RESEARCH TRIANGLE INSTITUTE

March 1994

Starch Manufacturing: A Profile

Final Report

Prepared for

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U.S. Environmental Protection Agency
Office of Air Quality Planning and Standards
Cost and Economic Impact Section
Research Triangle Park, NC 27711

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SECTION 1
INTRODUCTION

Currently, the U.S. Environmental Protection Agency (EPA) is preparing a new source performance standard (NSPS) for the starch manufacturing industry. The pollutant of concern is particulate matter (PM). The industry emits some sulphur dioxide and hydrocarbons, but these emissions are minor and EPA does not expect to address them in the NSPS. The PM emanates from grinding mills; feed, germ, and starch dryers; and grain handling and product transfer to storage and bagging. It is expected that starch dryers will be the focus of the NSPS.

In the U.S., starch is manufactured primarily from corn. However, it can also be produced from other sources, such as wheat, potato, rice, tapioca, and sago.[1] Currently, 17 companies own 47 facilities that produce starch in the U.S. Of these facilities, 20 produce starch from corn, 3 produce starch from wheat, 21 produce starch from potatoes, 1 produces starch from tapioca, and 2 produce starch from other sources. Starch has many beneficial characteristics that lead to its use as an input to a wide range of products in a very diverse set of industries, such as paper, paperboard, construction, and food. Starch manufac-turing plants also produce a variety of corn sweeteners and ethanol. Starch production also yields a number of by-products, such as corn oil and germ, hulls, fiber, steepwater, and gluten that are used to make feed and other products.

Starch manufacturing is covered by Standard Industrial Classification (SIC) code 2046, wet corn milling, that includes establishments manufacturing starch and related products by the corn wet milling process, as well as from the other vegetable sources. This classification does not include ethanol production by the corn wet milling process.* In 1991, the U.S. producers shipped $6.5 billion worth of products from SIC 2046, including $3.0 billion of corn sweeteners, $1.3 billion of manufactured starch, $0.9 billion of corn oil, and $1.2 billion of other starch by-products.[2] As of 1991, the industry employed approximately 9,700 workers.[3]

Section 2 of this profile characterizes the supply side of the wet corn milling industry, including the stages of the production process, major factors of production, product characteristics, and costs of production. Section 3 characterizes the demand side by concentrating on the desired characteristics of wet corn milled products and their primary consumers. The organization of the wet corn milling industry is discussed in Section 4, including a description of U.S. production facilities and the firms that own these facilities. Finally, Section 5 presents historical statistics on the U.S. production, consumption, and foreign trade of wet corn milled products.

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* Ethanol production, by corn wet milling and other processes, is covered by SIC codes 2085 (distilled and blended liquors), and 2869 (industrial organic chemicals, not elsewhere classified). However, since ethanol is only one of many products listed by these SIC codes, industrywide information on wet corn milled ethanol was not generally available. Therefore, statistics describing the wet corn milling industry in this report do not include ethanol, unless otherwise noted.

SECTION 2
THE SUPPLY SIDE OF THE WET CORN MILLING INDUSTRY

2.1 PRODUCTION PROCESS FOR STARCH

Although starch has many varieties, the three varieties that are primarily produced in the U.S. are corn, wheat, and potato starch. This section describes the production processes for these three starches.

2.1.1 Corn Starch Production

The corn wet milling process begins with the production of starch slurry. This slurry can be further processed to produce starch, dextrins, corn sweeteners, and ethanol.

2.1.1.1 Production of Starch Slurry. Figure 2-1 illustrates the production of starch slurry. First, shelled and cleaned kernels are placed in steep tanks and soaked in water containing small quantities of sulfur dioxide (SO_2) for 24 to 48 hours at a temperature of approximately 50°F. This process allows for extraction of soluble materials from the kernel. The SO_2 prevents fermentation and helps to separate the starch and protein. After steeping is completed, steepwater is drained from the kernels and concentrated. This concentrated steepwater is primarily used in producing animal feed products.[4,5]

Next, the kernels are ground in attrition mills to loosen the hull. Water is added to the mills, creating a mixture of macerated slurry and whole germ. This slurry is placed in hydroclone separators, which remove the lighter germ. The germ is then dried and either sold as is or further processed into corn oil and germ meal. The corn oil can be either refined to make a salad oil or cooking oil or a raw material

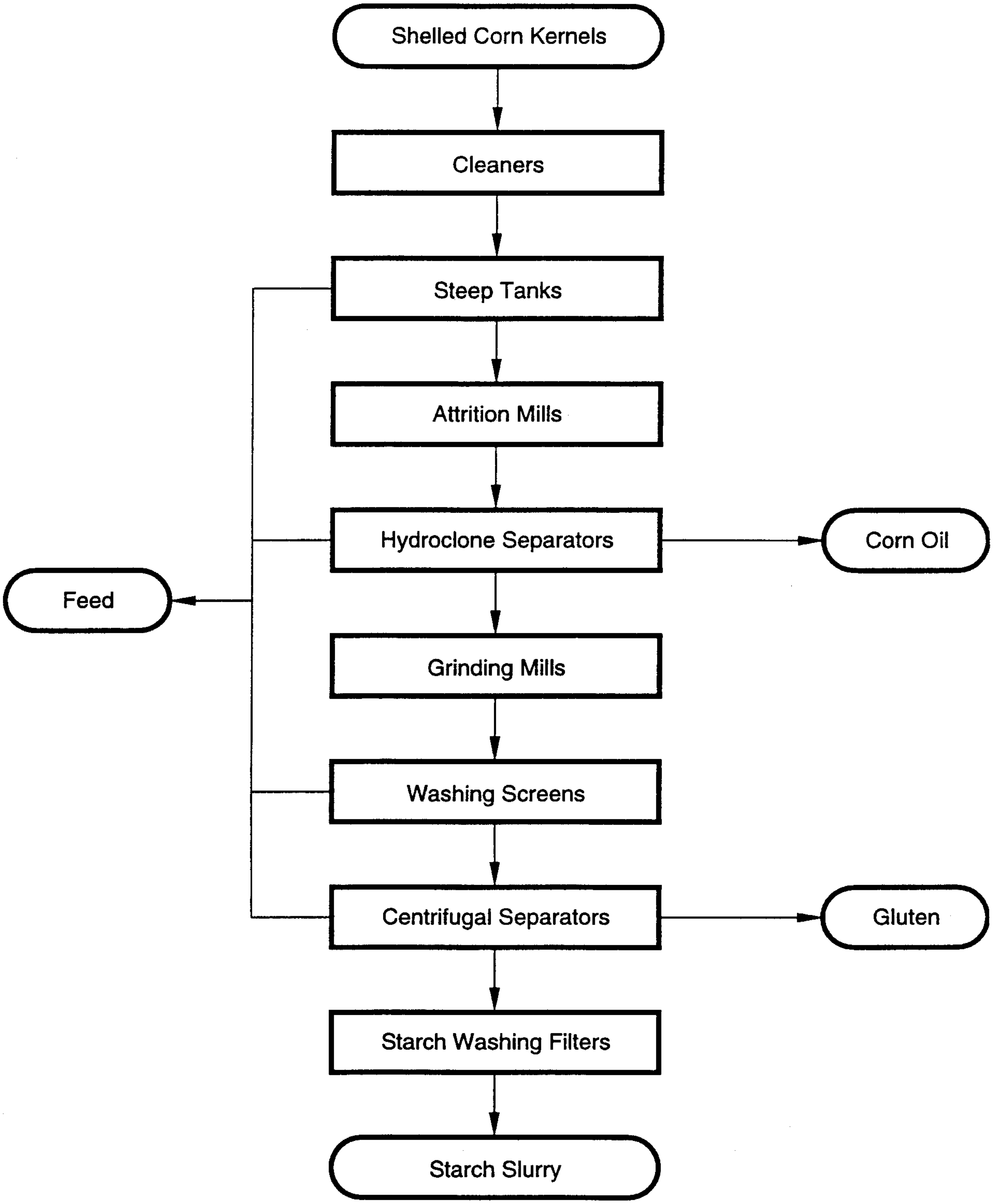


Figure 2-1. Production of starch slurry.

input to margarine. The germ meal is used in the production of animal feed.[6,7]

The remainder of the kernel, including the hull, gluten, and starch components, is sent through an additional series of grinding and screening processes. After passing through a grinding mill, the hull particles are caught on screens, while the gluten and starch particles pass through. The hulls are later used to make animal feed or refined corn fiber.[8,9]

The remaining slurry of gluten and starch, or mill starch, is then separated by centrifugation. The gluten is dried and either sold as corn gluten meal (60 percent protein) or used in producing corn gluten feed (21 percent protein). The starch slurry is then washed and dewatered using filters or centrifuges.[10,11] At this stage, the starch slurry can go through a number of processes that can yield starch and dextrins or corn sweeteners and ethanol.

2.1.1.2 Production of Starch and Dextrins. Figure 2-2 displays the process used to convert the starch slurry into starch and dextrins. Most of the slurry is passed through a starch dryer to produce unmodified corn starch. Alternatively, it can undergo treatment with chemicals or enzymes and then pass through a starch dryer to create a wide variety of modified starches.

The industry produces many types of modified starches, including acid thinned, oxidized, cationic, hydroxyethyl, acetate, succinate, and phosphate starches. Acid thinned starches are thinned by treatment with dilute mineral acid, resulting in pastes with decreasing viscosity.[12] Oxidized starches have reduced viscosity due to oxidation, primarily with sodium hypochlorite. Cationic and hydroxyethyl starches are stabilized against gelling by reacting with monofunctional reagents, giving the starch more strength.[13,14] Hydroxyethyl starch is produced by adjusting the pH of the starch and adding a salt, increasing its stability and resulting in a clear paste.[15,16] Starch acetates are produced by acetylating the slurry with acetic anhydride or vinyl acetate, reducing

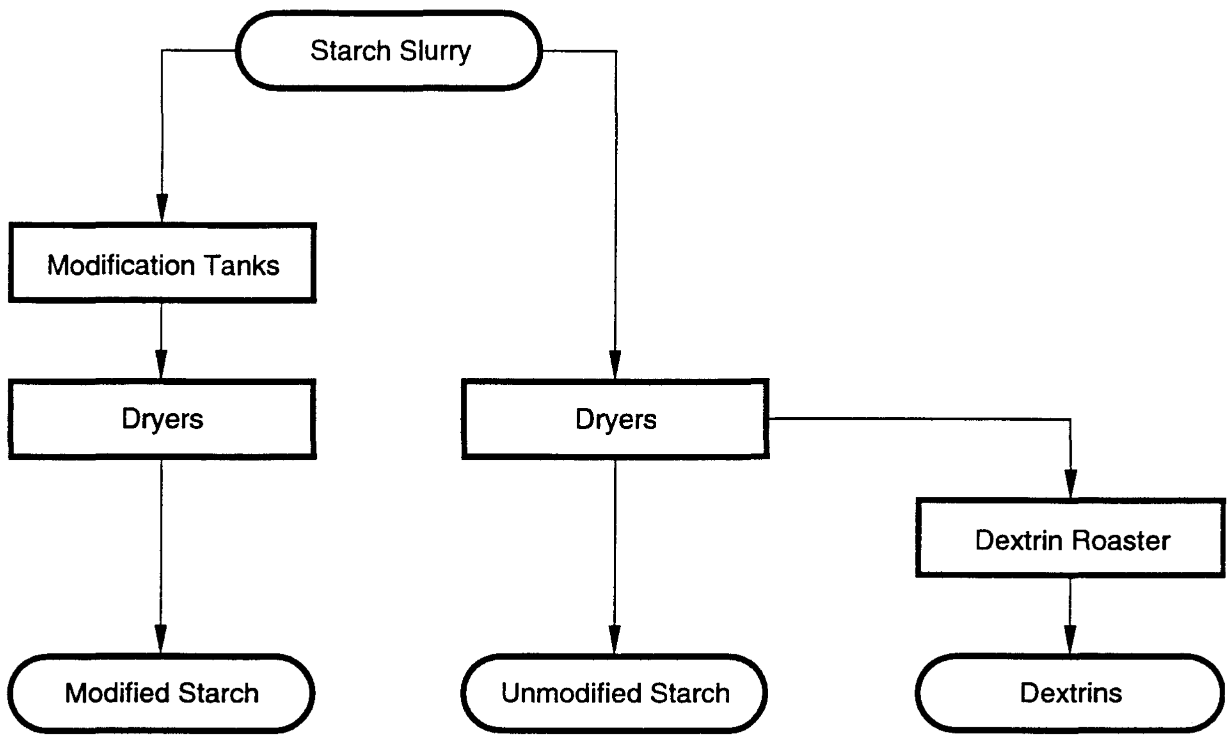


Figure 2-2. Production of starch.

the tendency of the starch to congeal. Starch succinates are made by using succinic anhydride instead of acetic anhydride, thereby improving the thickening quality of the starch. Starch phosphates are produced by esterifying starch with monosodium orthophosphate or sodium tripolyphosphate to increase the stability of the starch.[17]

In addition, the starch slurry can be passed through a starch dryer and then be dry-heated or roasted, with or without an acid or alkaline catalyst, to produce dextrins. This process gives the dextrins a lower viscosity, more cold water solubility, less tendency to gel, and more reducing power than common starch, leading to the use of dextrins as adhesives.[18]

2.1.1.3 Production of Corn Sweeteners and Ethanol. Figure 2-3 highlights the production process for corn sweeteners and ethanol. To produce corn sweeteners, the starch slurry is first treated with acid or enzymes and heated in a conversion process to break down the starch molecule, yielding corn syrup. The starch molecule can be broken down in varying degrees, ultimately resulting in producing a wide variety of corn sweeteners. Next, the corn syrup is refined using carbon to remove residual color, odor, taste, or flavor bodies. At this point, some of the corn syrup has the water removed from it to produce some types of glucose syrup (regular corn syrup). The remainder of the corn syrup goes through a process called ion exchange to remove additional flavor and color bodies that were missed during previous stages of production. In this process, the syrup passes through anion resin and cation resin vessels. In the case of fructose syrups, additional ion exchange steps may be necessary to remove certain additional substances. Finally, the water from this corn syrup is evaporated to yield some additional types of glucose syrup, dextrose, and high fructose corn syrup (HFCS).[19] To produce ethanol, the original starch slurry is simply fermented and distilled.[20]

2.1.2 Wheat Starch Production

Figure 2-4 presents a generalized wheat production process. Wheat starch can be produced by a number of methods. It can be made by wet-processing wheat grain, but, according to Galliard, all commercial wheat producers use flour produced by the dry-milling of wheat.[21] The primary method used by industry today is the Martin process.[22] In the Martin process, the wheat is first taken from storage and ground at the flour mill, where white flour is produced, and wheat germ and bran are separated out and used as feed. The white flour is then mixed with water to form a stiff dough. At this point, the dough is rolled or kneaded, and the starch is washed off by water sprays. The gluten is then separated from the starch slurry on screens, washed, and dried.[23]

