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POTENTIAL ADVERSE HEALTH EFFECTS OF GENETICALLY MODIFIED CROPS

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Genetically modified crops have the potential to eliminate hunger and starvation in millions of people, especially in developing countries because the genetic modification can produce large amounts of foods that are more nutritious. Large quantities are produced because genetically modified crops are more resistant to pests and drought. They also contain greater amounts of nutrients, such as proteins and vitamins. However, there are concerns about the safety of genetically modified crops. The concerns are that they may contain allergenic substances due to introduction of new genes into crops. Another concern is that genetic engineering often involves the use of antibiotic-resistance genes as "selectable markers" and this could lead to production of antibiotic-resistant bacterial strains that are resistant to available antibiotics. This would create a serious public health problem. The genetically modified crops might contain other toxic substances (such as enhanced amounts of heavy metals) and the crops might not be "substantially equivalent" in genome, proteome, and metabolome compared with unmodified crops. Another concern is that genetically modified crops may be less nutritious; for example, they might contain lower amounts of phytoestrogens, which protect against heart disease and cancer. The review of available literature indicates that the genetically modified crops available in the market that are intended for human consumption are generally safe; their consumption is not associated with serious health problems. However, because of potential for exposure of a large segment of human population to genetically modified foods, more research is needed to ensure that the genetically modified foods are safe for human consumption.

The utilization of biotechnology in agriculture is an important tool for improving food quality and quantity and the environment. Biotechnology is crucial to resolving the problems of food availability, poverty reduction, and environmental conservation in the developing world. Biotechnology does not benefit just the farmers who grow crops, but also the consumers who eat genetically modified food. Consumers include millions of children who might die each year because there is not enough food or are weakened due to deficiencies in essential vitamins, such as vitamin A. Further, approximately 350,000 persons go blind due to lack of food (Nash, 2000). Since 1994, many genetically modified

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foods have been developed and sold in both the domestic and international markets (Henney, 2000).

Agriculture has been suffering from pest and disease infestation since its beginning, causing large, unpredictable losses in food production. Genetic engineering of plants for resistance to pests and disease, by creating transgenic pest-protected plants, is one of the many tools for increasing food availability and security (National Research Council, 2000a, 2000b). The subject of transgenic crops and animals is one of the most controversial areas of scientific research. Genetically modified crops offer great promise to help solve one of humankind's basic needs by increasing global food supply. World population is expected to double to more than 10 billion people by the year 2050. No other apparent technology will be able to help avoid starvation in the future. Hunger and poverty must be addressed, while the natural environments remain undisturbed. To meet this challenge, new knowledge generated by continued research in biotechnology and a broad dissemination of the knowledge gained from that research throughout the world is necessary. It will also require that judicious policies be implemented through informed decision making on the part of nation, state, and local governments in each country (National Research Council, 2000a, 2000b).

By increasing the ability of a crop to withstand environmental factors, such as drought and poor soil conditions, growers will be able to farm in parts of the world that are currently unsuitable for crop yields. Biotechnology has greatly sped up the process of improving plants for human purposes, usually by both achieving higher yields and increasing plant tolerances to insects, diseases, drought, and poor soil conditions (Acosta, 2000). In addition to more food, biotechnology could enable growers to produce many enhancements in diverse plants. This would allow for the possibility of increasing the agricultural gene pool that billions of people rely on for basic foodstuffs. In addition, almost half of the $12 billion that American farmers spend each year on fertilizers simply evaporates in the atmosphere or washes away with the rain or irrigation water. Consequently, much of the fertilizer used is wasted and can end up in water sources, harming the environment. Some plants, such as corn, may be genetically altered to draw nitrogen from soil, reducing the need for fertilizers. Ongoing research shows that transgenic plants can produce nutritionally healthier foods. Foods can be produced through the use of biotechnology that are more nutritious, stable in storage, and promote better health in humans in both industrialized and developing nations (Young, 1999).

