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Full Length Research Paper

Health benefits and risk factors involved in Genetic modification of food

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Genetically modified (GM) foods are foods derived from genetically modified organisms. Genetically modified organisms have had specific changes introduced into their DNA by genetic engineering techniques. These techniques are much more precise than mutagenesis (mutation breeding) where an organism is exposed to radiation or chemicals to create a non-specific but stable change. Other techniques by which humans modify food organisms include selective breeding (plant breeding and animal breeding), and somaclonal variation. Genetic modification involves the insertion or deletion of genes. In the process of cisgenesis, genes are artificially transferred between organisms that could be conventionally bred. In the process of transgenesis, genes from a different species are inserted, which is a form of horizontal gene transfer. In nature, this can occur when exogenous DNA penetrates the cell membrane for any reason. To do this artificially may require attaching genes to a virus or just physically inserting the extra DNA into the nucleus of the intended host with a very small syringe, or with very small particles fired from a gene gun. However, other methods exploit natural forms of gene transfer, such as the ability of *Agrobacterium* to transfer genetic material to plants, and the ability of lentiviruses to transfer genes to animal cells. The large scale growth of GM plants may have both positive and negative effects on the environment. These may be both, direct effects on organisms that feed on or interact with the crops, or wider effects on food chains produced by increases or decreases in the numbers of other organisms.

Key words: Benefits, food, genetically, modified.

INTRODUCTION

Genetically modified (GM) foods are foods derived from genetically modified organisms. Genetically modified organisms have had targeted changes introduced into their DNA by genetic engineering techniques. These techniques are much more specific than mutagenesis (mutation breeding) where an organism is exposed to radiation or chemicals to create a non-specific but stable change (GMSRFR, 2003). Other techniques by which humans modify food organisms include selective breeding (plant breeding and animal breeding), and somaclonal variation.

GM foods were first put on the market in the early 1990s. Typically, genetically modified foods are transgenic plant products: soybean, corn, canola, and cotton seed oil. Animal products have also been developed, although as at July 2010, none are currently on the market (GMSRFR, 2003)(http://www.fda.gov/animalveterinary/developmentapprovalprocess/geneticengineering/geneticallyengineeredanimals/ucm113672.htm). In 2006, a pig was controversially engineered to produce omega-3 fatty acids through the expression of a roundworm gene. Researchers have also developed a genetically-modified breed of pigs that are able to absorb plant phosphorus

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more efficiently, and as a consequence the phosphorus content of their manure is reduced by as much as 60%.

Critics have objected to GM foods on several grounds (NRC, 2004), including possible safety issues, ecological concerns, and economic concerns raised by the fact that these organisms are subject to intellectual property law.

METHODOLOGY

Genetic modification involves the insertion or deletion of genes. In the process of cisgenesis, genes are artificially transferred between organisms that could be conventionally bred. In the process of transgenesis, genes from a different species are inserted, which is a form of horizontal gene transfer. In nature, this can occur when exogenous DNA penetrates the cell membrane for any reason. To do this artificially may require attaching genes to a virus or just physically inserting the extra DNA into the nucleus of the intended host with a very small syringe, or with very small particles fired from a gene gun. However, other methods exploit natural forms of gene transfer, such as the ability of *Agrobacterium* to transfer genetic material to plants, and the ability of lentiviruses to transfer genes to animal cells.

RESULTS

Development

The first commercially grown genetically modified whole food crop was a tomato (called FlavrSavr), which was modified to ripen without softening (James1996). Later a subsidiary of Monsanto. Calgene took the initiative to obtain approval from Federal Department of Agriculture (FDA) U.S.A for its release in 1994 without any special labeling. It was welcomed by consumers who purchased the fruit at a substantial premium over the price of regular tomatoes. However, production problems and competition from a conventionally bred, longer shelf-life variety prevented the product from becoming profitable. A tomato produced using similar technology to the FlavrSavr was used by Zeneca to produce tomato paste which was sold in Europe during the summer of 1996 (Julie et al, (1996). The labeling and pricing were designed as a marketing experiment, which proved, at the time, that European consumers would accept genetically engineered foods. Currently, there are a number of food species in which a genetically modified version exists (percent modified are mostly 2009/2010 data). In addition, various genetically engineered micro-organisms are routinely used as sources of enzymes for the manufacture of a variety of processed foods.