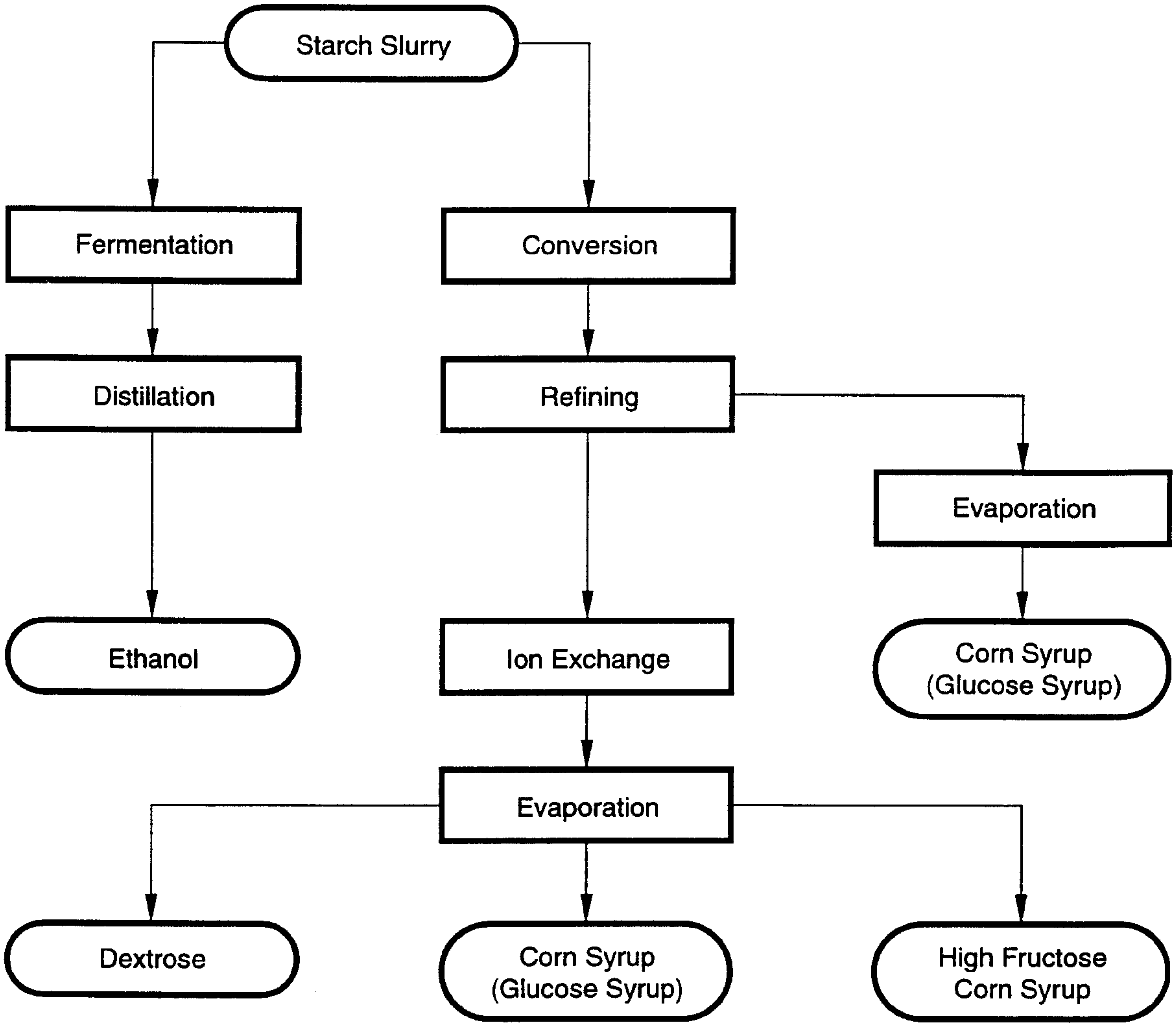


Figure 2-3. Production of corn sweeteners and ethanol.

The starch slurry then passes through a screening process to remove insoluble impurities. It then proceeds through a series of centrifuges and/or hydrocyclones that concentrate the slurry and facilitate its separation into two fractions: the purer "A" fraction and the less pure "B" fraction. These starch fractions are then typically dried and sold.[24,25]

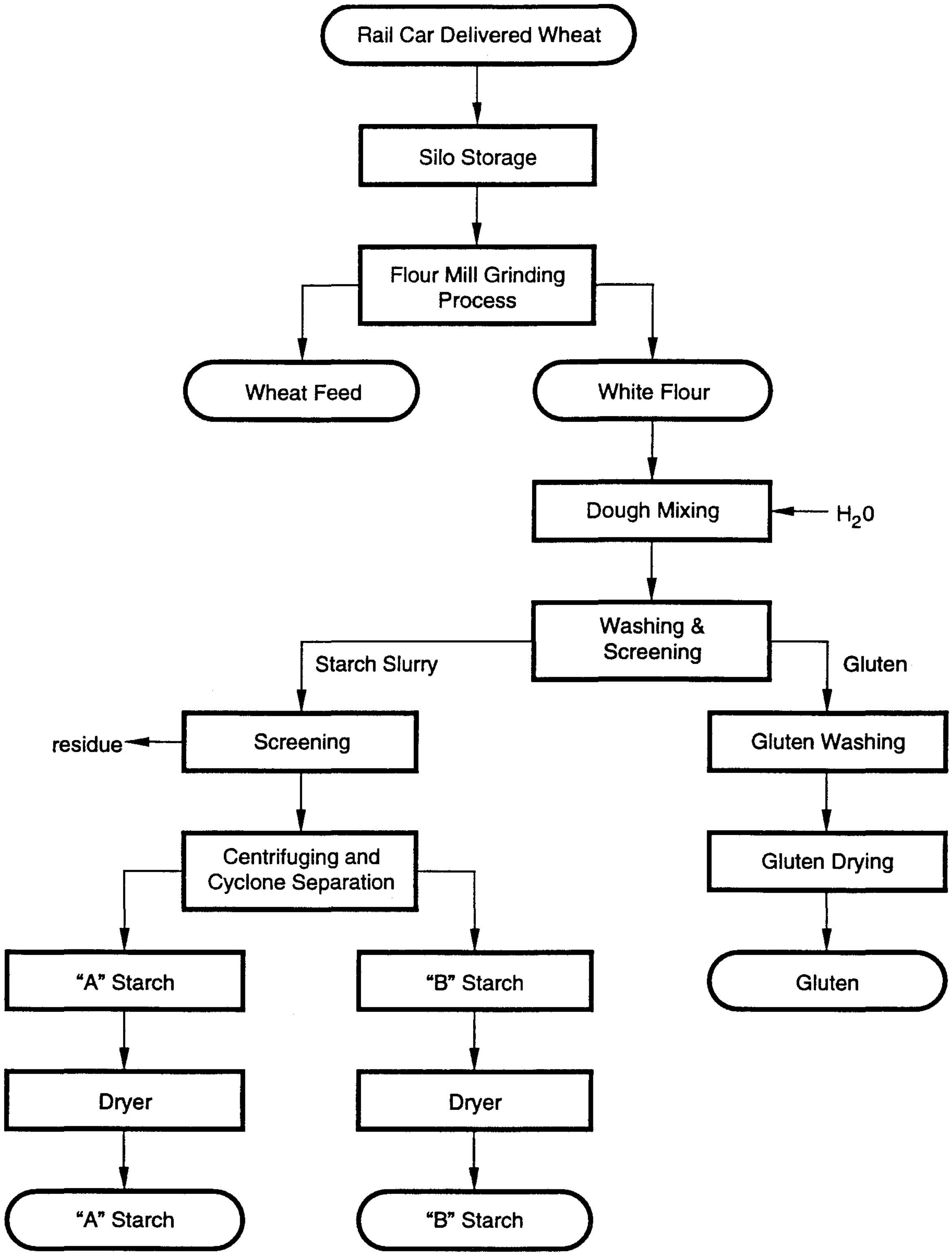


Figure 2-4. Wheat starch production process.

The separation of starch from gluten can also occur through the slack dough or batter process. In this process, water is mixed with wheat flour to form a batter. This batter is mechanically broken up while the starch is separated by water. The gluten is recovered in the form of fine curds, while the starch slurry is evaporated and dried.[26]

2.1.3 Potato Starch Production

The generalized process flow for potato starch production is shown in Figure 2-5. Many procedures and different types of equipment can be used to produce potato starch, but all of them use the same general steps.[27] Fresh potatoes, which are held in storage bins, are dropped into running water flumes. The flumes remove stones and dirt from the potatoes, while bringing them to a conveyor belt, which takes them to a washer, where they are cleaned more rigorously. The cleaned potatoes then pass through either a grinder or a crusher, which disintegrates the potato cells and frees the starch. The crushed potatoes proceed through a screen or rotary sieve, which separates the fiber and potato skin.[28,29]

The fiber and skins are dried and sold as animal feed. The starch solution is then further purified to remove both soluble and insoluble impurities. Alternate cycles of filtration and redispersion of the starch in water remove the soluble impurities. The insoluble impurities are removed by settling in settling vats, tables, nozzle separators, hydrocyclones, or a basket centrifuge with a scraper. The purified starch is then dewatered, dried, and bagged.[30,31]

2.2 EMISSIONS FROM THE PRODUCTION PROCESS

The various starch production processes include a number of sources of emissions. In corn wet milling, SO_2 and odorous vapor emissions come from the steeping tanks, as well as from the gluten, feed, and germ dryers. In addition, particulate emissions come from the loading sites, storage sites, and

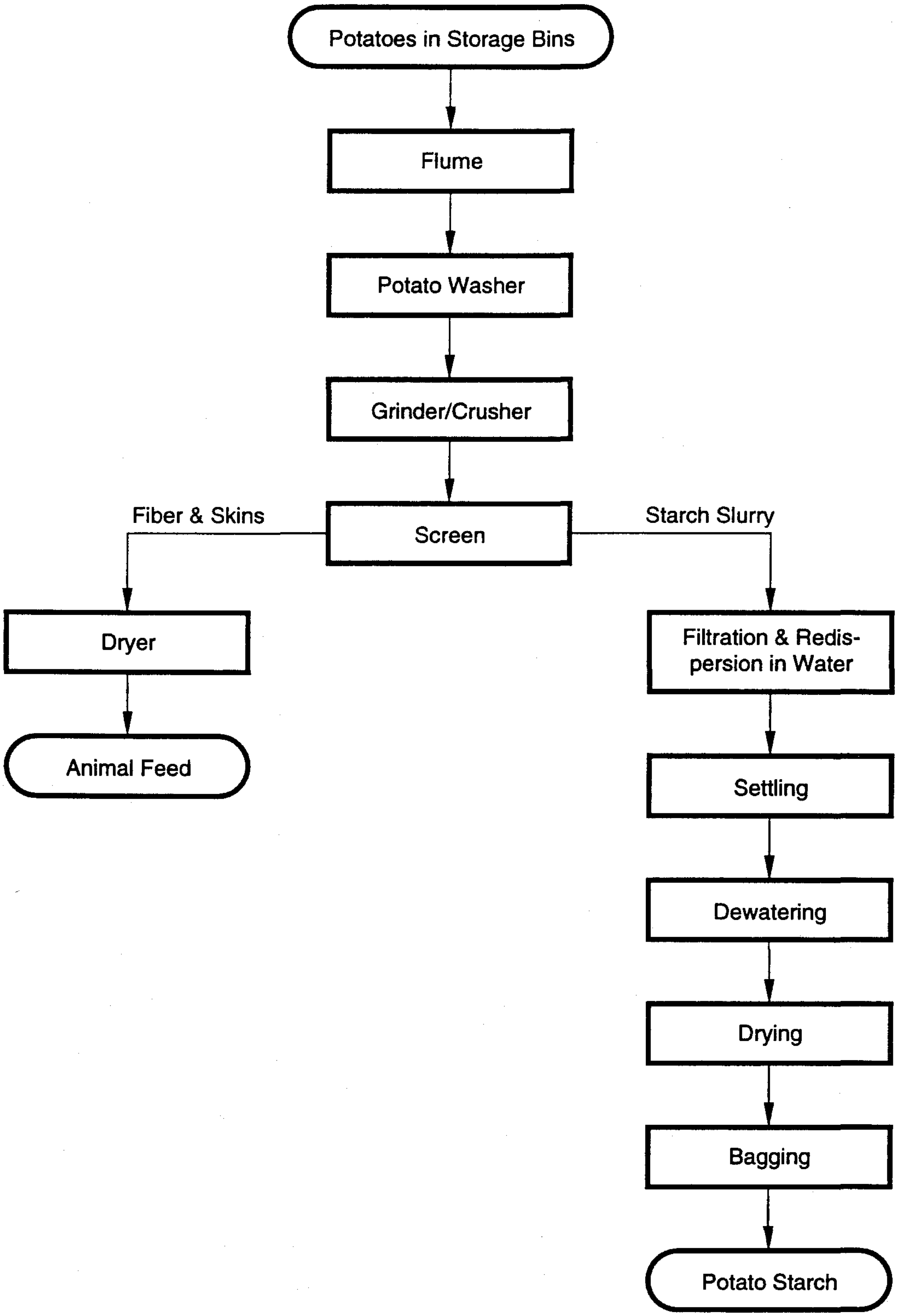


Figure 2-5. Potato starch process.

product dryers.[32] Wheat starch production results in particulate emissions, primarily from the dryers, but also from handling and dry milling.[33] Potato starch manufacturing generates particulate emissions from the fiber dryer exhaust and the starch dryer exhaust.[34]

2.3 COSTS OF PRODUCTION

The costs that a wet corn milling firm faces include capital, labor, materials, fuel and electricity, and other costs. This section discusses the first four categories. Other costs, which include administrative fees, insurance payments, property taxes, and research and development, are not covered because information is lacking.

2.3.1 Capital Cost

Capital costs for wet corn milling firms include buildings, other structures, machinery, and equipment. This category may also include capital costs associated with previous regulatory action. The stock of capital for these companies changes from year to year due to additions from new investment and reductions from depreciation and divestment. As of the end of 1987, the gross book value of depreciable assets for the wet corn milling industry was $3.8 billion.[35] Table 2-1 provides this statistic for the years 1977 to 1987. Table 2-2 shows new capital expenditures that were made by companies in the wet corn milling industry from 1981 until 1991. As shown, companies in this industry made $369.5 million in new capital expenditures in 1991.

Estimates by analysts indicate that corn refiners' construction costs amount to approximately $2,000 per bushel of daily grind. Therefore, a small plant that grinds 50,000 bushels per day would cost approximately $100 million for land, design, and construction, while a larger plant could cost as much as $250 million.[36]

TABLE 2-1. GROSS BOOK VALUE OF DEPRECIABLE ASSETS, END-OF-YEAR, FOR THE WET CORN MILLING INDUSTRY, 1977-1987[37,38,39]

Year	Value ($\$10^6$)
1977	1,424.9
1978	1,614.5
1979	1,616.6
1980	1,781.5
1981	2,196.8
1982	2,357.0
1983	2,235.0
1984	2,438.4
1985	2,746.8
1986	N.A.
1987	3,792.5

TABLE 2-2. NEW CAPITAL EXPENDITURES IN THE WET CORN MILLING INDUSTRY, 1981-1991[40,41]

Year	New Capital Expenditures ($\$10^6$)
1981	469.7
1982	326.2
1983	131.3
1984	179.3
1985	450.9
1986	340.5
1987	281.9
1988	383.2
1989	283.9
1990	290.4
1991	369.5

2.3.2 Labor Cost

Table 2-3 displays employment and earnings statistics for the wet corn milling industry from 1981 to 1991. During this time period, total employment in the industry fell by an annual average rate of 0.7 percent; however, from 1990 to 1991, it rose by 4.3 percent, to approximately 9,700. Total payroll rose by an annual nominal average rate of 3.8 percent from 1981 to 1991 to a level of $386.6 million in 1991. The nominal hourly wage of production workers rose by an annual average rate of 1.8 percent from 1981 to 1991, reaching a peak of $15.01 in 1990 and falling to $14.98 in 1991. However, as shown in Table 2-3, the real hourly wage of production workers has declined over the past decade.

