Chapter 3

Bask Grain Processing Industries

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Basic Grain Processing Industries

Wheat, corn, and soybeans can be used in a variety of ways. They can be used directly in food for human consumption, as in the case of wheat flour and soybean oil. Products from these grains can also be mixed with other ingredients, as is the case with corn starch and corn sugars, to produce a multitude of products for human consumption. Wheat and corn are fed directly to animals or mixed with other ingredients to produce balanced diets. Meal produced during soybean oil extraction is used as a feed supplement to increase the protein content of mixed feed. Byproducts from the various processes, such as millfeed produced from wheat milling and steep-water concentrates from corn wet milling, are used by the feed industry or for industrial use. In addition, new uses for these grains are constantly being developed–for example, ethanol and biodegradable plastics produced from corn. Therefore, the physical and intrinsic characteristics required of each grain vary; more important, they must be assessed in terms of their various commercial uses.

The basic uses for wheat, corn, and soybeans in the United States are very similar to those in countries that import these grains. The basic processes used to produce wheat flour, corn starch, soybean oil, and so on are similar everywhere. Yet, differences in processing technologies exist, as do cultural preferences for certain types of products. The specific physical and intrinsic attributes required of finished products for U.S. consumption may therefore differ from those required for a specific product in an importing country, even though the basic processing technology is similar.

When identifying the basic sanitary, physical, and intrinsic requirements for wheat, corn, and soybeans, it is important that the technology involved with producing the intermediate product and the quality required of the finished product be understood. This chapter thus provides basic information on grain processing industries and technologies.

GRAIN PROCESSING INDUSTRIES

Three basic industries–milling (wheat and corn), feed manufacturing, and soybean processing—process wheat, corn, and soybeans.

Milling Industries

Milling is a process by which kernel components are separated physically or chemically. Each milling process yields products indicative of the grain being milled. Wheat is milled to produce various types of flour. In the case of corn, dry or wet processes are used, and each results in different products and byproducts.

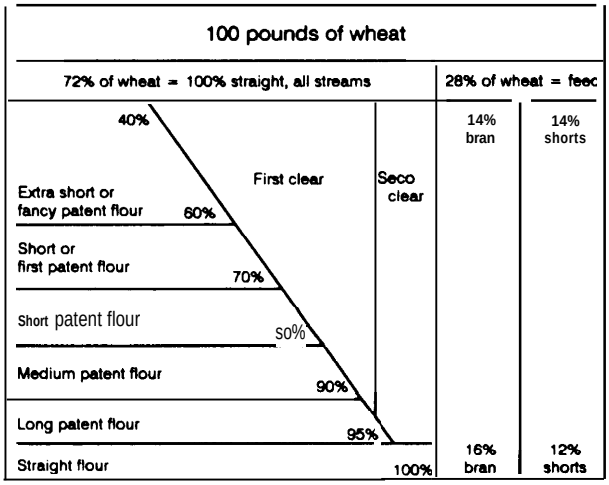
The many products of milling can be used directly as food or as ingredients in another type of food product. Specialty uses of milling products have also been developed, along with uses for the various byproducts. Thus each milling process entails almost complete utilization of all the grain.

Wheat Milling

Wheat is milled to remove the bran and germ and reduce the wheat kernel to flour to be used in various baked and nonbaked goods. Other products of the process, e.g., vital gluten, can supplement other edible products. Millfeed, the material remaining after all the usable flour is extracted, is used by the feed industry either directly or as a feed supplement.

In general, 100 pounds of wheat will produce 72 pounds of flour. The remaining 28 pounds is classified as millfeed (figure 3-1). In large flour mills, 30 or more flour streams of varying com-

Figure 3-1. - Flour Grades Obtained In the Process of Milling



SOURCE: Wheat Flour Institute, "From Wheat to Flour," revised ed., Washington, DC, 1981

position and purity may be collected, grouped, and merchandised. Combining all the streams results in a straight grade flour. The more highly refined flour streams are taken off separately and sold as patent grade flours. The remaining streams contain more bran and germ and are considered clear flour. Raising the proportion of this that is included in the patent flour lowers the quality of the remaining clear flour (8).

Flour is used in a variety of U.S. products. Fancy patent flour from soft wheats is used in cake products. In the case of hard wheats, short patent is used in premium breads, standard patent in featured breads, medium and long patent and straight in bread and rolls, and high gluten flour in hearth breads and Kaiser rolls. Flour types and grades produced in non-U.S. mills vary by mill and by the type of flour product.

The Association of American Feed Control Officials has defined eight different types of millfeeds: wheat bran, wheat feed flour, wheat germ meal, wheat mill run, wheat middlings, wheat shorts, wheat red dog, and defatted wheat germ meal (9). These products are used to feed cattle, poultry, and other small animals as part of a formulated ration.

In 1988, a total of 211 flour mills and 18 Durum mills were operating in the United States (5). The basic flour types produced and the daily production capacities from these mills are hard wheat flour (843,606 cwt), soft wheat flour (247,931 cwt), whole wheat flour (40,205 cwt), and Durum flour (96,540 cwt). Table 3-1 provides a breakdown of the 211 hard, soft, and whole wheat flour mills by size and capacity. Twenty-four percent of mills in the United States produce 84 percent of all flour.