These include alpha-amylase from bacteria, which converts starch to simple sugars, chymosin from bacteria or fungi that clots milk protein for cheese making, and pectinesterase from fungi which improves fruit juice clarity.

Growing GM crops

Between 1997 and 2009, the total surface area of land cultivated with GMOs had increased by a factor of 80, from 17,000 km^2 (4.2 million acres) to 1,340,000 km^2 (331 million acres). Although most GM crops are grown in North America, in recent years there has been rapid growth in the area sown in developing countries. For instance, in 2009, the largest increase in crop area used for GM crops (soybeans) was in Brazil. There has also been rapid and continuing expansion of GM cotton varieties in India since 2002. In India, GM cotton yields in Andhra Pradesh were no better than non-GM cotton in 2002, the first year of commercial GM cotton planting was due to a severe drought in Andhra Pradesh that year. The parental cotton plant used in the genetic engineered variant was not well suited to extreme drought. Maharashtra, Karnataka, and Tamil Nadu had an average 42% increase in yield with GM cotton in the same year (Qaim et al, 2006). Drought resistant variants were developed and, with the substantially reduced losses to insect predation, by 2009 87% of Indian cotton was GM (Kuiper et al, 2002). Some of the genetically modified crops are shown in Table 1.

In 2009, countries that grew 95% of the global transgenic crops were: the United States (46%), Brazil (16%), Argentina (15%), India (6%), Canada (6%), China (3%), Paraguay (2%) and South Africa (2%) (Kuiper et al, 2002).. The Grocery Manufacturers of America estimate that 75% of all processed foods in the U.S. contain a GM ingredient (AGEC in USA, 2008). In particular, Bt corn, which produces the pesticide within the plant itself, is widely grown, as are soybeans genetically designed to tolerate glyphosate herbicides. These constitute "input-traits", and are aimed at financially benefiting the producers, have indirect environmental benefits and marginal cost benefits to consumers.

In the US, by 2009/2010, 93% of the planted area of soybeans, 93% of cotton, 86% of corn and 95% of the sugar beet were genetically modified varieties (Kuehn, 2008). Genetically modified soybeans carried herbicide-tolerant traits only, but maize and cotton carried both herbicide tolerance and insect protection traits (the latter largely the *Bacillus thuringiensis* Bt insecticidal protein). In the period 2002 to 2006, there were significant increases in the area planted to Bt protected cotton and maize, and herbicide tolerant maize also increased in

Table 1. Characteristics of genetically modified crops.

Food	Properties of the genetically modified variety	Modification	Percent Modified in US	Percent Modified in world
Soybeans	Resistant to glyphosate or glufosinate herbicides	Herbicide resistant gene taken from bacteria inserted into soybean	93%	77%
Corn, field	Resistant to glyphosate or glufosinate herbicides. Insect resistance via producing Bt proteins, some previously used as pesticides in organic crop production. Vitamin-enriched corn derived from South African white corn variety M37W has bright orange kernels, with 169x increase in beta-carotene, 6x the vitamin C and 2x folate.	New genes, some from the bacterium *Bacillus thuringiensis*, added/transferred into plant genome	86%	26%
Cotton (cottonseed oil)	Pest-resistant cotton	Bt crystal protein gene added/transferred into plant genome	93%	49%
Alfalfa	Resistant to glyphosate or glufosinate herbicides	New genes added/transferred into plant genome	Planted in the US from 2005–2007; no longer planted currently due to court decisions	
Hawaiian papaya	Variety is resistant to the papaya ringspot virus	New gene added/transferred into plant genome	80%	
Tomatoes	Variety in which the production of the enzyme polygalacturonase (PG) is suppressed, retarding fruit softening after harvesting.	A reverse copy (an antisense gene) of the gene responsible for the production of PG enzyme added into plant genome	Taken off the market due to commercial failure.	Small quantities grown in China
Rapeseed (Canola)	Resistance to herbicides (glyphosate or glufosinate), high laurate canola	New genes added/transferred into plant genome	93%	21%
Sugar cane	Resistance to certain pesticides, high sucrose content	New genes added/transferred into plant genome		
Sugar beet	Resistance to glyphosate, glufosinate herbicides	New genes added/transferred into plant genome	95% (2010); planting in the US is halted as of 13 Aug. 2010 by court order	9%
Rice	Genetically modified to contain high amounts of Vitamin A (beta-carotene)	"Golden rice" Three new genes implanted: two from daffodils and the third from a bacterium	Forecast to be on the market in 2012	
Squash (Zucchini)	Resistance to watermelon, cucumber and zucchini yellow mosaic viruses	Contains coat protein genes of viruses.	13%	
Sweet Peppers	Resistance to virus	Contains coat protein genes of the virus.		Small quantities grown in China