TABLE 2-3. EMPLOYMENT AND EARNINGS FOR THE WET CORN MILLING INDUSTRY, 1981-1991[42,43]

	All Employees		Production Workers				
Year	Number (10^3)	Payroll ($\$10^6$)	Number (10^3)	Wages ($\$10^6$)	Hours ($\$10^6$)	Hourly Wage ($/hr)	Real Hourly Wage[a] ($/hr)
1981	10.4	266.6	7.4	185.2	14.8	12.51	15.86
1982	9.5	254.7	6.7	170.6	13.8	12.36	14.76
1983	8.9	254.0	6.3	171.2	13.5	12.68	14.55
1984	8.4	247.9	5.9	167.2	12.5	13.38	14.70
1985	8.7	266.5	6.1	177.5	13.0	13.65	14.46
1986	8.3	263.2	5.6	167.6	12.2	13.74	14.18
1987	8.6	298.9	5.9	192.8	12.9	14.95	14.95
1988	9.2	351.1	6.0	194.4	13.4	14.51	13.97
1989	9.3	359.4	6.0	193.7	13.5	14.35	13.24
1990	9.3	355.6	6.0	205.7	13.7	15.01	13.30
1991	9.7	386.6	6.2	217.2	14.5	14.98	12.80

[a] Real hourly wage expressed in constant 1987 dollars using the GDP deflator.

Table 2-4 presents state-by-state Bureau of Labor Statistics data for average hourly earnings for production workers in the food and kindred products industry (SIC 20) for 1990 to 1992. These data were not available for the wet corn milling industry specifically. As shown, hourly earnings varied widely by state.

2.3.3 Materials, Fuel, and Electricity

Table 2-5 provides the total cost of materials for the wet corn milling industry from 1981 to 1991 in both current and constant 1982 dollars. This category includes the following:

- all raw materials (such as corn and process chemicals), semifinished goods, parts, containers, scrap, and supplies put into production or used as operating supplies or repair and maintenance during the year;
- work done by others on materials or parts furnished by manufacturing establishments (contract work);
- products bought and resold in the same condition;
- electric energy purchased; and
- fuels consumed for heat, power, or the generation of electricity.

Table 2-6 shows a separate breakout of total expenditures for fuel and electricity from 1982 to 1991. As shown, in 1991, total industry expenditures were $159.5 million for electricity and $229.6 million for fuel.

In 1991, total materials cost was 59.7 percent of the value of shipments in the industry. Corn is the largest material input to the corn wet milling process. As presented in Figure 2-6, in 1987, corn (including sorghum grain) accounted for 53.3 percent of the materials cost for the industry. Table 2-7 displays the cost of yellow dent corn from 1981 to 1992. In 1992, the cost of yellow dent corn was $2.33 per bushel.

TABLE 2-4. AVERAGE NOMINAL HOURLY EARNINGS FOR PRODUCTION WORKERS IN THE FOOD AND KINDRED PRODUCTS INDUSTRY BY STATE, 1990-1992[44]

State	1990	1991	1992
Alabama	7.19	7.46	7.73
Arizona	8.78	8.92	9.17
Arkansas	6.99	7.30	7.53
California	11.23	11.58	12.02
Connecticut	10.27	10.63	11.19
Delaware	8.18	8.07	8.11
Florida	8.28	8.72	9.03
Georgia	8.56	8.96	9.04
Hawaii	9.42	9.66	9.74
Idaho	8.47	8.98	9.14
Illinois	10.78	11.06	11.22
Indiana	9.94	10.51	10.73
Iowa	10.35	10.65	11.22
Kansas	9.33	9.56	9.65
Kentucky	10.15	10.24	10.42
Louisiana	7.84	8.05	8.21
Maine	8.58	8.76	9.23
Maryland	10.24	10.38	11.00
Massachusetts	11.08	11.49	11.52
Michigan	11.15	11.50	12.44
Minnesota	9.70	10.03	10.18
Mississippi	7.19	7.56	7.43
Missouri	9.81	10.05	10.26
Montana	10.10	10.30	10.62
Nebraska	8.72	8.78	9.07
New Hampshire	14.90	14.46	15.14
New Jersey	11.38	11.56	12.30
New York	10.65	11.13	11.71
North Carolina	7.89	8.24	8.30
North Dakota	8.88	8.85	9.11
Ohio	11.33	11.74	12.14
Oklahoma	8.64	8.73	8.99
Oregon	9.15	9.56	9.80

(continued)

TABLE 2-4. AVERAGE NOMINAL HOURLY EARNINGS FOR PRODUCTION WORKERS IN THE FOOD AND KINDRED PRODUCTS INDUSTRY BY STATE, 1990-1992 (continued)

State	1990	1991	1992
Pennsylvania	10.94	11.32	11.66
Rhode Island	9.12	9.75	9.23
South Carolina	8.10	8.16	8.13
Tennessee	8.78	9.46	9.79
Texas	8.55	8.98	9.13
Utah	8.84	9.36	9.52
Vermont	8.91	9.52	10.30
Virginia	9.50	9.88	10.39
Washington	9.84	9.98	10.23
West Virginia	9.07	9.72	9.72
Wisconsin	10.20	10.37	10.73

TABLE 2-5. COST OF MATERIALS IN THE WET CORN MILLING INDUSTRY, 1981-1991[45,46]

	Cost of Materials ($$10^6$)	
Year	Current Dollars	Constant 1982 Dollars
1981	2,403.7	2,437.8
1982	2,101.0	2,101.0
1983	2,279.0	2,265.4
1984	2,803.4	2,719.1
1985	2,826.4	2,752.1
1986	2,778.7	2,803.9
1987	2,694.4	2,654.6
1988	3,230.7	3,016.5
1989	3,745.8	3,344.5
1990	3,860.1	3,371.3
1991	3,867.5	3,380.7

[a] Constant 1982 dollars calculated using producer price index for intermediate materials.

TABLE 2-6. TOTAL COST OF ELECTRICITY AND FUEL PURCHASED BY THE WET CORN MILLING INDUSTRY, 1982-1991[47,48]

Year	Electric Energy (10^6)	Fuel (10^6)
1982	96.5	208.0
1983	107.1	222.4
1984	116.9	235.8
1985	132.4	245.3
1986	144.8	226.9
1987	178.1	232.3
1988	193.1	206.8
1989	166.6	223.2
1990	161.6	223.5
1991	159.5	229.6

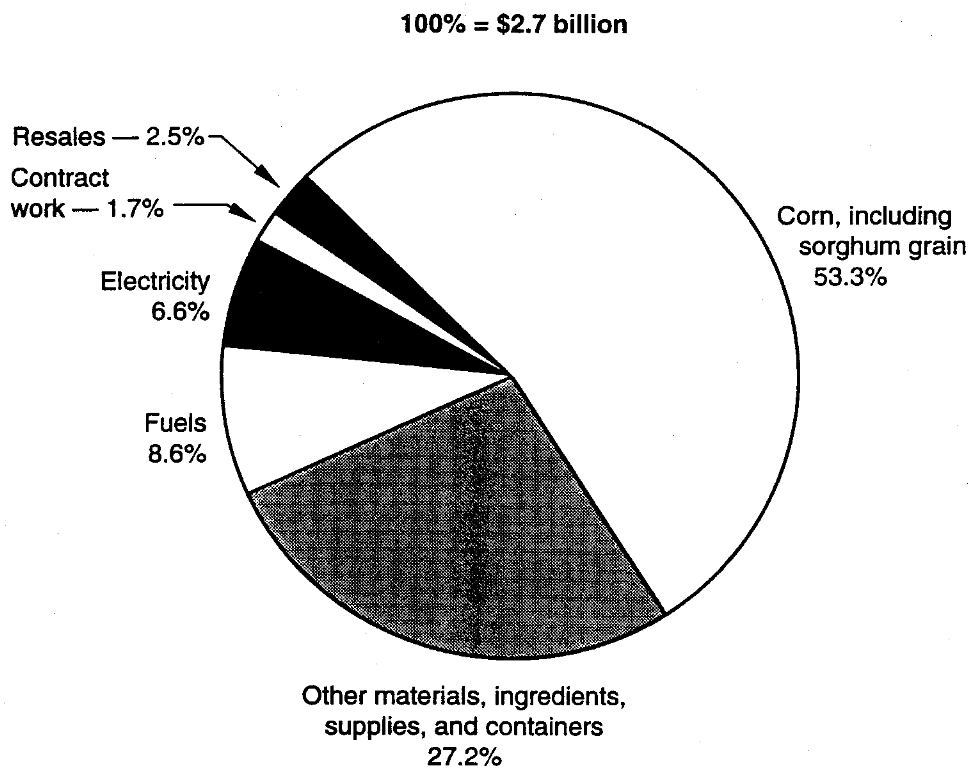


Figure 2-6. Composition of materials cost in the wet corn milling industry, 1987.[49]

Note: Resales are products bought and resold in the same condition, and contract work is work done by others on materials or parts furnished by manufacturing establishments.

TABLE 2-7. COST OF YELLOW DENT CORN, 1981-1992[50]

Year	Nominal Dollars per Bushel[a]	Real Dollars per Bushel[b]
1981	3.16	3.04
1982	2.48	2.48
1983	3.12	2.98
1984	3.11	2.99
1985	2.52	2.66
1986	1.95	2.09
1987	1.59	1.65
1988	2.36	2.22
1989	2.46	2.21
1990	2.45	2.17
1991	2.40	2.27
1992	2.33	N/A

[a] Reported nominal prices are for Illinois selling points in Midwest markets. These corn values represent county elevator producer bid prices, and do not reflect the additional costs of handling and transporting the corn to Midwest processing plants.
[b] Real prices reflect constant 1982 prices deflated using producer price index for crude food stuffs and feed stuffs.

Table 2-8 provides the amount of corn processed for wet milling from 1981 to 1991. While corn used for starch production has grown at an average annual rate of 4.2 percent during this time, corn used for HFCS has grown at a rate of 8.2 percent, glucose and dextrose at 2.7 percent, and fuel alcohol at 24.2 percent (but at only a 7.2 percent average annual rate since 1984). Not including wet milled ethanol, total wet milling use of corn amounted to 11.2 percent of the total U.S. corn crop in 1991.

Wheat and potatoes are the primary inputs into non-corn starch production. Table 2-9 lists the average nominal and real price of wheat in the U.S. from 1981 to 1992. In 1992, the nominal price was $3.25 per bushel. Table 2-10 presents the average nominal and real price of Irish potatoes in the U.S. from 1981 to 1991. In 1991, the nominal price was $4.96 per hundredweight.

TABLE 2-8. U.S. WET-MILLED USE OF FIELD CORN BY MARKETING YEAR, 1980/81-1991/92[a,b,51]

Description of Use	1980/81	1981/82	1982/83	1983/84	1984/85	1985/86
HFCS Glucose syrup and dextrose	165	183	214	265	310	327
Corn starch	151	146	150	170	172	190
Total wet-milling[c]	472	489	529	602	649	686
U.S. corn crop	6,639	8,119	8,235	4,174	7,672	8,875
Wet-milling share	7.11	6.02	6.42	14.42	8.46	7.73
	1986/87	1987/88	1988/89	1989/90	1990/91	1991/92[d]
HFCS Glucose syrup and dextrose	338	358	361	368	379	392
Corn starch	214	226	223	230	232	237
Total wet-milling[c]	723	757	766	791	811	839
U.S. corn crop	8,226	7,131	4,929	7,525	7,934	7,475
Wet-milling share	8.79	10.62	15.54	10.51	10.22	11.22

[a] September/August marketing year.
[b] Unit of measure for each use is 10^6 bushels except for wet-milling share, which is a percentage.
[c] Includes estimated use of field corn for sweetener and starch output, does not include estimates for wet-milled fuel ethanol.
[d] Preliminary.

TABLE 2-9. AVERAGE U.S. PRICE OF ALL WHEAT, 1981-1992[a,52]

Year	Average Nominal Price ($ per bushel)	Average Real Price[b] ($ per bushel)
1981	3.66	3.52
1982	3.65	3.65
1983	3.51	3.36
1984	3.39	3.26
1985	3.08	3.25
1986	2.62	2.81
1987	2.57	2.67
1988	3.72	3.51
1989	3.72	3.35
1990	2.61	2.31
1991	3.00	2.84
1992	3.25	N/A

[a] U.S. prices calculated as total U.S. value of shipments divided by total U.S. shipments (in bushels).

[b] Real prices reflect constant 1982 dollars deflated using producer price index for crude food stuffs and feed stuffs.

TABLE 2-10. AVERAGE PRICE OF UNITED STATES IRISH POTATOES, 1981-1991[a,53]

Year	Average Nominal Price ($ per cwt)	Average Real Price[b] ($ per cwt)
1981	5.42	5.22
1982	4.45	4.45
1983	5.82	5.56
1984	5.69	5.48
1985	3.92	4.14
1986	5.03	5.39
1987	4.38	4.55
1988	6.02	5.67
1989	7.36	6.62
1990	6.08	5.38
1991	4.96	4.70

[a] U.S. prices calculated as total U.S. value of shipments divided by total U.S. shipments (in cwt).
[b] Real prices reflect constant 1982 dollars deflated using producer price index for crude food stuffs and feed stuffs.

SECTION 3

THE DEMAND SIDE OF THE WET CORN MILLING INDUSTRY

This section characterizes the demand side of the market for wet corn milling products. It describes wet corn milling products in terms of their characteristics, uses and consumers, and consumption substitution possibilities.

3.1 PRODUCT CHARACTERISTICS

As Lancaster describes, goods are of interest to the consumer because of the properties or characteristics they possess with these characteristics taken to be an objective, universal property of the good.[54] Therefore, the demand for a commodity is not simply for the good itself but instead for a set of characteristics and properties that are satisfied by a particular commodity.

According to the Corn Refiners Association, starches have four major properties that are desirable in food and industrial uses. The first property is that, when heated in water, starch molecules form a paste. This thickening property is helpful in a wide variety of food products, such as puddings, gravies, sauces, and pie fillings and in certain industrial uses.[55] The second beneficial property of starches is that starch paste can suspend other ingredients or particles, such as fats and proteins in food, and clay particles in coatings for paper and some adhesives. The third property is that starch pastes can form a gel when they are cooled. This is a desirable quality for use in starch-based puddings, salad dressings, and some adhesives.[56] The fourth property is that starch can form strong adhesive films. This property leads to using starch in paper coating and sizing, textile sizing, corrugated board manufacture, and many adhesives.[57]

Corn sweeteners also have a variety of desirable characteristics that lead to their use in a wide range of products. Some examples of these properties include sweetness, desirable color and texture (i.e., for cake and pancake mixes), strength (i.e., in bread for better slicing), chewiness, smooth texture, quick energy release, moisture retention, freezing point depression for ice cream, solubility, and viscosity enhancement.[58]

3.2 USES AND CONSUMERS OF PRODUCTS FROM THE WET CORN MILLING INDUSTRY

The wet corn milling industry produces a wide variety of products, most of which are used as inputs to a diverse set of industries. This section describes the uses and consumers of these products.

