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viewpoint

Genetically Modified Foods: Threat or Opportunity?

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Summary

Gene technology has the potential to offer many improvements in the quality and quantity of the world's food supply provided that genuine concerns regarding safety, environmental impact, information and ethics are satisfactorily addressed. In this article, some of the benefits as well as concerns about genetically modified foods are discussed using examples such as tomatoes, soybeans, corn and rice.

Key words: gene technology, GM food, transgenic food, soybeans, corn, rice, tomatoes

Introduction

It has been estimated that about 800 million people worldwide have eaten genetically modified (GM) foods or food ingredients without adverse consequences on their health (*1*). There have been no reports of deaths caused by the consumption of GM foods. And yet, despite an exemplary safety track record so far, the average European citizen who reads a daily newspaper or watches television regularly regards GM foods with suspicion. In a 1999 Eurobarometer survey, two-thirds of European consumers said that they would not buy GM food products even if they tasted better than the conventional variety (*2*). A GM tomato paste (Fig. 1), which was cheaper and had outsold the conventional variety by 2:1, was withdrawn from supermarket shelves in the United Kingdom not because of any evidence of harm but because of perceived public opposition to GM foods (*3*). Labelling of GM foods is mandatory in Europe and new proposals for even more stringency concerning »GM-free« claims are being discussed in the European Council and Parliament for adoption in 2002/2003.

Fig. 1. The genetically modified tomato paste outsold the conventional variety by 2:1 in 1996. By 1998, it was withdrawn from the UK market because of consumer opposition to GM foods. Courtesy: Prof. D. Grierson

The European scene is a stark contrast to American consumer confidence in GM foods. A recent survey has shown that 54 and 69 % of American consumers would buy GM foods that »tasted better or fresher« and »insect-resistant food crops that needed less pesticide spray«, respectively (*4*). More than 60 % of respondents agreed with the statement that they would benefit from biotechnology in the next 5 years. The survey, conducted

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just after the U.S. Food and Drug Administration (FDA) had reaffirmed that it would not require mandatory labelling of GM foods, showed that nearly 70 % of American consumers agreed with this policy. Nearly 90 % of respondents also agreed that free phonelines, brochures and websites were a better way of informing consumers than labelling (*4*).

Gene technology has the potential to offer many improvements in the quality and quantity of the world's food supply. The ability to move genes across the species barrier makes this new technique revolutionary in terms of potential benefits but it also raises concerns regarding safety, environmental impact, consumer choice, equity of distribution and ethics. In this article, some of the benefits as well as the genuine concerns and uncertainties surrounding GM foods are discussed and illustrated with examples of recently developed crops including GM tomatoes, soybeans, corn and rice.

GM Crops Worldwide

Whilst regulations and public opinion are restricting commercial development of GM foods in Europe, the sowing of GM crops in the rest of the world has continued to rise unabatedly since 1996. In 2000, nearly 45 million hectares (equivalent to an area twice the size of the United Kingdom) of GM crops were planted worldwide (*5*). Although nearly 70 % of this land has been in the United States, substantial commercial planting has also occurred in Canada, Argentina, China, Australia and South Africa. Of the crops sown in 1999/2000, over one-half were soybeans, about one-quarter was corn, and the rest consisted of cotton, rapeseed and potatoes (*6*). Other fruits, vegetables, cereals and root crops (Table 1) have also been genetically modified and field-tested although they are not, as yet, grown on a commercial scale (*7*).

Table 1. Examples of food crops that have been genetically modified and field-tested but have not been commercially planted as of 2001 (Data from APHIS/USDA)

Food crop	GM cultivars released
Fruits and nuts	Apple, blueberry, cranberry, grape, kiwi, papaya, peanuts, plum, raspberry, strawberry, walnuts, watermelon
Vegetables	Asparagus, aubergine (eggplant), broccoli, cabbage, carrot, cauliflower, chicory (radicchio rosso), courgette (zucchini), cucumber, lettuce, mustard, pea, pepper
Staples	Barley, rice, sugar beet, sugar cane, sunflower, sweet potato, wheat

Nearly all the GM crops grown commercially since 1996 have been modified for traits of agronomic significance. From the technical viewpoint, agronomic traits such as herbicide tolerance and insect resistance have been relatively easy to engineer as they are under the control of single genes. Much of the early work in genetic modification in the 1980s required high levels of R&D investment and only very large companies or small entrepreneurs with venture capital could afford to undertake it. Consequently, herbicide-tolerant and insect-resistant crops developed by the large agrochemical companies have dominated the first wave of GM plants sown on a commercial scale. The lack of obvious consumer benefits in these GM crops has undoubtedly contributed to the rejection of GM foods by the European public (*8*).

