Genetically Modified Organisms (GMOs)

A Backgrounder by the Institute of Food Technologists

December 1999

Introduction

Since life began, genes have crossed the boundaries of related and unrelated species in nature. Biotechnology applications by humans date back to 1800 B.C., when people began using yeast to leaven bread and ferment wine. By the 1860s, people started breeding plants through deliberate cross-pollination. They moved and selected genes to enhance the beneficial qualities of plants through cross-breeding without knowing the traits for which the genes coded. Most foods, including rice, oats, potatoes, corn, wheat and tomatoes, are the products of traditional cross-breeding. This time-tested practice continues to produce crops with desirable traits.

However, traditional cross-breeding has its limitations. It can only occur in the same or related plant species, so genetic resources available to any one plant are limited. Moreover, when plants are cross-bred, all 100,000 or so of each plant's genes are mixed, producing random combinations. Since traditional plant breeders ultimately want only a few genes or traits transferred, they typically spend 10 to 12 years backcrossing hybrids with the original plants to obtain the desired traits and to breed out the tens of thousands of unwanted genes. Clearly, this process is not speedy or precise.

Modern biotechnology or genetic modification adds tremendous timeliness and precision to this process. It is the result of scientists understanding and using what nature has been doing unaided since life began.

What is genetic modification?

The term "genetically modified" is commonly used to describe the application of recombinant deoxyribonucleic acid (rDNA) technology to the genetic alteration of microorganisms, plants and animals. This advanced molecular technology, developed in 1973, allows for effective and efficient transfer of genetic material from one organism to another.

Instead of cross-breeding plants for several years to acquire a desired trait, scientists can identify and insert a single gene responsible for a particular trait into a plant with relative speed. Genes do not have to come from a related species in order to be functional; hence, genes can potentially be transferred among all living organisms.

What are the benefits of rDNA technology?

The World Health Organization estimates that the global population will double by 2050 to more than 9 billion people. Hence, food production must also increase, but little unused farmland remains. Simply put, rDNA technology is the most promising, precise and advanced strategy available today for increasing global food production by reducing crop losses and increasing yields while conserving farmland. Moreover, the use of rDNA technology has already shown that it can reduce the need for chemical pesticides and tillage, which can cause soil erosion, as well as enhance the nutritive value of crops. These benefits result from genetically engineering plants for:

• Increased biological resistance to specific pests and diseases, including those caused by viruses, thereby reducing the need for chemical pesticides, decreasing the risk of crop failure, and increasing yields. For example, when sweet potatoes grown in Africa were rDNA-engineered to withstand the feathery mottle virus, crop yields doubled. Without pesticide use, about 60 percent of the crop is normally lost each year to this virus. In the United States, corn was genetically modified with the *Bacillus thuringiensis (Bt)* gene to withstand the corn borer pest, which resulted in increased yields and reduced pesticide use. For example, 26 percent of farmers in the Midwest who planted the modified corn in 1998 decreased insecticide use and about half said they did not use any insecticides, reported a 1999 Iowa State University study.

Similarly, U.S. cotton farmers have cut their insecticide use by about two million pounds, or 12 percent, since pest-resistant cotton seeds were introduced in 1996, according to the National Center for Food and Agricultural Policy (June 1999).

• Adaptability to harsh growing conditions, such as drought, soil with high salt content, and temperature extremes. For example, by modifying a plant's production of linoleic acid, it can better withstand cold temperatures and frost.

• Tolerance to environmentally safe herbicides that discourage weeds but leave the desired plant unaffected. Herbicide tolerance allows crops to be grown with less or no tillage, thereby conserving soil, fuel and water. It can also reduce the number of herbicides that farmers must use to control all of the weeds in their crops. For example, herbicide-resistant soybeans can be maintained weed-free with only half the amount of herbicide normally applied.

• Desirable functional characteristics, such as reduced allergenicity or toxicity, delayed ripening, increased starch content, or longer shelf life. For example, potatoes rDNA-engineered for a higher starch content will absorb less oil when deep-fried, resulting in french fries with less fat. Tomatoes bioengineered for delayed ripening may stay on the vine longer, resulting in better flavor and color before picking and shipping to market.

