Corn

The A"maiz"ing Grain

By Gail Haines

There is a legend that old-timers tell of one particular summer when it got so hot that the corn in the fields started popping right off the stalks. The cows and pigs thought it was a snow blizzard, and they lay down and froze to death.

The popularity of corn cannot be denied. As Dr. Paul Mangelsdorf says in his book *Corn: Its Origin, Evolution, and Improvement*: "It is the most efficient plant that we have for capturing the energy of the sun and converting it into food. True, we consume directly only small amounts of corn: roasting ears, breakfast cereals, Indian pudding, and, for a somewhat different purpose, a beverage invented by a Kentucky minister of the Gospel, bourbon whiskey. But transformed, as three-fourths of it is, into meat, milk, eggs, and other animal products, it is our basic food plant, as it was of the people who preceded us into this hemisphere. Corn is as important today as it was for our native peoples." Native American legend has it that corn is of divine origin—the food of the gods that created the earth.

But as in many other instances, modern humanity has managed to stir up controversy with this "perfect" gift. Today, genetically modified corn, gasohol from corn, and even high fructose corn syrup have become sensitive issues with people taking sides. Meanwhile, industry leaders call corn a future "manufacturing plant"—pun intended; the list of corn-based products is constantly increasing.

The Spanish called it "maíz," and the botanical term became *Zea mays*. The English word was a bad choice, because "corn" refers to different grains in different places. The name gaining popularity among scientists today is "maize."

In less than a thousand years—cyber-speed by evolutionary standards—tiny "ears" of corn were growing all over Central America. Long before Columbus or Cortez arrived, corn had become a major food crop across both American continents. The explorers carried ears back home, and within another 100 years, corn spread as far as China. Now, corn is cultivated on six continents and is harvested in more countries than any other single crop.

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We need corn and corn needs us

Corn has partnered with humans for more than 8000 years. Early Mesoamerican wall paintings tell of the food's "discovery," in the flatulence of a fox. In a common Mesoamerican myth, a fox follows an ant inside a large mountain or boulder where the fox discovers a cache of maize. After eating the grain a vision of a wondrous new food was made evident in the haze of the fox's flatulence!

Possibly, a more likely scenario is that in ancient Mexico, people practiced selective breeding on a grass called teosinte the old-fashioned way. By only using the best/biggest/sweetest seeds, the ancestors of modern corn evolved over time. People have been modifying the genetics of crop plants since time immemorial by this type of selective breeding.

People needed maize to survive. Vegetarians, take note! Combined with beans and squash—the way native tribes prepared it—corn supplies all the amino acids needed for a healthy diet. And corn needs people, because the ears can't reseed themselves. Farmers must remove the kernels from the cob before they can be planted in the ground, and the seedlings must be nurtured for them to grow.

Consider a typical fast food meal: hamburger, fries, and a soft drink. The single food that links all these is … you guessed it, *corn* to feed the beef, *corn* syrup in the soft drink, the bun, and the ketchup, and *corn* oil to fry the potatoes. Every day, the average American eats around two pounds of corn in the form of dairy products and meat produced from corn-fed cows, not counting roasted ears, muffins, cereal, chips, and the 56 quarts of popcorn each of us consume every year. Much of it is grown in 12 contiguous Corn Belt states around Illinois.

Now for the biology

Maize is a cross-pollinating annual grass, with a tall stalk, male tassels, and female ears. Seeds consist of an oily germ and an endosperm composed of starch and protein. The outer shell or hull of the seed is the pericarp. Hundreds of different varieties still grow in rural Central America, with kernel colors ranging from white to purple. But most cultivated strains fall into five types (with the percent of commercial crops devoted):

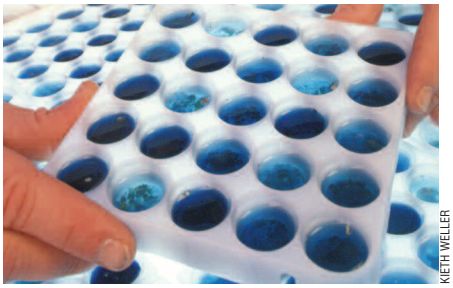
1. **Popcorn**—the original cultivated corn. Moisture in the starchy core explodes with heat into, arguably, the world's oldest snack food (<1%)
2. **Sweet corn**—more sugar than starch. Add salt and butter (<1%)
3. **Flour corn—**soft. Makes great tortillas (12%)
4. **Flint corn—**hard. Grows in colder weather, used industrially and for livestock feed (14%)
5. **Dent corn**, a flint/flour cross, accounts for a whopping 73% of commercial crops. The starchy interior feeds livestock and provides raw materials for the chemical industry. In the United States, much of it is genetically engineered.

