Genetically Modified Foods

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Food Biotechnology is defined as the application of biological techniques to food crops, animals and microorganisms with the aim of improving the attributes namely quantity, safety, ease of processing and production economics of the food. The traditional food such as bread, beer and cheese employ fermentation and are known to the world for hundreds of years. The most recent application of biotechnology to food is genetic modification (GM), also known as genetic engineering, genetic manipulation and/or recombinant DNA technology. The collective term "Genetically Modified Organisms" (GMO) describes plants, animals and microorganisms which have had DNA introduced by gene transfer techniques. Random genetic variation occurs naturally in all living things and is the basis of evolution of new species through natural selection. However these changes are random, slow and unpredictable unlike the genetic engineering which is very specific, quick and relatively predictable. Traditional selective breeding methods are based on the transfer of genetic material between individuals of the same species. However, gene technology also makes it possible to transfer genes across the species barrier. This property makes the technique revolutionary in terms of the potential benefits. At the same time, it gives rise to several issues caused concern regarding the safety, ethics and environmental impact. GM has huge potential for mankind in medicine, agriculture and food. In food, the longer-term benefit GM food offers especially to the third world is - its potential for elimination of hunger and malnutrition. Even today, there are 800 million people in the third world who are under nourished and do not receive enough nutrition due to starvation. This situation will be worsened as a result of the world's escalating population over the coming decades. For example, between 1995 and 2025 the world's population is predicted to increase by over 40% and rice consumption will increase by 65% from 457 million to 757 million [1]. GM food is perhaps the only solution to cope with the food demand and supply balance.

Rice yellow mottle virus (RYMV) is an example of an important developing country disease where farmers do not spray pesticides as there is no known control. However, the deployment of transgenics resistant to RYMV that have recently been produced *at the Sainsbury Laboratory will have indirect* environmental benefits. Reduction in crop losses that lead to increased production per unit area reduces the pressures on marginal land. The biotechnology to produce RYMV resistance operates at the level of RNA. No foreign proteins are expressed, thus eliminating any possible risks concerning food quality. A functioning regulatory framework is not yet in place in RYMV-affected countries. There is a risk that in the year 2005, while it is predicted that half of the crops in the USA will be transgenic, developing countries will hardly have benefited at all[2].

Genetic Modification of Food

Biotechnology techniques are being applied to plants to produce plant materials with improved composition, functional characteristics, or organoleptic properties. Applications of biotechnology in plant breeding require more time to develop than pharmaceutical applications because of difficulties associated in working with living tissue. The pace of implementation is also limited by growing seasons. Barriers to applications of biotechnical methods with plants are minor, however, compared with barriers to applications of biotechnical methods in the breeding and production of animal foods.

Genetic modifications have produced fruits that can ripen on the vine for better taste yet have a longer shelf life through delayed pectin degradation [3,4] Yet another modification in fruits is altered responses to the plant hormone ethylene[5].

Plant foods with enhanced processing and/or nutritional characteristics are other interesting applications of GM technique. In 1992, Monsanto Company successfully inserted a gene from a bacterium into the Russet Burbank potato. This geneincreases the starch content of the transgenic potato. Higher starch content reduces oil absorption during frying, thereby lowering the cost of frying french fries and chips and reducing the oil content in the finished product[6]. In the future, such genetic applications as altering the fatty acid profile in oil seeds and producing wheat with no phenylalanine may be possible.

Advantages and Potential Benefits of GM Food

- Allows a much wider selection of traits for improvement: e.g. pest, disease and herbicide resistance in plants is already achieved. There is a potential to develop drought resistance, improved nutritional content and improved sensory properties of the crop.
- It is faster and lower in cost
- Desired change can be achieved in very few generations
- Allows greater precision in selecting characteristics

These advantages could, in turn, lead to a number of benefits, especially in the longer-term, for the consumer, industry, agriculture and the environment:

- Improved agricultural yields with reduced use of pesticides
- Ability to grow crops in previously inhospitable environments (e.g. via increased ability of plants to grow in conditions of drought, salinity, extremes of temperature, consequences of global warming, etc.) leading to improved ability to feed an increasing world population at a reduced environmental cost
- Improved sensory attributes of food (e.g. flavour, texture, etc.)
- Improved nutritional attributes, e.g. combatting anti-nutritive and allergenic factors and increased Vitamin A content in rice helping to prevent blindness in Southeast Asia
- Improved processing characteristics leading to reduced waste and lower food costs to the consumer.

