AGRICULTURE

The Versatile Kernel

Corn's undisputed value to man continues to increase with new advancements that provide such diverse products as drugs, plastics, textiles and lysine-rich protein.

By RUBY YOSHIOKA

➤ THE MIRACLE of chemistry has made corn the most versatile of grains. Plastics, livestock feed, antibiotics, textile fibers and plain cornstarch are only a few of the diverse products born of the humble corn kernel.

Corn, which played an important role in the making of American history, continues to maintain its importance today. It provided the necessary food for the Spaniards who made their slow and arduous way across the continent to the Pacific in the early days after Columbus' discovery of America. Later it saved English colonists from starvation during their first hard winters in the New World. Now it is providing us with not only a valuable food, but a variety of products that have become essential to our way of living.

Main Agricultural Product

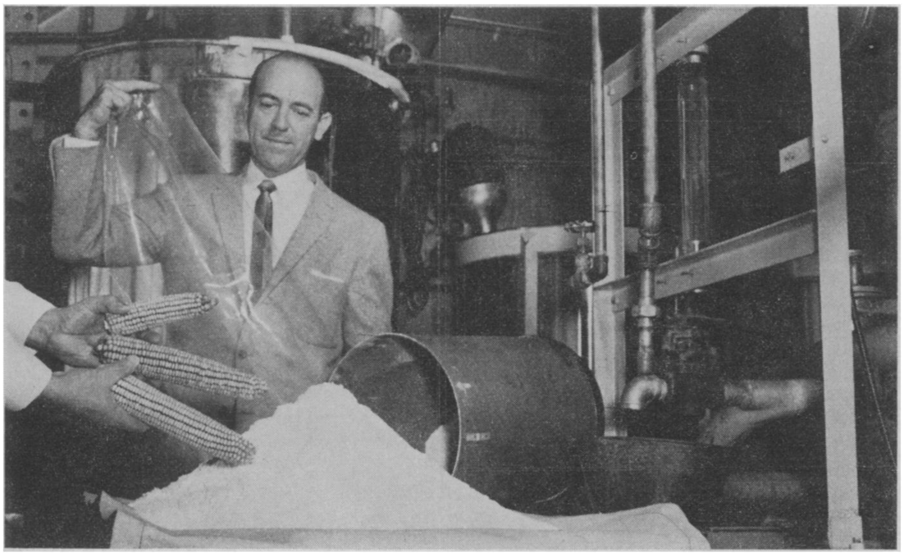
Corn today is the main agricultural product in the United States, more than four billion bushels being produced annually. It has entered virtually every aspect of our daily life. The average person uses corn in some form each day, through the meat and eggs he eats, the clothes he wears and the paper he uses. All are in some way dependent on corn.

The meat and poultry on his table, for example, are from animals fed and fattened by corn. Eighty-five percent of the total yearly corn crop is used as livestock and poultry feed. In addition, a substantial part of the balance of 15% used by industry for various purposes goes to food for farm animals.

Corn has been developed to its present form with its large full ears of kernels purely through cultivation by man through hundreds of centuries and through hybridization by present-day agronomists. Although the exact origin of corn still remains a mystery, it is believed to have originated somewhere in the Americas from an ancient wild grass that grew some 60,000 years ago. A grass, teosinte, which grows today in Mexico and Central America, is believed by some scientists to be the ancestor of corn.

The plant as we know it today cannot survive without the aid of man. Left to grow by itself, corn would in a few years revert to its former grassy form devoid of its precious kernels that give corn its value.

Although corn as such is not important today as a vital human nutrient because of its incomplete protein balance, it is the most important and most abundant source of starch. About 200 million bushels of corn a year are processed for starch. In fact, the reason for corn refining is starch. The processing which produces the all-important starch is also responsible for valuable coproducts that result during starch extraction—corn oil from the germ, gluten containing most of the corn protein, and steepwater.



USDA

EDIBLE FILM—Dr. F. R. Senti, deputy administrator, Nutrition, Consumer and Industrial Research Program of the Agricultural Research Service, USDA, shows the transparent and edible film along with ears of the new high-amylose corn and the starch from which it is made.

Each kernel of corn contains, on the average, 80% carbohydrates, 10% protein, 4.5% oil, 3.5% fibers and 2% minerals. These proportions vary somewhat according to the type of seed, soil, fertilizer and weather conditions.

