Impact of Biotechnology on Future Nutrient Intakes

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Biotechnology has the potential to dramatically modify the nutritional quality of the food supply. The purpose of this presentation is to provide an overview of the tools of biotechnology, how they can be used to modify plants, animals, and microorganisms used in food production, and the potential impact on the nutritional quality of the food supply.

The information contained in nutrient databases is critical to the biotechnologist. To gain regulatory approval for genetically modified foods will require comparison of engineered varieties to their traditional counterparts. If we don't have a clear understanding of the composition of traditional foods, there is no benchmark for determining in what ways the engineered counterpart has been altered or improved.

What is biotechnology? My definition of biotechnology is broad. "Bio" refers to life or living systems - if you took a biology course in high school you studied living systems - plants, animals, microorganisms and any part of these organisms. "Technology" is a method for achieving a practical purpose. Biotechnology is a collection of industrial processes that involve living systems. Biotechnology is a toolbox of techniques that can be used to modify living organisms.

Those of us in food science, have been doing "biotechnology" for thousands of years. Microorganisms such as yeast and bacteria have been used to make industrial products like bread, cheese, wine and a host of other fermented foods. Traditional plant and animal breeding and selection have also been used to improve the food supply. The original ancestors of corn look quite different than the hybrid seed corn that dominates agricultural production today. It has been modified by years of traditional breeding and selection. We have been doing biotechnology for literally thousands of years since the discovery of food fermentation and the domestication of plants and animals.

What separates "traditional" biotechnology from the "new" biotechnology is genetic engineering. Genetic engineering allows one to isolate DNA from any living organism and using restriction enzymes that function like scissors, isolate and identify specific genes. That genetic information can then be spliced or recombined with circular piecies of DNA called plasmids or vectors and transferred into a new cell (Fig. 1). DNA in all living cells is structurally and functionally identical; therefore, genetic engineering can be used to transfer DNA between organisms that do not normally mate. Human insulin can be produced by genetically engineered organisms that have received a single gene from a human pancreas cell. The bacterial cell then functions as a little factory to produce human insulin.

Genetic engineering is a powerful technology that is more precise, controllable and predictable than traditional breeding. For example, when a plant variety is crossed with a related species, all of the thousands of genes of both plants are shuffled. Genetic engineering allows the transfer of a single gene - a single trait -into a plant, an animal or a microorganism in a very predictable way because only one property is being modified. It took over 20 years to develop hybrid seed corn using traditional breeding and selection techniques; in the course of one generation, or 3 to 4 months, we can alter plants, animals, or microorganisms using genetic engineering.

Both traditional breeding and selection, and genetic engineering can be used in a number of ways to improve the food supply. Today we will focus on the use of biotechnology to enhance the nutritional quality of the foods we consume. In the immediate past, biotechnology has focussed on production agriculture

