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**IMPACTS**

# Cornucopious Corn

BY MICHAEL WOODS

**Long revered as a basic food crop, maize plays an often-unheralded role as a versatile component in thousands of everyday products.**



*Michael Woods is contributing editor for THE WORLD & I. A Washington, D.C., writer who specializes in science and health, he has received numerous science writing award*

Mention the words *corn* or *maize* and people think of golden-yellow ears of grain, eaten fresh with butter or transformed into bread, snacks, tortillas, or tamales. Indeed, maize is one of six cereals that feed the world.

In the United States and other industrialized countries, corn's predominant role in the food supply is in the production of animal protein. Corn provides more animal feed than any other grain, and thus ranks as the basic source of meat, milk, and eggs for hundreds of millions of people.

In developing nations of Central America, South America, and Africa, where poverty puts such protein-rich foods generally beyond reach, corn is the dietary staple for about 200 million people.

Yet *Zea mays* is far more than a cornucopia of nutrition, providing sweet corn, snack foods, margarine, cooking oil, corn syrup sweeteners, and other refined corn products found in hundreds of different food products.

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"Anything that can be made from a barrel of petroleum can be made from a bushel of corn," says William M. Doane, the leader of the renowned plant polymer research group at the U.S. Department of Agriculture's Northern Regional Research Center in Peoria, Illinois. The group has pioneered research on new uses for corn, including super-absorbent materials and biodegradable plastics. "For many products it's already economically feasibly to [substitute corn]," Doane says. "For others, the technology still must be developed."

Corn's role in modern society already is so pervasive that it would be difficult to pass an hour without coming into contact with some product that has utilized it. Often, corn's contribution is unapparent, with most people not even recognizing corn-based products.

The smooth surface on paper used in THE WORLD & I and other publications results from processing with specially prepared or "modified" cornstarch. Cornstarches and syrups are also used in shampoo, toothpaste, underarm deodorants, hair spray, and cosmetics. Ethyl alcohol distilled from dextrose feedstock obtained from corn is an octane booster in gasoline. And dextrose from corn is the raw material in the manufacture of sorbitol, the sweetener in some low calorie foods. Corn products are used to tan and polish shoe leather, size and dye denim jeans and rayon dresses, make wallboard, wallpaper ceiling tiles, flooring, adhesives, antibiotics and other pharmaceuticals, chemicals, plastics, matches, hand soap, disposable diapers, fiberglass insulation, charcoal briquettes, and dry-cell batteries.

**Grass Family Member**

*Zea mays* is a member of the grass family, Gramineae. Along with rice, wheat barley, oats, and rye, corn supplies food for virtually all of the world. Several different varieties of Z. *mays* exist, each with a different seed type. They are Z. *mays indentata* (dent corn), *Z. mays indurata,* (flint corn), *Z. mays saccharata,* (sweet corn), *Z. mays amylaceae,* (flour corn), *Z. mays everta,* (pop corn), and *Z. mays tuncicata,* (pod corn). Corn's seeds or kernels consists of a hard outer coating called the hull; the oil-rich germ, which contains the embryo of the young corn plant; and the endosperm, which contains starch.

Dent or field corn is by far the most important variety, accounting for about 90 percent of U.S. production, which totaled 4.92 billion bushels in 1988. Dent corn is named for distinctive indentation visible at the top of each kernel. The dent results from the uneven drying and shrinking of hard and soft starch in the endosperm.

Farmers around the world today grow about 450 million tons of maize per year, about 200 pounds for each person on earth. Corn provides 19 percent of the world's food crop calories and 15 percent of its crop protein.

Until 1492, maize was known only to inhabitants of the Americas. Corn was the staple food of the Mayas of Central America, the Incas of Peru, and the Aztecs of Mexico, and it has been growing in North America for at least 60,000 years. Christopher Columbus took corn back to Spain as one of the wonders of the New World, and merchants transported it widely throughout the Old World.