A sixth type of corn called pod corn is only used for research. Each kernel has its own husk, so it is too labor intensive to use commercially.

Genetically modified corn—isn't that frankenfood?

Who eats genetically modified or transgenic (GM) corn? If you live in the United States, you do. Cows, pigs, chickens, and dogs do too. Some 70% of the processed food on grocery store shelves contains genetically modified corn and other plants in use since the early 1990s. In the United States, GM foods are considered "nutritionally identical" to the ordinary kind, so they are not normally labeled.

How does genetically modified compare with selective breeding? Well, selective breeding is really just a primitive form of genetic tinkering. A farmer must choose a male and a female plant, hoping that the gene responsible for a desired trait is transferred to their offspring. The breeder can only guess, however, that the desired gene is present in the parent plants based on visual inspection; there is no guarantee that the offspring will indeed have the desired traits. Success in selective breeding only comes after a long trial-and-error process.



KIETH WELLER

A qualitative test for GM corn. Hybrid corn samples turn test solution dark blue, while normal kernels do not.

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Genetic engineering is a more targeted approach, allowing the breeder to take selected genes from one organism and place them into another. The offspring in this case is called a genetically modified organism (GMO), or a transgenic organism. This is pretty straightforward and direct—plus, it allows something the selective breeder can never accomplish—genes from one species can be transferred to another, different species. Want grape-flavored corn? Not a problem, but impossible with selective breeding. But seriously, although the process is not quite that simple, enhancing flavor, crop yields, and resistance to herbicides are desirable traits that have already been engineered into GM corn. Genetic engineering has also allowed the incorporation of a gene that codes for the *Bacillus thuringiensis* toxin, protecting corn plants from insects.

Genetic modification may sound like biology, but chemistry makes it fly. DNA molecules get cut and pasted by chemicals called restriction enzymes, and "gene guns" shoot gene-coated, microscopic particles of gold or tungsten directly into plant cells. Again, it is not as simple as injecting a single gene into the plant's cells. A combination of genes from bacteria, viruses, and the gene from the donating organism is assembled. The bacterial and viral genes are used to break down barriers between the two species being crossed, and they allow a mechanism for making sure the desired gene is incorporated. As the genes are injected into the plant's cells, it is suspected that the injection triggers a wound response which helps its DNA integrate the new gene. With the new genes on board, one may engineer increases in the corn's productivity, or protein concentration or whatever is desired.

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Sounds great ... why isn't everyone on board?

Europeans are not fond of GM crops; only within the last two years have GM crops been allowed in Europe, where each product must display a special GM label. And in spite of the United Nations official support, many developing nations still are hesitant to consume GM crops, including corn. GM agriculture has had bad press around the world; some activists call it Frankenfood. Many people are not interested in eating unnatural food; corn is not supposed to taste like grapes!

Also, there are fears that unpredictable results may occur when multiple copies of a foreign genetic code are injected into the plant. Critics of genetic engineering fear that new pathogens may be created within the plant, including bacteria that will be resistant to available antibacterial drugs.

Experimental attempts to coax corn into producing protein-based drugs and vaccines inside the kernel are called "pharming." This process is thought by some to be safer and cheaper than growing drugs in animal cell cultures. But in 2002, "pharm" corn that was engineered to produce a pig vaccine slipped into food fields by accident. In another case, some untested GM corn was processed into taco shells before the mistake was caught; no one ate any of the shells and the foods were destroyed. Still … corn pollen spreads far and wide, riding on the wind and farm machinery. Transgenic strains have been found fertilizing other varieties. Scientists are supposed to test every new strain for possible allergens. Some people are worried that new "superweeds" or resistant insects will develop in response to genetic tinkering with nature.

You don't want pig vaccine in your taco, and preserving genetic diversity is very important, but transgenic plants are already controlled far more rigorously than other foods. Fear of GM corn is costing lives in a few African countries that have refused American food donations because they contain GM products, which Americans eat every day. Scientists try to stay ahead of the game, developing corn strains that are sterile and even strains that grow underground, where no pollen can escape.