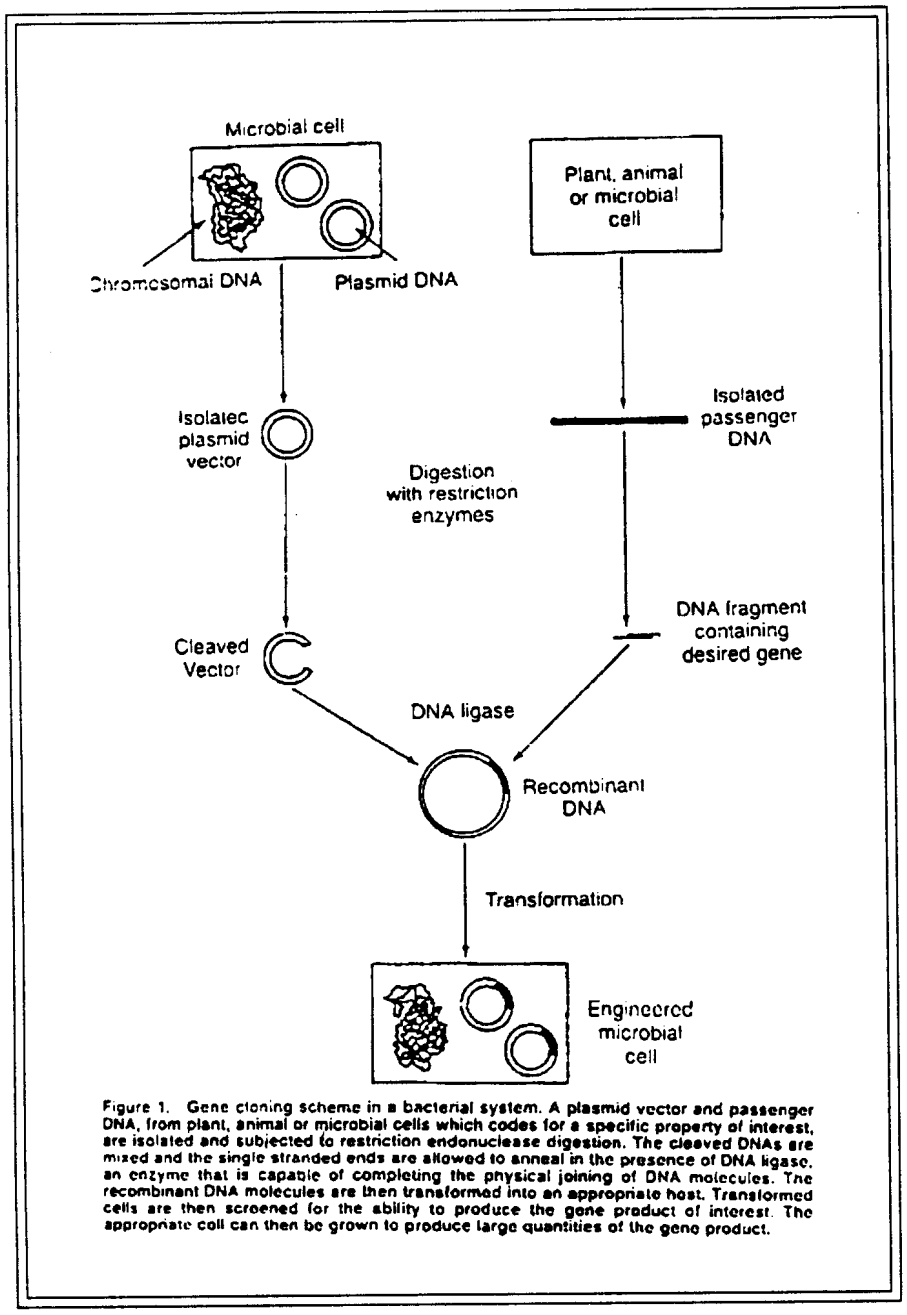

Figure 1. Gene cloning scheme in a bacterial system. A plasmid vector and passenger DNA, from plant, animal or microbial cells which codes for a specific property of interest, are isolated and subjected to restriction endonuclease digestion. The cleaved DNAs are mixed and the single stranded ends are allowed to anneal in the presence of DNA ligase, an enzyme that is capable of completing the physical joining of DNA molecules. The recombinant DNA molecules are then transformed into an appropriate host. Transformed cells are then screened for the ability to produce the gene product of interest. The appropriate cell can then be grown to produce large quantities of the gene product.

(how to produce foods more efficiently), but in the future, biotechnology will expand into value-added and consumer-driven areas.

In order to enhance the nutritional quality of the food supply, the biotechnologist needs to know which nutrients or components of foods would be desirable to increase or decrease. Interestingly, although there is consensus on the general categories of foods we should be consuming, controversy remains over the level of specific nutrients for optimum health. The 7 food groups I learned about as a child became the 4 major food groups in 1956. Even today, the debate on how to most accurately convey nutrition information to consumers continues with the proposed pyramid being considered by the U.S. Department of Agriculture. Additionally, there may be components of foods yet undiscovered that will impact nutrient requirements and health. It is probably safe to say that we do not understand everything there is to know about nutrients and nutrient interaction in our present diet. Yet this information is critical if our goal is to engineer foods with improved nutritional quality using biotechnology.