• Desirable nutritional characteristics, such as altered protein or fat content and increased phytochemical or nutrient content. Malnutrition problems worldwide--such as deficiencies in vitamin A, iron, iodine, and zinc--may be targeted by using rDNA technology to introduce or concentrate these nutrients in plants. For example, rice has been genetically modified to contain beta carotene and more iron to help overcome deficiencies of these nutrients in countries where rice is a staple food. Nutritionally enhanced foods may even help prevent chronic diseases, not just deficiencies, by delivering optimal levels of key nutrients.

Is rDNA technology safe?

According to the National Academy of Sciences, genetic transfers between unrelated organisms do not pose hazards or risks different from those encountered by natural selection or traditional cross-breeding between similar species. Moreover, there is no evidence that transferring genes between unrelated species, especially those already in the food supply, will convert a harmless organism into a hazardous one. The process itself by which genes are transferred does not make living organisms harmful.

Transferring genes between unrelated species is possible because of the genetic similarities of all living organisms. Natural history shows that many genetic traits for common metabolic processes have been conserved throughout time in microbes, plants and animals. Although a few proteins from an organism may be unique to it, many plant and animal proteins have the same or closely related functions. For example, both the human brain and rice plant carry the same genetic material for the production of an enzyme called lysozyme.

Furthermore, nature itself transfers genetic material across sexual boundaries. For example, strains of the crown gall bacterium carry genes that can transfer to and be expressed in plant cells. These bacteria transfer their genes to plant cells, which then make compounds that feed the bacteria.

The transfer of genetic material between unrelated species will not turn them into each other, such as a fish into a tomato or vice versa. It may simply allow a beneficial trait to be expressed in the organism to which a targeted gene is transferred. As each plant and animal are made up of tens or hundreds of thousands of genes, one or two transferred genes could not alter the identity of an organism.

According to the World Health Organization and Food and Agriculture Organization of the United Nations (1991), "Biotechnology has a long history of use in food production and processing. It represents a continuum embracing both traditional breeding techniques and the latest techniques based on molecular biology. The newer biotechnological techniques, in particular, open up very great possibilities of rapidly improving the quantity and quality of food available. The use of these techniques does not result in food which is inherently less safe [to humans or the environment] than that produced by conventional ones."

Are foods derived from GMOs safe?

In the United States, it is the responsibility of the Food and Drug Administration (FDA) to provide oversight for all foods, including those derived from GMOs. More than 15 years of laboratory research and field trials with rDNA-engineered plants indicate that the risks posed by these plants are not any greater than or different from the risks posed by plants produced by traditional breeding methods used for more than 100 years.

Scientific evidence to date continues to support the FDA's conclusion in its May 1992 *Federal Register,* "The agency is not aware of any information showing that foods derived by these new methods differ from other foods in any meaningful or uniform way, or that, as a class, foods developed by the new techniques present any different or greater safety concern than foods developed by traditional plant breeding."

Most importantly, all food developers and manufacturers are required by the FDA to ensure the safety and quality of their products. According to its Food, Drug and Cosmetic Act, "Producers of new foods have an obligation under the act to ensure that the foods they offer consumers are safe and in compliance with applicable legal requirements."

These requirements include 1) demonstrating that genetically modified foods do not contain substantially increased levels of previously known toxic substances, new hazardous substances, or different levels of nutrients than traditional counterparts; and 2) addressing whether known or potentially new allergens have been transferred to the modified product. If so, then the product must be labeled as such. This labeling policy applies to all foods to avoid the possibility that they may unexpectedly contain allergenic proteins.

In addition, while not currently mandatory, developers of genetically engineered foods consult with FDA prior to the commercialization of a product. This consultation procedure, which entails a science-based safety assessment of the product, protects both consumers and developers. This is a higher standard than for conventional foods. Thus, developers have a strong incentive to consult with FDA prior to marketing their products.

Who ensures that GMOs do not threaten the environment?

As with assessing food safety, ecological safety is assessed according to the biological properties of genetically modified plants. The U.S. Department of Agriculture (USDA) oversees the field trials and large scale production of these plants. The U.S. Environmental Protection Agency regulates the pesticidal properties of plants rDNA-engineered to resist pests.

In addition, both genetically modified and conventionally bred plants undergo review and approval procedures that have been established through the State Agricultural Experiment Station system. Private companies conduct similar biological and environmental evaluations, frequently in conjunction with land-grant universities. One advantage of rDNA technology is that, because it allows scientists to answer questions about outcomes specifically related to the genetic modification at hand, it provides safety and risk information unobtainable with conventionally bred plants. Thousands of field trials with rDNA-engineered plants have not revealed a single example of negative environmental consequence caused by these plants.