How Safe are GM Foods?

Consumers often ask: »Are GM foods safe?« or »Can you guarantee that GM foods are 100 % safe?« Unfortunately, science cannot guarantee absolute safety because »absence of evidence« is not the same as »evidence of no harm«. So, the question we should be asking is: »How safe are GM foods?«

One of the main aims of regulatory control in the food chain is to protect human health. Many countries have introduced new regulations to control gene technology well before any GM foods appeared on the market. The concept of substantial equivalence, first developed in the late 1980s by several national regulators and formalised by the OECD in 1993, forms the basis of safety regulations in most countries today. The concept is based on the assumption that existing foods can serve as a basis for comparison when assessing the safety of modified foods or ingredients. Acceptability or non-acceptability is established by determining if the new food is substantially equivalent to a conventional food in terms of composition, nutritional properties, toxin and allergen content, the amount likely to be consumed, the type of processing (industrial and domestic) the food is likely to undergo, and consumption by vulnerable groups of people such as infants or the elderly. Where no substantial differences are found, the new food can be considered »as safe as« a conventional food. Where differences are found, further testing such as animal feeding studies and toxicological trials are required.

The safety assessment of the glyphosate-tolerant soybean provides a good example of the comparative approach. The GM soybean had been produced by the introduction of a gene coding for 5-enolpyruvylshikimate-3-phosphate (EPSP) synthase from *Agrobacterium* sp. into the plant genome. The expression of the enzyme in soybeans rendered the plants tolerant to glyphosate. The latter is a broad-spectrum herbicide that inhibits synthesis of phenylalanine and tyrosine in plants and has a history of low persistence in the environment. The use of glyphosate in conjunction with the GM soybean allows for reduced levels of herbicide application, thereby conferring benefits for the environment, as well as for the farmer *via* higher crop yields and improved harvesting efficiency (Fig. 2).

Results of over 2 000 tests have shown that the herbicide tolerant soybeans and their products (oil, protein isolate and concentrate, toasted meal, flour, lecithin) are the same as the conventional equivalents by composition (protein, fat, fibre, carbohydrate, amino acids, fatty acids), anti-nutrient content (trypsin inhibitor, lectins, isoflavones, phytoestrogens, urease, stachyose, raffinose, phytate) and nutritional equivalence (tested in feeding trials on rats, quail, chicken, cows and fish) (*9,10*). Since the EPSPS synthase constituted 0.1 % of the total protein

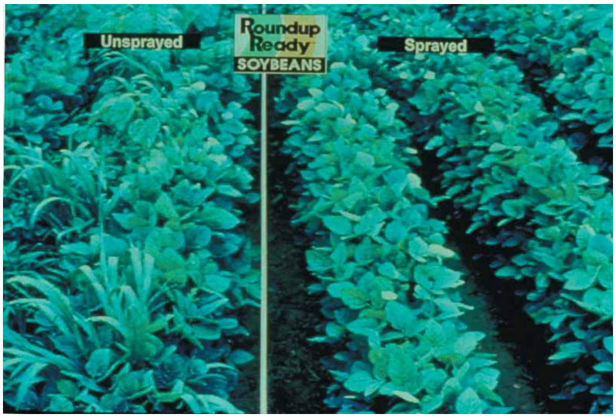

Fig. 2. Herbicide-tolerant soybeans sprayed and unsprayed with glyphosate.
Weeds decrease yields and quality of seed, decrease harvest efficiency and act as reservoirs for crop pests. Farmers often use a cocktail of inefficient, narrow-spectrum herbicides in excess of requirements thus contributing to environmental pollution. Glyphosate-tolerant soybeans need spraying less often and at lower concentrations. Courtesy: Monsanto

in the GM soybean, additional safety testing focused on the new protein. The enzyme was shown to degrade within seconds in simulated gastric fluid and within minutes in intestinal fluid. No allergic or toxic reactions were reported following acute 7-day feeding trials in rats or 91-day sub-chronic feeding trials. No toxic effects were observed in mice when the new protein was administered at a level 1 000 times of the anticipated consumption level in food products (*11*). Therefore, it was concluded that the herbicide-tolerant soybean was substantially equivalent to the conventional soybean.