Ethanol

Ethanol, the chemical name for ethyl alcohol, CH_3CH_2OH, is in beer, whiskey, and wine and is one of the first chemicals people learned to make. Corn whiskey was the original "White Lightning" of Prohibition days. The largest volume corn-based product on the market today is fuel-grade ethanol—4 billion gallons of it is made each year. You already burn some "gasohol" in your tank. All cars now sold in the U.S. can handle a 15% ethanol, 85% gasoline fuel mix. "Flex-Cars" can burn at least 85% ethanol—E-85. The 2007 Indianapolis 500 will run on 100% ethanol fuel made from corn—bringing new meaning to "lightning fast!"

Ethanol burns cleaner than gasoline, producing little to none of the black, sooty smoke you see pouring out of an old car's exhaust pipe.

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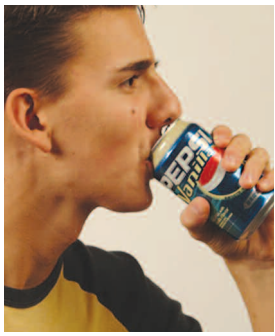
$$CH_3CH_2OH + 3\ O_2 \rightarrow 2\ CO_2 + 3\ H_2O$$

Both ethanol and gasoline produce carbon dioxide when burned, which becomes atmospheric "greenhouse gas" pollution. But there is a difference—corn captures CO_2 from the air as it grows. Petroleum-based fuels, on the other hand, release tons of CO_2, which have been trapped underground for millions of years.

You may have heard gasohol production uses more energy than it provides. Critics count every BTU of energy used to produce the gasohol, grow the corn, make the fertilizer, irrigate, and even build the farm machinery. Proponents use the newest technological data for growth and production, and then they subtract coproducts made from corn protein and corn oil and the energy value of sunshine. A cradle-to-grave analysis of the costs of producing ethanol would be a useful exercise, perhaps one that might be suggested by your teacher. What we do know is that, thermodynamically, every energy conversion uses more raw energy than it produces in fuel. The gain is convenience: coal to electricity, crude oil to gasoline, corn to ethanol. Better technology favors the proponents, and ethanol already is replacing gasoline-from-petroleum at an ever-increasing rate.

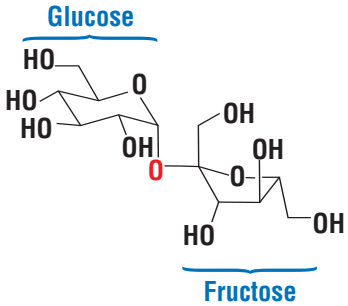
Oh, the sweet taste of—corn?

Along with CO_2 in your can of soda, the sweetener is almost certain to be pure corn. High fructose corn syrup (HFCS) is corn's major refined food product.

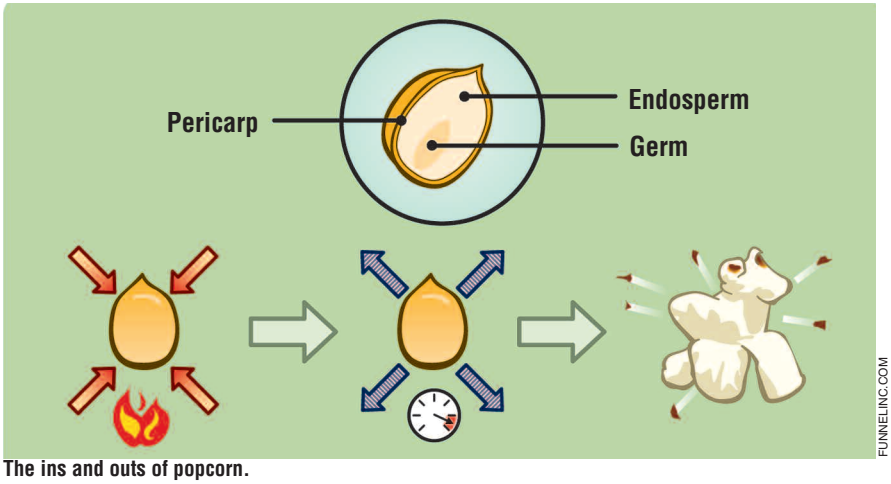

MIKE CIESIELSKI

Corn syrup, mostly glucose, is not very sweet. Table sugar (sucrose $C_{12}H_{22}O_{11}$)—with each molecule composed of one glucose and one super-sweet fructose—has the taste we love. Food chemists found ways to get that taste from corn. They increased the fructose level in corn syrup to 42% (HFCS-42), 55% (HFCS-55) or 90% (HFCS-90), to make it as sweet as—or sweeter than—table sugar.