Advances over the last two decades in our understanding of genetics and molecular biology are permitting scientists to find specific genes that can be moved from one species to another, and between viruses, bacteria, plants, and animals to produce significant changes in the host species. This is quite different from traditional breeding because it (1) allows the transfer of genes between organisms from different species, (2) permits the transfer of only those selected genes that produce the desired outcome, and (3) is done in controlled laboratory conditions (Foreman, 2000). The current technologies used to develop organisms for creating genetically modified crops generally entail the transfer of desirable gene(s) along with a promoter and a gene that codes for a selectable marker; the marker permits the efficient isolation of organisms that have been genetically transformed from those that have not; markers generally employed include herbicide or antibiotic resistance (Society of Toxicology, 2002).

However, there are potential adverse health effects of consuming genetically modified crops; they are discussed later.

POTENTIAL ADVERSE HEALTH EFFECTS OF GENETICALLY MODIFIED CROPS

Along with the beneficial potential of genetically modified crops, concerns about the adverse human health consequences of consumption of those products have been raised. Genetically modified crops raise fear and concern in many people's minds about the safety or adverse health effects (Godfrey, 2000). Some of the adverse effects attributed to genetically modified crops in humans include new allergens in the food supply, antibiotic resistance, production of new toxins, concentration of toxic metals, enhancement of the environment for toxic fungi to grow, increased cancer risks, degradation of the nutritional food value, and other unknown risks that may arise later (Acosta, 2000).

Allergenicity

Food allergy is an important health issue with the prevalence of immunoglobulin E (IgE) antibody-mediated food allergies among adults being approximately 2% and nearly 5% in children (Lehrer, 1999a, 1999b; Ladics & Dong, 2002). Protection of food-allergic persons from unwanted exposure to protein, which causes their clinical symptoms, represents a major public health priority for plant biotechnology (Astwood et al., 1996). It is important to note that the consumption of conventional foods can trigger allergic reaction. Kiwi fruit introduced into this country in the 1960s was not initially associated with any allergies. However, there are some people who are currently allergic to it; the allergenic protein in the kiwi fruit was identified to be actinidin (Pastorello et al., 1998). In 1996, a major concern for consumption of genetically modified crops materialized when studies demonstrated that Brazil-nut gene spliced into soybeans could induce potentially fatal allergies in humans allergic to Brazil nuts (Nordlee et al., 1996). The Brazil-nut gene was inserted into soybean plants to improve their protein content for animal feed. In an in vitro test and a skin prick test, the transgenic soybeans reacted with immunoglobulin E (IgE), a class of antibody molecules involved in allergic reactions, of individuals with Brazil-nut allergy in a way that indicated that these individuals would have an adverse, perhaps even fatal, reaction to transgenic soybeans (Nordlee et al., 1996). However, this case was not an accurate representation of foods causing allergic reactions. Marion Nestle of New York University wrote in an editorial in *New England Journal of Medicine*, "In the special case of transgenic soybeans, the donor species (Brazil nut) was known to be allergenic; serum samples from persons allergenic to donor species were available for testing and the product was withdrawn" (Nestle, 1996).

In September 2000, a variety of transgenic corn, called StarLink, prohibited for human consumption was discovered in Taco Bell taco shells. This transgenic corn species was produced by Aventis Corporation, which was approved by federal agencies in 1998 for animal feed. However, because the corn has been genetically modified in a way that makes it harder to break down in the human gastrointestinal tract, agencies have refused to approve it for human use (Kaufman, 2000). It is postulated that the ability of a protein to withstand heat and gastric juices is an indicator that it will cause an allergic reaction (Taylor & Lehrer, 1996; Lehrer, 1999a). Peanuts, which can cause fatal allergic reactions, possess this characteristic, and so do other foods that are known to be allergenic. People, however, would have to be exposed to the special StarLink protein, known as Cry9C, many times over an extended period to develop an allergy to it (Taylor & Lehrer, 1996). The Cry9C protein accounts for only 0.013% of the corn grain, whereas most allergenic proteins account for 1–40% of the food ingredients in which they occur (Taylor & Lehrer, 1996). StarLink corn contains a gene from the bacterium *Bacillus thuringiensis*; that gene, known as Bt, makes the plant toxic to insect pests. The National Research Council (2000a, 2000b) recently recommended additional research on the allergy issue and singled out the Cry9C protein as needing special attention. This protein takes at least 30 min to break down in gastric juices, about four times as long as proteins in other Bt corn varieties (Associated Press, 2000).The Bt gene that produced the insect toxin was inserted by the Monsanto Company to grow Bt corn to provide high yield of the crop. That corn has environmental and human health benefits. It also helps farmers significantly reduce insecticide use. In order to create a pest-resistant variety of cotton, genetic enginees spliced a Bt toxin gene into the cotton plant. That gene enabled the transgenic cotton to produce the insecticidal toxin throughout the plant. The two major concerns about Bt crops are that pests will develop resistance to the Bt toxin and that the Bt gene will become established in wild relatives of Bt crops. This resistance would develop because insect pests feeding on Bt crops are exposed to toxins continuously and they are likely to develop resistance from mutations. Also, where Bt crops are grown near wild relatives, it is highly likely that the Bt gene will transfer to the wild populations as a result of movement of pollen from the Bt crop to its unmodified relatives. Some of the resultant plants may produce enough Bt to ward off insects that normally feed on them, and this may cause harmful results to the ecosystem (Rissler, 1997).