Since the first spectacular achievements in hybridization in 1916 and the first hybrid made available commercially in 1923, scientists have continued their experimentation to produce better corn for eating as well as to provide special properties for industrial purposes.

Corn Protein

The protein in corn, although containing all eight of the essential amino acids, is not adequate as a protein source for animals or humans. Its most limiting factor is its low lysine content. (Essential amino acids are those among the some 20 in the body proteins that must be obtained through the diet because the body cannot synthesize them.) Therefore, to have a nutritionally balanced diet, it must be supplemented with a food that contains a sufficient amount of this amino acid. In areas such as Latin America, where corn is the staple diet, the protein deficiency disease kwashiorkor is common.

Scientists at Purdue University, Lafayette, Ind., have come up with a corn that may help solve this problem. They have developed a high-lysine corn which holds great promise. This corn, produced by a mutant gene called opaque-2, has a lysine content 50% to 100% higher than that of regular hybrid corn. Extensive nutrition tests show that white rats fed on this corn grow three times as fast as those fed on regular feed, eat twice as much and develop smoother hair coats. Dr. Edwin T. Mertz, biochemist at Purdue and holder of a Corn Industries Research Foundation fellowship believes use of the high-lysine corn would require modification of protein supplements now used.

Not only are scientists trying to improve the protein content of corn, they are making studies to change its starch composition.

Starch that appears to be just a plain white powder used for cooking and laundering, familiar to every housewife, is intricate in its molecular structure and chemical nature. Examined under the microscope, its granules vary in size and shape according to its botanical variety. Thus, cornstarch granules are polygonal in shape, while those of wheat flour are much larger and oval-shaped. Furthermore, each tiny granule possesses a complicated internal structure arranged in an orderly pattern just like in crystals.

Chemically, starch is a carbohydrate syn-

Corn Industries Research Foundation

SEPARATION PROCESS—Corn germ is separated from kernels by flotation. The separated germ is exhibited at lower right.

thesized by the plant by the polymerization, or linking together, of many dextrose molecules composed of carbon, hydrogen and oxygen atoms.

The molecular units that make up polymers such as carbohydrates may be linked to each other in a straight chain or in a branched form like the branches of a tree. Starch has been found to contain molecules of both varieties. The straight chain fraction is known as amylose and the branched chain fraction as amylopectin. Each type has its own special characteristics and the properties of a particular starch are determined by these fractions.

Amylose produces tough flexible films and strong gels because its molecules, made up of linear chains, tend to line up in parallel bundles. Thus amylose can be made into fine silk-like glossy fibers. Amylopectin on the other hand, does not associate readily because its molecules are large and branched.

Recently scientists at Northern Utilization Research Division of the U.S. Department of Agriculture, Peoria, Ill., with researchers from the Missouri Agricultural Experiment Station and Bear Hybrid Corn Company, Decatur, have been able to develop a species of corn containing more than 80% amylose in its starch. The normal level is 27%. The use of a gene, usually referred to as *ae,* discovered by Bear Company, is responsible for the high amylose content. Their success has stimulated the scientists to further efforts with the objective of developing hybrids with 100% amylose.

Amylose film is normally insoluble in water and with the development of high amylose starch, scientists foresee its use for textiles as well as for transparent packaging.

The film, which can be made soluble by chemical treatment, has potential use as packaging for pre-measured amounts of detergents, dyes, insecticides and other materials, and also as an edible water-soluble film for wrapping foods such as quick frozen meats and vegetables to be cooked without unwrapping, and grease-resistant sausage casings. Since it is a component of ordinary starch, scientists reason that it should be edible. An edible film is now being experimentally produced and tested by American Maize-Products Company, Roby, Ind.

The opposite extreme is a special type of corn, different botanically from regular corn with starch consisting solely of amylopectin. This species, known as waxy maize, has a waxy appearance when cut—thus its name. It differs from regular cornstarch, which contains about 27% amylose, in both its molecular structure and physical qualities.

Pastes made from waxy maize are translucent and tasteless, while those made from regular starch are cloudy and opaque and have a distinct flavor. The non-gelling quality of waxy maize makes it useful for stabilizing other starches by reducing their tendency to gel. It is particularly useful in the manufacture of adhesives, in textile printing and finishing, and as a thickener and stabilizer in pie fillings, salad dressings and canned foods.

