STARCH is one of the most important industrial commodities derived from agricultural crops. Just before the war the annual domestic production was nearly 4 billion pounds. More than 98 percent of it was produced from corn, and only about 1 percent from wheat. The almost complete reliance on corn as a raw material has been due to the normally higher price of wheat as compared with corn. Another factor is the good return of oil as a byproduct from the milling of corn for starch.

Shortly after we entered the war, when large quantities of corn were being diverted to livestock production and industrial alcohol, it became apparent that a starch shortage would ensue. Because of the scarcity of cane and beet sugar, it was also evident that the production of corn sugar and sirup would be inadequate to meet the increasing demand for sweetening agents.

Accordingly, investigations were undertaken at the Northern Regional Research Laboratory in Peoria, Ill., for working out new processes whereby starch could be produced from wheat and wheat flour, both of which were plentiful then. There were two necessary restrictions: The processes should require a minimum of equipment for new installation, and, if possible, they should be adaptable to existing available plants. As a result of the work, two processes were developed for producing wheat starch for conversion into sirup, sugar, or industrial alcohol.

The use of wheat flour as a raw material for the production of starch had several advantages. The ample flour-milling capacity available permitted the use of existing equipment to remove more than 25 percent of the starch-poor constituents in the form of bran and other feed products. This initial purification saved the installation expense of hard-to-get new equipment in starch-processing plants. A rather ample supply of clear
grade flour also was available, a byproduct of milling wheat for other products. The two major constituents of wheat flour are starch and gluten. Accepting wheat flour as a raw material, the problem was to develop a process that would give a separation of the two in relatively pure form.

**Starch and Gluten From Wheat Flour**

A successful process was developed at the Northern Regional Research Laboratory that required no extensive installation of equipment. It was called the batter process because it involved mixing flour and water to give an elastic but free-flowing batter. The basic principle involved is readily understood by anyone who has chewed wheat grain. Slow mastication leaves in the mouth a gummy, chewy mass of gluten—a farm-made chewing gum of years past.

One part of flour and about one and one-fourth parts of warm water (depending on the type of flour and gluten content) are mixed. The batter, after thorough mixing for 10 to 20 minutes, should be quite smooth and free of lumps. Compared with the usual pancake batter, this is a stiff batter because it contains about one-third less water.

In the next step the batter is mechanically broken up in the presence of about 2¼ parts of cold water. The starch is quickly and almost completely washed out of the batter, and the gluten is left suspended in the slurry of starch and water in the form of lumps or curds. The gluten is separated by allowing the whole slurry to be drained or pumped onto a vibrating screen that has 60 to 80 meshes to the inch. The lumps of gluten collect into larger masses on the screen and fall off the end. The starch and the water that contains other flour solubles pass through the screen. The suspension of starch in water is usually called starch milk.

This starch milk, containing some fine fiber, soluble protein, and a small amount of fine gluten particles, may be used directly for fermentation into industrial alcohol. Without further purification, the starch milk may also be converted into glucose sirup or dextrose by being cooked in the presence of hydrochloric acid. The sirup and sugar produced by the use of the starch milk as it comes through the screen will not be of the highest quality. Unless extra-large quantities of decolorizing agents are used, the sirup and sugar will be slightly dark in color. Also, the protein contained in the sirup will cause it to become cloudy on long standing. To make the best refined sirup and sugar, the starch has to be purified by removing the protein and impurities in the starch milk.

Prime-quality starch is obtained by allowing the starch to settle out on starch tables. In large-scale practice, the tables are long troughs about 2 feet wide and 90 to 120 feet long. They are set on an inclined base, dropping about 5 inches from the head to the tail end. The settled starch is flushed off the tables by strong streams of water, collected in tanks, and
finally filtered. Besides being used to prepare refined sirup and dextrose sugar, the purified starch may be dried and used for numerous other purposes. Sirup may also be made by the action of malt on either the crude-starch milk or the purified starch. The resulting product is either crude or refined malt sirup, depending on the purity of the raw material.

The crude gluten passing over the end of the mechanical screen contains 72 to 75 percent protein and about 20 percent starch on the dry basis. When this first crude gluten is washed again in fresh water, the protein content is easily raised to about 85 percent, and the starch content is reduced to about 10 percent on a moisture-free basis. Gluten containing up to 95 percent protein can be prepared by repeated washings in water.

