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Agricultural Biotechnology

Before You Judge

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Introduction

Biotechnology offers new opportunities and challenges. But what is it? How will it affect our food and agricultural system? Will it be good for consumers, farmers, and the environment?

After you read this publication, we hope that you will be better prepared to judge for yourself the contributions that biotechnology may make to our food and agricultural system, and how you might participate in the development, regulation, adoption, and use of agricultural biotechnology.

Biotechnology and Agriculture

What is biotechnology?

Biotechnology is a set of tools that utilize living organisms or parts of organisms to make or modify products, to improve plants or animals for agriculture, or to engineer microorganisms for specific purposes. People have been doing this for centuries. Breeding livestock is one example. Another is using bacteria, yeast, and other living organisms to make such familiar foods as bread, cheese, beer, wine, sausage, pickles, and yogurt.

Our understanding of biology and how to use it has grown tremendously over the last 200 years, and especially in the last 30 years. Scientists' greater understanding of life and its processes has enabled them to develop newer, more specialized techniques. These modern techniques using molecular biology have been labeled "biotechnology."

Think of biotechnology as a scientific toolbox filled with many tools. Some of the tools developed in recent years include cell and tissue culture, embryo transplantation, microbial fermentation, and genetic engineering. Scientists use these tools to do many things. They make new food products. They breed improved plants and animals. They do research on how living systems interact, such as plants with insects and soil organisms.

What is the connection between biotechnology and agriculture?

The techniques of biotechnology can be used to modify plants and animals and to change

agricultural production systems on the farm. But the use of biotechnology in the food chain doesn't stop with the farmer. Many food processing techniques also are based on living systems. Food scientists can use biotechnology to modify food processing techniques and food ingredients.

What agricultural products and improvements can we expect from biotechnology?

For plants, biotechnology research has focused on two fronts. One is to make crop production more efficient. Scientists are working to develop crop varieties that can withstand environmental stresses such as drought, flood, frost, or extreme temperatures. A related area of research is adapting crops to regions where they are not normally grown because of climate, altitude, or rainfall.

Biotechnology also is being used against plant pests such as weeds, insects, and diseases. These pests cause significant crop losses each year. Some researchers are using biotechnology to develop biological pest controls. Others have genetically engineered crops to resist diseases and insects. Herbicide tolerance has been engineered into some crops to increase weed control options.

The second front of crop biotechnology research is the creation of "designer" crops, genetically engineering new varieties for specific purposes. Scientists are developing fruits and vegetables that have longer shelf lives, transport better, look or taste better, or that are higher in nutritional quality. Food processors sometimes desire crops with particular characteristics. For example, tomatoes containing less water have been developed to reduce processing and transportation costs. Some field crops, like corn or potatoes, could be more useful to food processors if there were varieties with better processing qualities or additional nutritional qualities such as protein or starch content. Crops also are being altered to develop varieties for specific industrial purposes. Oilseed crops such as soybeans and canola may be engineered to produce new fuels or industrial lubricants.

Animal agriculture also is being affected by biotechnology. Safer, more effective vaccines are already in use. Biotechnology is being used to develop diagnostic tests for a wide range of diseases and viruses. Animal reproduction is being improved through a technique called "embryo transplantation." Bovine somatotropin (BST), sometimes called bovine growth hormone (BGH), is already being used by many U.S. dairy farmers to increase milk production per cow and reduce production costs.

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How will biotechnology affect food processing?

The tools of biotechnology are being used to produce improved microbes, such as yeast and bacteria, which are used in food processing. Microbes are used broadly in such processes as baking bread, brewing beer, making wine, and fermenting milk to produce yogurt and cheese.

Biotechnology has provided more pure and economical sources of a number of enzymes used to produce food. An example is the enzyme rennin, which occurs naturally in the stomachs of calves and has been used for centuries to produce cheese from milk. Scientists have isolated the gene responsible for rennin production and genetically engineered microbes to produce the enzyme in large quantities. Today, nearly all cheese in the United States is produced using rennin produced through biotechnology.

Processed food commonly contains a number of additives to enhance aesthetic characteristics (flavor, color, aroma, texture), nutritional value (vitamins, amino acids), or shelf life (antioxidants). After isolating the genes responsible for coloring agents, flavors, fragrances, or nutrients, scientists engineer bacteria to act as chemical factories to produce these ingredients.