Generally, food allergens share several common properties. They are proteins or glycoproteins with acidic isoelectric points and are usually in the molecular mass range of 10,000 to 80,000 Da (Lehrer, 1999b). Most characterized food allergens are stable to digestion and processing, and many of the major allergens are generally proteins that are present in large amounts in allergenic foods (Lehrer, 1999b).

People with food allergies, whose symptoms can range from mild effects to sudden death, may likely be affected by exposure to foreign proteins introduced into foods by genetic engineering. Genetically modified foods can introduce novel proteins into the food supply from organisms that are never consumed as foods. Some of those proteins could be allergenic. It is difficult to predict whether a particular protein will be a food allergen if consumed by humans. The only reliable method to determine whether a protein in food will be an allergen is through consumption of the engineered food. Therefore, incorporating genes that produce novel proteins into crops by genetic engineering, especially from nonfood sources, might pose a health risk (Union of Concerned Scientists, 2000; Lachman, 1999).

However, measures can be taken to reduce the possibility that a newly introduced protein will be an allergen. The structure of that protein can be compared to the structures of allergenic proteins, and if a similarity is found and if sera from sensitive individuals are available, an analysis of possible cross-reaction can be performed. If there is similarity, then that engineered crop is not fit for consumption, and further genetic modification is necessary. Many proteins in bioengineered foods have been derived from microbial sources, and producers of genetically modified foods have shown that those proteins do not possess characteristics associated with food allergens—that is, those proteins do not share structural similarity to known allergens and are not resistant to digestive enzymes and acid. In addition, it is known which foods trigger the majority of the allergic reactions (Metcalfe et al., 1996). Cow's milk, eggs, fish and shellfish, tree nuts, wheat, and legumes—especially peanuts—and soybeans produce approximately 90% of all food allergies in the United States (Lehrer, 1999b). The assessment of the allergenicity of proteins from unknown protein sources continues to be a challenge to the food industry. According to Taylor and Lehrer (1996), there is no cause for concern about allergenic potential of proteins introduced into plants from sources (1) with no history of allergenicity, (2) with no amino acid sequence similarities to known food allergens, or (3) that are rapidly digested, or are expressed at low levels compared to the expression of major allergens.

The World Health Organization (WHO) and the Food and Agriculture Organization of the United Nations (FAO) (FAO/WHO, 2001) and Lehrer (1999a) have recently described a hierarchical approach to evaluate the allergenicity of genetically modified foods or crops. The three main approaches that can be utilized to identify allergen sources include (1) amino acid sequence characterization—that method would increase the number of allergenic sequences in the data bank; (2) identification of the amino acid sequences that define allergenic epitopes to develop more precise sequence-screening criteria; and (3) development of an animal model(s) that can recognize food allergens in a manner similar to that which occurs in human disease. Widely accepted animal models are not currently available to identify potential allergens; however, some progress has been made in this area by using rodents and other species (Kimber & Dearman, 2001). Other factors in determining potential allergenicity of modified gene products include molecular mass (the molecular mass of most known allergens is between 10,000 and 40,000 Da), heat and processing stability (labile allergens in foods that are ingested after cooking or undergo other processing before consumption are of less concern), pH and gastric juices (most allergens are resistant to gastric acidity and to digestive proteases), and prevalence in foods (for example, new proteins expressed in nonedible portions of plants are not a concern in terms of food allergy). There is a good correlation between the resistance of proteins to proteolytic digestion and their allergic potential (Astwood et al., 1996). The issue of labeling is also important. Genetically modified food should be labeled to make people aware of what they are buying, and individuals who have allergies should read the labels and not buy foods they think may be harmful to them (Miller, 1999). Presently, there are no in vitro and animal models that have been validated for the identification of protein allergens (Ladics & Dong, 2002). Recently, various animal species have been used to study the allergenic potential of genetically modified foods. The animals tested included Balb/c mice (Kimber & Dearman, 2002), brown Norway rats (Knippels et al., 2002), and pigs (Helm, 2002). In all these studies, allergenic responses were noted with considerable success, although the responses were not observed in 100% of the animals. It is hoped that reliable in vitro and in vivo models would be available in the next few years.