Dry Milling Corn

The dry milling process requires the miller to remove the corn hull and germ without reducing the endosperm. The dry milling and alkaline cooking industries processed about 161 million bushels of corn in 1986. Total corn usage has ranged from a low of 154 million bushels in 1975 to a high of 170 million bushels in 1982 (table 3-2).

This process produces flaking grits, meals, flours, oil, and other products. Low-fat flaking grits are the highest valued grit product and are used primarily in breakfast foods. General food use accounted for 1,125 million pounds of dry milling product in 1977, with breakfast cereals using the most (table 3-3).

Table 3-4 shows the yield of primary and alternate products produced by dry milling. Breakfast cereal is produced from large flaking grits. Coarse and regular grits **are** used by the brewing industry, while corn meal is made from material too small to make grits. Corn meal and flour are made from finely ground starchy endosperm and used in various baked goods, snack foods, and mixes, but they also have in-

Table 3-1.-Active Wheat Flour Capacity by Size Group (wheat, soft wheat and whole wheat flour)

Hundredweights per day	Number of mills	Active capacity	Inactive capacity
Under 200	21	2,371	—
200-399	22	6,415	—
400-999	17	10,330	—
1,000-4,999	61	168,670	—
5,000-9,999	48	317,200	–
10,000 & over	42	615,750	–
Total	211	1,120,736	—

SOURCE: *Milling and Baking News,* "1988 Milling Directory/Buyers Guide" (Merriam, KS: Sosland Publishing Co., 1988).

Table 3-2.—Amount of Corn Used Annually for Dry Milled and Alkaline Cooked Products in the United States

Year[a]	Dry-milled and alkaline cooked products (million bushels)	Total U.S. corn production (million bushels)	Dry-mill share (in percent)
1975 . . .	154	5,841	2.6
1976 . . .	155	6,289	2.5
1977 . . .	158	6,505	2.4
1978 . . .	155	7,268	2.1
1979 . . .	158	7,928	**2.0**
1980 . . .	**160**	**6,639**	**2.4**
1981 . . .	**162**	**8,119**	**2.0**
1982 . . .	**170**	**8,235**	**2.1**
1983 . . .	**164**	**4,175**	**3.9**
1984 . . .	**160**	**7,674**	**2.1**
1985 . . .	**161**	**8,865**	**1.8**
1986 . . .	**161**	**8,253**	**2.0**

[a]Year begins Sept. 1,

SOURCE: U.S Department of Agriculture (USDA), Economic Research Service, "Feed Situation and Outlook Report," FdS-302, Washington, DC, May 1987; USDA, *Agricultural Statistics, 1986* (Washington, DC: U S Government Printing Office, 1986).

Table 3-3.—Estimated Dry Milling Product Quantities Classified According to End Use, 1977

Use	Quantity (million lbs)
Brewing ... , ...	1,850
Food, general	1,125
Breakfast cereals 800	
Mixes (pancake, cookie, muffins, etc.) . . . 100	
Baking 50	
Snack foods. 100	
Breadings, batters, baby foods, etc. 75	
Fortified Public Law 480 foods	485
Nonfood	530
Gypsum board 100	
Particle, fiber board, plywood. 40	
Pharmaceuticals, fermentation. 200	
Foundry binders 90	
Charcoal binders. 75	
Other (paper, corrugating, oil well drilling fluids 25	
Animal feed	2,200
Total	6,190

SOURCE: R.J. Alexander, "Corn Dry Milling" Processes, Products and Applications," *Corn Chemistry and Technology,* S.A. Watson and P.E. Ramstad (eds) (St. Paul, MN American Association of Cereal Chemists, 1987),

dustrial uses. Corn oil obtained from dry milling is used in food products and in industrial uses. Hominy feed consists of all the byproducts such as hull fractions, inseparable mixtures of hull, endosperm, germ, germ meal, and corn cleanings. It is the single largest product sold by dry millers (6).

The number of corn dry mills in the United States has dropped from 152 in 1965 to only 68 in 1986. Of these, 55 had daily capacities of under 12,000 bushels, 8 could handle between 12,000 and 36,000 bushels, and 5 could process 36,000 bushels a day (4). The majority of corn dry mills are located in the midwestern and southeastern part of the United States. The 13 largest mills have a combined estimated daily capacity of 445,000" bushels, about **69** percent of the total corn usage for dry milling,

Table 3-4.—Typical Proportion of Corn Products From a Degerming Dry Mill (percent)

Product	Yield
Flaking grits	12
Coarse grits	15
Regular grits.	23
Coarse meal	3
Dusted meal	3
Flour	4
Oil	1
Hominy feed	35
Shrinkage	4

SOURCE: O.L. Brekke, "Corn Dry Milling Industry," *Corn: Culture, Processing, Products,* G.E. Inglett (cd.) (West port, CT: AVI Publishing Co , Inc , 1970).