Today corn is grown so extensively that somewhere in the world a maize crop is being harvested every month of the year. It has become especially popular in scores of developing countries and is the staple food crop in Brazil, E1 Salvador, Ecuador, Guatemala, Haiti, Honduras, Mexico, Nicaragua, Paraguay, Venezuela, Benin, Ghana, Kenya, Malawi, Nigeria, South Africa, Tanzania, Zaire, Zambia, and Zimbabwe. It also important food in parts of Asia, the Middle East, and the Mediterranean.

Maize owes its popularity to a combination of attributes. It is one of the most versatile of all agricultural products, used as human food, animal feed, and ingredient in thousands of industrial products. Maize also gives one of the highest yields per hour of labor; is a good source of protein and calories; stores well and is easily transported; competes with weeds better than other cereals; is easy to harvest and can be shelled by hand; can be left standing in the field at maturity; and has husks that protect from rain and birds.

In developing countries, most corn is consumed directly as food, usually ground or pounded into meal and then baked, fried, or boiled.

**Corn's Nutritional Flaw**

However, maize poses problems when used as a dietary staple. It is deficient in two essential amino acids--lysine and tryptophan--that the body needs for producing proteins, yet cannot manufacture itself. It also is low in niacin, a B-vitamin needed to prevent pellagra. Thus, corn must be eaten in combination with other protein sources--such as beans--to sustain growth and health. But reliance on corn reaches an extreme in some developing countries. In Central America, for example, the typical daily diet for a poverty-stricken adult may consist of 20 tortillas, hot peppers, and greens. Thus, protein deficiency looms as a serious problem, especially for children and pregnant and lactating women. Indeed, fully half of the world's chronically undernourished people live in countries where corn is the dietary staple.

In the 1960s, researchers developed a strain of nutritionally improved maize, richer in lysine, tryptophan, and niacin. But this strain--called *opaque-2 maize* because its kernels were soft and chalky--had drawbacks that limited its adoption by farmers. Its soft kernels were vulnerable to rot and insect damage during storage, yields were low, and it could not be used to make traditional foods like tortillas.

Now scientists at the International Center for the Improvement of Maize and Wheat (CIMMYT) in Mexico have developed a new high-protein corn without these drawbacks. Called *quality protein maize* (QPM), it incorporates the best of opaque-2 and standard corn. The kernel is virtually identical to traditional corn, so that it stores well and can be used to make tortillas and other traditional foods. But QPM is nearly as good a protein source as skim milk. In 1988, a study by the National Academy of Sciences concluded that QPM could dramatically improve nutrition for many of the world's most undernourished people.

In the United States (which accounts for 40 percent of world corn production), corn makes its most important dietary contributions indirectly. Each year about 50 percent of the U.S. corn crop is

consumed as livestock and poultry feed. Corn is the dominant component of poultry and swine feed, and make sup a large proportion of dairy and beef feeds. Every bushel of corn used in combination with other ingredients for animal feed will result in 37 pounds of retail poultry, 26 pounds of retail pork, or 15 pounds of retail beef. The amount of corn devoted to animal feeds has decreased from the 1960s, when about 9 out of every 10 bushes never left the farm. Today, more corn is processed into food and nonfood products.

**Corn Processing**

There are three major corn processing technologies: dry milling, wet milling, and fermentation.

About 2 percent of each year's crop undergoes dry milling or grinding, resulting in corn products tht are familiar to most consumers. These include "flaking grits," used to produce breakfast cereal and snack foods; corn meal used in corn bread, hush puppi4es, and pancake and bakery mixes; and small quantities of crude corn oil. Other products of dry milling are used in brewing, animal feed, and "masa flours," the basis of corn chips, tostadas, taco shells, tortilla chips, and other Mexican foods.