When it is dried at a low temperature, the gluten is called “undevitalized,” or natural-gum gluten. This dried product, when water is added, reverts to the natural gumlike gluten and is, therefore, suitable for fortifying low-protein flour for bread making or use in other food products. Gluten dried at temperatures substantially higher than 112° F. yields a product that does not become gummy upon the addition of water. Such a product is suitable for raising the protein content of foods in which the properties of an “undevitalized” gluten are not needed or wanted. Devitalized gluten is also useful for making high-protein stock feed and industrial products.

The chief industrial use of wheat gluten now is as a raw material for making monosodium glutamate. Heating the wheat gluten with strong hydrochloric acid breaks down the proteins into amino acids. Glutamic acid is recovered from the mixture of amino acids by crystallization and then converted into the monosodium salt, a product that gives a meatlike flavor to foods.

The batter process can be applied to flours from practically all types of wheat except those whose protein content is less than 7 to 8 percent. Its advantages lie in the speed and simplicity of operation, the fact that no chemicals are required, and the practically complete recovery of the wheat gluten in an undevitalized state. The process is especially valuable for making non-highly-refined glucose sirup because there is no loss of dry substance. Typical yields from 100 pounds of dry wheat flour containing 12 percent protein are 100 to 104 pounds of glucose sirup and 12 pounds of dry gluten having a protein content of 80 to 85 percent.

Many commercial organizations have tested the batter process on a pilot-plant scale; several have installed equipment to produce sweetening agents, industrial alcohol, and wheat gluten. Recent annual-production rates have been: Dextrose sugar and glucose sirup, 150 to 200 million pounds; devitalized wheat gluten, 20 to 30 million pounds; and several million gallons of industrial alcohol. The production varies because some producers depend upon alternate sources of raw material for starch.
The process developed at the laboratory for producing wheat starch from the whole wheat kernel is analogous to that used in the wet milling of corn. Indeed, with only minor alterations in equipment and operating procedure the process can be conducted in corn wet-milling plants. The starch obtained from sound wheat is of excellent quality. It may be converted to sirups and sugar by the same methods used in the conversion of cornstarch. Good starch can be extracted from damaged wheat that otherwise is unsuitable for use as food or feed.

The wheat is steeped in water that contains sulfur dioxide. This steep water, maintained at a temperature of 100° F., is circulated over the wheat for about 15 hours. Corn, on the other hand, is steeped at a temperature of 130° F. for about 40 hours. The lower temperature for wheat is necessary in order to avoid any gelatinization of the starch, but even at the low temperature the grain is softened sufficiently in a much shorter time. At the end of the steeping period the steep water is allowed to drain from the grain. It contains soluble materials that have been extracted from the wheat and is concentrated in a multiple-effect evaporator. The resulting sirup is used later in preparing a byproduct cattle feed.

The steeped wheat is ground in a buhrstone mill with water, which serves as a lubricant. In the pilot plant the slurry from the buhrstone mill is screened over a 26-mesh stainless-steel wire gauze to remove coarse fibers; the material that passes through is screened over No. 17 standard silk bolting cloth to remove the fine fibers. The fiber fractions are washed twice in order to remove additional starch. The washings are combined with the suspension of starch and gluten that passed through the screens, and the combined liquor is known as mill starch. Both fiber fractions are utilized in the preparation of feed. As the process has been conducted in two corn wet-milling plants, the ground wheat has been passed through the regular mill-house equipment for the production of coarse fibers, fine fibers, and mill starch. The coarse fibers are squeezed in a mechanical press to reduce their moisture content to 74 percent, and the slurry of fine fibers is filtered through a filter press to give a cake containing 72 percent water.