Wet Milling Corn

The amount of corn processed by the wet milling industry has increased from 155 million bushels in 1960 to **645** million bushels in 1985, accounting for some 12 percent of domestic corn use **(3).**

Wet milling corn produces starch, oil, and sweeteners (table 3-5). Corn starch is used in food and nonfood products by the brewing and baking industries; in the production of chemicals, drugs, and pharmaceuticals; by the paper industries; and in the production of ethanol. Sweeteners are used by the baking, beverage, canning, and feed industries. Byproducts from the wet milling process, including the water used to steep the corn prior to milling, are used by the feed industry.

Feed Manufacturing

Livestock and poultry consumed 85 percent of domestic corn during the 1980s. Over the past 5 years, swine consumed 34 percent of the corn; beef, **22.3** percent; dairy, 18.2 percent; poultry, 21.3 percent; and other classes of animals, 5.1 percent. Wheat use in feed, on the other hand, is significantly lower. In 1985 wheat

Table 3-5.—Shipment of Products of the Corn Refining Industry in the United States, 1983-85 (thousand pounds)

Product	1983	1984	1985
Starch products			
(includes corn starch, modified starch, and dextrin)	4,018,905	4,182,866	4,225,171
Refinery products			
(includes glucose syrup, high-fructose corn syrup dextrose, corn syrup solids, and maltodextrins)	16,005,529	17,921,126	20,341,535
High-fructose corn syrup	9,707,041	11,502,324	13,920,406
Other products:			
Corn oil crude	72,612	116,142	164,382
Corn oil refined	399,919	407,456	382,234
Corn gluten feed	7,391,069	8,739,730	8,811,476
Corn gluten meal			
41% protein	19,115	20,272	18,503
60% protein	1,383,129	1,635,228	1,609,112
Corn oil meal	28,728	29,465	48,585
Steepwater	211,937	300,770	282,333
Hydrol	208,807	216,558	228,742
Ethanol (thousand gallons, 100%)	325,000	375,000	425,000

SOURCE: Stanley A. Watson and Paul E. Ramstad (eds), Corn: *Chemistry and Technology* (St Paul, MN: American Association of Cereal Chemists, 1987)

and rye combined accounted for 16.9 percent of total feed grain consumption by livestock.

Wheat and corn can be ground and fed to animals or ground and mixed with other ingredients to produce a balanced diet for a particular species. Each animal species has specific dietary requirements; when corn and wheat are used, ingredients must be added to overcome certain deficiencies in these grains (7). Feed concentrates, byproducts from wheat and corn milling processes, soybean meal, animal protein, and other byproducts are mixed with other feeds or fed directly to livestock.

The modern feed manufacturer blends ingredients using a computer program designed to select the lowest priced ingredient that is a significant source of the desired nutrients. For most nutrients, published average values are used and any deviation from these values will render the feed deficient and affect animal performance.

Soybean Processing

Soybean processing separates oil by solvent-extraction from the nonoil portion of the bean. The soybeans are cleaned prior to being cracked, hulls are removed, and the cracked dehulled pieces are heated and rolled into flakes. Crude oil is then extracted from the flakes. After extracting the oil, the flakes can be toasted and ground into meal products.

The two major products from soybean processing are high-protein meal and oil. Food uses of oil include shortening, margarine, and cooking and salad oils; nonfood uses include paint, varnish, resins, and plastics. Soybean meal, which is the largest product produced from this process, is used by the feed industry as a protein supplement unmanufactured feeds.

BASIC PROCESSES USED TO PRODUCE GRAIN PRODUCTS

To fully understand the quality requirements of each industry, a general knowledge of the basic technologies used to process the various grains is important. Since such technologies are similar worldwide, general descriptions are provided in this section. Modifications of and improvements to these will vary by individual company within the United States and among countries around the world.

Dry Milling Wheat and Corn

The basic process used to mill wheat and corn involves cleaning, conditioning, grinding, and

sifting. In the case of dry milling corn, degerming also takes place.

Samples are taken from each incoming shipment of wheat and corn and tested. The characteristics of the wheat determine how it will be handled, since different types are usually blended before milling to meet various flour requirements. Figure 3-2 provides a simplified wheat milling flowchart, and figure 3-3 is a dry corn milling flowchart. The sequence, number, and complexity of different operations will vary somewhat between mills.

The first step in milling involves cleaning the grain to remove weed seeds, other grains, and material such as sticks, stones, dirt, and other debris. This involves the use of scalpers to remove large material, aspiration to remove fine material, and screens. Magnetic separators can also be used to remove any metal from the grain.

Disc separators are used to catch individual kernels and reject larger or smaller ones, thus creating a uniform kernel size for milling. In the case of wheat, the grain passes through a scourer that throws the kernels against a surface, buffing each one and breaking off the beard. Air currents remove the dust and 1oosened particles of the bran coat.