Antibiotic Resistance

Antibiotic resistance, which is the ability of an organism to be unaffected by the antibiotic, occurs naturally by evolution. The widespread use of antibiotics provides conditions that enable resistant organisms to survive and multiply disproportionately at a greater rate compared with susceptible bacteria. Genetic engineering often involves the use of genes for antibiotic resistance as "selectable markers." These markers help select cells that have incorporated foreign genes. There are concerns that these genes might unexpectedly recombine with pathogenic bacteria in the environment or with naturally occurring bacteria in the gastrointestinal tract of mammals who consume genetically modified food, contributing to the growing public health risk associated with antibiotic resistance for infections that cannot be treated with traditional antibiotics.

The presence of antibiotic resistance genes in foods might produce harmful effects. First, consumption of these genetically modified foods might reduce the effectiveness of antibiotics to fight bacterial diseases; antibiotic resistance genes produce enzymes that degrade antibiotics. Second, antibiotic resistance genes might be transferred to human or animal pathogens, making them resistant to antibiotics.

A genetically engineered Bt corn variety from Novartis includes an ampicillin resistance gene (Cannon, 1996). Ampicillin is an antibiotic that is used to treat a variety of bacterial infections in humans and animals. A number of European countries, including Britain, have refused to allow the Novartis Bt corn to be grown because of concern that the ampicillin resistance gene might be transferred from Bt corn to bacteria, making ampicillin a far less effective antibiotic against bacterial infections. In September 1998, the British Royal Society released a report on genetic engineering that recommended the termination of the use of antibiotic resistance marker genes in engineered food products. According to one prediction, alternative types of marker genes will be developed in approximately 5 yr and no new transgenic crops using antibiotic resistance marker genes will appear on the market (Henney, 2000).

It should be noted that organisms containing DNA encoding for antibiotic resistance proteins are common and of increasing prevalence in the environment (Society of Toxicology, 2002). However, the contribution of the antibiotic resistance markers in genetically modified organisms to antibiotic resistance in bacteria in the gastrointestinal (GI) tract has not been studied; it is expected to be very small (Royal Society, 1998) for several reasons—efficient destruction of the resistance gene in the human gastrointestinal tract and the very low intrinsic rate of plant-microbe gene transfer. However, it should be noted that resistance genes occur widely in nature and the antibiotics involved are not widely prescribed by physicians (Society of Toxicology, 2002). In addition, recent advances in genetic engineering do not employ the use of such selection markers (Goldsbrough et al., 1996; Koprek et al., 2000) and their use is likely to diminish.

Production of Natural Pesticides

In 1999, front-page headline stories in the British press disclosed Rowett Institute scientist Dr. Arpad Pusztai's research findings that genetically modified potatoes are poisonous to mammals. Those potatoes were engineered to produce a molecule called *Galanthus nivalis* agglutinin (GNA). This is a natural insecticide, usually found in snowdrops. The engineered potatoes were very different in chemical composition compared to ordinary potatoes and were found to damage vital organs and immune system of rats; the most alarming discovery was the toxic effects the altered potatoes had on the stomach lining of rats (Pusztai & Ewen, 1999). Stanley Ewen, a pathologist from the University of Aberdeen, indicated the damage was due not to GNA but to a component in the genetic engineering process itself, because the genetically modified potatoes produced more damage to the rats than for a control group fed ordinary potatoes with GNA added. Studies suggest it was the 35S cauliflower-mosaic-virus (CaMv) promoter, a promoter spliced into almost all genetically engineered foods and crops. The promoter could have ended up in the wrong chromosome and started switching the wrong genes on (Anonymous, 1999). This is not the only possibility, but is certainly one explanation. The Pusztai and Ewen (1999) studies were discontinued because the British government suspended his research funding.