GM Food: Commercial Aspects

The first commercially available whole food products was the Flavr Savr (Calgene, Inc) slow-ripening tomato, which US Food and Drug Administration (FDA) approved in May 1994; the gene for polygalacturonase, the enzyme responsible for softening, is turned off in this tomato[7]. A variety of squash that is resistant to two plant viruses was approved by FDA in 1994. In 1995, the Environmental Protection Agency (EPA) gave clearance for development of transgenic corn seed, cotton seed, and seed potatoes that contain the genetic material to resist certain insects[8]. FDA approved these biotechnology applications in 1994. The US Department of Agriculture (USDA) is considering herbicide-resistant soybeans and cotton seed for animal feed. The advantage of such products is that they allow the use of less toxic and more environmentally friendly herbicides and pesticides[9]. Today, the list of approved and marketed GM foods in USA includes several products (Table 1).

Safety and Regulation of GM foods

When introducing any new technology, including gene technology, into the food chain, there is a need to adopt appropriate safeguards to protect human health. Most countries in the Western hemisphere started developing regulatory controls well before any GM foods reached the market. These controls were put in place not because safety problems had been identified but because of a lack of familiarity with GMOs. Although many of the early concerns regarding the safety of GM foods have not materialised, the precautionary approach has continued as it remains important to ensure that no new hazards are created. One will appreciate that the safety aspect concerned is likely to be dependent on the type of genetic modification. Given below are some of these factors.

Potential public health hazards posed by introduction of a genetically engineered product into the food supply include[10].

- increase in toxins naturally occurring in the parent line,
- inclusion of a new and potentially allergenic protein derived from the originator of the genetic material, introduction of "unnaturally occurring" hormones into the food supply
- the possibility that bacterial resistance from genetically engineered organisms could transfer to pathogenic strains of bacteria

The possible introduction or amplification of allergenicity is a concern. A situation has already occurred where a research attempt to produce a soya bean with an increased methionine content by a gene transfer from a brazil nut was found also to transfer the allergenicity from the brazil nut.

Unintended horizontal gene transfer is another fear. Safety evaluation of horizontal gene transfer from genetically modified organisms to the microflora of the food chain and human gut is very important and several animal studies are being conducted. Detection of Unintended Effects is another very important factor which needs attention. For example feeding transgenic crop to livestock and its effect on the meat, milk and animal products (insect / herbicide resistant corn, soyabean or heat stable glucanase Barley to poultry, Beef, Dairy Cows, Sheep Herbicide - Tolerant Sugar Beets to Swine, Herbicide - Tolerant Soybeans to Catfish)are important[11].

Labelling : Labelling food from genetically modified plants and animals has become an important issue. Some consumers and consumer groups believe they have a right to know whether genetic engineering was used to produce a food, some want to be able to choose food on the basis of how it is produced, and some believe labels are needed to notify consumers of potential allergens[12]. Others believe labeling is not necessary If foods are essentially equivalent in composition.

Before May 1997, labelling of GM foods in many countries, including the UK, was not explicitly mandatory. Nevertheless, some food manufacturers and retailers labelled GM foods on a voluntary basis (e.g. the Co-op's vegetarian cheese prepared using GM chymosin and Sainsbury's and Safeway's GM tomato puree) to allow consumers to exercise choice and to gain consumer confidence. Labelling guidelines developed by a number of bodies including the independent Food Advisory Committee in 1993 (revised in 1996) and the Institute of Grocery Distribution in 1997. These guidelines took into account the need for labelling of novel foods which contain material (e.g. allergens) which may have implications for the health of some sections of the population (e.g. infants or the elderly) as well as those which contain "ethically sensitive genes". The latter include foods that contain copy genes originally derived from humans or from animals which are the subject of religious dietary restrictions (e.g. pig genes for Muslims) or any animal genes for vegetarians. Much of the provision on ethically sensitive genes has been based on the findings of the UK Polkinghorne Committee, which reported on the ethics of genetic modification in 1993.

Presently biotechnology applications in food and agriculture are the subject of extensive regulatory review to protect against potential negative effects on food safety and the environment. Federal agencies involved in biotechnology regulation include USDA, which evaluates whole foods and production processes; FDA, which evaluates whole foods, food ingredients, and food additives; and EPA, which evaluates production process[13]. The FDA currently evaluates each application of biotechnology to animal food products on a case-by-case basis. In contrast, FDA has determined that plant foods produced through biotechnology present no inherent risk and, therefore, should be regulated as any other food entering the marketplace[14,15].