Wheat and corn are conditioned prior to milling. This process, called tempering, involves adding moisture. Tempering is done to aid in removing the bran from the endosperm during grinding, since the outer bran layers are brittle and must be toughened. Wheat is held in tempering bins for usually 8 to 24 hours, depending on the type of wheat. The percent of moisture added, the amount of soaking time, and the temperature differ for soft, medium, and hard wheats. Corn is injected with steam or sprayed with warm water in a tempering chamber. This may occur in one to three stages before the corn finally reaches 18- to 24-percent moisture. The moist corn is then held in the tempering bin for up to 6 hours, Corn moisture, holding time, and the temperature during conditioning are critical for obtaining correct moisture gradients in the kernel.

Wheat Milling Process

After tempering, wheat is moved to an entoleter, which consists of discs revolving at high speed that crack unsound wheat kernels and separate them from the grain stream. Wheat flows from the entoleter to the grinding bin, where it is held and metered into the mill itself.

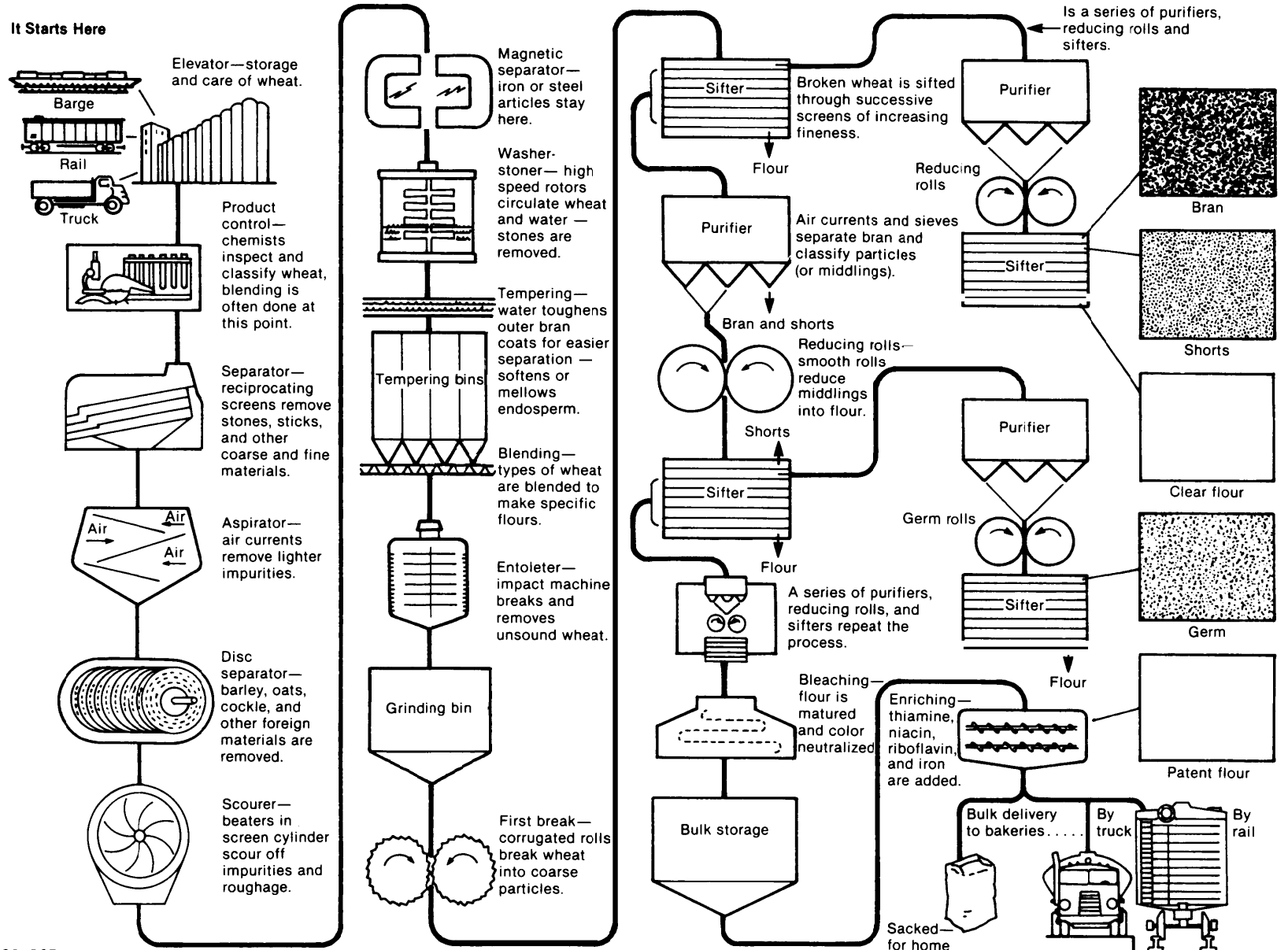
Corrugated rolls are used to break the wheat into coarse particles. The initial set of these (referred to as the “first break” rolls) break the kernel into very coarse pieces. These rolls can be adjusted for spacing as well as speed to achieve the exact milling surface desired, depending on the type of wheat and its condition. As many as four to six break rolls, with successively smoother surfaces, can be used to further reduce the kernel into flour.