Phytoestrogens

In 1999, it was shown that concentrations of phytoestrogen compounds, which are believed to protect against heart disease and cancer, were lower in genetically engineered soybeans than in traditional strains (Lappe & Bailey, 1999). This and other studies demonstrate that genetically engineered food has the potential to have less nutritional value (Fagan, 1996). For example, the milk from cows injected with gamma bovine growth hormone (rBGH) contains higher levels of fat and bacteria, and can therefore go sour faster. New proteins in foods could alter the cellular metabolism of the food-producing organism in unintended and unanticipated ways. As a result, the food-producing organism might fail to make an important vitamin or nutrient that it naturally synthesizes. Therefore, it is possible that genetically modified food will lack important nutrients that are normally present in the corresponding natural, nongenetically engineered food.

Heavy-Metal Sequestration

Sludge contains plant nutrients, but it cannot be used as a fertilizer because it is contaminated with toxic heavy metals. The purpose of creating some genetically modified crops is to utilize municipal sludge as fertilizer. However, introduction of some genes into crop plants can remove heavy metals such as mercury or lead from the soil and concentrate them in the plants. The goal is to genetically engineer plants to localize those metals in inedible parts of plants to prevent adverse health effects from consumption of such crops. In a tomato, for example, the metals would be sequestered in the roots; in potatoes, they will be sequestered in leaves. Turning on the genes in only some parts of the plants requires the use of genetic "on" and "off" switches that turn on only in certain tissues, like leaves. Such products pose risks of contaminating foods with high levels of toxic metals if the on and off switches are not completely turned off in edible tissues (Cummins, 2000). It is important to keep in mind that the crops used in heavy metal extraction should not be consumed as human food.

Effect of Removal or Inactivation of Genes

It may seem as if many of the health risks of genetically modified food are due to newly added genes, but the removal of genes from plants and other organisms can lead to the production of desirable or undesirable traits. Genetic engineers may intentionally remove or inactivate genes to achieve desirable effects. Such genes, however, may also play other roles, and consideration must be given to the possibility that removal of a gene may have an unexpected detrimental effect on food quality (Union of Concerned Scientists, 2000). For example, decaffeinated coffee can be made by genetic engineering. In decaffeinated coffee plants, genes coding for caffeine synthesis are deleted or turned off. But the removal of the caffeine gene may have an undesirable side effect. Caffeine inhibits the synthesis of aflatoxin, a potent toxin and a carcinogen, produced in certain molds. Coffee beans lacking caffeine genes may be subject to greater contamination by aflatoxin-producing mold. This toxin may remain active through processes of food preparation, but no experimental data have shown that decaffeinated coffee contains aflatoxin (Union of Concerned Scientists, 2000).

Adverse Effects on Nontarget Species

Many environmentalists are concerned that the pesticidal gene product of the genetically modified crops might be toxic to nontarget organisms that consume it; for example, the incorporation of Bt genes into crop plants for insect control. The adverse health effects of Bt endotoxins in nontarget species have been reported (Betz et al., 2000). They show a narrow range of toxicity that is limited to specific groups of insects, Lepidoptera, Coleoptera, or Diptera—depending on the Bt strain. Plant species containing Bt genes have been tested to determine whether any alterations in this limited spectrum of toxicity occurs and no unexpected results were reported (Orr & Landis, 1997; Pilcher et al., 1997; Lozzia et al., 1998).

Concern has been expressed about the potential toxicity of the Bt toxin in corn pollen to the monarch butterfly because initial laboratory studies showed increased mortality in larvae (Losey et al., 1999). However, Sears et al. (2001) believe that it is unlikely that a significant risk to those butterflies exists in the field.