3.2.1 Starch

Approximately 75 percent of all starch in the U.S. is used for industrial purposes, mainly in the paper and textile industries. The rest is used in the food industry.[59] Most of the starch sold in the U.S. is unmodified starch.[60]

The paper industry uses starch for a wide variety of purposes. Unmodified starch and oxidized starches are both used for paper coating and sizing. Cationic starch strengthens sheet and gives paper improved opacity. Hydroxyethyl starch is used to produce a high-quality paper coating. In addition, some lower viscosity acid-thinned starches are used to improve printability and abrasion resistance on paper surfaces, as well as in calendar and size press applications.[61]

The corrugated box industry uses unmodified starch as an adhesive.[62] In the textile industry, acid-thinned starches, starch acetates, and oxidized starches are all used as warp sizes to protect yarn during weaving. Oxidized starches are also used as adhesive components.[63,64] Furthermore, starch has a variety of other industrial uses. For example, unmodified starch is used as moulding starch and laundry starch, and cationic starches are used as flocculants to clean up wastewater.[65,66]

Starch has a wide variety of applications in the food industry. Unmodified starch is used in the production of many foods, including salad dressings, canned foods, and dry food mixes.[67] It also is used in the fermentation process for beer. Modified starches are used to impart stability to a large number of food products. They can also be used to maintain a high viscosity level over the shelf life of the food.[68] The gelling properties of acid-thinned starches lead to their use in the candy industry in products such as gum candies.[69] Starch acetates are used as thickeners, texturizers, or stabilizers in a wide range of foods. Starch phosphates, oxidized starch, and hydroxpropyl starch are also used in a variety of food products.[70]

Another potentially significant use for modified starches is as fat substitutes. A number of companies are currently marketing starch-based products that replace fats and oils in various products, including frozen desserts and sausages.[71]

Dextrins are typically used as adhesives for such applications as seam gums for envelopes and adhesive for bottle labels, remoistening surfaces, and postage stamps.[72] Dextrins and some modified specialty starches are also used as filler in biodegradable plastics, rubber hardeners for tire manufacturing and super water absorbents for health care (e.g., disposable diapers and bedsheets, sponges) or for horticultural needs.[73]

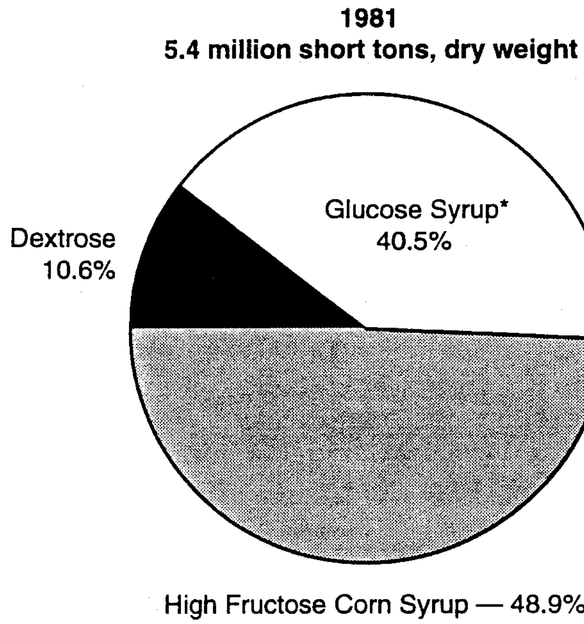
3.2.2 <u>Corn Sweeteners</u>

Most corn sweeteners are sold from wet corn millers to industrial food and beverage manufacturers. Glucose has both the lowest price and lowest sweetness of the three types of corn sweeteners. High fructose corn syrup (HFCS) is the sweetest, while dextrose has the highest price.[74] Domestic consumption of these corn sweeteners was 10.3 million short tons, dry weight in 1991.[75] Figure 3-1 displays the domestic consumption of corn sweeteners by type in 1981 and 1991. The volume of U.S. corn sweetener consumption has increased by an annual average rate of 6.7 percent from 1981 to 1991. In addition, the mix of sweeteners consumed in the U.S. has shifted towards HFCS: HFCS consumption increased from 48.9 percent of the volume of total corn sweetener consumption in 1981 to 63.6 percent in 1991 because of a shift in the U.S. soft drink industry from sugar to HFCS in the mid 1980s.[76]

In 1991, 94.3 percent of the volume of U.S. domestic consumption of corn sweeteners was for use in a variety of food products, including beverage, processed food, bakery and cereal, confectionery, dairy, and multiple and miscellaneous products. Figure 3-2 provides the domestic disappearance of corn sweeteners by use in 1981 and 1991. The major change in the mix is in the beverage industry, which accounted for 33.3 percent of the volume of corn sweeteners consumed in 1981 and increased to 50.9 percent in 1991. This increase is also largely due to the increased use of HFCS in the U.S. soft drink industry.[77]

Almost 90 percent of the corn sweeteners used in the U.S. beverage industry are HFCS, mostly in soft drinks.[78] Glucose syrup's primary beverage use is in brewing because it is a low-cost source of carbohydrates for brewing yeast. Dextrose is also used in malt beverages, primarily in light beer to lower the calorie content, because dextrose dissipates almost completely during fermentation.[79]

All three corn sweeteners are used in producing various processed foods. However, using dextrose in these products is declining rapidly because food processors are replacing added caloric sweeteners with HFCS and other high-intensity sweeteners.[80]



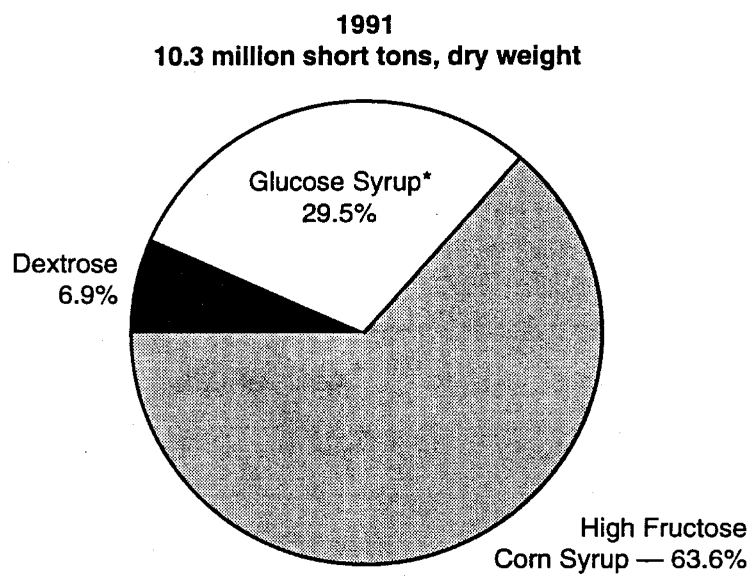


Figure 3-1. U.S. domestic consumption of corn sweeteners, by type, 1981 and 1991.[81]

*Includes estimates for glucose syrup solids and maltodextrin, as well as glucose syrup.

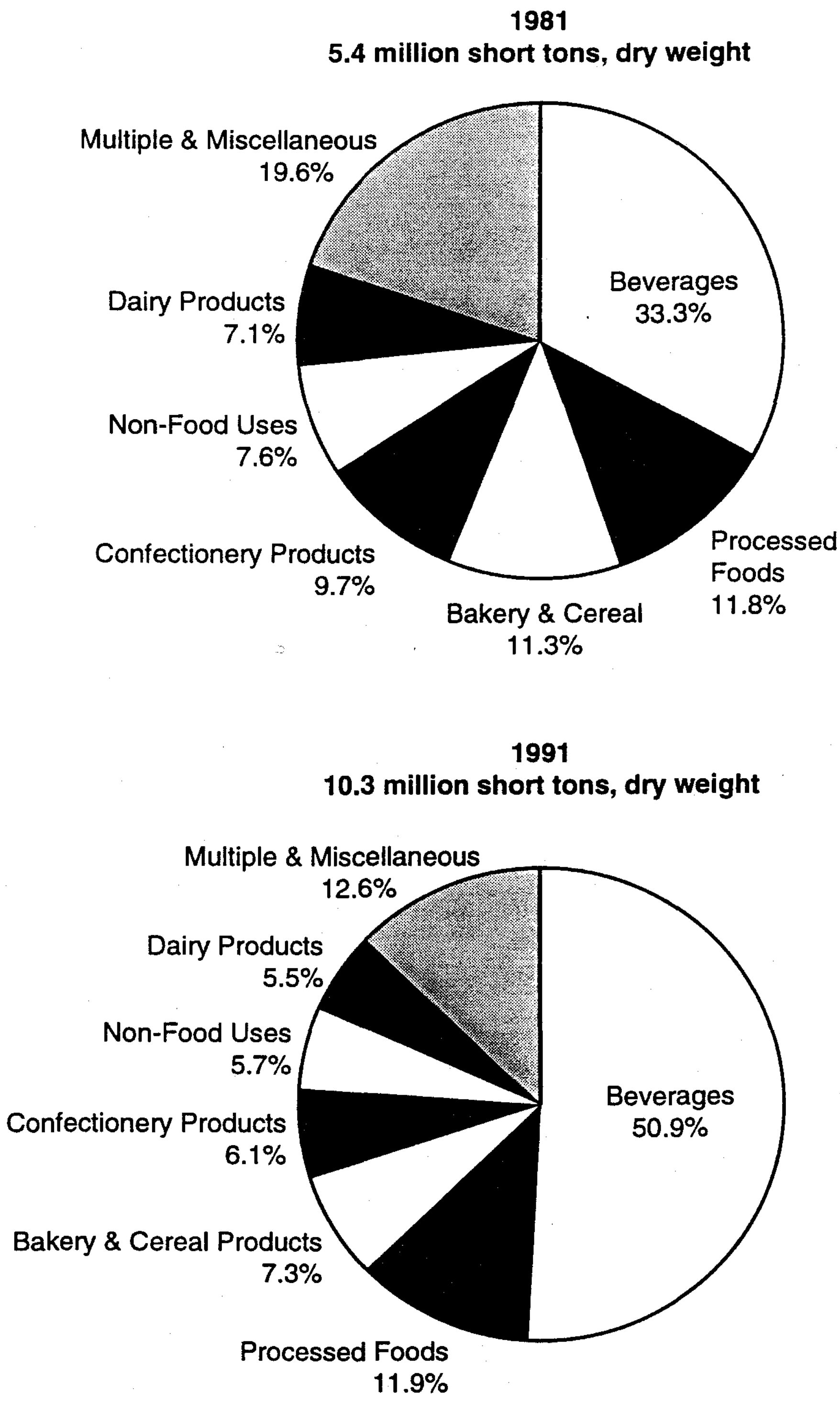


Figure 3-2. U.S. domestic consumption of corn sweeteners, by type of use, 1981 and 1991.[82]

While all three sweeteners have significant use in bakery and cereal products, HFCS is replacing glucose syrup and dextrose in many of these products, because HFCS has many of the desirable characteristics of the other two sweeteners, plus additional sweetness. Dextrose will continue to be widely used in bakery products because of certain characteristics, such as causing certain browning reactions in baking.[83]

The confectionary products that use glucose include caramel, nougat, and similar fillings, where it has a desirable texture, moisture retention, chewiness, and energy release. Dextrose is used in certain confectionary products, because certain properties are favorable to those products. For example, it is used to make chocolate chips stiffer for use in baking and to provide a cooling smooth texture in mint and other flavored confectionery. HFCS is not widely used in confectionery products.[84,85]

Glucose syrup accounts for most of the corn sweetener use in the dairy industry. In ice cream, it provides chewiness and smooth texture. It also makes the ice cream's freezing point higher than HFCS does. In certain other dairy products, such as imitation coffee creamers, glucose is preferred to dextrose, HFCS, and sugar because of its lack of sweetness. HFCS is also used in a number of dairy products, but dextrose has limited use.[86]

Nonfood applications of glucose include the production of pharmaceutical and organic chemical products. Dextrose is used in the production of drugs, chemicals, and pharmaceuticals. HFCS is not widely used in nonfood products.[87]

3.2.3 Corn Oil

Both crude and refined corn oil are used in foods.[88] Approximately 90 percent of corn oil is used in edible products such as mayonnaise, margarine, and cooking or salad oil and in baking or frying fats.[89] In addition, it is used to make nonedible products such as soap powders, paints, and varnishes.[90]

3.2.4 Ethanol

Ethanol is used as a fuel oxygenate to enable certain metropolitan areas and counties to meet carbon monoxide air quality standards set by the Clean Air Act. The gasoline sold in the moderate or serious nonattainment areas of the country must contain 2.7 percent oxygen by weight during at least the four winter months.[91] It is also used to enhance the octane level in gasoline.[92] Because of its high cost, however, ethanol's use as an oxygenate currently depends on federal and state tax subsidies. Moreover, ethanol's use as a blending component with gasoline has some disadvantages, including high volatility, a significantly lower energy content than gasoline, and limited transportation and storage options.[93]

Ethanol is also used in fermented and distilled liquors. About 60 percent of total ethanol production is by wet milling.[94] It can also be made by dry milling corn.

3.2.5 Wet Process Corn By-products

The five primary wet process corn by-products are germ, hulls, fiber, steepwater, and gluten. These by-products can be used to make feed products such as corn gluten feed, which is used in complete feeds or concentrates for dairy and beef cattle, poultry, swine and as a carrier for added micronutrients.[95] In addition some of these by-products are used for other purposes. Steepwater is used in producing enzymes, antibiotics, and other fermentation products. Gluten can be used to produce amino acids and zein (a protein) or dried and sold as corn gluten meal.[96,97] Corn gluten meal is used as a feed ingredient for cattle.[98] Wheat gluten, which is recovered from wheat starch production, is used as a low flavor, low odor protein supplement in baked goods and flour.[99] Corn hulls are used for producing refined corn fiber (bran) for food use.[100]

3.3 SUBSTITUTION POSSIBILITIES IN CONSUMPTION

The elasticity of demand for wet corn milling products with respect to price depends in large part on the substitution possibilities for each product. Thus, this section discusses the substitution possibilities for the relevant products.