In other cases, scientists have learned to grow parts of plants in the laboratory that synthesize flavorings, such as vanilla or cocoa, so that it is no longer necessary to grow the whole plant. In some cases, vegetables or fruits may be engineered directly to produce either more or unique flavors, colors, and nutrients, eliminating the need for some food additives.

Since we already have enough food, why do we need biotechnology?

Over the course of history, scientists, farmers, and food processors have focused on producing food that is more plentiful and higher in quality. As the world's population has grown, however, the total supply of land available for agriculture has remained about the same. In some regions, cropland has declined as a result of urban development and/or environmental degradation, such as soil erosion or salinity from irrigation. So the focus of agricultural research in recent years has been on how to use available land more efficiently and in a more environmentally friendly way.

Gains in agricultural productivity in the United States over the last 75 years have been tremendous. Examples of technologies that have contributed to productivity gains are machinery, fertilizer, pesticides, animal genetics, hybrid seed, integrated pest management, and no till farming. These technologies have increased yields and labor productivity, while also reducing soil erosion and pesticide use. Many people think that in the future biotechnology can help significantly increase agricultural productivity to feed a growing world population.

Why have the promised benefits of biotechnology been so long coming?

There are several reasons for this. One is the complexity of nature. As biotechnology research progressed, researchers encountered unanticipated technical challenges. Each new stage or area of research, testing, and product development has had its own share of problems. So progress from the idea stage to the laboratory stage to the test plot stage to the final product stage has been slow.

People's desire to "do the right thing" with biotechnology is another reason progress has been slow. Scientists have been cautious and careful with the new powers unleashed by biotechnology. Private sector, university, and government scientists have developed guidelines for contained laboratory research. They have sought input from local communities prior to outdoor testing of new products. This takes time.

In addition to the guidelines scientists have developed, biotechnology is subject to government regulation. A number of federal agencies, such as Food and Drug Administration (FDA), Environmental Protection Agency (EPA), and U.S. Department of Agriculture (USDA), have overlapping regulatory authority over biotechnology. Thorough regulatory procedures followed by government agencies cost time and money.

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Agricultural Biotechnology Issues and Impacts

Consumer Issues and Impacts

Are foods made from biotechnology products or processes different from conventional foods?

At this time, foods produced using processes or products of biotechnology are not new or unusual; they are just produced in a different way or have ingredients that are produced differently. High fructose corn syrup (HFCS) is one example. This product has almost totally replaced sugar as a sweetener in soft drinks. HFCS could not be produced profitably until

someone developed a new biotechnology method for making the enzymes used to produce the syrup.

Cheese is another example. Scientists have figured out how to use bacteria to mass produce the enzyme that is used to make cheese. Before, the enzyme came from calf stomachs.

Milk produced by cows injected with BST is another example. Each cow produces more milk. Scientists have determined that milk from treated cows is the same as milk from untreated cows.

Are food made from biotechnology products or processes safe?

Foods produced from biotechnology products or processes should be just as safe to eat as today's familiar foods. New foods developed by a food processor using biotechnology must pass all the same regulatory tests for food safety as any other new food. Nowhere in the food chain from scientist to farmer to consumer are food safety standards lowered for foods produced from biotechnology processes or products. In fact, they are more stringent under current regulatory guidelines.

How will biotechnology affect food saftey?

As discussed above, foods made from biotechnology processes or products are at least as safe as foods produced by conventional means. However, in the future, all foods (conventional and those from biotechnology) are likely to be safer because of biotechnology. This new technology will help scientists in food companies and in government regulatory agencies improve their food safety testing practices. Scientists will be able to detect smaller quantities of food contaminants than before, and the testing methods will take less time. They also will be able to develop new tests for contaminants which could not be detected previously. Food safety monitoring should become faster, easier, more accurate, and less costly because of biotechnology.

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How will biotechnology benefit consumers?

Biotechnology will bring health benefits to consumers by providing a wider variety of foods which are more plentiful, more convenient to use, and more nutritious. Foods with longer shelf life and higher quality ingredients should lead to healthier diets.

Greater sensory appeal is another likely advantage of agricultural biotechnology. Using the new technology, foods which taste, smell, and look better will be produced by farmers and food processors. Other foods may receive improvements in texture, such as crunchiness, softness, or smoothness.

Currently, U.S. consumers spend about 11.5 percent of their disposable income on food, the lowest of any country in the world. However, the efficiencies in food production brought about by biotechnology should result in U.S. consumers spending even less on food.

What concerns consumers about agricultural biotechnology?