Substantial Equivalence

The current basis used by regulatory agencies in Europe and the United States for evaluating human safety of genetically modified foods is to compare them to products that are currently being used. This gives rise to the concept of "substantial equivalence." If a transgenic food is substantially equivalent in composition and nutritional characteristics to an existing food, it is considered to be as safe as the conventional food (FDA, 1992; OECD, 1993) and therefore does not require extensive safety testing. To evaluate substantial equivalence, the characteristics of the transgene and its potential effects within the host; levels of protein, fat, and starch content; and amino acid composition and vitamin and mineral equivalency, along with levels of known allergens and other potentially toxic components, are considered. Genetically modified foods can be either substantially equivalent to an existing counterpart, substantially equivalent except for certain specified differences (for which further safety assessments would be done), or nonequivalent, which implies that more extensive safety testing is warranted. The Royal Society of Canada (2001) recently recommended that "substantial equivalence" should only be considered if there is equivalence in the genome, proteome, and metabolome of the modified food when compared with the non-modified food. The assessment of substantial equivalence provides an excellent tool in assessing potential hazards from genetically modified foods. Several transgenic crops, such as herbicide-resistant corn, canola, soybeans, and cotton, as well as insecticide-protected corn and cotton, have undergone this assessment and have been shown to be substantially equivalent to commercial crop varieties (Munro, 2002).

Toxicity Testing of Whole Foods

The health risk assessment of genetically modified foods currently relies on the testing of the toxicity of single chemicals. However, food is a complex mixture of thousands of chemicals. The evaluation of the safety of single components of the diet, such as a Bt toxin, can easily be accomplished by studying their toxicity in experimental animals at high doses (Society of Toxicology, 2002). However, whole foods cannot be tested at high doses—the protocol currently used for testing single chemicals to increase the sensitivity for detecting toxicity (MacKenzie, 1999; Royal Society of Canada, 2001).

The National Research Council (2000a, 2000b), Society of Toxicology (2000), and Royal Society of Canada (2001) have recently recommended that effective toxicity protocols be developed to determine the safety of whole foods.

Other adverse health effects could result from overexpression of existing protein or other toxicologically active constituent, resulting in much greater exposure to that constituent than previously encountered by humans in their diet (Royal Society of Canada, 2001).

According to the World Health Organization (1995), the safety of whole genetically modified foods can be assessed by comparing the toxicity of the safety of whole genetically modified food to the food or food constituent from which it is derived.

Meher et al. (2002) studied the acute oral toxicity of Bt (variety kenyae) (B.t.k) in rats and acute dermal toxicity, ocular irritation, and skin irritation in rabbits. They also studied its toxicity in freshwater fish (*Gambusia affins*). The oral lethal dose for 50% (LD50) of the rats was 5 ml and 1000 mg/L containing 2.5×10^7 spores/ml, respectively. The dermal LD50 was greater than 2.5×10^7 spores/ml. The authors concluded that B.t.k was nontoxic to the three species tested. The LD50 in fish was not determined because lethality was not observed even at 1000 mg/L (2.5×10^7 spores/mg) level (Meher et al., 2002).

Sidhu et al. (2000) studied the food and feed safety of Roundup Ready corn (GA21) developed by the Monsanto Company, which included both compositional and toxicological studies. Compositional analysis showed that, except for a few minor differences that are unlikely to be of biological significance, the grain and forage of GA21 corn were comparable to that of the control line and to conventional corn (Sidhu at al., 2000). Similar results were obtained for the toxicological end points—the magnitude of the significant differences was small and the values were within historical limits (Ridley et al., 2002). These data taken together demonstrate that Roundup Ready corn is as safe and nutritious as conventional corn for food and feed use (Ridley et al., 2002).

Many transgenic crops that are herbicide tolerant or insect protected (e.g., corn, soy, canola, cotton) have been fed to chickens, beef and dairy cattle, swine, sheep, and fish in universities around the world using commercial feeding conditions. Findings from over 30 independently conducted studies have indicated no differences for nutrient composition, digestible matter, and animal performance when livestock were fed feedstuffs from conventional and biotech crops (Glen, 2002). Furthermore, in independent studies conducted to determine whether transgenic DNA and proteins can be detected in animal products, no transgenic plant-source DNA and proteins were found in milk, meat, and eggs (Glen, 2002).