The mill starch is a suspension of starch and gluten in water. The starch is heavier than the gluten and to separate them the slurry is allowed to flow over starch tables. The pitch of the table and the rate at which the mill starch flows over it are such that the bulk of the starch settles out and practically all of the gluten is carried over the end of the table in suspension. The starch is flushed from the table with water, and the resulting slurry is screened through No. 17 standard silk bolting cloth to remove small quantities of fiber and foreign material. The slurry is then filtered, and the starch is washed two or three times with fresh water. If the starch is to be marketed as such, it is dried; but this is unnecessary if it is to be converted into sirup or sugar.
The gluten slurry that flows over the end of the table is allowed to settle and the clear supernatant liquid is drawn off. Part of the clear liquor is used in preparing steep water for processing fresh grain, and the remainder is used as process water for washing the fiber fractions. The thick gluten slurry is centrifuged to recover the suspended gluten for use in preparing feed; and the clear liquor is used as process water. The sirup produced by evaporating the steep water is combined with the fiber fractions and the gluten, and the mixture is dried for the production of a byproduct feed of excellent quality.

In this process no attempt is made to recover the wheat germ. In the wet milling of corn the steeped grain is degerminated and the germ is processed for corn oil. Wheat contains less than half as much oil as does corn and a much smaller proportion of the wheat oil is concentrated in the germ. The small size of the wheat germ makes its separation from the ground grain very difficult. For these reasons it does not seem practical to recover the wheat germ. During the milling operations the bulk of the wheat oil stays with the gluten and some of it remains in the fibers, but fortunately it does not contaminate the starch. Except for minor losses, all of the oil appears in the byproduct feed.

The starch produced by this process is of excellent quality; on the average it contains 0.25 percent protein, whereas cornstarch contains 0.35 percent. From a 60-pound bushel of soft winter wheat containing 60 percent starch, the yield of commercial starch, containing 12 percent moisture, amounts to 33 pounds. In the wet milling of corn, the yield of commercial starch averages 34 pounds per 56-pound bushel. In the wet milling of wheat the yield of commercial feed, containing 12 percent moisture, is approximately 22 pounds per 60-pound bushel; that in the commercial wet milling of corn averages 16.7 pounds per 56-pound bushel. This type of feed has sold for about 2 cents a pound.

In the Corn Belt, where the price of wheat exceeds that of corn, the wet milling of wheat has been conducted only during periods of acute shortages of cash corn. In the summer of 1945 a corn wet-milling company processed approximately 2 million bushels of wheat for the production of glucose sirup. Careful study of both processes revealed that only minor changes are required in plant equipment and operating methods in order to utilize wheat in a corn wet-milling plant. The objection to the change arises from the fact that the capacity of the plant is greatly reduced. In order to obtain wheat starch of high quality it is necessary that the density of the mill starch to the tables should not be greater than 6° Baumé. The volumetric rate of feed to a given table is the same in both instances; hence the table capacity in a corn wet-milling plant will be reduced by approximately 50 percent. Because the quantity of wheat that can be processed in such a plant is limited by the tables available, the remaining equipment will not be used to full capacity. If a plant
were being designed specifically for the utilization of wheat the condition obviously would not obtain.

Both processes that have been described contributed materially to our war effort, and undoubtedly their use will continue in suitably located plants. The batter process appears to be ideally adaptable as an adjunct to beet-sugar factories. The wet-milling process will probably continue to be used in areas where the price of wheat is normally less than that of corn.

Advantageous use of the batter process can be made in beet-sugar factories and sugar refineries to produce starch for conversion into sweetening agents. At such sites equipment is available for processing the saccharified starch liquor into sirup or sugar. Because beet-sugar factories operate on a seasonal basis, the production of sweetening agents from starch could be carried out during the off season. Such a scheme would keep the plants and labor force occupied throughout the year. Some installations of the process have been made in beet-sugar factories.

In the Pacific Northwest, where the price of soft white wheat is relatively low and, in normal times, is invariably lower than that of corn at Chicago, the wet-milling process appears to be economically feasible. For a small plant with a capacity of 10,000 bushels a day, the total cost of processing is estimated to be 23 cents a bushel. Assuming a price of $1 a bushel for soft wheat, the cost of raw material and processing amounts to $1.23. With no credit for oil, the only byproduct credit is that for feed, amounting to 44 cents a bushel. Thus the net production cost for 33 pounds of marketable starch is 79 cents or an average cost of 2.39 cents a pound. That figure probably exceeds the production cost of cornstarch, but it is much lower than the 1947 market price of wheat starch and is considerably less than the market price of cornstarch.

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