Styrene-butadiene latex is a significant competitor with starch in the area of binders, while polyvinyl acetate, alcohol, and protein compete in specialty markets. Starch is used primarily because of its relatively low cost; varying levels of quality depend on how it is modified. In any case, however, synthetics tend to give better sheet and ink gloss.[101]

Gum arabic is a substitute for corn-based emulsion starches in food products. According to the Corn Refiners Association, starches have a number of advantages over this substitute product. First, the starches are available at a lower cost, in part due to recent droughts in Africa that have affected gum arabic supplies. Second, starches can be used at lower levels in food products. Moreover, corn starches are a purer ingredient than gum arabic, which can contain trapped insects and dirt.[102]

Starch adhesives dominate the natural adhesives market. The main substitute for starch adhesives is synthetic adhesives: they are typically tougher and more water resistant than starch adhesives. However, starch adhesives are generally less expensive and do not have the unpleasant odors associated with some animal glues.[103]

Corn sweeteners and refined sugar are very close substitutes. Table 3-1 lists U.S. per-capita quantity of sweetener consumption from 1981 to 1992. Per-capita corn sweetener use has grown at an annual average rate of 5.4 percent during this time period, while refined sugar fell at a rate of 1.9 percent. In 1992, corn sweeteners accounted for 54.0 percent of the total sweetener market, while refined

TABLE 3-1. U.S. PER-CAPITA CONSUMPTION OF CALORIC SWEETENERS, 1981-1992[a,105]

Year	Refined Sugar[b]	Corn Sweeteners[c]				Pure Honey	Edible Syrups	Total Caloric Sweeteners	U.S. Population (10^3)[d]
		HFCS	Glucose Syrup	Dextrose	Total				
1981	79.4	22.5	16.9	3.8	43.2	0.8	0.4	122.6	229,958
1982	73.7	26.8	17.3	3.9	48.0	0.9	0.4	121.7	232,192
1983	70.3	31.5	17.6	4.0	53.1	0.9	0.4	123.4	234,321
1984	66.7	37.5	17.9	4.1	59.5	1.0	0.4	126.2	236,370
1985	62.7	44.9	18.1	4.2	67.2	1.0	0.4	129.9	238,492
1986	60.0	45.6	18.3	4.2	68.1	1.0	0.4	128.1	240,380
1987	62.4	47.2	18.4	4.2	69.8	1.0	0.4	132.2	242,836
1988	62.1	48.5	18.8	4.3	71.6	1.0	0.4	135.1	245,021
1989	62.8	49.4	19.3	4.4	73.1	1.0	0.4	137.3	247,343
1990	64.4	50.3	20.1	4.5	74.9	1.0	0.4	140.7	249,900
1991	63.7	51.4	20.7	4.5	76.6	1.0	0.4	141.7	252,671
1992[e]	64.5	51.7	21.1	4.5	77.3	1.0	0.4	143.2	255,462

[a] Totals may not add due to rounding. Unit of measure for each sweetener is pounds, dry weight.
[b] Does not include sugar imported in blends and mixtures.
[c] Glucose syrup includes estimates for glucose syrup solids and maltodextrin, as well as glucose syrup.
[d] Total population, including armed forces overseas, July 1 of year indicated.
[e] Preliminary.

sugar accounted for 45.0 percent. Honey and edible syrups made up the remaining 1.0 percent.[104]

Corn oil competes with a wide variety of fats and other oils. Soybean oil is the most widely used substitute. In 1992, 11.1 million pounds of soybean oil were used in edible products, compared with 1.1 million for corn oil. Other significant substitutes include cottonseed oil, lard, tallow, sunflower oil, peanut oil, palm oil, and coconut oil.[106]

Methyl tertiary butyl ether (MTBE), which is produced from methanol and isobutylene, is a substitute for ethanol both as a fuel oxygenate and as an octane enhancing agent. Ethanol and MTBE each account for approximately half of total U.S. oxygenate consumption by weight. MTBE can be blended at the refinery and handled as normal gasoline, while fuel alcohol (95 percent alcohol and 5 percent unleaded gasoline) must be kept dry and cannot be shipped by pipeline. MTBE is also used as a blendstock to replace lead due to its low volatility and high octane.[107,108,109]

SECTION 4
ORGANIZATION OF THE WET CORN MILLING INDUSTRY

This section describes the structure of the wet corn milling market, the facility characteristics, and firm characteristics.

4.1 MARKET STRUCTURE

In addressing the economic impacts of air pollution regulations, market structure is of interest because of the effect it has on the behavior of producers and consumers. A market is generally considered the locus where producers and consumers interact to trade goods and services. Economic theory usually takes the market as given; however, when considering regulatory impacts, the analyst must define products and producers that constitute the market. The products of interest here include starch, corn sweeteners, corn oil, ethanol, and other wet process corn by-products, and the number of producers included is determined by the geographic bounds of the market. Because many different product categories are produced and consumed by a wide variety of industries across the U.S., wet corn milling products are not a homogeneous product.

The Census of Transportation reported that 28.4 percent of all wet corn milling shipments were within a radius of 200 miles and 56.8 percent were within a distance of 500 miles in 1977, the last year for which this information was collected.[110] This information suggests that the market for starch-related products may cut across regional boundaries.

Once the market structure is defined, the analyst models the behavior of consumers and, most importantly, producers of starch. The discussion on behavior generally focuses on monopolistic, oligopolistic, or competitive pricing. Making inferences about the behavior of producers often requires developing a measure of the concentration of an industry or market. A concentration measure should reflect the ability of firms to raise prices above the competitive level. Less concentrated markets are predicted to be more competitive and should result in a low value of the concentration measure, while a higher value should indicate a higher price-cost margin or a higher likelihood of noncompetitive behavior on the part of producers. A widely used measure is the concentration ratio. The n-firm concentration ratio reflects the share of total industry sales accounted for by the n largest firms. Unfortunately, concentration ratios only describe one point on the entire size distribution of sellers or producers.

Table 4-1 provides concentration ratios for the wet corn milling industry for 1972, 1977, 1982, and 1987. In 1987, the top four companies in the industry accounted for 74 percent of the total value of shipments. The eight largest companies were responsible for 94 percent of the total value of shipments for that year. As Table 4-1 indicates, the industry appears to be getting more concentrated over time.

TABLE 4-1. CONCENTRATION RATIO OF FIRMS IN THE WET CORN MILLING INDUSTRY: 1972, 1977, 1982, 1987[111]

Year	Percentage of value of shipments accounted for by the:		
	4 largest companies	8 largest companies	20 largest companies
1972	63	86	99+
1977	63	89	99+
1982	74	94	100
1987	74	94	99+

The U.S. Department of Justice uses the Herfindahl index to measure market concentrations. This index measures the concentration by summing the squares of the market shares (based on value of shipment) of all firms in the industry. For example, in the case of a pure monopoly, one firm would have 100 percent of the market share. In this case, the Herfindahl index would be 10,000. If the market comprised 100 firms, each with a share of 1 percent, the index would be 100. The Department of Justice considers a market with an index of 1,000 or less to be relatively unconcentrated and a market with an index of 1,800 or more to be highly concentrated.[112] The Herfindahl index for the 50 largest companies in the wet corn milling industry in 1987 was 1,639. This index does not, however, serve as an ideal measure for the market concentration level of starch products, because most firms in the wet corn milling industry produce multiple products, including starch and sweeteners.

The primary product specialization ratio measures the extent to which plants classified in an industry specialize in making products regarded as primary to the industry; that is, the value of primary product shipments of plants in the industry to a ratio of the total shipments of all products made by these plants (excluding miscellaneous receipts, such as receipts for contract and commission work on materials owned by others, scrap, salable refuse, and repairs, for example). In 1987, the primary product specialization ratio for the wet corn milling industry was 88 percent.[113]

The coverage ratio measures the extent to which all shipments of primary products are made by plants in the industry, as distinguished from secondary producers elsewhere; that is, the ratio of value of shipments of the primary products made by plants classified in the industry to the total shipments of primary products made by all producers, both in and out of the specified industry. In 1987, the coverage ratio for the wet corn milling industry was 94 percent.[114]

Table 4-2 displays the "free on board" (fob) price received by producers of corn starch in the midwest from fiscal year 1981 to 1993. In 1993, the price was $10.70 per hundredweight. Table 4-3 lists wholesale list prices for glucose corn syrup, dextrose, HFCS-42 (42 percent fructose), and HFCS-55 (55 percent fructose) from 1981 to 1992. In 1992, glucose corn syrup cost 15.19 cents per dry pound, dextrose cost 24.50 cents per dry pound, HFCS-42 cost 20.70 cents per dry pound, and HFCS-55 cost 23.00 cents per dry pound. Table 4-4 provides the average price of crude corn oil from 1981 to 1992. In 1992, this price was $0.26 per pound. Table 4-5 presents the prices of corn gluten feed and corn gluten meal from 1981 to 1992. In 1992, the price of a short ton of corn gluten feed was $102.80, while the price of corn gluten meal was $259.72 per short ton.

TABLE 4-2. CORN STARCH AVERAGE PRICE IN MIDWEST MARKET 1981-1993[115,a]

Year[b]	Average Nominal Price ($/cwt)	Average Real Price[c] ($/cwt)
1980/1981	11.67	11.83
1981/1982	10.44	10.44
1982/1983	10.44	10.37
1983/1984	13.09	12.69
1984/1985	13.08	12.74
1985/1986	9.69	9.78
1986/1987	9.52	9.38
1987/1988	10.70	9.99
1988/1989	10.20	9.11
1989/1990	10.66	9.31
1990/1991	11.02	9.63
1991/1992	11.03	N/A
1992/1993	10.70	N/A

[a] Corn starch prices reflect "free on board" (f.o.b.) prices received by producers, excluding transport costs borne by consumers.
[b] September-August fiscal year.
[c] Real prices reflect constant 1982 dollars deflated using producer price index for intermediate materials.

TABLE 4-3. ANNUAL AVERAGE WHOLESALE LIST PRICES IN MIDWEST MARKET FOR GLUCOSE CORN SYRUP, DEXTROSE, HFCS-42, AND HFCS-55, 1981-1992[a,116]

Year	Glucose Corn Syrup[b] (cents per pound, dry weight)	Dextrose[c] (cents per pound, dry weight)	HFCS-42[d] (cents per pound, dry weight)	HCCS-55[d] (cents per pound, dry weight)
1981	15.98	29.52	21.47	23.59
1982	13.56	27.07	14.30	18.81
1983	12.86	26.14	18.64	21.06
1984	12.89	26.41	19.94	22.69
1985	11.11	24.12	17.75	19.95
1986	10.59	23.55	18.07	19.96
1987	10.10	22.70	16.50	17.46
1988	11.66	25.39	16.47	18.68
1989	13.66	25.30	19.24	21.41
1990	14.25	24.50	19.69	21.88
1991	15.40	24.50	20.93	23.25
1992	15.19	24.50	20.70	23.00

[a] To convert to prices based on wet weights multiply by 0.803 for glucose, 0.92 for dextrose, 0.71 for HFCS-42, and 0.77 for HFCS-55.
[b] In tank cars (jumbos to west coast). Prices are revised starting February 1990 using the Midwest price rather than the Midwest price based on Illinois selling points as published earlier.
[c] In railroad cars, 600 bags of 100 pounds each.
[d] In tank cars (jumbos to west coast). These are delivered prices with a 2-percent cash discount.

TABLE 4-4. AVERAGE PRICE OF CRUDE CORN OIL, 1981-1992[117]

Fiscal Year Ending September[a]	Average Nominal Price[a,b] ($ per pound)	Average Real Price[c] ($ per pound)
1981	0.252	0.243
1982	0.234	0.234
1983	0.238	0.228
1984	0.266	0.256
1985	0.311	0.328
1986	0.170	0.182
1987	0.214	0.222
1988	0.233	0.219
1989	0.210	0.189
1990	0.247	0.218
1991	0.276	0.262
1992	0.258	N/A

[a] October - September. Fiscal year ends in September of year listed.
[b] 1981-1985: Free-on-board Decatur, Tank Cars. 1986-1992: Chicago, spot price.
[c] Real prices reflect constant 1982 dollars deflated using producer price index for crude food stuffs and feed stuffs.

TABLE 4-5. PRICES OF CORN GLUTEN FEED AND CORN GLUTEN MEAL IN MIDWEST MARKETS, 1981-1992[118]

Year	Corn Gluten Feed ($/short ton)	Corn Gluten Meal ($/short ton)
1981	115.06	257.03
1982	113.53	235.31
1983	123.83	267.15
1984	94.05	243.12
1985	75.63	200.40
1986	94.78	213.92
1987	98.28	251.62
1988	122.01	306.14
1989	113.17	281.39
1990	100.17	245.58
1991	101.57	256.07
1992	102.80	259.72

4.2 MANUFACTURING PLANTS

According to information collected by the Midwest Research Institute, 17 companies own 47 facilities that currently produce starch in the U.S. Of these facilities, 20 produce starch from corn, 3 produce starch from wheat, 21 produce starch from potatoes, 1 produces starch from tapioca, and 2 produce starch from other sources.[119] According to data provided by the U.S. Department of Agriculture (USDA), six facilities owned by four companies engage in corn wet milling but do not produce basic or modified starch.[120] This section describes the location and products, employment, and current trends of establishments that produce wet corn milling products.

4.2.1 Location and Products Produced

Figure 4-1 depicts the location of facilities in the U.S. that produce starch. The facilities are concentrated primarily in the Midwest, typically in states that are significant corn producers. Table 4-6 identifies the plant locations, employment, and sales volume at U.S. corn wet-milling facilities.

Table 4-7 shows selected products produced at U.S. corn wet-milling facilities in 1992. As shown, some of these plants are highly specialized, such as National Starch's North Kansas City plant, where basic and modified starch is its only primary product. Others produce a diversified set of corn products. A.E. Staley Manufacturing Company's Decatur, Illinois, plant, for example, produces common corn starch, a variety of modified food and industrial starches, glucose syrups, dextrose, and high fructose corn syrup.[121]

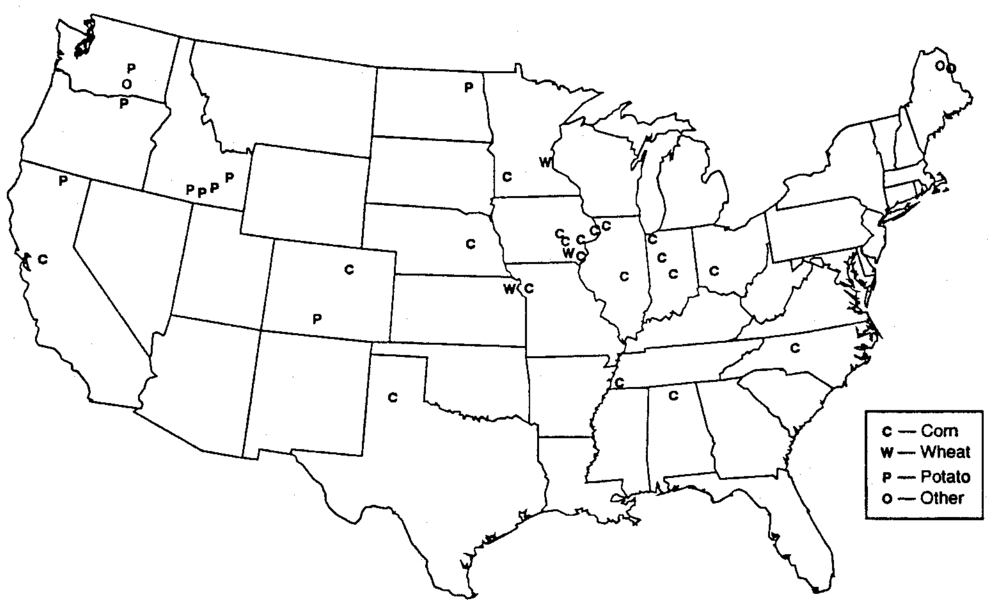


Figure 4-1. Location of starch producers, all types, U.S.[122,123]

TABLE 4-6. EMPLOYMENT, SALES VOLUME, AND TYPE OF STARCH PROCESSED FOR U.S. STARCH MANUFACTURING FACILITIES[a,124]