The real interest in diet right now relates to the diet/health interface. Diet has been implicated as a causative factor in a number of chronic diseases like heart disease and hypertension, osteoporosis, diabetes, obesity, cancer, aging and possibly others. Consumers are being bombarded with this information in the press. One article might discuss the concept that certain foods contain nutrients that are protective against cancer; another article indicates that the same foods contain natural toxicants that may be cancer-causing. We have overwhelmed people with information about nutrition and it's really difficult for the average consumer to sort all the information. Biotechnologists also need some help in deciding which foods and which nutrients might have the biggest nutritional impact on the largest population of consumers.

As we understand more about human genetics, we will also understand more about how an individual's diet impacts health. The human genome project will ultimately provide the genetic blueprint for humans. With that information, one should be able to design a diet to fit each individual. My nutritional needs may be quite different than yours, and these differences will be reflected in our genes. Ultimately we will have enough information to predict what the perfect diet should be,

and then it is up to you and I to design that perfect diet.

I'd like to tell you about how I believe biotechnology will be used to help design the perfect diet. If one could modify the food supply using biotechnology what are some of the things that should be done to improve nutritional quality? Which nutrients should we focus on? Some that come to mind include the following:

- increasing the level of specific amino acids deficient in cereal grains
- increasing fiber content or specific components of fiber (i.e., soluble fiber)
- decreasing fat and/or cholesterol
- increasing caloric density and/or decreasing total caloric content
- increasing vitamin, mineral and trace element content
- making foods inherently digestible

Nutritionists could surely expand this list - the limit is based on one's imagination - as the possibilities are endless.

Plant biotechnologists have successfully modified the nutritional quality of protein by altering amino acid content. Cereal grains are deficient in certain amino acids and genetic engineering has been used to increase the level of these amino acids. That may not have much of an impact on nutritional quality of the food supply in this country because we have numerous protein sources in our diet. In developing countries that rely on a single cereal grain as their sole source of protein, improving the nutritional quality or the ratio of amino acids could have a major impact. The fatty acid composition of oils can also be modified. The ratio of saturated, unsaturated, and monounsaturated fatty acids in canola oil has been altered using genetic engineering. If nutritionists tell biotechnologists that it's important to increase or decrease the level of certain fatty acids in food products, genetic engineering will be able to do it.

There is concern about the safety of the food supply and most of that concern is associated with pesticide residues in foods. Pesticides are used to control insect pests. As agricultural areas interface more closely with urban areas, the concern about low level contaminants in foods will surely increase. Using genetic engineering, it is possible to build directly into plants an ability to naturally resist insects, thus decreasing the need for agricultural pesticides. A single gene from the bacterium **Bacillus thuringiensis**, an organism that has been used as a natural pesticidal agent in this country for over 20 years, can be transferred to plants. The single gene codes for a toxin that is lethal to insects, but has no effect on humans or animals, thus the engineered plant is naturally resistant to insects.

The food supply could also be modified to make it more appealing. A company in California has created the "antisense" tomato. A single gene has been removed from the tomato and reinserted back into the same plant in the opposite orientation. One sense copy of the gene the same gene inserted in the opposite direction (the `antisense' gene) blocks the action of that single gene. The particular gene that's been blocked in this example is the gene that codes for the enzyme endopolygalacturonase. This enzyme causes the tomato fruit to start breaking down when you leave it on the vine to ripen. By blocking the action of that one gene, tomato fruit can be ripened on the vine, shipped without refrigeration and has an extended shelp life. With recommendations to consume more fresh fruits and vegetables, `antisense' technology could have a major impact on the quality of fresh produce.

Many of the foods commonly consumed contain low levels of natural toxicants. This is not normally a problem as long as a well balanced diet is consumed. Overindulgence of a limited number of foods; however, could contribute to dietary carcinogen exposure. Antisense technology could be used to selectively shut off the genes involved in producing natural toxicants. Caffeine-free coffee has been developed by selectively shutting off the genes involved in caffeine production. If natural toxicants are understood, 'antisense' technology could be used to inactivate their production. In the same way, if biotechnologists understand that certain components, whether they be antioxidants, vitamins, minerals, trace elements or other compounds, are important in nutrition, then genetic engineering can be used to design foods that contain these compounds.

Antibodies are produced in humans and animals to fight diseases. Antibodies are proteins; they can be genetically engineered into plants. In the future it may be possible to deliver disease-fighting antibodies directly in the food products we consume. This may sound futuristic today, but this powerful technology can be harnessed in many ways to make the food supply healthier.