Every technology can have both positive and negative attributes. Biotechnology is no exception. Consumers want to make informed choices about their diet. They want to be assured that the food they eat is safe.

Modern biotechnology makes it possible to transfer genes between organisms that could not be transferred through traditional breeding processes. As a result, genetically engineered foods may contain components not normally found in the traditional versions of a food. To increase

the freeze tolerance of vegetables, for instance, scientists can transfer genes for antifreeze proteins from arctic fish to tomatoes. Similarly, insect resistant potatoes have been created by adding a gene from soil bacteria. Some people believe it is not ethically or morally acceptable to alter food in this way. They prefer "natural" food.

The incorporation of genes from other organisms may change specific properties of an altered food, but not necessarily its appearance&emdash;another concern. People who suffer from food allergies will require food labels or other new forms of information to allow them to identify potential sources of an allergic reaction from foods altered by biotechnology. For example, genetically engineered tomatoes could potentially contain a protein gene from wheat that could cause an allergic reaction in some people.

How will biotechnology affect consumers in contries where hunger is a serious problem?

It is hoped that people in many less developed countries will be better off with biotechnology. First, the countries that import most of their food should be able to afford more food as the use of biotechnology reduces food production costs in the exporting countries. Second, biotechnology may help some developing countries feed a greater number of their people themselves. This will occur in those developing countries where farmers are able to use biotechnology to grow food more efficiently. Unfortunately, not all developing countries will have the necessary economic, educational, or research conditions for their agricultural system to benefit from biotechnology.

Agricultural Issues and Impacts

How will biotechnology benefit farmers?

Biotechnology should offer several economic advantages to farmers. Production costs should decrease because of more efficient production methods. Farmers who adopt the technology first could earn extra profits. Those who improve their management skills as they adopt new biotechnology products also should earn extra profits.

Biotechnology is expected to expand farmers' production and marketing options. One example is contract sales to processors or for niche markets. A second is new crops. A third is the alteration of a crop for specific purposes. A fourth could be adaptation of crops to withstand adverse conditions in states, regions, or countries where they could not be raised before.

What challenges will biotechnology create for farmers?

Biotechnology will require farmers to make many adjustments in their production and marketing practices. New biotechnology products and inputs are likely to require more sophisticated farm management skills and marketing and technical support services.

Biotechnology will reinforce the trend towards fewer and larger input supply companies. Fewer and larger input firms could result in these firms gaining more market power. Such integration and market coordination agreements may leave farmers feeling less independent.

As with the introduction of any new technology, farmers may find themselves in unwanted situations. Those farmers unable or unwilling to learn or pay for the management skills required to adopt the products of biotechnology may be forced out of business. Others may leave farming if financial, market, land, climate, or other situations do not allow them to buy or profitably use the new technologies. There may be some farmers who do not want to use the new technologies, but may feel forced to use them.

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What impact will agriculture biotechnology have on the family farm?

U.S. agriculture has a long history of technological change. Previous technologies have caused structural change resulting in fewer farmers, larger farms, and the decline of many rural communities. However, new technologies have helped American farmers produce more food. This has resulted in lower consumer food costs. Biotechnology will reinforce these historic trends.

Some people are concerned that biotechnology may cause smaller farms to disappear. For many biotechnology products, farm size will not be a factor in whether or not a farmer will be able to use them profitably, as often is the case for large capital investments in machinery or livestock production facilities. However, since education and specialized management skills will be important, operators of small, part-time farms may be at a disadvantage.

How will agricultural biotechnology affect U.S. trade?

Biotechnology may have both positive and negative impacts on U.S. trade in agricultural commodities and processed foods.

The United States imports many foods or crops that cannot be grown in this country, like cocoa and vanilla. Good-tasting, artificial substitutes for these food ingredients have not been discovered. Biotechnologists are working on growing those plant parts that make the cocoa and vanilla flavoring. U.S. companies could then make these and other food ingredients. This would reduce U.S. imports.

Scientists around the world are genetically engineering crops to withstand adverse growing conditions. This may allow countries with harsher climates to grow some crops more successfully. This could reduce U.S. exports.

Biotechnology is being used to improve U.S. foods and crops, and lower production costs. For example, new crop varieties may be developed that are higher in quality (such as wheat with unique proteins), have new uses (such as canola with a specific industrial oil), or can be produced more cheaply (insect resistant cotton). This should result in more U.S. exports.