Facility ID	Company Name	City	State	Employee Size	Sales Volume Code	Type of Starch
1	AE Staley Manufacturing Company	Decatur	IL	1,355	J	Corn
2	AE Staley Manufacturing Company	Lafayette	IN	194	I	Corn
3	American Maize-Product Company	Decatur	AL	101	H	Corn
4	American Maize-Product Company	Dimmitt	TX	118	H	Corn
5	American Maize-Product Company	Hammond	IN	-[b]	-	Corn
6	Archer Daniels Midland	Clinton	IA	450	I	Corn
7	Cargill, Inc.	Cedar Rapids	IA	150	I	Corn
8	Cargill, Inc.	Dayton	OH	50	G	Corn
9	Cargill, Inc.	Memphis	TN	-	-	Corn
10	CPC International, Inc.	Stockton	CA	-	-	Corn
11	CPC International, Inc.	Summitt Argo	IL	200	I	Corn
12	CPC International, Inc.	Winston Salem	NC	100	H	Corn
13	Coors Biotech	Johnstown	CO	-	-	Corn
14	Grain Processing Corporation	Muscatine	IA	150	H	Corn
15	Minnesota Corn Processors	Columbus	NE	-	-	Corn
16	Minnesota Corn Processors	Marshall	MN	100	H	Corn
17	National Starch & Chemical Company	Greenwood	IN	650	I	Corn
18	National Starch & Chemical Company	North Kansas City	MO	-	-	Corn/Tapioca
19	Penwest, Ltd.	Cedar Rapids	IA	265	I	Corn

(continued)

TABLE 4-6. EMPLOYMENT, SALES VOLUME, AND TYPE OF STARCH PROCESSED FOR U.S. STARCH MANUFACTURING FACILITIES[a] (CONTINUED)

Facility ID	Company Name	City	State	Employee Size	Sales Volume Code	Type of Starch
20	Roquette America, Inc.	Keokuk	IA	475	I	Corn
21	Archer Daniels Midland	Keokuk	IA	100	H	Wheat
22	Manildra Milling Corporation	Minneapolis	MA	9	E	Wheat
23	Midwest Grain Products, Inc.	Atchinson	KS	100	H	Wheat
24	AE Staley Manufacturing Company	Monte Vista	CO	60	G	Potato
25	AE Staley Manufacturing Company	Blackfoot	ID	-	-	Potato
26	AE Staley Manufacturing Company	Murtaugh	ID	-	-	Potato
27	AE Staley Manufacturing Company	Stanfield	CR	-	-	Potato
28	Dakota Starch, Inc.	Park River	ND	-	-	Potato
29	J.R. Simplot	Heyburn	ID	-	-	Potato
30	Penwest, Ltd.	Idaho Falls	ID	-	-	Potato
31	Western Polymer Corporation	Tulelake	CA	-	-	Potato
32	Western Polymer Corporation	Moses Lake	WA	45	G	Potato
33	National Starch & Chemical Company	Island Falls	ME	75	H	Tapioca
34	AE Staley Manufacturing Company	Houlton	ME	53	E	Undetermined
35	Penwest, Ltd.	Richland	WA	-	-	Undetermined

[a] This table does not include 12 potato chip manufacturing plants that recover and dry starch.
[b] Indicates that data were not available for this plant.

Sales Volume Codes:
Code A - $0 - $499,999
Code B - $500,000 - $999,999
Code C - $1,000,000 - 2,499,999
Code D - $2,500,000 - $4,999,999
Code E - $5,000,000 - $9,999,999
Code F - $10,000,000 - $19,999,999
Code G - $20,000,000 - $49,999,999
Code H - $50,000,000 - $99,999,999
Code I - $100,000,000 - $499,999,999
Code J - $500,000,000 - $999,999,999
Code K - Over $1,000,000,000

TABLE 4-7. U.S. CORN WET-MILLERS; PLANT LOCATIONS AND SELECTED PRODUCTS PRODUCED AT EACH FACILITY, 1992[125,126]

	Plant Location		Products Produced at Wet-Milling Facilities					
			Basic and modified starches	Glucose corn syrup	Crystal-line dextrose	HFCS		Fuel ethanol
Company	City	State				42	55	
ADM (Archer Daniels Midland)[a]	Clinton[b]	Iowa	x		x	x	x	x
American Maize Products Company	Decatur	Alabama	x			x	x	
	Hammond	Indiana	x	x				
	Dimmitt	Texas	x			x	x	
Cargill, Inc.	Cedar Rapids	Iowa	x	x				
	Dayton	Ohio	x	x		x	x	
	Memphis	Tennessee	x	x		x	x	
Coors Biotech	Johnstown	Colorado	x			x	x	
CPC International, Inc.	Stockton	California	x			x	x	
	Argo[c]	Illinois	x	x	x	x	x	
	Winston-Salem	N. Carolina	x			x	x	
Grain Processing Corp.	Muscatine[d]	Iowa	x					x
Roquette America, Inc.	Keokuk	Iowa	x	x		x	x	x
Minnesota Corn Processing	Marshall	Minnesota	x	x				x
	Columbus[d]	Nebraska	x					x
National Starch & Chemical Co.	Indianapolis[d]	Indiana	x					
	Kansas City[d]	Missouri	x					
Penford Products Co.	Cedar Rapids	Iowa	x	x				
A.E. Staley Manufacturing Co.	Decatur	Illinois	x	x	x	x	x	
	Lafayette, N.	Indiana	x	x				
						x	x	
						x	x	x
No. of processing facilities	20		20	10	3	11	11	5

[a] ADM's plant in Montezuma, NY, closed in 1986 as did Staley's plant in Morrisville, PA.
[b] Plants also produce and market crystalline fructose.
[c] Plants also produce and market liquid dextrose (a 99-percent pure dextrose product, dry basis).
[d] Plant does not produce corn sweeteners.
[e] Plant has capability to produce one type of modified starch, but is currently shut down.

The Snack Food Association (SFA) reports that some snack manufacturers extract starch from their wastewater to reduce the organic load on their water treatment facilities. These manufacturers derive a starch in a slurry form with a 62 percent moisture level or a de-watered starch cake with a 40 percent moisture level. These starch by-products is sold or given away for reuse as animal feed or for further processing by other industries. However, of the nearly 200 facilities that manufacture potato chips in the U.S., only one major manufacturer dries its starch beyond a de-watering process. This manufacturer is Frito-Lay, which further dries its starch by-product at 12 facilities in the U.S.[127]

4.2.2 Employment

According to the Corn Refiners Association, a typical small-scale plant employs approximately 125 people, a medium-sized plants employs 275, and a large plant employs about 550 people.[128] Figure 4-2 displays 1987 wet corn milling facilities by number of employees. As shown, 28 of the facilities, or 46.7 percent, had fewer than 50 employees and 47 of the facilities, or 78.3 percent, had fewer than 500 employees.

4.2.3 Current Trends

Wet milling companies have recently made a number of plant openings and expansions and announcements concerning future plant openings. In 1992, Minnesota Corn Processors opened its Columbus, Nebraska, plant. Future openings that were announced during 1992 include Cargill's future corn refining plant in Blair, Nebraska, and CPC International Inc.'s new corn oil facility in Argo, Illinois. Recent expansions include American Maize-Products' specialty starch operations in Indiana, Penford Products Company's starch operation, and Staley's crystalline fructose, granular starches, and hydroxyethylated starches businesses.[129]

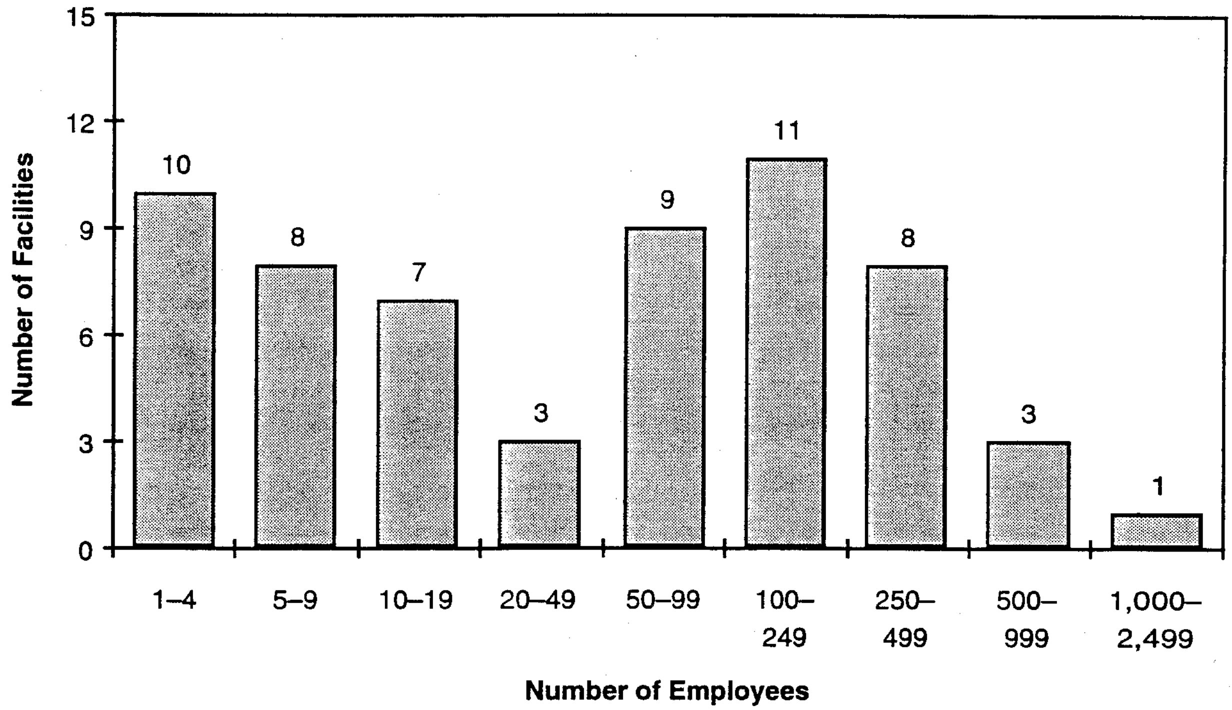


Figure 4-2. Wet corn milling facilities by number of employees, 1987.[130]

4.3 FIRM CHARACTERISTICS

The NSPS will cover new, modified, or reconstructed dry starch production facilities. Thus, potentially affected firms include both of the following:

- firms currently owning plants that produce dry starch and that may be considering building a new starch plant, expanding existing starch capacity, or performing a major reconstruction or modification at an existing starch plant, and

- firms that currently do not produce starch but that may be considering building a new plant.

The former are readily identified by information from the Midwest Research Institute that indicates 17 companies own 47 facilities producing starch across the U.S.[131] Table 4-8 displays sales, employment, and legal form of organization for

TABLE 4-8. SALES, EMPLOYMENT, AND LEGAL FORM OF ORGANIZATION FOR U.S. WET CORN MILLING COMPANIES[132]

Company ID	Company Name	Legal Form of Organization	Number of Employees	Sales ($ 10^6)
1	AE Staley Manufacturing Company	Subsidiary of Tate & Lyle, PLC	2,300	1,400.0
2	ACX Technologies[a]	Public Corporation	4,200	570.8
3	American Maize-Product Company	Public Corporation	2,154	542.1
4	Archer Daniels Midland	Public Corporation	13,524	9,231.5
5	Cargill, Inc.	Private Corporation	38,482	30,090.0
6	CPC International, Inc.	Public Corporation	36,000	6,599.0
7	Dakota Starch, Inc.	N/A[b]	N/A	N/A
8	Frito Lay	Subsidiary of Pepsico	26,000	6,132.0
9	Grain Processing Corporation	Subsidiary of Varied Investment, Inc.	815	300.0
10	J.R. Simplot	Public Corporation	9,050	1,500.0
11	Manildra Milling Corporation	Subsidiary of Honan Holding, PTY, Ltd.	40	14.0
12	Midwest Grain Products, Inc.	Public Corporation	560	227.0
13	Minnesota Corn Processors	Private Corporation	250	51.0
14	National Starch & Chemical Company	Subsidiary of Unilever United States, Inc.	7,400	1,700.0
15	Penwest, Ltd.	Public Corporation	350	126.0
16	Roquette America	Subsidiary of Roquette Freres	N/A	N/A
17	Western Polymer	Private Corporation	50	10,000.0

[a] Information for this company was obtained from Moody's OTC Industrial Manual (1993).
[b] Indicates that information was not available.

these companies. The latter are, and will remain, unidentified unless a plant announcement has been made by a firm not currently operating in this industry.

Companies that own starch manufacturing facilities, or other facilities that dry starch, are legal business entities that have the capacity to conduct business transactions and make business decisions that affect the facility. The terms company and firm are synonymous and refer to the legal business entity that owns one or more facilities. Companies include those owned directly by the shareholders/owners and those owned by a "parent" company. As seen in Figure 4-3, the chain of ownership may be as simple as one facility owned by

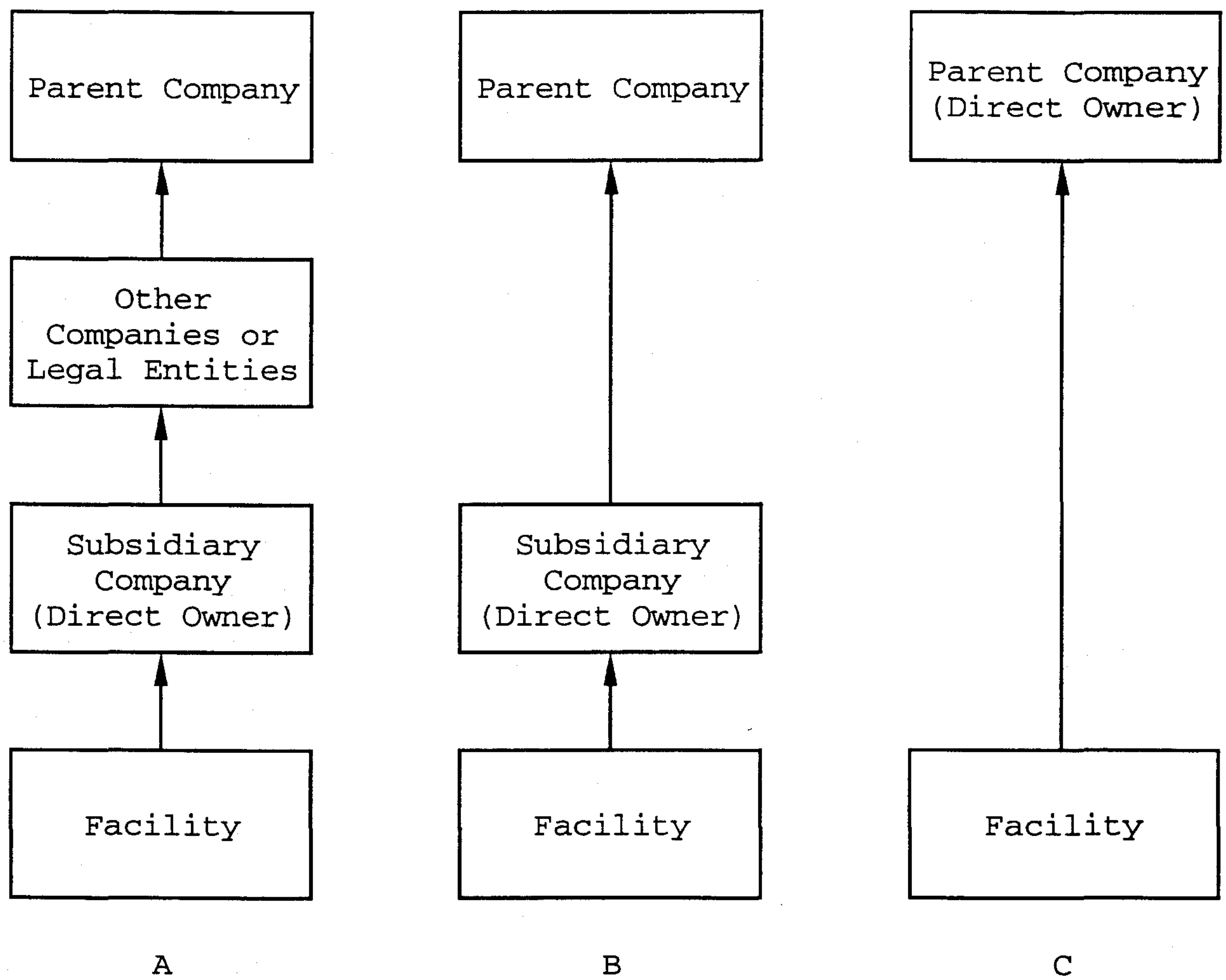


Figure 4-3. Chain of ownership.

one company or as complex as multiple facilities owned by subsidiary companies. Where data are available, this analysis focuses on firms that currently directly own the existing starch manufacturing facilities.