During genetic engineering procedures, not all cells are successfully modified and so it is necessary to »tag« the genetic material targeted for transfer using so-called »marker genes«. Antibiotic resistance is often used as a marker since such a property is easily and rapidly measured in the laboratory. Although the transfer of antibiotic resistance from a marker gene in a plant to a microorganism in the human gut has not been demonstrated experimentally, it has been suggested that there may be a potential risk, however small, of spreading resistance to therapeutic antibiotics in this way. Since alternative marker genes based on, for example, lactose utilisation, are now available, it is likely that antibiotic resistance markers such as those coding for tetracycline and ampicillin in corn, or kanamycin in tomatoes, will no longer be used in food crops in the future (*8*).

Although the determination of substantial equivalence is a useful exercise, it fails to detect unintended effects. With increasing numbers of GM crops containing more than one modified gene, there is a clear need for new methods that will detect possible »cassette effects« when multiple genes are transferred into a GM organism. Several multinational research projects are underway in Europe and elsewhere to find ways of analysing gene expression (genomics), determining the overall protein produced (proteomics) and profiling the secondary metabolites (metabolomics) using a range of innovative techniques including microarray technology and mRNA fingerprinting. The European Union is funding a cluster of research projects in this area at a level of over 10 million € (*12*).

In 1997, the EU Novel Foods Regulation introduced mandatory safety testing and marketing approval for all novel foods, including GM foods. Subsequently, several amendments and additions to the Regulation were debated and enacted, including the concept of the »precautionary principle«. This principle states: »in cases of uncertainty or where there is a risk of danger, the Commission will err on the side of caution in authorising scientific developments«. Whilst this may seem an eminently sensible approach, an over-zealous application of the precautionary principle may stifle innovation in Europe. In the early 19th century, the fastest means of transportation was by horse at about 15 km/h. In 1829, the first steam train travelled from Manchester to Liverpool at 50 km/h. During the ceremony organised to mark the maiden voyage, one government official was killed. Many regrettable accidents, illnesses and deaths have been caused directly or indirectly by mechanical means of transportation since then. However, if the precautionary principle had been invoked after the first accident, we would still be riding horses as our principal means of transportation today. It remains to be seen how the precautionary principle will be applied in European practice.

Environmental Impact of GM Crops

The second most important concern about GM crops is their environmental impact. Many questions abound. For example, could herbicide tolerant GM crops become »superweeds«? The results of recent studies have shown that GM crops do not become self-seeding or spread into neighbouring areas (*13*, *14*). Pesticide-tolerant corn, sugar beet and rapeseed and insect-resistant potatoes together with controls were planted at 12 sites in the United Kingdom in 1990 and the sites were monitored for 10 years. All the plants, whether modified or not, died out within 4 years of sowing except one unmodified potato, which lasted for 10 years (*14*).

Of greater concern is the risk of a herbicide-tolerant gene spreading through pollen to plants which are already weeds. Field studies have shown that pollen from GM plants is rarely carried over very long distances. For example, the percentage of cross-pollination in a field of GM rapeseed has been determined experimentally as 0.1 %, 0.0003 %, and zero at distances from the test site of 6, 47 and 70 m, respectively (*15*). For GM potato, cross-pollination was 0.02 % at 10 m and zero at 20 m from the site. A problem that remains is in predicting the effects of extremely rare hybridisation events that may not be evident in relatively small plots of a hectare or two but may occur when GM crops are grown on thousands of hectares of land (*15*). There are historical examples of genes moving from one organism to another by unknown mechanisms over several million years and such events may eventually result in the transfer of the GM trait to a weed. However, these occurrences are so rare that it would be impossible to monitor them in practice (*16*).