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Environmental Issues and Impacts

What are the potential environmental benefits of biotechnology

Biotechnology may solve some environmental problems. Scientists have already genetically engineered microbes that "eat" oil and reduce the environmental damage from oil spills. Still other enzymes are being genetically altered to convert waste products from food processing into useful food or nonfood products.

For the farm, scientists are genetically engineering crops to tolerate selected herbicides which require lower application rates, do not move in the soil profile, and are less toxic (i.e., are more environmentally friendly). For example, in 1995 EPA approved genetically engineered soybeans which are tolerant to glyphosate, an environmentally benign herbicide.

Also, scientists have developed genetically altered crops that are able to fight off pests (insects, diseases, viruses) and therefore do not require pesticides. Examples of crops already approved for commercial production by government regulatory agencies are cotton, corn, and potatoes

engineered to express a gene from the soil bacterium Bacillus thuringiensis (often abbreviated Bt). When certain insects eat the genetically engineered plant they will die. Chemical insecticides are not required.

What are the potential environmental risks in using biotechnology products on farms?

Increased pest resistance is an environmental concern. Insects exposed to a genetically engineered crop with the Bt gene may mutate over time and become resistant to Bt. This concerns organic farmers who use Bacillus thuringiensis on their crops as an alternative to chemical insecticides.

Another environmental concern is that over time, as a single herbicide is repeatedly applied to a crop tolerant to that herbicide, some weed species may develop a tolerance to that herbicide and become more difficult to control. A transgenic crop might cross with another crop or weed. This could result in an undesirable crop or weed species.

Finally, some argue that reliance on a few genetically modified crops may further reduce biological diversity. Reliance on a few crops with a relatively narrow genetic base could increase the risk of crop failure and threaten our food security. Critics point to the U.S. corn blight in 1970 as an example of what can result from a lack of genetic diversity in agriculture.

Regulation of Agricultural Biotechnology

How is biotechnology regulated?

Since June, 1986, the federal government has regulated biotechnology and its products through the Federal Coordinated Framework for Regulation of Biotechnology. The three government agencies involved are the Environmental Protection Agency (EPA), the Food and Drug Administration (FDA), and the U.S. Department of Agriculture (USDA). Each regulates the aspects of the research and development of biotechnology products that are similar to those it regulates for non-biotechnology products.

The federal government has determined that the products and not the techniques of biotechnology will be regulated. As a result, federal agencies within the Coordinated Framework regulate biotechnology based on existing legislation rather than new laws specific to biotechnology.

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Is labeling of foods produced by biotechnology required?

Whether foods that involve biotechnology should be labeled remains controversial. Current FDA guidelines require labeling to inform consumers of changes in nutritional composition or the presence of potential health hazards. If, as a result of genetic engineering, a food product is significantly altered or might be harmful to someone's health, a label will be required. Examples might include a possible allergic reaction to a protein that has been transferred from one crop to another. How to label fresh, or unprocessed, foods will be challenging, however. While voluntary labeling is permitted, the information must be factual and not misleading.

Is our current regulatory system doing an adequate job of regulating biotechnology?

The Coordinated Framework has some limitations. Regulators have found that in some cases it can be very difficult to classify some biotechnology products using traditional categories. For example, how do you classify genetically modified soil microbes or tomatoes genetically engineered to resist insects? Are these products environmental contaminants, pesticides, food

ingredients, or none of the above? Sometimes, the authority of two or more agencies may overlap so that approval from more than one agency is necessary. An example is the insect resistant tomato described above, which is regulated by USDA as an altered plant, by EPA as a pesticide, and by FDA as a food.

How much regulation of biotechnology is enough, and can there be too much regulation?

Too little regulation can lead to health and safety problems. Too much regulation, however, can keep good products off the market and increase cost.

With biotechnology, there are both risks and benefits. To date no bad things have happened from the use of biotechnology. This suggests that the present system is adequately regulating biotechnology. However, some people lack confidence in government regulatory agencies. Some researchers think that the current regulatory system is too complex and has discouraged some research efforts. The challenge will be to modify the regulatory system so that biotechnology products are adequately regulated in a system that operates in a timely, understandable, cost-effective, and credible way.

Conclusion

We have tried to respond to some of the questions and concerns you might have about agricultural biotechnology. Biotechnology and its application to our food and agricultural system will continue to evolve in the years ahead. We encourage you to learn more about agricultural biotechnology. The materials on biotechnology listed on the next page, many of which may be available at your local public or school library or through your county Extension office, will help you judge for yourself.

More About Biotechnology

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