4.3.1 Ownership

The legal form of ownership affects the cost of capital, availability of capital, and effective tax rate faced by the firm. Business entities that own wet corn milling facilities are generally one of three types of entities:

- sole proprietorships
- partnerships, and
- corporations.

Each type has its own legal and financial characteristics that may influence how firms are affected by the regulatory alternatives. Table 4-9 provides information about the legal form of ownership of firms for wet corn milling (SIC 2046). Figure 4-4 compares the legal form of ownership of all firms in the U.S. and the wet corn milling industry.

TABLE 4-9. LEGAL FORM OF FIRM ORGANIZATION IN THE WET CORN MILLING INDUSTRY: 1987[133]

	Legal Form of Organization			
Item	Corporation	Sole Proprietor-ship	Other and Unknown	Total
Single-Facility Firms	10	2	3	15
Multi-Facility Firms	16	0	0	16
All Firms	26	2	3	31

4.3.1.1 Sole Proprietorship. A sole proprietorship consists of one individual in business for him/herself who contributes all of the equity capital, takes all of the risks, makes the decisions, takes the profits, or absorbs the losses. Behrens reports that sole proprietorships are the most common form of business.[134] The popularity of the sole proprietorship is in large part due to the simplicity of establishing this legal form of organization. For 1987, Internal Revenue Service (IRS) data indicate that nonfarm sole proprietorships represented almost 72 percent of U.S. businesses but accounted for only 6 percent of business receipts.[135] The 1987 Census of Manufactures reports, however, that a relatively small proportion of firms in the U.S. wet corn milling industry are sole proprietorships--only two of the 31 firms under SIC 2046. Therefore, this type of firm accounts for a fairly small proportion of the industry at less than 7 percent.[136]

Legally, the individual and the proprietorship are the same entity. From a legal standpoint, personal and business debt are not distinguishable. From an accounting standpoint, however, the firm may have its own financial statements that reflect only the assets, liabilities, revenues, costs, and taxes of the firm, aside from those of the individual.

When a lender lends money to a proprietorship, the proprietor's signature obligates him or her personally of all of his/her assets. A lender's assessment of the likelihood of repayment based on the firm and the personal financial status of the borrower is considered legal and sound lending practice because they are legally one-and-the-same. Table 4-10 highlights the advantages and disadvantages of this ownership type.

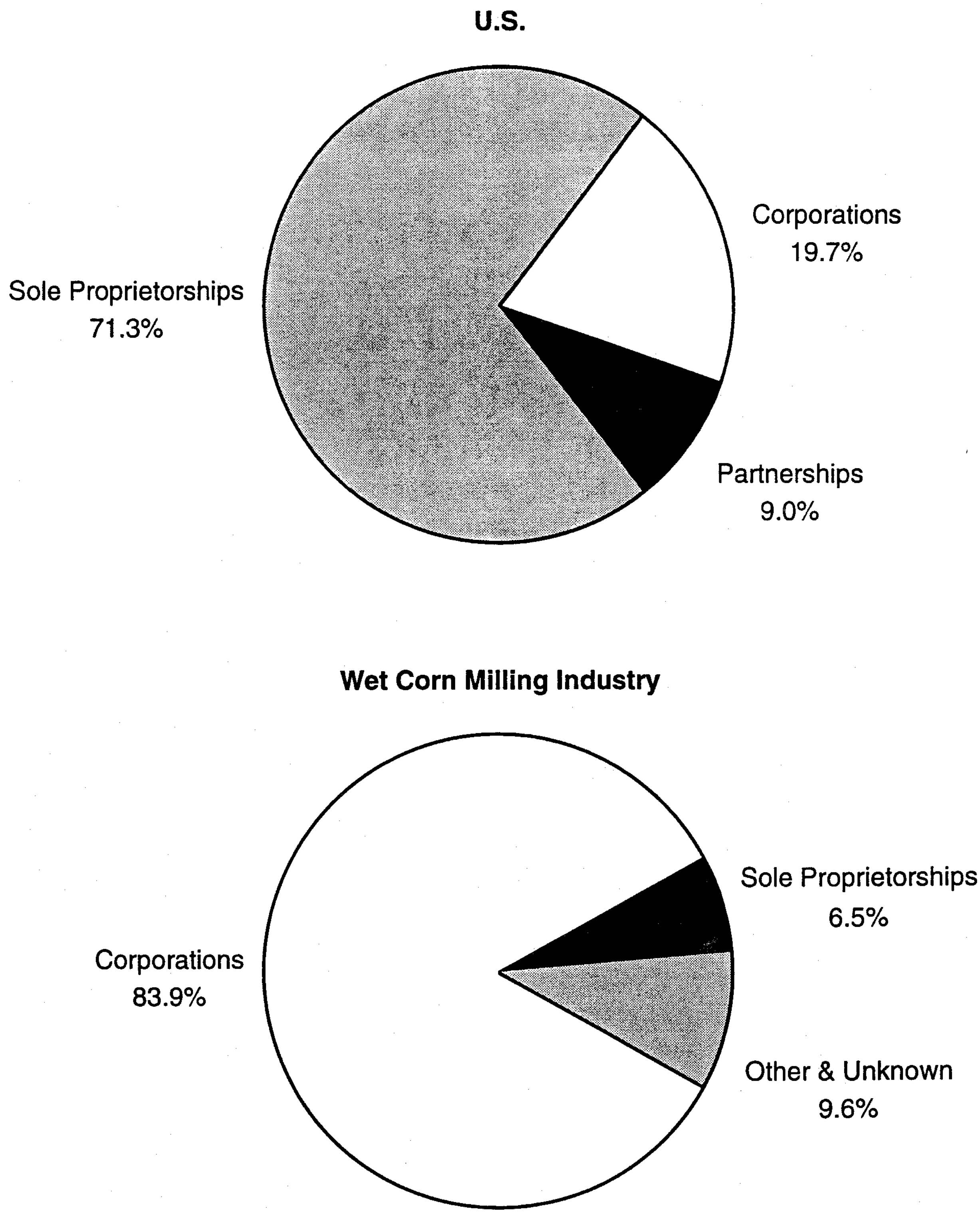


Figure 4-4. Comparison of the legal form of organization for firms in the U.S. and wet corn milling industry: 1987.[137,138]

TABLE 4-10. ADVANTAGES AND DISADVANTAGES OF SOLE PROPRIETORSHIP[139]

Advantages	Disadvantages
Simplicity of Organization	Owner's possible lack of ability and experience
Owner's freedom to make all decisions	Limited opportunity for employees
Owner's enjoyment of all profits	Difficulty in raising capital
Minimum legal restrictions	Limited life of the firm
Ease of discontinuance	Unlimited liability of proprietor
Tax advantages	

Note: A brief evaluation of these advantages and disadvantages is available in Steinhoff and Burgess (1989).

4.3.1.2 Corporations. According to IRS business tax returns for 1987, corporations represented only 19.7 percent of U.S. businesses but accounted for 90 percent of all business receipts.[140] For 1987, the Census of Manufactures reports that 26 of 31 firms listed under SIC code 2046 for wet corn milling, or over 83 percent, are corporations. Therefore, corporations represent the vast majority of the firms involved in wet corn milling.[141]

Unlike proprietorships and partnerships, a corporation is a legal entity separate and apart from its owners or founders. Financial gains from profits and financial losses are borne by owners in proportion to their investment in the corporation. Analysis of credit availability to a corporation must recognize at least two features of corporations. First, they have the legal ability to raise needed funds by issuing new stock. Second, institutional lenders (banks) to corporations assess credit worthiness solely on the basis of the financial health of the corporation--not the financial health of its owners. A qualification of note is that lenders can require (as a loan condition) owners to agree to separate contracts obligating them personally to repay loans. Table 4-11 highlights the advantages and disadvantages of this ownership type.

TABLE 4-11. ADVANTAGES AND DISADVANTAGES OF THE CORPORATION[142]

Advantages	Disadvantages
Limited liability to the stockholders	Government regulation
Perpetual life of the firm	Expense of organization
Ease of transferring ownership	Capital stock tax
Ease of expansion	Danger of disagreement
Applicability for both large and small firms	Unlimited liability of proprietor

Note: A brief evaluation of these advantages and disadvantages is available in Steinhoff and Burgess (1989).

4.3.2 Size Distribution

Firm size is likely to be a factor in the distribution of the regulatory action's financial impacts. Grouping the firms by size facilitates the analysis of small business impacts, as required by the Regulatory Flexibility Act (RFA) of 1982. Firms are grouped into small and large categories using Small Business Association (SBA) general size standard definitions for SIC codes. These size standards are presented either by number of employees or by annual receipt levels, depending on the SIC code.

Wet corn milling is covered by SIC code 2046. Thus, according to SBA size standards, firms owning wet corn milling plants are categorized as small if the total number of employees at the firm is less than 750; otherwise the firm is classified as large. Based on employment data from Table 4-8, a total of five firms, or 9.4 percent, are categorized as small, while eleven firms, or 64.7 percent, are in the large category, and one firm is not categorized due to lack of employment data. However, one of the five "small" firms, Manildra Milling Corporation, is owned by a holding company of unknown size, Honan Holding, Ltd.

Firms may differ in size for one or more of the following reasons:

- Wet corn milling plants vary by size. Firms with large plants are larger than firms with small plants.
- Firms vary in the number of plants they own. Firms with more plants are larger than those with fewer plants.
- Firms engage in varying amounts of business outside of the wet corn milling industry.

Control economies are typically plant-related rather than firm-related. For example, a firm with six uncontrolled plants with average annual receipts of $1 million per plant may face approximately six times the control capital requirements of a firm with one uncontrolled plant whose receipts total $6 million per year. Alternatively, two firms with the same number of plants facing approximately the same control capital costs may be financially affected very differently if the plants of one are larger than those of another.

Table 4-12 shows the average size of facility (based on total employment) represented in each company size category. As expected, larger firms own larger facilities on average. Table 4-13 shows the distribution of firms by the number of facilities owned. A correlation does seem evident between the number of starch manufacturing facilities owned and the size of the firm. The average number of facilities owned by small firms is 1.8 (9 facilities ÷ 5 firms) as compared to an average of 3.4 facilities (37 facilities ÷ 11 firms) owned by large firms. However, non-starch facilities are not reflected in this distribution.

TABLE 4-12. AVERAGE SIZE OF STARCH MANUFACTURING FACILITY BY FIRM SIZE CATEGORY[a,143]

Firm Size Based on Employment	Average Number of Employees at Facility[b]
Small (<750)	103.8
Large (>750)	267.6
Total, all firms	228.6

[a] Facility size is measured as total employment listed by American Business Information (ABI), an online database that is updated periodically.
[b] Average number of employees at facility calculated for only those facilities with employment data as given in Table 4-6.

TABLE 4-13. DISTRIBUTION OF FIRMS BY NUMBER OF STARCH MANUFACTURING FACILITIES OWNED: 1992[144]

Firm-Level Size Based on Employment	Number of Facilities Owned Per Firm				
	1	2	3	Over 4	Total
Small (<750)	2	2	1	0	5
Large (>750)	4	1	4	2	11
Undetermined	1	0	0	0	1
Total, all firms	7	3	5	2	17

4.3.3 Issues of Vertical and Horizontal Integration

The vertical aspects of a firm's size reflects the extent to which goods and services that can be bought from outsiders are produced in house. Vertical integration is a potentially important dimension in analyzing firm-level impacts because the regulation could affect a vertically integrated firm on more than one level. For example, the regulation may affect companies for whom wet corn milling is only one of several processes in which the firm is involved. A company that produces starch may also be involved in cardboard production. This firm would be considered vertically integrated because it is involved in more than one level of production involving starch. A regulation that increases the cost of producing starch may also affect the cost of producing paper, cardboard, certain foods, and any other products that use starch in the production process.

Some of the firms in the wet corn milling industry are vertically integrated. For example, CPC International, Inc., not only produces wet corn milled products, but it also produces consumer foods such as soups, sauces, mayonnaise, bouillons, peanut butter, and margarine, many of which use corn products as inputs. Archer Daniels Midland is similarly vertically integrated, producing consumer food products and malt products.[145]

The horizontal aspect of a firm's size refers to the scale of production in a single-product firm or to its scope in a multiproduct one. Horizontal integration is also a potentially important dimension in firm-level impact analysis for one or more of the following:

- A horizontally integrated firm may own many facilities, of which only some are directly affected by regulation.
- A horizontally integrated firm may own facilities in unaffected industries. This type of diversification would help mitigate the financial impacts of the regulation.
- A horizontally integrated firm could be indirectly as well as directly affected by the regulation. For example, if a firm is diversified in manufacturing pollution control equipment (an unlikely scenario), the regulation could indirectly and favorably affect it.

Some of the firms in the wet corn milling industry are horizontally integrated. For example, in addition to engaging in corn wet milling, American Maize Products Company also manufactures and markets cigars and various smokeless tobacco products. Archer Daniels Midland is also horizontally integrated. In addition to being one of the largest corn refiners and wheat flour millers in the U.S., it also processes oilseeds, shells peanuts, and refines sugar from raw cane sugar.[146] The range of SIC codes represented by firms owning wet corn milling facilities includes those presented in Table 4-14.

4.4 GROWTH PROJECTIONS

This section, provided by Midwest Research Institute, presents projected starch production growth rates and estimates of the number and types of affected facilities (i.e., plants installing new starch production equipment between 1993 and 1997 that generates PM emissions). All information in this section comes from the Midwest Research Institute profile.[147]

4.4.1 Projected Production Growth Rates

In addition to the starch production in 1992, Table 4-15 shows the estimated growth in production for 1993 through 1997 and the total production in 1997. The estimates are based on projected annual growth rates of 2 percent for starch from each raw material. One value was selected for the entire industry because few projections were available (and most of those were for corn) and to maintain the same relative market shares observed from historical data.

