New Uses for Waxy-Cereal Starches

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Waxy starch exists in the endosperm of the grains of some varieties of corn, sorghum, rice, millet, barley, and Job's tears. The term "waxy" refers to the waxlike appearance of the endosperm of the grain when it is cut or broken; it does not indicate the presence of true wax.

In the Orient, waxy grains are called glutinous; it is because of the glue-like character of the cooked or the wetted grain, flour, or starch. Glutinous varieties of rice and also millet have been known in China for many centuries, and glutinous sorghum has been grown there for at least 300 years. Many varieties of waxy rice, millet, and sorghum are grown in China and other Eastern countries. A few waxy rices have been grown in the United States at times to supply special holiday delicacies to Oriental people living here. The chromosomes in the reproductive cells of corn occasionally undergo sudden changes and give rise to waxy grain.

It remained, however, for the Chinese to discover this new type in a crop that originated in the Americas. The existence of waxy corn (or maize) became known in 1908 when a missionary in China, the Reverend J. M. W. Farnham, sent a sample to the United States Department of Agriculture.

Amber waxy sorghum from China reached the United States about 1854, and that variety or selections from it have been grown here since that time. Its waxy character was unknown, however, until about 1933, when J. C. Stephens discovered that several other American varieties also were waxy.

From 1944 to 1947, 20,000 to 40,000 acres of waxy corn and sorghum were grown and the grain processed in the United States each year. About 32,000 acres of waxy corn and 5,000 acres of waxy sorghum were grown in 1949.

Waxy-cereal starch produces pastes with higher viscosity and less rigidity than does ordinary cornstarch. Those characteristics make it adaptable to many special industrial uses. The properties of waxy starch resemble those of tapioca starch. We are all familiar with the difference between soft tapioca pudding and stiff cornstarch pudding. Waxy and ordinary starch also differ in their molecular structure.

Waxy starch is entirely amylpectin, a type in which the molecules are arranged with many branches. Ordinary starch is a mixture of the amylpectin (71 to 72 percent) and amylose (28 to 29 percent) types. The amylose molecules are arranged in straight unbranched chains. Tapioca starch is about 80 percent amylpectin and 20 percent amylose.

One of the distinctive characters of waxy starch and grains is that they stain red when they are treated with iodine. Ordinary starch stains blue. The difference was discovered in France by A. Gris, in 1860. In 1921, F. R. Parwett, an Englishman working in India, discovered that the pollen of waxy cereals also stains red rather than blue when treated with iodine. Starch in the stems, leaves, and seed coats of waxy cereals gives a blue reaction to iodine, which indicates that the waxy type of starch is formed only in the endosperm and in the pollen. Apparently the factors of heredity in waxy
barley, and at least one waxy gene in corn, do not effect complete conversion to waxy starch, because the starch of the mature grain contains 2 to 3 percent of amylose.

The first attempt to promote industrial use of waxy grain in the United States was made by R. E. Karper, of the Texas Agricultural Experiment Station. In the early 1930's he crossed the Bataud variety of waxy sorghum, introduced from Java, with a domestic kafir variety. From that cross he developed a new waxy variety otherwise like the kafir parent. When the grain supply had been increased to about a ton, he offered it to several processors with the suggestion that it might have special uses. Karper then had visions of new types of baby foods, health foods, or desserts. But no processor could be interested in undertaking the development of products from this strange grain, and so the waxy kafir was used in a hog-feeding experiment. The hogs thrived as well as but no better than did those consuming ordinary kafir.

Interest was revived after 1936 with the discovery of the similarity between waxy starch and tapioca starch. The discovery was made at the Iowa Agricultural Experiment Station by R. M. Hixon, after separating the starch from waxy corn and sorghum supplied by the writers. In 1938, F. H. Thurber, of the Department of Agriculture, made some limited tests of starch which he had separated from waxy and non-waxy sorghums. Chemists at the Kansas and Nebraska Agricultural Experiment Stations started experiments shortly thereafter.

The war cut off our supplies of tapioca flour from the Netherlands Indies, which had furnished about 97 percent of the 300 million to 400 million pounds we imported annually. The emergency focused attention on waxy grains. Representatives of the starch industries began experimenting with the waxy starches for various uses and also with commercial methods for separating the starch from waxy grains.