Wet milling separates the corn kernel into components that yield so many different food, feed, and industrial products that the process often is called "corn refining." During a typical year, refiners process about 600 million bushels of corn. Refining begins by steeping corn for 30-40 hours in warm water to soften the kernels and help free the starch for further processing. After steeping, the kernels are coarsely ground, and the steepwater is recovered and used in the production of animal feeds, antibiotics, and chemicals.

The ground corn then flows in a water slurry to giant centrifuge-like devices that separate the germ, which contains about 85 percent of corn's oil. Refiners use mechanical and chemical solvent processes to extract the oil, which then is refined to produce table-quality corn oil. Germ residue is recovered and used in animal feeds. Corn oil has been increasingly popular with health-conscious consumers. It is high in polyunsaturated fats, which help to decrease blood cholesterol levels. About 50 percent of corn oil is used as frying or salad oil, and 35 percent is used to make corn oil margarines.

The remaining corn and water slurry continues its journey from the germ separators, undergoing further processing to separate starch from the gluten and fiber. Both are used in animal feeds. All that remains of the corn kernel at this pint is starch, typically 99.5 percent pure.

Small amounts of the starch are dried and marketed directly as unmodified cornstarch. Some is processed further to make specialty starches with specific properties. Hundreds of modern convenience foods would disappear from supermarket shelves without specialty corn starches. Specialty starches allow foods to retain proper textural characteristics during freezing, thawing, and heating. They keep fruit juices from boiling out of pastries; prevent salad dressings from separating and deep-fried products from absorbing too much oil; keep sauces in microwave foods smooth and glossy; help breading adhere to fried foods; reduce the need for cooking in instant puddings and pie fillings; and have innumer-instant puddings and pie fillings; and have

innumerable other uses in canned, baked, and frozen foods.

Cornstarch also ranks as a basic industrial commodity. Although the paper industry is the biggest consumer, cornstarch does everything from "wick" moisture into pharmaceutical tablets so that they quickly release medication to help cool oil drilling bits by serving as an ingredient in "drilling mud."

Much starch produced at corn refining plants undergoes acid or enzyme treatment to convert its molecules into sugars such as dextrose for different kinds of syrups. Perhaps the most familiar of the sweeteners also is one of the newest to emerge from corn processing technology--high-fructose corn syrup (HFCS). Treating dextrose with enzymes causes it to undergo a chemical change called *isomerization* that yields HFCS. Numerous different forms of HFCS are produced, each with different properties. 42-HFCS, for example, is about as sweet as sugar, and is used in canned fruits and other processed foods that require mild sweetness without masking natural flavors. 55-HFCS is sweeter, and has taken a commanding position in soft drinks, ice cream, and frozen desserts. 90-HFCS is so sweet--50 percent sweeter than cane sugar--that only small quantities are necessary to sweeten "light" foods for weight conscious consumers.

Corn syrups have other characteristics, aside from sweetness, that further increase their utility in processed foods. They are used to control viscosity so that products like catsup and salad dressings flow at the proper rate. In ice creams and frozen desserts, corn syrups impart desirable texture by preventing formation of ice crystals. In hot dogs, sausages, and luncheon meats, they keep spices and other ingredients mixed together in suspension. In bread, corn syrups hold moisture to maintain freshness and help to produce a brown crust during baking. In caramel candy, corn syrups provide the characteristic brown color.

Dextrose, which is an ideal substrate for yeast growth during fermentation, is also fermented into ethyl alcohol or ethanol for beverages and fuel. And carbon dioxide produced during fermentation is sold for use in soft drinks and other carbonated beverages.

Ethanol was first used as a "fuel extender" during the gasoline shortages and price increases of the 1970s. In recent years it has assumed an additional role as an octane enhancer. When blended into gasoline at a 10-percent concentration, ethanol boosts the octane rating by an average of 3 points. Ethanol is now used as a safe substitute for potentially toxic lead additives, which are being phased out. About one billion gallons of ethanol were produced from corn in 1988, while alcohol blends accounted for about 8 percent of all gasoline sold in the United States.