Let's say we need to construct a diet that is reduced in sodium. Can we develop things like potatoes that have natural buttery flavor and aroma, so that butter or salt doesn't need to be added? What about a variety of

corn genetically engineered to produce a salty tasting protein; thus, eliminating the need for added salt? Think about the components that you perceive to be negative in the diet. There are ways to modify the food supply in such a way that the diet can deliver valuable nutrients without having to add things like butter, fat or salt. Many of the examples of plant biotechnology just discussed are currently being developed and in some cases they are already in small-scale field trials. The future is not that far away!

Biotechnology can also be applied in the animal world. Pork chops from a pig supplemented with porcine somatotropin, a growth hormone that can be produced by genetic engineering, has significantly less fat than meat from unsupplemented animals. PST causes more of the energy to be used by the pig to produce muscle rather than fat. Once it is understood how animals process nutrients into fat and cholesterol, it should be possible to genetically program cows to produce less of these compounds in meat or milk. There is tremendous concern about cholesterol in the diet. Eggs have high levels of cholesterol. Could genetic engineering be used to decrease the amount of cholesterol produced by chickens, or alter the partitioning of cholesterol in the bird? As pointed out by the previous speaker, it is critical to keep track of modifications in the food supply in nutrient databases. The food supply of the future is going to look quite different than what we have today and this historical information will help us more intelligently and expediently chart the course.

One of my areas of research focuses on the bacteria used to produce yogurt. Genetic engineering can be used to make dairy foods inherently more digestible for lactose intolerant individuals. Over 25% of the people in this country are lactose intolerant. The bacteria in yogurt help lactose intolerant individuals digest the product. These organisms produce the enzyme - galactosidase that is missing in the gut of lactose intolerant individuals. The gene for this enzyme can be transferred to bacteria used to produce other kinds of fermented dairy products.

Organisms like **Lactobacillus acidolphilus** present in Sweet Acidophilus Milk can naturally assimilate cholesterol. They are also capable of implanting in the gut, and may help your body reduce serum cholesterol levels. Other properties could also be built into bacteria and yeast using genetic engineering - whether it be anti-carcinogenic factors, stimulation of the immune response, or factors that would allow organisms to function as competitive inhibitors of other organisms present in the GI tract. The gene for the naturally sweet plant protein, thaumatin, has been inserted into yeast. Imagine making bakery products that are naturally sweet without adding sugar. As a protein, thaumatin would be digested just like any other protein. Yeast strains could be engineered to produce beta-glucans and soluble fibers that have demonstrated cholesterol-reducing properties. These could be used in a whole host of food products to help reduce serum cholesterol levels. Algae are an excellent source of beta carotine, a component implicated as an anticarcinogen. Engineered organisms could serve as sources for these valuable food ingredients.

This was a very brief overview of how biotechnology could affect the food supply - from the seed to the stomach - and beyond, to the nutritional impact of food. The goal is to deliver safe, nutritious and affordable foods that consumers want. Biotechnology is just one of many tools that will be used to provide fresh foods that are nutritious and convenient.

Todays' consumers live in urban areas - less than 2% of the population produce all the food in this country. Few of us have any understanding of how food is grown, processed, or distributed. The public is very concerned about the environment; therefore, the use of agricultural chemicals in food production is extremely important to people. Todays' consumers are also very health conscious. They read nutritional labels; they want to know what's in their food and they want to understand how that food is going to impact their health. At the same time, they are afraid of technology and they really don't have a very good understanding of the science behind biotechnology, nutrition, or food science. Science illiteracy is pervasive in this country -of 23,000 high schools in the U.S., 1900 offer no biology program, students graduating from high school are not going to have the rudamentary skills to understand what nutrition and biotechnology are all about.

Abraham Lincoln said, "Public opinion is not always right but it always prevails." We have tremendous potential to positively modify the food supply using biotechnology. If you as nutritionists will work with biotechnogists, along with biochemists, biologists, chemists, physicians, agronomists, animal scientists, and food scientists, we can create a tremendously healthful food supply. The challenge will be communicating that to the consuming public. So it's not just a matter of science and technology, it's also a matter of communication.