The coarse pieces of wheat and bran produced from the first break are sifted over a series of bolting cloths or screens to separate larger from smaller particles. Sifters consist of as many as **27** frames of bolting cloth with meshes that grow progressively smaller from top to bottom. Larger material is shaken off at each step and the finer flour sifts to the bottom. The coarse pieces are sized and carried to the second set of break rolls. The second break rolls are spaced closer together, producing a finer material, This material is then sent to a sifter and the process repeats itself.

Flour is obtained from each break roll and sifting operation. However, fragments of endosperm, bran, and germs called middlings remain after each sifting. These are sent to purifiers, where air removes bran particles and bolting cloth is again used to separate coarser fractions by size and quality. The coarse material is then sent to reduction rolls and again sifted (8).

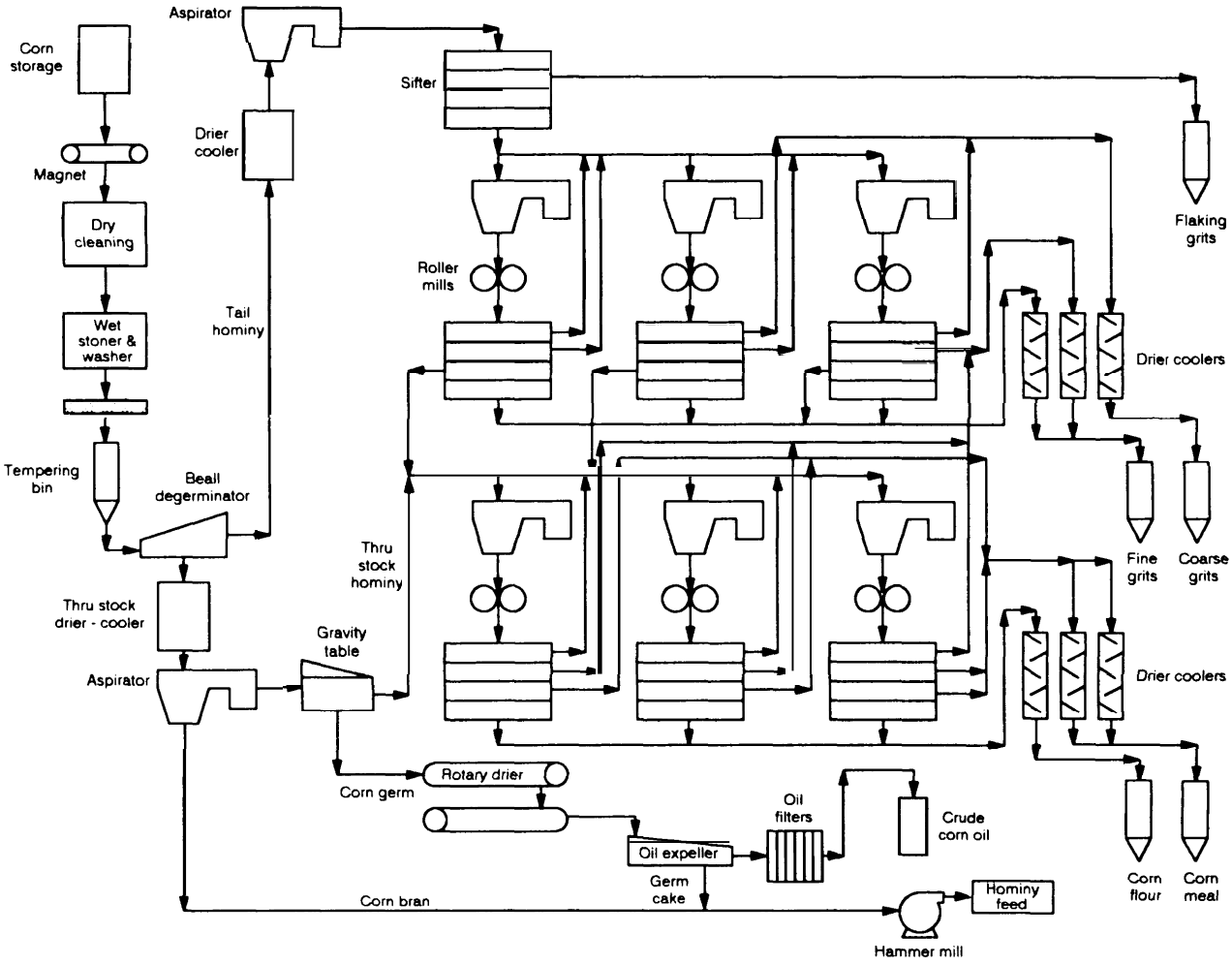
The process of grinding, sifting, purifying, and reducing is repeated many times until the maximum amount of flour is obtained. Each process results in a separate flour stream. For example, flour is produced from each break and middlings reduction (first, second, third, etc.).

Figure 3-2.—How Flour is Milled (a simplified diagram)



SOURCE Wheat Flour Institute, "From Wheat to Flour," revised ed., Washington, DC, 1981.