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sown area (Sears et al, 2001 and Roh et al, 2007).

Crop yields

Some scientific studies have claimed that genetically modified varieties of plants do not produce higher crop yields than normal plants. Genetically engineered Roundup Ready soybeans do not increase yields (Trewavas,1999). The report reviewed over 8,200 university trials in 1998 and observed that Roundup Ready soybeans yielded 7 to 10% less than similar natural varieties. In addition, the same study observed that farmers used 5 to 10 times more herbicide (Roundup) on Roundup Ready soybeans than on conventional ones. However, research published in Science as shown that genetically modified crops can increase yield while reducing the number of applications of insecticides (Qaim and Zilberman,2003).

DISCUSSION

Genetically modified food controversies

The genetically modified foods controversy is a dispute over the relative advantages and disadvantages of genetically modified (GM) food crops and other uses of genetically-modified organisms in food production. The dispute involves biotechnology companies, governmental regulators, non-governmental organizations and scientists. The dispute is most intense in Japan and Europe, where public concern about GM food is higher than in other parts of the world such as the United States. In the United States, GM crops are more widely grown and the introduction of these products has been less controversial. The five key areas of controversy related to genetically engineered food are food safety, the effect on natural ecosystems, gene flow into non GE crops, moral/religious concerns, and corporate control of the food supply (USACGMP, 2009).

While it is evident that there is a food supply issue, the question is whether GM food can solve world hunger problems, or even if that would be the best way to address the issue. Several scientists argue that in order to meet the demand for food in the developing world, a second green revolution with increased use of GM crops is needed (Ruskin 2003). Others argue that there is more than enough food in the world and that the hunger crisis is caused by problems in food distribution and politics, not production (Lappe et al, 1998 and Boucher, 1999). It has been widely noted that there are those who consider over-population the real issue here, and that food production is adequate for any reasonable population size. Some people believe that Genetic modification offers both faster crop adaptation and a biological, rather than chemical approach to yield increases. On the other hand, many believe that GM food has not been a success and that we should devote our efforts and money to another solution. Some claim that genetically modified food help farmers produce, despite the odds or any environmental barriers (Streit, 2001).

Economic and environmental risks and benefits

The large scale growth of GM plants may have both positive and negative effects on the environment. These may be both, direct effects on organisms that feed on or interact with the crops, or wider effects on food chains produced by increases or decreases in the numbers of other organisms. Many proponents of genetically engineered crops claim they lower pesticide usage and have brought higher yields and profitability to many farmers, including those in developing nations (Valley, 2009). As an example of benefits, insect-resistant Bt-expressing crops will reduce the number of pest insects feeding on these plants, but as there are fewer pests, farmers do not have to apply as much insecticide, which in turn tends to increase the number of non-pest insects in these fields. There has been controversy over the results of a farm-scale trial in the United Kingdom comparing the impact of GM crops and conventional crops on farmland biodiversity. Some claimed that the results showed that GM crops had a significant negative impact on wildlife. They pointed out that the studies showed that using herbicide resistant GM crops allowed better weed control and that under such conditions there were fewer weeds and fewer weed seeds. This result was then extrapolated to suggest that GM crops would have significant impact on the wildlife that might rely on farm weeds.