Insect resistant GM crops have raised particular concerns because of potential adverse effects on populations of non-target species. The soil bacterium *Bacillus thuringiensis* produces specific proteins (collectively known as Bt) active against many agricultural pests such as beetles, moths and flies. Several thousand tonnes of these proteinaceous bacterial toxins have been in use for a number of years as biopesticides with no detrimental effects on the environment. However, because of their poor stability and high cost, they have not achieved extensive market penetration. To get around this problem, several genes encoding for insecticidal Bt proteins have been inserted into food crops, most notably corn. Corn is particularly vulnerable to attack by the European corn borer, which causes millions of dollars worth of damage every year (Fig. 3). Since the introduction of Bt corn,

Fig. 3. Comparison of conventional corn field (left) infected with corn-borer and Bt-corn field (right). Courtesy: Monsanto

corn borer levels in the USA have been at their lowest ever but several more years need to pass before the true success of the insect-resistant cultivar can be established. In the meantime, the results of a laboratory study have shown that larvae of the Monarch butterfly, a sensitive indicator of environmental disturbance in the USA (Fig. 4), fed exclusively on milkweed dusted with pollen from Bt-corn ate less, grew more slowly and had a significantly higher mortality rate than larvae fed on leaves

Fig. 4. The Monarch butterfly: An indicator of environmental disturbance for Bt-corn? Courtesy: www.MonarchWatch.org

dusted with conventional pollen (*17*). On the face of it, this was an alarming finding and many popular media sensationalised the results. Subsequent field trials showed that there were no differences in survival patterns between larvae feeding on GM crops and those feeding on conventional crops but these more reassuring findings were not reported widely (*18*).

It has been suggested that the widespread adoption of insect-resistant crops by farmers worldwide may lead to the extinction of certain insect species thereby reducing the biodiversity of the planet. Given the gaps in our current level of knowledge about the environment, it would be difficult to calculate with any certainty the likelihood of a catastrophic environmental event occurring as a result of worldwide GM sowing. Environmental monitoring over several generations and across all continents would be virtually impossible to undertake in practice. The need for further research into the environmental consequences of modern agriculture including GM crops is greater now than ever before.

Food Quality and the Genetic Modification of Nutritional Content

Whilst the genetic modification of agronomic traits has already produced many new crop varieties, improvements in food quality brought about by the genetic route have been slower to emerge for both technical and regulatory reasons. Rice is one of the few examples of a crop that has been nutritionally enhanced using gene technology. Rice is the staple food for nearly one-half of the world's population and in Asia, it provides 50–80 % of the average daily calorie intake (*19, 20*). Although thousands of varieties of rice are available, all are poor in Vitamin A content. It has been calculated that 124 million children worldwide are deficient in Vitamin A intake leading to 14 million cases of poor vision and 500 000 cases of irreversible blindness (*20*). Increased intake of green vegetables and animal products as well as vitamin supplements are all possible conventional solutions to the problem of Vitamin A deficiency but are too costly for long-term implementation in countries where the majority of people are very poor. The genetic solution to this problem has been to introduce genes coding for phytoene synthase and desaturase, carotene desaturase and lycopene cyclase from the daffodil into rice to produce a GM cultivar high in β-carotene, a precursor of Vitamin A. The new rice has a yellow hue and has been named »golden rice«. It has been calculated that 300 g of cooked »golden rice« could provide an adult's daily requirement of Vitamin A although these estimates need to be confirmed experimentally.

In an unprecedented gesture, the scientists, research funding bodies, companies and technology licence owners involved in the development of »golden rice« gave up their intellectual property rights in 2000 for the benefit of resource-poor farmers in the developing world. Samples of the rice were delivered to the International Rice Research Institute in Los Banos, Phillippines in early 2001 for further safety and utility testing (*20*). It remains to be seen whether »golden rice« fulfils its promise but if successful, it will be given free-of-charge to subsistence farmers in developing countries.

Epilogue

Responsible scientists recognize that there are genuine concerns regarding the introduction of genetically modified organisms on the planet. The application of every new technology involves some risk and may produce unforeseen problems. As with any human endeavour, mistakes will be made when applying GM technology to food production. The challenge will be to use scientific tools and knowledge to attempt to predict problems and solve them before they happen. There is a need for public concerns to be addressed by continuous research, communication, and appropriate legislative measures. As James D. Watson, co-discoverer of the structure of DNA, said:

»Never put off doing something useful for fear of evil that may never arrive.«

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Genetički modificirana hrana: prijetnja ili pogodnost?

Sadržaj

Genska tehnologija omogućava mnoga poboljšanja kakvoće i količine hrane koja se priprema u svijetu ako su zadovoljeni osnovni uvjeti s obzirom na sigurnost, utjecaj na okolinu, informacije i etičnost. U članku su prikazane neke prednosti, ali i oprez od genetički modificirane hrane, navodeći kao primjer rajčicu, soju, kukuruz i rižu.