Figure 3-3. – Production Flow Chart for a Typical Corn Tempering-Degerming System



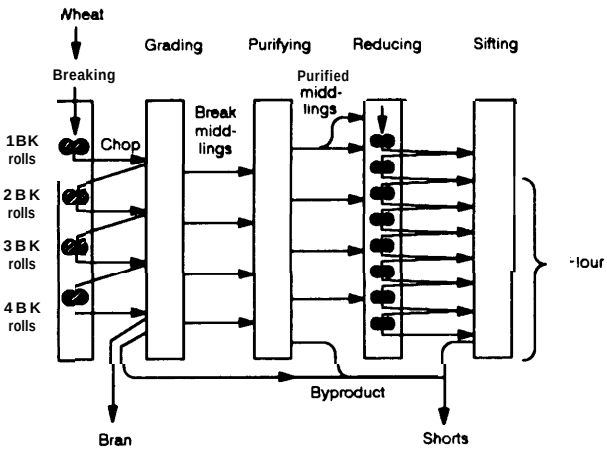
SOURCE: Richard J Alexander, "Corn Dry Milling: Processes, Products, and Applications" m Corn *Chemistry and* Technology (St Paul, MN: American Association of Cereal Chemists, 1987)

Figure 3-4 shows an example of a milling process with four breaks. In this case, 12 different flours are produced–four from each break and eight from each reduction (2).

Flour from each point in the process has different characteristics and baking properties and can be combined in many different ways. Flour from the first few middlings separations is the most highly refined. After each additional process the flour contains more bran and germ. In large mills, there can be 30 or more separate streams.

Some mills, in addition to producing flour, produce vital wheat gluten, essentially a powdery product containing 75 to 80 percent protein with a bland flavor that is able to absorb water 2.5 times its dry weight. This product is relatively simple to produce in that flour is washed with water and then dried. Vital wheat gluten is used as a supplemental ingredient in

Figure 3-4.– Block Flow Sheet



SOURCE: Canadian International Grams institute, "Gram& Oil seeds, Handling, Marketing, Processing- 3rd ad, rewed, Winnipeg, MB, Canada, 1982

breadmaking especially by commercial bakers. It is added to a dough that requires additional protein to develop properly.

Corn Dry Milling Process

Determination is the process by which the corn kernel is broken apart into endosperm, germ, and pericarps (6). Although a few companies use impact mills or granulators, about 90 percent of the dry mills producing flaking grits use the Bean degermer almost exclusively. This is a cone-shaped mill with rows of small conical protrusions that rotate within an outer conical surface that also has protrusions. This process causes corn-on-corn rubbing to remove germs, pericarps, fines, and a few small grits called through-stock. Tail-stock consists primarily of grits that are free of attached germs and pericarps.

After degerming, through-stock is normally wetter than the tail-stock and must be dried. This is accomplished by rotary steam-tube dryers that quickly heat the products to 140 to 160 'F. After drying, the stock is cooled to 90 to 100 'F.

Tail-stocks consisting of large pieces of endosperm are aspirated to remove loose pericarps. The material is then sieved. Material passing through a 3.5 mesh/inch sieve but not a 5 mesh/inch sieve is considered large flaking grits. Material that will not pass through the 3,5 mesh/inch sieve is recycled for retempering and degermination. Whatever passed through the 5 mesh/inch sieve is then sieved using **6** and 10 mesh/inch sieves. Anything passing through the **6** but not the 10 mesh/inch sieve is considered brewers and coarse grits. If there are any attached germs or pericarps, the material will be roller-milled.

Several sets of corrugated rollers are used in a manner similar to that described in the wheat milling section. Smaller numbers of corrugations are used for the first break to produce coarse grits. Second and third break rolls use more corrugations, resulting in more finely ground products. After grinding, the material is sifted and then aspirated to remove free pericarps.

Through-stock containing germs is aspirated to remove loose pericarps and then sent to gravity tables for separation. The germ fractions can then be dried and sent to an oil expeller or solvent oil extraction process to recover the crude oil. The germ meal remaining after the crude oil has been extracted is used in hominy feed. The material other than the germ separated with the gravity table is recycled back to the first break rolls to be processed with the tail-stock.