Environmental issues : Since 1987, more than 25,000 field trials of GM plants have been carried out in 45 countries without adverse environmental consequences. Furthermore, the rate of field-testing has increased rapidly especially in the USA where the number of trials has doubled each year since 1987. In terms of field releases, the European Union lags well behind North America. More than 70% of field trials were conducted in the USA and Canada followed in descending order by Asia, Europe and Latin America, with very few trials conducted in Africa. These trials represent considerable accumulate evidence in support of a favourable safety an environmental record for the new gene technology

The relevance of environmental data obtained from small field trials to large-scale sowing on several million acres of land has been questioned. Towards the end of the 1990s, more than 80 GM variants of several food crops including maize, rapeseed and soyabean had received regulatory approval for large-scale sowing and use in foods in the USA and Canada. It has been estimated that in 1998 40.4 million hectares (100 million acres) of land have been planted world-wide with transgenic crops. By far the largest acreage of land planted with GM crops has been in USA and Canada, although plantings in China and Argentina have also been significant. Although taking place mainly outside of Europe, these large-scale developments cannot be ignored within the context of a global economy. In addition, the first ever field trials of transgenic life forms other than plants such as arthropods and nematodes have been approved in 1998.

Past experience with introductions of new species to environments where they are not naturally present has shown that potential problems may take several generations to manifest themselves. The problem of possible cross-pollination from GM crops to non-GM crops is of concern to organic farmers, who fear that, if it occurs, their produce could no longer be said to be "organic", and to those who wish to have the right to choose non-GM foods. There is also concern that traits such as herbicide resistance may spread to weeds and that the problem of insect resistance may be aggravated. It has been suggested that the adoption of insect-resistant crops by farmers worldwide may lead to the extinction of certain insect species (e.g. Lepidoptera) thereby reducing the biodiversity of the planet[16]. Some of the potential environmental risks are almost impossible to predict. Environmental regulation is difficult to enforce when there are no clear standards against which the performance of a product can be measured (e.g. how many birds, butterflies and wild flowers should there be on a farm and to what extent can their numbers be affected before the environment is harmed?).

Waste Management : Waste management, or bioremediation, is an area of increasing interest to consumers. In response, dietetics and food professionals are initiating efforts to control the amount of waste generated in foodservice operations. Through application of biotechnical methods, enzyme bioreactors are being developed that will pretreat some disposable serviceware or food waste components and allow their removal through the sewage system rather than through solid waste disposal mechanisms or will allow their conversion to biofuel for operating generators[17]. Microbes can be induced to produce enzymes needed to convert biodegradable materials into the building blocks for new polymers. Waste streams can be controlled to convert by-products to biofuel (wheat straw to glucose to ethanol), specialty chemicals (sugar or fat substitutes), or feedstocks and other useful materials (packaging materials or coatings)[18].

Socio-economic concerns : An example of a socio-economic concern has been about the potential for misuse of the so-called terminator genes which prevent seeds from germinating. Although patents exist for terminator technology, it is not yet available commercially. There are fears that large corporations might use such genes in all their GM crops to prevent farmers from storing seed and that plants that produce barren seed could make life more difficult for poor farmers in the developing world. However, farmers would only buy these seeds if they found an overall advantage in doing so; otherwise they could continue to grow conventional cultivars and save the seed in the traditional way. Furthermore, if cross-pollination occurs, GM plants with terminator genes could transfer their sterility to other plants grown nearby. However, on the positive side, terminator technology could ensure that GM plants do not themselves become weeds.

Benefits Versus Risks - and the Consumer Opinion

If biotechnology is to be used to ensure a safe, abundant, and affordable food supply, it must be accepted by the public. Increasingly, public interest groups are questioning whether technological change is good or needed, particularly as it affects food safety, the environment, animal rights, and the changing structure of agriculture. Recent surveys regarding consumer attitudes about biotechnology have shown that consumers are not well informed about biotechnology, but are interested in it and are cautiously optimistic about its use in food production and processing[19,20]. Using biotechnology to change plants was considered much more acceptable than using it to change animals. Transgenic applications of biotechnology, such as the insertion of animal genes into plants, were unacceptable to many consumers. Environmental concerns were important to most people and many considered ethical issues important as well. Some survey showed that consumer concerns about biotechnology related to perceived unpredictability, risks to the environment, alterations in the ecosystems, and moral and social questions.

Conclusion

Food scientists and technologists can support the responsible introduction of GM techniques provided that issues of product safety, environmental concerns, information and ethics are satisfactorily addressed. Only in this way may the benefits reach the society that this technology can help in feeding the world's escalating population in the coming decades.