Not all questions about the environmental effects of plant breeding can be answered either for genetically modified plants or for those modified by conventional methods. Questions about increasing weediness of closely related plants and the long-term effects of herbicide tolerance are unknown. However, monitoring and control mechanisms are in place to detect and minimize potential risks.

What is the potential for rDNA-engineered plants to outcross to weedy relatives?

Outcrossing, the unintentional breeding of a domestic crop with a related plant, is considered by the USDA's Animal and Plant Health Inspection Service (APHIS) during review of new plant varieties. The agency ensures that herbicide-tolerant or pest-resistant plants do not become plant pests themselves by outcrossing to weedy relatives. Plant breeders take care to release only new varieties with low or negligible risk of transferring genes to weedy relatives. They also assure that methods are available to manage any weeds that might acquire new genes by outcrossing.

Like traditionally bred plants, genetically modified plants cannot transfer traits to unrelated species in nature. For cases in which weedy relatives exist, APHIS assesses the risk and impact of potential gene transfers. If there is high potential for a new plant variety to outcross with a weedy relative and if transfer of the new trait to the weed could be problematic, APHIS has the authority to halt field trials or further development of the proposed new variety.

The potential for herbicide-tolerant plants to increase the weediness of closely-related plants cannot be known ahead of time. However, traditionally bred plants also have the potential to create weeds. Therefore, crop management practices always need to be monitored and refined as agricultural and environmental conditions change. For example, if an herbicide-resistant gene transferred to a weed, then a different herbicide would be needed to control that weed.

Will pest-resistant plants cause pests to become "super pests?"

The concept of a "super pest," one that cannot be controlled or overcome, contradicts the principles of biology. The ability of a pest population to adapt to pesticides or genes used to control it is nature's way of assuring its survival. However, even if pests develop resistance to one pesticide or gene, they are still vulnerable to new or older control mechanisms, such as a different pesticide or a re-modified plant. This process has been repeated many times in agriculture, horticulture, and forestry. Scientists also have several ways to extend the life of pest control mechanisms. With rDNA engineering, for example, it would be possible to rotate pest-resistant genes in a plant, modify the plant's own resistance mechanisms, or transfer more than one pest-resistant gene to the plant, making it very difficult for pests to defeat the new resistance.

Pest-resistant plants are more effective and advantageous than chemical pesticide sprays in killing target pests for two reasons: 1) Gene products for pest control are usually more target-specific than pesticides—like vaccines compared with antibiotics. For example, *Bt* corn kills almost 100 percent of the corn borer and corn earworm, but traditional pesticides do not because these pests burrow into plants, where sprays cannot penetrate. The greater the number of pests that survive exposure to a pesticide, the greater the chance they will develop resistance. 2) The pest-control mechanisms provided by genes tend to kill only insects that chew on the plant, not those in the plant's vicinity. Externally applied pesticides kill both pests and innocent and often beneficial insects that are in the field.

All living organisms are continually adapting through natural selection to stresses in the environment. In rare cases, they do not adapt and hence, die out, such as the American chestnut. Hence, the eventual development of resistance in pests to both chemical pesticides and pest-resistant plants is expected, but protective measures can delay its occurrence. One such measure is the planting of a small percentage of unmodified (refuge) crops in or adjacent to a field of pest-resistant crops. The refuge sites keep the vulnerability trait in the gene pool of pests. Currently, manufacturers of pest-resistant seeds instruct farmers when they purchase the seeds to plant refuge sites. The success and management of the refuge strategy, however, needs to be more fully evaluated.

Another way to delay the onset of pest resistance is to stack genes with different modes of action, thereby requiring a pest to simultaneously develop resistance to two or more types of control. In addition, the time-honored practice of crop rotation is effective in many cases for minimizing increases in pest populations.

Will *Bt* corn harm monarch butterfly larvae?

Because monarch butterflies belong to the same order of insects *(Lepidoptera)* as the corn borer, *Bt* corn pollen has the potential to harm monarch larvae if they eat it. This is not a surprise. The key questions are: Are monarch butterflies exposed to *Bt* corn pollen and if so, to what degree? Would their larvae eat plants with *Bt* pollen instead of plants without it? What amount of pollen could be harmful to the larvae? Does milkweed, the primary source of monarch food, grow close enough to corn fields to be exposed to *Bt* corn pollen? Up to what distance is pollen drift possible?