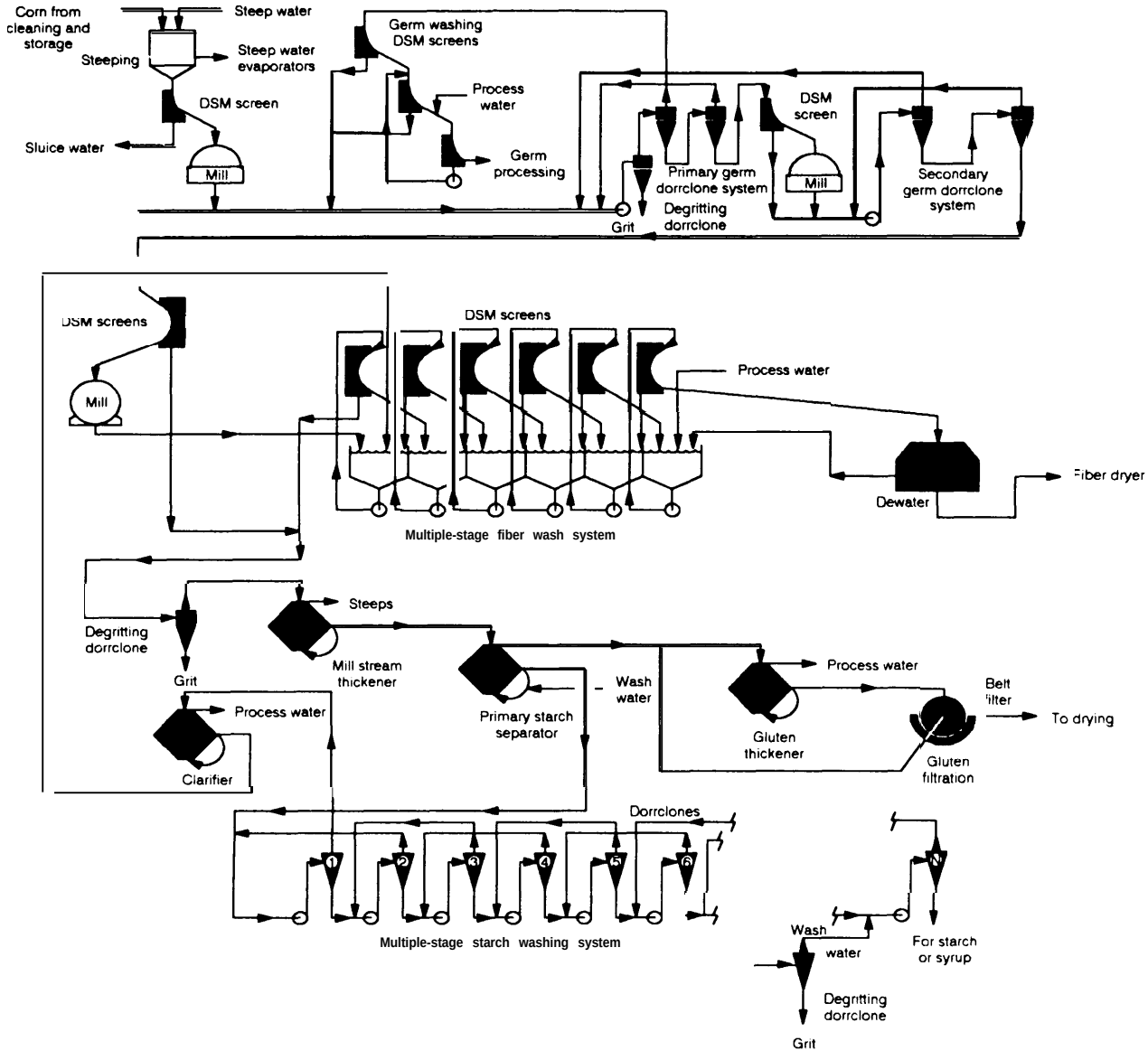
Wet Milling Corn

Corn is first cleaned by screening and aspiration to remove dust, chaff, cobs, stones, and so on, similar to the processes described for dry milling (figure 3-5). After cleaning, the corn is moved on to the refining process (3).

As in dry milling, corn must be tempered. This is accomplished by placing the grain in steeping tanks and adding water containing sulfurous acid that has been heated to *125* 'F. Corn is held in steeping tanks for 22 to **50** hours. During this time the water is recirculated and reheated.

Water is used to transport the corn from the steeping tanks to holding bins. It is screened off prior to the wet corn being placed in the

Figure 3-5. - Wet-Milling Process Flow Diagram (showing equipment arrangement for the separation of the major components --steepwater, germ, fiber, gluten, and cornstarch)