Benefits of Genetically Modified Crops

Genetically modified food does have potential risks but also has benefits. The new food biotechnology will produce grains, fruits, and vegetables that contain more nutrients, such as proteins, vitamins, and minerals, and have reduced fatty acid profiles. Biotechnology will also make better-tasting food crops that will ripen less quickly after picking so that there is an improved flavor and the foods remain fresh longer. The crops will be disease and insect resistant and have increased tolerance to herbicides and drought. The use of pesticides will decrease and there will be faster growing crops (Paarlberg, 2000). There is a need to double food supply by 2025 due to expected population increases. Less arable land will be available and there will be a need to destroy more primary habitat unless genetic engineering is utilized. In addition, genes that produce vaccines are being inserted into crops so that those people who eat them would be healthier, because they would be protected from infectious organisms. For example, researchers at Cornell University have genetically altered a potato to contain a vaccine for viral diseases (Griffith & Cookson, 2000). Rice has also been genetically modified so that it is enriched with vitamin A, preventing blindness for those who eat it, especially in famine-stricken countries in Africa and Asia. Therefore, genetically engineered food can be a potential lifesaver and its benefits should not be overlooked.

CONCLUSIONS

A review of the literature on health effects of genetically modified foods developed for human consumption indicates that they are generally safe. Similar conclusions have been drawn by many authoritative government agencies and other scientific organizations (FAO/WHO, 2001; Royal Society, 2002; National Research Council, 2000a, 2000b; Society of Toxicology, 2002). However, there are reports of adverse effects when humans consumed genetically modified foods that were developed as animal feed, such as StarLink corn. But genetic engineering of crops is a new technology in its embryonic stages. There are many other risks that have not been identified. Scientists still have an incomplete understanding of physiology, genetics, and nutritional value of genetically engineered crops, which leads to the inability to predict everything that can go wrong. It is essential to list any and all concerns about commercializing genetically modified food. Scientists still do not know enough about the way genes operate and interact in genetically engineered organisms to be confident of what the outcome of any modification will be. There is considerable scientific uncertainty about what the immediate or long-term effects will be of placing genetically modified foods into the food chain (Union of Concerned Scientists, 2000).

From the standpoint of the Food and Drug Administration (FDA), the important thing for consumers to understand about these new foods is that they are likely to be as safe as the foods now on store shelves. All foods, whether traditionally bred or genetically engineered, must meet the provisions of the Federal Food, Drug, and Cosmetic Act (Henkel, 1998). The Food Standards Agency monitors shopping habits as part of its research on the possible impact of genetically modified food on human health. That agency will be checking sales data for food containing genetically modified soybeans and corn, which could be used in oils and processed foods. Consumption patterns will be linked to such data as the number of birth defects or increased cases of cancer, diabetes, and other diseases become available. Any health benefit from eating the food will also be assessed. It is predicted that it will take about 18 mo to determine if a model can be established that can act as an early warning system for foods that adversely affect human health (Elliott, 2000). Decisions regarding safety should be based on the nature of the product, rather than on the method by which it was modified. It is important to bear in mind that many of the crop plants used contain natural toxins and allergens. The potential for human toxicity or allergenicity should be kept under scrutiny for any novel proteins produced in plants with the potential to become part of human food or animal feed. Health hazards from food, and how to reduce them, are an issue in all countries, apart from any concerns about genetically modified technology (National Research Council, 2000a, 2000b).

Food is different from other consumer products since it is ingested. People naturally care about their food and feel they have a right to know what they are eating and what it can do to their bodies. Food holds a position of inviolability in our culture because of the involuntary nature of its consumption and the pleasure with which we fulfill our nutritional needs (Burdoch, 2002). This cultural demand for absolute purity is under assault with seeds of doubt about the integrity and thoroughness of the vetting process for safety of biotechnologically produced substances and has given rise to the generalized fears, as exemplified by the Precautionary Principle (Burdoch, 2002). When a new technology, such as genetic engineering of food crops is developed, not all problems it may cause can be foreseen. Genetic engineering is creating living things that have not previously existed. Although authoritative government agencies and health organizations believe that genetically modified foods marketed for human consumption are generally safe, consumers have the right to demand further research to ensure that indeed is the case. The pressure for more research would force the government agencies and food corporations to increase their research funding. If the results of new research confirm the safety of genetically modified foods, that would help assure the public that genetically modified foods are safe for human consumption.

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