For several years, work had advanced toward the development of a waxy hybrid corn similar to the non-waxy hybrid, Iowa 939. Each of the inbred lines used in producing that hybrid had been crossed with a waxy corn. Waxy progenies from the crosses were backcrossed repeatedly upon the original inbred lines until the waxy counterparts were recovered. The first test of the new waxy hybrid (Iowax 1), in 1939, indicated that it yielded only slightly less than did the ordinary hybrid, Iowa 939. Waxy kernels frequently weigh 3 to 5 percent less than nonwaxy kernels, with a corresponding reduction in yield. Unfortunately, in the fall of 1941 less than 2 bushels of Iowax 1 seed was available. Only 335 and 3,800 kernels, respectively, of the two single crosses and limited quantities of seed of the four inbred parental lines needed to produce the hybrid were on hand at that time. The seed supply was increased in large greenhouses at Beltsville, Md., in the winter of 1941-42, and in the field at Ames, Iowa, during the following summer. In 1942, 326 acres of the second-generation hybrid of Iowax 1 was grown, harvested, and processed. That was the beginning of the waxy-corn industry. The growing of such lower-yielding second-generation hybrid corn was merely a temporary expedient. By 1944, some 10,000 acres of the first-generation hybrid was grown; since 1946, about 20,000 acres of waxy corn has been grown annually. An open-pollinated variety of waxy corn developed at the Nebraska Agricultural Experiment Station was grown to some extent for a time.

Breeding operations to convert additional inbred lines of corn to the waxy condition were expanded immediately with the development of interest in the commercial production of waxy corn. Hybrids involving the additional lines were released as rapidly as they became available. As a result, there have been rapid shifts in acreage to the improved hybrids. Iowax 2 was released in 1945, and by 1947 it comprised the bulk of
the crop. That hybrid now has been largely replaced by Iowax 4 and Iowax 5. Small acreages of the waxy counterparts of U. S. 13 and Kansas 2275, a white hybrid, were grown in 1948. The acreage of waxy U. S. 13 was expanded in 1949. Waxy hybrids developed by a commercial hybrid-corn company also have been grown on a limited acreage.

At the beginning of the war we had more waxy sorghum than waxy corn, but no methods for processing the grain. The two leading waxy-sorghum varieties then being grown commercially, Leoti and Schrock, had colored seeds that were difficult to process. Unless bleached, the starch from Leoti was about the color of a strawberry sundae; the Schrock starch resembled malted milk. It was found that by grinding the grain in a wheat-flour mill the bran could be separated from the flour, which would yield a white starch. The waxy-sorghum industry started on that basis, but satisfactory wet-milling procedures have since been developed.

By this time, the waxy white kafir that had been unacceptable a few years earlier was in demand, but only 100 pounds of seed was available in 1941. This was increased in 1942, and several thousand acres were harvested and processed in 1943. For several years, A. F. Swanson, of the Bureau of Plant Industry, Soils, and Agricultural Engineering, cooperating with the Kansas Agricultural Experiment Station, had been experimenting with several strains of waxy sorghum selected from crosses with the Leoti variety. The best of these, a Leoti-Club kafir derivative later named Cody, was increased in 1942 from a seed supply of only 24 pounds. In 1943 this was planted in early spring in southern Arizona and California, and the crop threshed in June was shipped to Kansas and Texas for growing the same year.

From 1944 to 1946, all the waxy sorghum processed was the Cody variety, grown on 10,000 to 20,000 acres annually. Cody grain was entirely free from objectionable pigments. Now several varieties of suitable grain type are available. A waxy white-seeded sorghum called Ellis was distributed to Kansas farmers in 1947. Although this is a sweet-stalked variety grown for forage, the seed can be threshed and processed whenever there is sufficient demand for it. About 5,000 acres of a new variety called Miloca was grown in western Texas and Kansas in 1949 for processing. This variety was developed and distributed by the Texas Agricultural Experiment Station. This station also developed some combine-type waxy white-seeded kafirs.