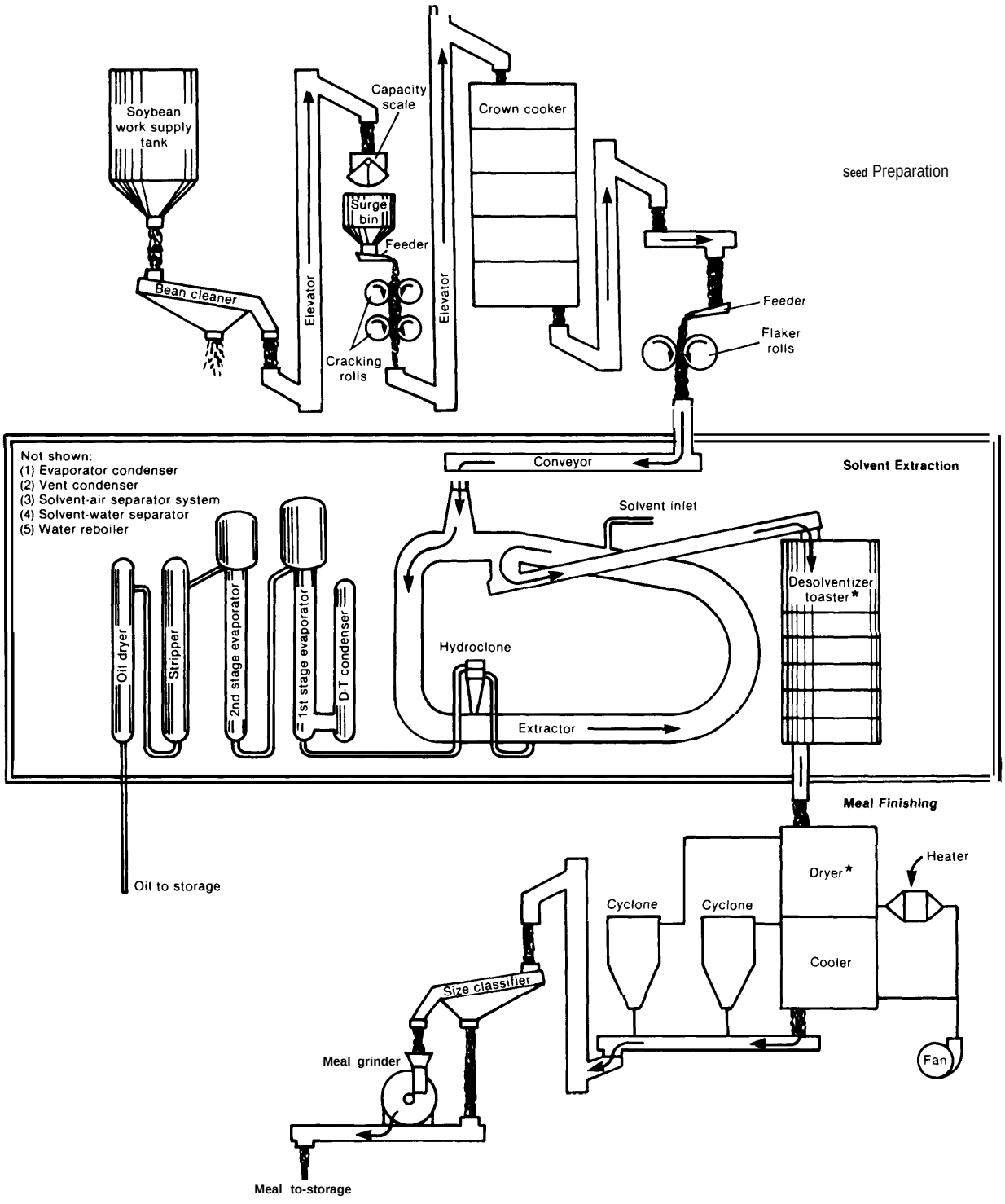


SOURCE: James B Mag, "Wet Milling: Process and Products" in Corn *Chemistry* and *Technology* (St Paul, MN: American Association of Cereal Chemists, 1987)

bin, From the holding bin the corn moves into grinders that break up the kernel. Water is again added and the material is transported to flotation tanks, where the germ floats to the top. The germs are recovered, washed, and screened. The recovered germs are then dried and further processed to remove the oil,

The material remaining in the flotation tanks is screened to separate fiber from starch and gluten. About 30 to 40 percent of all the starch is separated at this stage. The remaining material is further processed, washed, and screened to separate more starch and gluten. Starch is purified by washing and can be dried, treated

Figure 3-6.—Typical Soybean Extraction Process Flow



*Alternative - A crown desolventizer toaster dryer cooler may be furnished in lieu of desolventizer toaster and dryer cooler

SOURCE' Crown Iron Works, 1987.

with chemicals to modify the starch to meet various requirements, and then processed for its various uses. The gluten is also washed and then dried, forming corn gluten meal.

Corn steepwater is processed to remove the corn solubles by evaporation. The corn solubles removed during this process are used directly by the feed industry or in the production of corn gluten feed. The corn germ meal remaining after the oil is extracted is also used in the feed industry,

Soybean Processing

Soybeans are first cleaned to remove dust, weed seeds, stones, and so on. Then they are cracked by means of corrugated rolls and moved to the dehuller (l). The hulls are drawn off between the first and second cracking rolls by dehulling equipment, using air suction (figure 3-6). Screens remove any portions of the seeds that have been removed with the hulls. Seed hulls are transported to a grinder, where they can be kept separate or recombined with the extracted meal.

The moisture content of the soybeans being processed must be between 9.5 and 10 percent. The cracked soybeans are first heated to about 140 'F and then proceed through a series of rollers, where they are flaked, Following a cooling period, the flakes are exposed to continuous extraction with hexane to reduce the oil remaining in the soybean flakes to 0.5 percent or less. The extracted flakes are then transported to dryers and held at 208 'F for approximately 10 minutes to drive off any residual hexane. From the dryer, the flakes are moved to a toaster for a 90-minute toasting at 220 'F. Then the flakes are cooled and moved to the grinder for reduction into the ultimate soybean-meal-sized product.

Crude soybean oil extracted from the meal contains impurities that can affect its quality and must be removed. The various processes used to remove objectionable impurities are designed to minimize the effect on the finished oil and the loss of oil.

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