In July 2005, British scientists showed that transfer of an herbicide-resistance gene from GM oilseed rape to a wild cousin, charlock, and wild turnips was possible (VanBeilen and Oirier (2008).

A 2006 study of the global impact of GM crops, published by the UK consultancy PG Economics and funded by Illinois-Missouri Biotechnology Alliance, concluded that globally, the technology reduced pesticide spraying by 286,000 tons in 2006, decreasing the environmental impact of herbicides and pesticides by 15%. By reducing the amount of ploughing needed, GM technology led to reductions of greenhouse gases from soil equivalent to removing 6.56 million cars from the roads. However, a 2009 study published by the Organic Center stated that the use of genetically engineered corn, soybean, and cotton increased the use of herbicides by 383 million pounds (191,500 tons), and pesticide use by 318.4 million pounds (159,200 tons). In 2010, the U.S.

National Academy of Sciences reported that genetically engineered crops had resulted in reduced pesticide application and reduced soil erosion from tilling. The report also stated that the advent of glyphosate-herbicide resistant weeds that have developed because of the use of engineered crops has had substantial negative impacts. A 2010 study by US scientists, observed that the economic benefit of Bt corn to farmers in five mid-west states was $6.9 billion over the previous 14 years. They were surprised that the majority ($4.3 billion) of the benefit accrued to non-Bt corn. This was because the European Corn Borers that attack the Bt corn die and there are fewer left to attack the non-GM corn nearby.

Many agricultural scientists and food policy specialists view GM crops as an important element in sustainable food security and environmental management (Shell, 2001). It has been reported that improvement of global food security is hardly being addressed by genetic research, and lack of yield is often not caused by insufficient genetic resources. Regarding the issues of intellectual property and patent law, an international report from the year 2000 states: "If the rights to these tools are strongly and universally enforced - and not extensively licensed or provided *pro bono* in the developing world - then the potential applications of GM technologies described previously are unlikely to benefit the less developed nations of the world for a long time (that is until after the restrictions conveyed by these rights have expired) (Lehrer and Banno,2005)."

Bans

In 2002, Zambia cut off the flow of Genetically Modified Food (mostly maize) from UN's World Food Programme. This left a famine-stricken population without food aid. In December 2005 the Zambian government changed its mind in the face of further famine and allowed the importation of GM maize. However, the Zambian Minister for Agriculture Mundia Sikatana has insisted that the ban on genetically modified maize remains, saying "We do not want GM (genetically modified) foods and our hope is that all of us can continue to produce non-GM foods." In April 2004 Hugo Chávez announced a total ban on genetically modified seeds in Venezuela. In January 2005, the Hungarian government announced a ban on importing and planting of genetic modified maize seeds, which was subsequently authorized by the EU. On August 18, 2006, American exports of rice to Europe were interrupted when much of the U.S. crop was confirmed to be contaminated with unapproved engineered genes, possibly caused by cross-pollination with conventional crops. On February 9, 2010, Indian Environment Minister, Jairam Ramesh, imposed a moratorium on the cultivation of GMFR (2003)" for as long as it is needed to establish public trust and confidence". His decision was made after protest from several groups

responding to regulatory approval of the cultivation of Bt brinjal, a GM eggplant in October, 2009.