The 42% fructose syrup is produced by adding an enzyme that interconverts glucose



Sucrose is made of one glucose and one fructose unit.



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The ins and outs of popcorn.

and fructose; the 42% fructose/58% glucose represents the equilibrium ratio. The 90% fructose syrup is produced by a partial separation of the two sugars using a column that has a high affinity for fructose. The 55% fructose syrup is made from blending the 90% and the 42% and seems to be the standard sweetener for products such as soft drinks.

HFCS is cheaper than sucrose. It also promotes browning in bread, makes cookies chewy, prevents freezer burn, preserves canned fruit texture, enhances flavors, and more. HFCS is in ketchup, hamburger buns, bacon, lunch meat, whole wheat bread, and products you would never suspect had sugar at all.

Popcorn

Long, long before there were movies there was popcorn. Popcorn thought to be 5,600 years old was found in a cave in central New Mexico. Today's typical American eats over 50 liters of popcorn each year. And Americans don't just eat the stuff — they are the world's largest producers. Most of the world gets its popcorn from the U.S. Midwest: Indiana, Iowa, and Nebraska.

A popcorn kernel is simply a seed with three parts: the germ is the part that sprouts out of the seed during growth; the endosperm is the starch that expands during the popping process; and the pericarp, or outer hull, which is made partly of cellulose. Now, not all corn has the potential to pop. The maize must have the right type of pericarp to produce the fluffy food. The pericarp needs to keep moisture trapped inside the corn kernel while it's being cooked. As the temperature of the kernel increases, the pressure exerted by the gaseous H_2O inside the kernel also increases. Once the internal pressure exceeds that outside and the pericarp can no longer withstand the force, the kernel splits open, turning the kernel inside out.

No one likes chomping down on unpopped kernels. The highest quality popcorn has a pericarp with a highly ordered crystalline arrangement of its cellulose molecules. The two main reasons why kernels don't pop is they have insufficient moisture, or that the hull leaks. The ideal popcorn has about 14% moisture and must be stored in a tightly sealed container so it won't dry out.

Eating popcorn is typically considered to be a healthy act. It is fat-free, low in calories, and provides fiber. And it's natural — according to the Popcorn Board (a nonprofit group of popcorn processors), there is no genetically modified popcorn currently available for sale in domestic or international markets.

Increased use of HFCS = increased size of American?

Now HFCS is getting blamed for making Americans fat. Is this true? Or is it "Frankenfat"? Evidence shows today's average American is heavier than previous generations, and the time frame of the weight increase—since the mid-1970s—matches the huge spike in HFCS use. But over the same 30 years, among other things, Americans have supersized their diets, averaging 300 extra calories a day.

Chemically, HFCS-42 and HFCS-55 are similar to sucrose at 50–50%, but the body handles extra glucose or fructose differently. Glucose is used directly by the body's cells; fructose goes first to the liver. Glucose spikes a surge of insulin and also leptin, a hormone that signals you have eaten enough. Fructose doesn't, so you may just keep eating! Fructose you don't burn for energy and converts easily into body fat.

Research is under way. Meanwhile, if weight is a problem, avoiding those 32-ounce "super" drinks—sweetened with HFCS or sucrose—would be a no-brainer.

Solving controversy can supercharge science. Maize is already a great human achievement—8000 years and still growing. Watch for further developments.

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In American Indian folklore, some tribes were said to believe that quiet, contented spirits lived inside of each popcorn kernel. When their houses were heated, the spirits would become angrier and angrier, shaking the kernels, and when the heat became unbearable, they would burst out of their homes and into the air in a disgruntled puff of steam.

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Other information courtesy of Linda Stradley and her web site, What's Cooking America, at http://whatscookingamerica.net.

Other references may be found in the Teacher's Guide.

Gail Haines is a science writer and book author from Olympia, WA. Her most recent article, "Honey: Bee Food Extraordinaire," appeared in the December 2005 issue of *ChemMatters*.