Dextrose also is widely used in the chemical industry in the manufacture of citric acid, enzymes, amino acids, lactic acid, and other chemicals. In the pharmaceutical industry, dextrose is used in intravenous solutions and as a raw material for production of vitamin C, penicillin, and other antibiotics.

## The Future

Although corn syrups and fuel alcohol have been the most rapidly expanding new markets for corn

in recent years, several newer applications promise to trigger a further surge in the grain's popularity.

One is in the production of calcium magnesium acetate (CMA), which the Federal Highway Administration views as a promising alternative to sodium chloride for winter road deicing. Conventional deicing with salt annually causes an estimated $5 billion in corrosion and other damage to reinforced concrete roads, bridges, cars, and underground utilities.

CMA, in contrast, is not only noncorrosive and nonpolluting, but is effective at lower temperatures than salt. Its major drawback is its cost--about 34 cents per pound compared to about 1 cent per pound for slat. Acetic acid, currently produced from petroleum, is needed to make CMA and accounts for about 85 percent of its cost.

Mixtures of CMA and sand and CMA and rock salt already are being used on a limited basis. Chevron's Ortho division has marketed a commercial CMA product, "Ice-B-Gon."

"More economical acetic acid could clear the way for wider use of CMA as an alternative to deicing salts," according to William L. Bryan, a chemical engineer with the U.S. Department of Agriculture's Northern Regional Research Center in Peoria, Illinois.

Bryan and his associates have developed such a method, which produces acetic acid from corn. One study estimated that CMA could be produced from corn, assuming prices of $2.80 per bushel, for about 19 cents per pound. Estimates suggest that demand for CMA eventually could require about 60 million bushes of corn per year.

Another big potential use--totaling perhaps 300 million bushels per year--is in the production of biodegradable plastics. Plastics now pose a major litter and solid-waste-disposal problem because they disintegrate so slowly, requiring 200-400 years. Thus laws to curb the use of plastic packaging are being considered or enacted in many areas of the country.

But researchers are developing degradable plastics that disintegrate within a few years. One approach involves incorporating about 6 percent cornstarch and an oxidizing agent international the long chains of molecules that make up plastics. When plastics made with cornstarch and oxidants are buried in a landfill, bacteria in the soil consume the starch, opening the polymer matrix in a way that accelerates breakdown. At the same time, metal salts in the soil react with the oxidizing agent to form peroxides that chemically destroy the bonds in the plastic molecule.

Yet another major potential market involves the use of cornstarch to encapsulate herbicides, insecticides, fertilizer, and other agricultural chemicals. The encapsulation process involves embedding pesticides inside the honeycomb-like pores in starch granules. As the granules disintegate in the soil, the chemicals are released at a controlled rate. Controlled release reduces undesirable leaching of pesticides into the groundwater.

"Considerably less pesticide is needed if it is encapsulated than sprayed," says W.G. Kinsel, a hydraulic engineer of the U.S. Department of Agriculture. His research has found that starch

encapsulation reduces by 60-90 percent the amount of pesticide that leaches below the root zone of a plant. The USDA has patented several processes for encapsulating chemicals in cornstarch and plans to encourage use of starch encapsulation on a nationwide basis.

Doane noted that corn's success as a plant has become a major factor driving the quest for more and more new uses. Hybrid strains and modern cultivation technology have produced bumper crops year after year, encouraging corn producers to find applications for the surplus.

He foresees the time when corn--an abundant and renewable resource--assumes an even broader role in substituting for dwindling supplies of petroleum and natural gas. Corn will not only provide fuel alcohol, but it also may become a basic feedstock in the production of the world's supply of organic chemicals. Currently, the United States alone produces 200 billion pounds of these chemicals from petroleum and natural gas each year.

"I'm convinced that advances in biotechnology and fermentation technology will make corn the source of more and more chemicals, plastics, synthetic fabrics, and other products now made from petroleum," Doane says. "I really believe that the uses of corn will expand beyond anything that we can imagine today."