Waxy sorghum, like waxy corn, requires special handling in growing and marketing. It is desirable to avoid contamination with the pollen of nonwaxy varieties. When pollen from a nonwaxy variety fertilizes the flowers of a waxy variety, the grain produced is nonwaxy because of the dominance of the gene that controls the inheritance of the nonwaxy character of the endosperm starch. It is possible to utilize waxy grain that contains not more than 5 percent of nonwaxy kernels. Nevertheless, the seed stocks must be kept pure, and pollen contamination and mechanical mixtures with ordinary corn should be avoided. Like waxy corn, most strains of waxy sorghum tend to yield less than corresponding nonwaxy strains. Thus far, waxy corn and sorghum for processing have been grown under contract and have sold at a premium over the price of nonwaxy grains, because of higher production costs.

Breeders of sorghum have tried to develop waxy varieties and hybrids that are sufficiently productive and otherwise desirable for growing as a feed crop. Manufacturers could then select the lots reaching the market that are pure enough for processing, probably by paying a small premium to encourage the shipment of reasonably pure waxy grain. Such a procedure, which is now followed by processors of barley and oats, would result in lower costs of the raw material.

The starch of waxy corn and waxy white-seeded sorghums can be sepa-
rated from the germ, bran, protein, and cellulose of the grain by the procedure that is used in the wet milling of the nonwaxy grains. The waxy starch, however, requires special handling, and the mill must be thoroughly cleaned before changing from one type of starch to the other. Mixtures of waxy and nonwaxy grain or starch cannot be processed satisfactorily. In a large wet-process mill, there are several miles of pipes, besides numerous containers, that must be cleaned before shifting to another type of starchy material. Therefore, the processing can be justified only when large quantities of waxy grain are available. Because larger mills may have capacities of 10,000 to 30,000 bushels a day, it is necessary to assemble 100,000 to 300,000 bushels for a 7- to 10-day run on waxy grain.

Waxy-corn starch has been used chiefly for making adhesives for articles in which tapioca starch formerly was used, and for textile and paper sizings. The adhesives are used on stamps, envelopes, gummed tapes and labels, corrugated cardboard cartons, and ordinary plywood for indoor use.

Waxy sorghum was first used industrially for preparing Minute Dessert to replace Minute Tapioca during the Second World War. Its manufacture was stopped when tapioca starch from Brazil became available in 1947. Pure waxy-sorghum starch produces a softer gel than does tapioca. For this reason it may require less cooking to reach the right consistency. Some of the first Minute Dessert was not of the most uniform quality, but methods of manufacture have since been perfected. At present prices, waxy-sorghum starch competes satisfactorily with tapioca starch for food purposes. However, it cannot be marketed as tapioca, which is a recognized product with an established trade.

Waxy starch is excellent for many adhesive uses because it makes a free-flowing paste with much less water than is possible with ordinary starch. Thus the waxy-starch gums can be applied to paper without leaving the paper appreciably wet. The resultant thin-gummed layer is remoistened easily when sticking stamps or paper.

The soft puddings made from waxy starch are pleasant to eat. They are especially good for people unable to swallow solid food following a tonsillectomy. There are possibilities for a great variety of food products from waxy starch besides the two that already have been marketed in the United States. Waxy corn makes a tasty corn bread. People of the Orient make many different cakes, confections, puddings, and other foods from waxy (or glutinous) grains. The future industrial uses of waxy starch in the United States may include adhesives, paper and textile sizings, and drilling muds, as well as several new food and industrial products.

Glutinous rice is suitable for the manufacture of waxy starch, but it usually costs considerably more than either corn or grain sorghum. Also, broken rice and rice flour, which are byproducts of milling, already have special uses. Waxy barley shows no superiority over nonwaxy barley for malt-ting, but other possible uses have received little attention. An adapted variety of waxy barley was developed by repeated backcrossing, the waxy character having been derived from a variety from Japan. Waxy varieties of millets and Job's tears are not grown in the United States, and are unlikely to be established here. The Job's tears plant is a coarse grass that produces beadlike, hard-shelled seeds. The grain is sometimes eaten in the Orient.

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