The 2 percent growth rate is based on five factors. First, a Corn Refiners Association (CRA) representative estimated corn starch production growth will average about 2.5 percent annually over the next several years. Second, an industry representative estimated wheat starch production would increase about 10 percent over the next five years, which is equivalent to an annual rate of nearly 2 percent. Third, the USDA projects 2 percent growth in corn starch production for the September 1993-August 1994 year. Fourth, the USDA projects an average annual increase of 3.4 percent in

TABLE 4-14. SIC LISTING FOR COMPANIES OWNING U.S. WET CORN MILLING FACILITIES[148]

SIC Code	Description	Number of Companies
0175	Deciduous and Tree and Fruits	1
2015	Poultry Slaughtering and Processing	1
2033	Canned Fruits and Vegetables	1
2035	Pickles, Sauces, and Salad Dressings	1
2041	Flour and Other Grain Mill Products	3
2045	Prepared Flour Mixes and Doughs	1
2046	Wet Corn Milling	10
2048	Prepared Feeds NEC	4
2051	Bread, Cake, and Related Products	1
2075	Soybean Oil Mills	2
2076	Vegetables Oil Mills NEC	3
2079	Edible Fats and Oils	1
2085	Distilled and Blended Liquors	2
2099	Food Preparation NEC	2
2121	Cigars	1
2131	Chewing and Smoking Tobacco	1
2675	Die-Cut Paper and Board	1
2821	Plastics Materials and Resins	2
2834	Pharmaceutical Preparations	1
2869	Industrial Organic Chemicals NEC	2
2879	Agricultural Chemicals NEC	1
2891	Adhesives and Sealants	1
3089	Plastics Products NEC	1
3264	Porcelain Electrical Supplies	1
3363	Aluminum Die-Castings	1
3449	Miscellaneous Metal Work	1

(continued)

TABLE 4-14. SIC LISTING FOR COMPANIES OWNING U.S. WET CORN MILLING FACILITIES (CONTINUED)

SIC Code	Description	Number of Companies
3699	Electrical Equipment and Supplies NEC	1
4424	Deep Sea Domestic Transportation of Freight	1
4449	Water Transportation of Freight NEC	1
5051	Metals Service Centers and Offices	2
5148	Fresh Fruit and Vegetables	1
5149	Groceries and Related Products NEC	1
5153	Grain and Field Beans	1
6211	Security Brokers and Dealers	1
6621	Commodity Contracts Brokers and Dealers	1
6719	Holding Companies NEC	2
8734	Testing Laboratories	1

TABLE 4-15. CURRENT DRY STARCH PRODUCTION AND PROJECTED GROWTH[149]

Type of Starch	Percent of Total Production	Production Rates (10^9 lb/yr)		
		1992 Production Rate[a]	Projected Production Growth in 1993 through 1997[b]	Total Production Rate in 1997
Corn	92	6.34	0.660	7.00
Wheat	4	0.276	0.029	0.305
Potato[c]	3	0.207	0.0215	0.229
Tapioca	1	0.069	0.0072	0.076
Total	100	6.89	0.718	7.61

[a] Based on 1) production for domestic markets of 5.4 billion lb at CRA member plants in 1992, 2) the assumptions that exports account for 5 percent of the total production and the CRA plants produce 90 percent of the total corn starch, and 3) the estimated percentages of total production.

[b] Assuming 2 percent annual growth rates for all types of starch.

[c] Seven percent of the total (13.8 million lb) is for potato chip manufacturing plants that recover and dry starch from their wastewater. The remainder is for plants that process cull potatoes and potato processing plants that reclaim starch from wastewater.

industrial (i.e., excluding food) corn starch production between September 1992 and August 1995. Fifth, the average annual increase in production since 1988 is estimated to be between 1.8 percent (USDA figures) and 4.2 percent (CRA figures). The CRA growth figure of 4.2 percent is known to be biased high because it includes the production rates for new members added in recent years; the USDA figure of 1.8 percent may be more representative. The average of these five figures is 2.3 percent, which was rounded to 2 percent.

4.4.2 Projected Number and Type of Affected Facilities

This section discusses the number of affected facilities and the rationale for their selection. The results are summarized in Table 4-16.

TABLE 4-16. PROJECTED AFFECTED FACILITIES[150]

Emission Source	Number of Projected Affected Facilities						
	New Plants			Expansion at Existing Plants			
	Corn	Potato Chip Producer	Cull Potato and Food Processor	Corn	Wheat	Cull Potato and Food Processor	Tapioca
Dryers							
Flash	1	1	1	3	1	2	0
Drum	0	0	0	2	0	0	1
Tunnel	0	0	0	1	0	0	0
Spray	0	0	0	0	0	0	0
Storage Silos/ Blending Bins	2	0	0	12	2	1	0
Bulk Loadout System	1	0	0	0	0	0	0
Bag Packing Equipment	1	1	0	0	0	0	0
Bag Dump	1	0	0	0	0	0	0

4.4.2.1 Corn Starch. To meet the projected increase in demand for corn starch over the next five years, it is estimated that up to five existing facilities would expand starch production, and one new facility would be constructed. Existing facilities would expand by installing three flash dryers, one tunnel dryer, two drum dryers and twelve storage silos. The new facility would consist of one flash dryer, two storage silos, one bulk loadout facility, one bagging system (with two nozzles), and one bag dump. A spray dryer is used by at least one existing plant, but because this design is not energy efficient, it is unlikely that new spray dryers will be installed.

Considering only one new plant has been constructed in the last 10 years, it is unlikely that more than one new plant will be built in the next five years. (However, the increased demand for ethanol may result in several additional plants. If they also decide to produce starch, the industry-wide capacity utilization may fall.) It is assumed that this plant would install a flash dryer, two storage bins, a bulk loadout facility, bagging equipment, and a bag dump.

It is not clear how many existing plants would install the other projected dryers. Assuming the six dryers are distributed among six plants, it is likely that no additional loadout, bagging, or bag dump equipment would be needed because most facilities have significant excess capacity. Based on the storage silo-to-dryer ratio at existing facilities, an estimated 12 additional storage silos would be installed with the 6 dryers.

4.4.2.2 Wheat Starch. One new dryer with a capacity of 3,900 lb/hr would be needed to produce the projected increaseof 29 million lb/yr in the next 5 years. This correlates well with historical trends, which show one plant having installed a new dryer in 1987 or 1988, and another plant installing a new dryer in 1992 or 1993. It is assumed that the new dryer would be a flash dryer because at least one of the two dryers installed recently was a flash dryer. The projected size, however, is only about 50 percent of the size of dryers at existing plants.

It is also assumed that the new dryer would be installed at an existing facility. The ratio of the number of storage silos to the number of dryers at wheat starch plants is unknown. Thus, it is assumed that two additional silos would be need, just as for the corn starch plants. Additional loadout, bagging, and bag dump equipment should not be needed.

4.4.2.3 Potato Starch From Food and Cull Potato Processing Plants. As shown in Table 4-15, an estimated 20.1 million lb/yr of new production will be added by 1997. This amount could be supplied by one new flash dryer producing 2,700 lb/hr (essentially the average production at existing facilities, as described above). However, this analysis assumes that the new production will occur through expansion at an existing plant and construction of a new plant.

A new plant was selected because one new plant opened in the last 5 years. It will include a flash dryer designed to produce 700 lb/hr and operating at 350 lb/hr. This size was selected because it represents the facility that opened recently, and it also represents the small end of the range reported in 1984. The recently constructed plant has no storage facilities; all dried starch is sent directly to be bagged for shipment.

The remaining 2,350 lb/hr will be produced through expansion at an existing plant using a new flash dryer with a design capacity of 2,800 lb/hr. Expansion at only one existing plant was selected because the only known dryer capacities (other than the small one described above) are larger than 2,800 lb/hr. Just as for the existing corn and wheat starch plants, the existing potato starch plant is assumed to have sufficient excess capacity in the loadout, bagging, and bag dump equipment to accommodate the increased production rate. Possibly one additional storage bin will be needed.

4.4.2.4 Potato Starch From Potato Chip Manufacturing Plants. According to a potato chip manufacturer that recovers starch from the wastewater at many of its facilities, possibly one new plant will be constructed in the next five years with equipment to dry recovered starch. The estimated growth can be supplied by a new plant with the same rated capacity and approximately the same capacity utilization as the existing facilities. These plants have no separate storage container. Temporary storage occurs in the cyclone hopper and a wide section of the ductwork. When enough starch has collected, it is discharged to a large plastic bag. Thus, the dryer and bagging equipment will be the only sources of PM emissions at the new plant.

4.4.2.5 Tapioca. At least two plants produce modified tapioca starches. One is primarily a corn starch manufacturer and uses flash dryers exclusively. The other exclusively imports dry starch (both tapioca and corn) and modifies it using both flash and drum dryers. The projected growth of 7 million lb/yr over the next 5 years can be produced by one drum dryer with a design capacity of 1,000 lb/hr--a size that is comparable to those of dryers at one existing plant. Presumably, this dryer would be installed at an existing facility. Thus, no additional loadout, bagging, or bag dump equipment would be needed. One of the tapioca starch manufacturing plants mixes additives with the starch in a blending bin before bagging for shipment. It was assumed that one additional dryer would not require an additional blending bin.

SECTION 5
WET CORN MILLING MARKETS

Wet corn milled products are produced and consumed domestically as well as traded internationally. Therefore, domestic producers export some of these products to other countries, and foreign producers supply their wet corn milled products to U.S. markets. This section includes information on value, and quantity trends over the past decade for wet corn milled products, where statistics are available. The products that are concentrated on starch, corn sweeteners, corn oil, and wet process corn by-products, which are mainly composed of gluten and other feed products. Ethanol produced from wet corn milling is not included in this discussion.

5.1 PRODUCTION

This section describes the domestic and foreign production of wet corn milled products.

5.1.1 Domestic Production

Table 5-1 presents the value of U.S. shipments of the major product classes from 1982 to 1991. In 1991, the U.S. shipments of wet corn milling products were valued at $6.5 billion, reflecting a 3.2 percent nominal increase over 1990. In total, the nominal value of wet corn milling industry shipments grew at an annual average of 8.5 percent from 1982 to 1991. During this time, the nominal value of U.S. corn sweetener shipments grew at an average annual rate of 7.3 percent, manufactured starch shipments at 8 percent, corn oil at 16.3 percent, and wet process corn by-products at 8.5 percent. Table 5-2 shows the quantity of shipments of wet corn milled products from 1979 to 1992. This table includes only corn milled products shipped by members of the Corn

TABLE 5-1. VALUE OF SHIPMENTS BY PRODUCT CLASS FOR THE WET CORN MILLING INDUSTRY, 1982-1991[a,151]

	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
Corn Sweeteners	1,610.4	1,661.1	1,879.2	2,132.4	2,202.9	2,182.5	2,185.2	2,777.6	2,996.8	3,038.4
Manufactured Starch	655.1	778.8	936.4	854.4	817.6	774.3	970.4	1,120.9	1,211.8	1,310.3
Corn Oil	234.9	278.9	269.9	498.9	304.1	613.1	775.0	775.2	938.9	911.2
Wet Process Corn By-Products	577.7	678.6	791.3	734.1	785.3	845.8	1,043.0	1,127.7	1,100.3	1,199.8
All Other	27.6	47.5	34.2	38.7	20.3	30.5	23.1	44.7	36.4	23.0
TOTAL	3,105.7	3,445.0	3,911.0	4,258.5	4,130.3	4,446.2	4,996.8	5,846.1	6,284.2	6,482.8

[a] Values in units of $\$10^6$ are reflecting current, or nominal, U.S. dollars.

TABLE 5-2. SHIPMENTS BY CORN REFINERS ASSOCIATION MEMBERS, 1979-1992[a,152]

Year	Starch Products	Refinery Products	Oil Products	Feed Shipments	Total
1979	3,945	10,800	605	6,740	22,090
1984	4,185	17,920	985	10,940	34,030
1989	4,490	21,580	1,110	11,690	39,180
1990	4,960	22,770	1,130	11,460	40,930
1991	5,150	23,755	1,100	11,590	42,290
1992	5,420	25,490	1,030	13,220	45,845

[a] Shipments are in 10^6 lbs. Estimated from industry and government sources. Table does not include shipments of alcohol or by-products from alcohol production. Product categories may not match totals because of rounding. Statistics represent shipments by Corn Refiners Association members only.

Refiners Association and not products from other corn wet millers or from other sources, such as wheat or potatoes.

5.1.2 Foreign Production (Imports)

Table 5-3 provides the total value of imports to the U.S. of wet corn milled products between 1985 and 1992. The value of imports to the U.S. rose by an annual average nominal rate of 26.7 percent from 1985 to 1992, to reach a level of $233 million in 1992. In 1992, 46.9 percent of the value of U.S. wet corn milled imports was supplied by Canada, 14 percent by the Netherlands, 10.9 percent by Australia, 7.2 percent by Germany, 6.7 percent by France, and 14.3 percent by other countries.[153]

5.2 CONSUMPTION

This section describes the domestic and foreign consumption of wet corn milled products.

TABLE 5-3. VALUE OF IMPORTS OF WET CORN MILLING PRODUCTS TO THE U.S., 1985-1992[a,154]

Year	Customs Value
1985	44.5
1986	57.9
1987	57.1
1988	58.0
1989	188.7
1990	199.4
1991	194.3
1992	233.0

[a] Values are in units of $\$10^6$ reflecting current, or nominal, U.S. dollars.

5.2.1 Domestic Consumption

Table 5-4 provides the value of domestic consumption of wet corn milled products from 1985 to 1991. The value of domestic consumption is calculated as the value of U.S. shipments plus the value of imports, minus the value of exports. The nominal value of domestic consumption of these products rose from $3.6 billion in 1985 to $5.4 billion in 1991, reflecting an average annual nominal increase of 6.9 percent.

Table 5-4 also displays the import share of the value of U.S. consumption during the period 1985 to 1991. The share of imports rose from 1.2 percent in 1985 to 3.7 percent in 1990, before falling to 3.6 percent in 1991.

5.2.2 Foreign Consumption (Exports)

Table 5-5 provides the total value of exports from the U.S. of wet corn milling products between 1985 and 1992. U.S. value of exports rose at an average annual nominal rate of 11 percent from 1985 to 1991, to reach a level of $1.3 billion, or 20 percent, of the value of domestic shipments in 1991. In 1992, the nominal value of exports increased by another

TABLE 5-4. VALUE OF U.S. DOMESTIC CONSUMPTION OF WET CORN MILLING PRODUCTS: 1985-1991[a,155,156,157]

Year	Domestic Consumption	Import Percentage (%)
1985	3,610.3	1.2
1986	3,277.9	1.8
1987	3,583.6	1.6
1988	4,000.9	1.4
1989	5,038.0	3.7
1990	5,342.4	3.7
1991	5,379.7	3.6

[a] The value of domestic consumption, or apparent U.S. consumption, is defined as the value of U.S. shipments minus the value of exports plus the value of imports. Values are in units of $\$10^6$ reflecting current, or nominal, U.S. dollars.

TABLE 5-5. VALUE OF U.S. EXPORTS OF WET CORN MILLING PRODUCTS, 1985-1992[158]

Year	Value ($\$10^6$)
1985	692.7
1986	910.3
1987	919.7
1988	1,053.9
1989	996.8
1990	1,141.2
1991	1,297.4
1992	1,374.6

6 percent to reach a level of $1.4 billion. In 1992, the largest export market for these products was the Netherlands, which had 23.7 percent of the value of the exports. Other large export markets include Spain (9.4 percent), Portugal (7.2 percent), Canada (7.2 percent), Ireland (6.3 percent), United Kingdom (5.7 percent), Mexico (5.5 percent), and Germany (5.3 percent).[159] NAFTA may have a significant

impact on exports of wet corn milled products to Mexico, because the Mexican market will be open to U.S. corn products.[160]

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