Intellectual property

Traditionally, farmers in all nations saved their own seed from year to year. Allowing to follow this practice with genetically modified seed would result in seed developers losing the ability to profit from their breeding work; hence, genetically-modified seed are subject to licensing by their developers in contracts that are written to prevent farmers from following this traditional practice. Many objections to genetically modified food crops are based on this change. Enforcement of patents on genetically modified plants is often contentious, especially, due to gene flow. In 1998, 95-98% of about 10 km^2 planted with canola by Canadian farmer Percy Schmeiser were found to contain Monsanto Company's patented Roundup Ready gene although Schmeiser had never purchased seed from Monsanto. The initial source of the plants was undetermined, and could have been through either gene flow or intentional theft (Munzer, 2006). However, the overwhelming predominance of the trait implied that Schmeiser must have intentionally selected for it. The court determined that Schmeiser had saved seed from areas on and adjacent to his property where Roundup had been sprayed, such as ditches and near power poles.

Although unable to prove direct theft, Monsanto sued Schmeiser for piracy since he knowingly grew *Roundup Ready* plants without paying royalties (Ibid). The case made it to the Canadian Supreme Court, which in 2004 ruled 5 to 4 in Monsanto's favor. The dissenting judges focused primarily on the fact that Monsanto's patents covered only the gene itself and glyphosate resistant *cells*, and failed to cover transgenic plants in their entirety. All of the judges agreed that Schmeiser would not have to pay any damages since he had not benefited from his use of the genetically modified seed. In response to criticism, Monsanto Canada's Director of Public Affairs stated that "It is not, nor has it ever been Monsanto Canada's policy to enforce its patent on Roundup Ready crops when they are present on a farmer's field by accident...Only when there has been a knowing and deliberate violation of its patent rights will Monsanto act."

Future developments

Future envisaged applications of GMOs are diverse and include drugs in food, bananas that produce human vaccines against infectious diseases such as Hepatitis B, metabolically engineered fish that mature more quickly, fruit and nut trees that yield years earlier, foods no longer containing properties associated with common intolerances, and plants that produce new plastics with unique properties. While their practicality or efficacy in commercial production has yet to be fully tested, the next decade may see exponential increases in GM product development as researchers gain increasing access to genomic resources that are applicable to organisms beyond the scope of individual projects. Safety testing of these products will also, at the same time, be necessary to ensure that the perceived benefits will indeed outweigh the perceived and hidden costs of development. Plant scientists, backed by results of modern comprehensive profiling of crop composition, point out that crops modified using GM techniques are less likely to have unintended changes than are conventionally bred crops.

Health risks and benefits

In the United States, the FDA Center for Food Safety and Applied Nutrition reviews summaries of food safety data developed and voluntarily submitted by developers of engineered foods, in part on the basis of comparability to conventionally-produced foods. There are no specific tests required by FDA to determine safety. FDA does not approve the safety of engineered foods, but after its review, acknowledges that the developer of the food has asserted that it is safe. A 2004 report from the US National Academies of Sciences stated no adverse health effects attributed to genetic engineering have been documented in the human population. A 2004 review of feeding trials observed no differences among animals eating genetically modified plants, and a 2005 review, concluded that first-generation genetically modified foods had been found to be similar in nutrition and safety to non-GM foods, but noted that second-generation foods with "significant changes in constituents" would be more difficult to test, and would require further animal studies. A 2008 review published by the Royal Society of Medicine noted that GM foods have been eaten by millions of people worldwide for over 15 years, with no reports of ill effects. A 2009 review, however, observed that although most studies concluded that GM foods do not differ in nutrition or cause any detectable toxic effects in animals, some studies did report adverse changes at a cellular level caused by some GM foods, concluding that "More scientific effort and investigation is needed to ensure that consumption of GM foods is not likely to provoke any form of health problem".

In 2010, three scientists published a statistical re-analysis of three feeding trials that had previously been published by others as establishing the safety of genetically modified corn. The new article claimed that their statistics instead showed that the three patented crops (Mon 810, Mon 863, and NK 603) developed and owned by Monsanto cause liver, kidney, and heart damage in mammals.