But the most important use of corn starch is in the paper industry. It is used to provide strength and body to paper and also to provide gloss and finish to the final product.

Modifying Starches

To impart starches with special characteristics for use in papermaking and other purposes, refiners use various methods. They can modify the cornstarch using acid, alkali, oxidation or enzyme treatments. Molecular rearrangements and repolymerizations may take place during these processes, but the starches remain essentially the same. Such starches are known as converted starches.

Pregelatinized starch, for example, is first cooked and then dried. When cold water is added to the product, it gels immediately. Thus, it behaves differently from regular starch but is still starch. This starch, which helps produce stronger papers, is also used for the manufacture of instant puddings and aids in the drilling of oil wells. Thousands of oil wells have been drilled with the aid of pregelatinized starches in the drilling mud.

Thin-boiling starch for sizing textiles and use in confections is also a modified starch. Oxidized starches are widely used in the paper industry mixed with clay to make an excellent binder. British gum, a strong adhesive, is made by roasting wet starch, while starches treated similarly, but at lower temperatures, produce dextrins, excellent finishes for textiles and adhesives.

Another method of changing or improving a starch is by adding entirely new chemical groups to the starch molecule, usually by replacing the hydrogen atoms of some of the hydroxyl groups of the polymer. This process is known as derivatization.

For example, a hydrophobic, or water-hating starch with many valuable uses, has been produced by this means. Water-repelling chemical groups are substituted

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for some of the hydroxyl groups in the starch. Hydrophilic, or water-loving, starch may be made in the same way by adding groups that attract water to the molecule.

The derivative dialdehyde starch plays many roles. When added to pulp, it increases not only the wet strength of paper, but also improves strength and insulating properties of insulation board. Further, in recent research at Peoria, dialdehyde starch has been combined with soybean protein to make a new glue that is water resistant and suitable for use with southern pine plywood. Casein glues and casein paper coatings are improved by the addition of this derived starch.

Corn is almost neutral electrochemically, but by adding certain chemical groups, its starch can be made either positively charged or negatively charged. When a positively charged derivative is added to negatively charged cellulose fibers, the starch is strongly attracted to the fibers to form a very strong bond, thus increasing the strength of the paper.

Crosslinking the molecules in the starch is another method used. By applying this technique a nongelatinizing starch is produced which is useful as a surgical dusting powder.

Scientists of USDA's Agricultural Research Service have shown that cereal xanthates, chemical derivatives of starch, and also of flour, increase the strength of paper when added to wood pulp. These reactions, too, involve cross-linking. Their use in the paper industry should provide a large new market for grains, they said. Further studies on this chemical are being made by scientists at Battelle Memorial Institute, Columbus, Ohio.

Stronger linerboards for paper boxes and improved insulation boards also result from adding cereal xanthates to pulp, studies by USDA scientists show.

Another recent derivative of starch is rigid urethane foam. Starch, like plastics, is a polymer. The new plastic is made by treating starch with either ethylene glycol or glycerol and then with propylene oxide to make polyethers from which the foam is formed.

Sugars and syrups with their many uses primarily in foods are derived from starch by breaking the long polymer chain into smaller chains and single units of dextrose. When the chain is completely broken down and converted by hydrolysis, the resulting product is dextrose. It is actually a predigested food and is administered for intravenous feeding in hospitals. The familiar corn syrup produced by partial starch hydrolysis also has nonfood uses such as in the tanning and finishing of leather, the manufacture of rayon and the making of adhesives. Many medical preparations contain corn syrup or dextrose.

From the coproduct, steepwater, soluble materials as proteins, minerals and carbohydrates are recovered. These products are valuable as feed for livestock as well as for penicillin and Aureomycin and other antibiotic molds. A more recent derivative of steepwater is a medically important chemical, inositol, a member of the B-complex vitamins. It is produced from phytin, a constituent of corn steepwater.

Thus corn's uses extend from the basic need for food to almost every other necessity of our daily lives. Corn is truly a versatile grain.

Things of Science unit #297 on Corn By-Products is available from SCIENCE SERVICE, at 75¢ each.

• Science News Letter, 88:250 October 16, 1965