 percent and total corn sweeteners 46 percent. Corn sweeteners by 1990 are expected to total 7.2 million tons, of which 4.5 million would be HFCS.

Prospects for U.S. consumption of HFCS by 1990 are tentative. The rising popularity of low-caloric soft drinks in the largest sweetener market, beverages, may lower HFCS's growth potential. Much depends on how low-caloric sweetener use complements rather than replaces demand for caloric sweeteners. □

GLOSSARY

Saccharide: A sugar carbohydrate.

Glucose: The most common monosaccharide or simple, 1-molecule, sugar.

Dextrose: One of three forms of glucose, often used synonymously with glucose. Commercial dextrose, produced by almost complete conversion of starch into dextrose, is usually called simply "dextrose," or "refined corn sugar," or just "corn sugar."

Glucose syrup: A product obtained by partial conversion of starch into dextrose. Usually called "corn syrup" or simply "glucose."

Fructose: A monosaccharide which has the same elements in the same proportions as glucose but whose molecular structure is different, thereby giving a sweeter taste than glucose.

Sucrose: Ordinary sugar from sugarcane or sugarbeets. Sucrose is a disaccharide, made up of a dextrose molecule and a fructose molecule.

Invert sugar: The liquid sweetener that results when sucrose is hydrolyzed (treated with water, and usually some acid), and containing equal amounts of dextrose and fructose.

High Fructose Corn Syrup (HFCS): The liquid sweetener that results when glucose from starch is treated with an enzyme (a protein that speeds up chemical reactions without itself being altered or destroyed) to produce a combination of dextrose, fructose, and small amounts of other saccharides.

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