Research in both the private and public sectors is currently underway to address these questions, but it must be noted that the U.S. monarch butterfly population has not decreased since *Bt* corn was first commercially planted in 1996. In fact, according to researchers at the University of Kansas, the monarch butterfly population increased significantly in 1997 compared to the previous five years.

Greater threats to monarch butterflies are use of externally applied *Bt* and destruction of wildlife habitats by humans. Pesticides are also more likely to harm non-target insects besides the monarch butterfly because they get into the soil and may be carried by water to non-farmland areas. Planting pest- or disease-resistant crops can help reduce pesticide use and conserve farmland, preventing expansion into wildlife habitats. In this sense, *Bt* corn may help protect monarch butterflies.

Moreover, the use of pest- and disease-resistant crops allows farmers to practice no-till farming, which reduces soil erosion and protects beneficial soil organisms, such as earthworms. Agriculture, by its nature, is disruptive to wildlife. The key is to minimize the disruption, while maximizing the use of farmland. Modern biotechnology gives farmers tools to do so.

What are common non-plant applications of rDNA technology?

Recombinant DNA technology has been applied to livestock breeding and microbial production of substances used in food processing and human medicines. A familiar application is the use of recombinant bovine somatotrophin (growth hormone) to increase milk production in cows. Genetically modified microorganisms aid in food processing and pathogen detection. For example, most cheese today is produced with an rDNA-engineered enzyme called chymosin. Prior to the creation of chymosin, its natural equivalent, rennet, was derived from the stomachs of calves. Not only is the use of chymosin in the best interest of calves, it is produced with greater purity, consistency, and quality than rennet. Numerous pharmaceutical applications have also resulted from rDNA technology, including the mass production of pure human insulin for diabetes management.

Should foods derived from GMOs be labeled?

Although providing consumers with information about genetically modified foods is important, labels may not be the best way to do so because they are inherently pejorative. Food labels were established by the FDA to provide “material information” about a product, such as ingredient and nutrition information, or warnings about a health risk, such as the presence of a potential allergen. Because genetically modified foods are already scrutinized to ensure that they do not pose new or unique risks, such labels are likely to mislead consumers by implying a warning. For the same reason, labels are excluded from conventional foods that cause sensitivity or illness in a small fraction of consumers. For example, though some people may be sensitive to milk due to lactose intolerance, milk is not labeled as such.

Moreover, labeling rDNA-engineered foods would not be economically prudent because thousands of common foods containing small amounts of genetically modified ingredients, such as soybean and corn products, would have to be labeled. Costs associated with this would be passed on to producers and consumers. Farmers, in particular, would absorb significant costs by having to pay for equipment and/or other resources to separate genetically modified crops from non-modified ones.

Conclusions

The Institute of Food Technologists has reviewed the scientific and policy issues concerning food derived from GMOs and concluded that:

- Recombinant DNA technology has great promise to increase world food production and improve the characteristics of plants in ways that will benefit farmers, consumers, and the environment;
- The safety of food derived from GMOs is adequately assured by the science-based procedures effectively used by the FDA and plant breeders;
- More than a decade of safety evaluation and experience with genetically modified plants has provided evidence and assurance that risks to the environment posed by these plants are no different from those of plants bred by traditional methods;

• There is no evidence that genetic transfers between unrelated organisms pose hazards that are new or different from those encountered with any new plant variety;

• Growing plants rDNA-engineered for pest resistance can reduce the need for chemical pesticides, thereby offering safer environmental strategies for pest and disease control;

• Genetic modification is compatible with environmental conservation and sustainable agriculture because it takes advantage of biological control mechanisms already adapted to nature;

• Policy to assure food safety and environmental protection should be based on the characteristics of foods, not on the methods used to develop them; and

• Social and economic consequences of the applications of rDNA technology raise issues that warrant public debate by all stakeholders.

Institute of Food Technologists ❖ Science Communications Department
221 N. LaSalle St., Suite 300 ❖ Chicago, IL 60601-1291
Phone 312/782-8424 ❖ Fax 312/782-8348 ❖ E-mail <sciencecom@ift.org> ❖ Web <http://www.ift.org>

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