Table 1: Genetically engineered crops allowed in the US food supply

Product	Institution(s)	Engineered Trait(s)ce	Sources of New Genes	Name
Canola	Aventis	Resist glufosinate herbicide to control weeks	Bacteria, virus	Name ?2000
Canola	Monsanto	Resist glyphosate herbicide to control weeds	Arabidopsis, bacteria, virus	Roundup Ready 1999
Canola	Monsanto	Altered oil (high lauric acid) for soap and food products	Calif bay, turnip rape, bacteria, virus	Laurical 1995
Corn	Aventis	Resist glufosinate herbicide to control weeds/male sterile to facilitate hybridization	Bacteria, virus	SeedLink Date ?
Corn	Aventis	Resist glufosinate herbicide to control weeds	Bacteria, virus	LibertyLink Date?
Corn	Aventis	Resist glufosinate herbicide to control weeds/Bt toxin to control insect pests (European corn borer)	Bacteria, virus	StarLink 1998
Corn	Dow/Mycogen	Bt toxin to control insect pests (European corn borer)	Corn, bacteria, virus	Nature Gard 1995
Corn	Dow Mycogen DuPont/Pioneer Hi-Bred	Resist glufosinate herbicide to control weeds/Bt toxin to control insect pests (Lepidopteran)	Corn, bacteria, virus	Herculex I 2001
Corn	DuPont/Pioneer Hi-Bred	Male sterile to facilitate hybridization	Potato, corn, bacteria, virus	Name? 1998
Corn	Monsanto/ DeKalb	Bt toxin to control insect pests (European corn borer)	Bacteria	Bt-Xtra 1997
Corn	Monsanto/ DeKalb	Resist glufosinate herbicide to control weeds	Bacteria, virus	Name, date ?
Corn	Monsanto	Bt toxin to control insect pests (European corn borer)	Bacteria	Yield Gard 1996
Corn	Monsanto	Resist glyphosate herbicide to control weeds/Bt toxin to control insect pests (European corn borer)	Arabidopsis, bacteria, virus	Name? 1998
Corn	Monsanto	Resist glyphosate herbicide to control weeds	Arabidopsis, bacteria, virus	Roundup Ready 1998
Corn	Syngenta	Bt toxin to control insect pests (European corn borer)	Bacteria	Bt11 1996
Corn	Syngenta	Bt toxin to control insect pests (European corn borer)	Corn, bacteria, virus	Knock Out 1995
Corn (pop)	Syngenta	Bt toxin to control insect pests (European corn borer)	Corn, bacteria, virus	Knock Out 1998

Corn (sweet)	Syngenta	Bt toxin to control insect pests (European corn borer)	Bacteria	Bt11 1998
Papaya	Cornell Univ/ Univ Hawaii	Resist papaya ringspot virus	Bacteria, virus	Sunup, Rainbow 1997
Potato	Monsanto	Bt toxin to control insect pests (Colorado potato beetle)	Bacteria	NewLeaf 1995
Potato	Monsanto	Bt toxin to control insect pests (Colorado potato beetle)/resist potato virus Y	Bacteria, virus	NewLeaf Y 1999
Potato	Monsanto	Bt toxin to control insect pests (Colorado potato beetle)/resist potato leafroll virus	Bacteria, virus	NewLeaf Plus 1998
Soybean	Aventis	Resist glufosinate herbicide to control weeds	Bacteria, virus	Name? 1998
Soybean	DuPont	Altered oil (high oleic acid) to increase stability, reduce polyunsaturated fatty acids	Soybean, bean, bacteria, virus	Name? 1997
Soybean	Monsanto	Resist glyphosate herbicide to control weeds	Petunia, soybean, bacteria, virus	Roundup Ready 1995
Squash	Seminis Vegetable Seed	Resist watermelon mosaic 2 and zucchini yellow mosaic viruses	Bacteria, virus	Freedom II 1995
Squash	Seminis Vegetable Seed	Resist watermelon mosaic 2, zucchini yellow mosaic, cucumber mosaic viruses	Bacteria, virus	Name? 1997
Sugarbeet	Aventis	Resist glufosinate herbicide to control weeds	Bacteria, virus	Name ? 2000
Sugarbeet	Monsanto/ Syngenta	Resist glyphosate herbicide to controle weeds	Bacteria, virus	Name? 1999
Tomato (cherry)	Agritope	Altered ripening to enhance fresh market value	Bacteria	Name? 1996
Tomato	DNA Plant Technology	Altered ripening to enhance fresh market value	Tomato, bacteria, virus	Endless Summer 1995
Tomato	Monsanto/ Calgene	Altered ripening to enhance fresh market value	Tomato, bacteria, virus	FlavrSavr 1994
Tomato	Monsanto	Altered ripening to enhance fresh market value	Bacteria	Name unknown 1995
Tomato	Zeneca/ PetoSeed	Thicker skin and altered pectin to enhance processing value	Tomato, bacteria, virus	Name unknown 1995

Source: Webpage of USDA at www.aphis.usda.gov

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