Risk and effects of horizontal gene transfer

The risk and effects of horizontal gene transfer have also been cited as concerns, with the possibility that genes might spread from modified crops to wild relatives. As at January 2009, there has only been one human feeding study conducted on the effects of genetically modified foods (LeCueux-Belfond et al,2009). The study involved seven human volunteers who had previously had their large intestines removed. These volunteers were to eat GM soy to see if the DNA of the GM soy transferred to the bacteria that naturally lives in the human gut. Researchers identified that three of the seven volunteers had transgenes from GM soya transferred into the bacteria living in their gut before the start of the feeding experiment. As this low-frequency transfer did not increase after the consumption of GM Soya, the researchers concluded that gene transfer did not occur during the experiment. In volunteers with complete digestive tracts, the transgene did not survive passage through intact gastrointestinal tract. Anti-GM advocates believe the study should prompt additional testing to determine its significance. Other studies have found DNA from M13 virus, GFP and even ribulose-1,5-bisphosphate carboxylase (Rubisco) genes in the blood and tissue of ingesting animals (Conner et al, 2003).

Two studies on the possible effects of feeding genetically modified feeds to animals observed that there were no significant differences in the safety and nutritional value of feedstuffs containing material derived from genetically modified plants. Specifically, the studies noted that no residues of recombinant DNA or novel proteins have been observed in any organ or tissue samples obtained from animals fed with GMP plants (Gasson, 1999).

Allergenicity

Worldwide, reports of allergies to all kinds of foods, particularly nuts, fish and shellfish, seem to be increasing. Some environmental organizations, such as the European Green Party and Greenpeace, have suggested that GM food might trigger food allergies, although other environmentalists have implicated causes as diverse as the greenhouse effect increasing pollen levels, greater exposure to synthetic chemicals, cleaner lifestyles, or more mold in buildings. In the mid 1990s, Pioneer Hi-Bred tested the allergenicity of a transgenic soybean that expressed a Brazil nut seed storage protein in the hope that the seeds would have increased levels of the amino acid methionine (Magana-Gomez and Barca, 2009).

The tests (radioallergosorbent testing, immunoblotting, and skin-prick testing) showed that individuals allergic to Brazil nuts were also allergic to the new GM soybean. Pioneer has indicated that it will not develop commercial cultivars containing Brazil nut protein because the protein is likely to be an allergen (Nordlee, 1996).

However, a 2005 review in the journal *Allergy* of the results from allergen testing of current GM foods stated that "no biotech proteins in foods have been documented to cause allergic reactions". A well-known case of a GM plant that did not reach the market due to it producing an allergic reaction was a new form of soybean intended for animal feed. The allergen was transferred unintentionally from the Brazil nut into genetically engineered soybeans, in a bid to improve soybean nutritional quality for animal feed use. This new protein increased the levels in the GM soybean of the natural essential amino acid methionine, which is commonly added to poultry feed. Investigation of the GM soybeans revealed that they produced immune reactions in people with Brazil nut allergies, since the methionine rich protein chosen by Pioneer Hi-Bred happened to be a major source of Brazil nut allergy (Herman et al, (2004). Although this soybean strain was not developed as a human food, Pioneer Hi-Bred discontinued further development of the GM soybean, due to the difficulty in ensuring that none of these soybeans entered the human food chain.

Genetic modification can be used to remove allergens from foods, which may, for example, allow the production of soy products that would pose a smaller risk of food allergies than standard soybeans. A hypo-allergenic strain of soybean was tested in 2003 and shown to lack the major allergen that is found in the beans. A similar approach has been tried in ryegrass, which produces pollen that is a major cause of hayfever: here a fertile GM grass was produced that lacked the main pollen allergen, demonstrating that the production of hypoallergenic grass is also possible (Seralini, 2007).

Safety

Safety is a major issue in this controversy. The contentious concept of substantial equivalence has been established to address that. "Substantial equivalence embodies the concept that if a new food or food component is found to be substantially equivalent to an existing food or food component, it can be treated in the same manner with respect to safety (i.e., the food or food component can be concluded to be as safe as the conventional food or food component)". Adverse health effects need to be screened for, because health effects are dependent upon the modifications made. The need for screening and testing increases as more changes are made, and "second-generation" GMs will require more testing (McHughen, 2000). To date, no adverse health effects caused by products approved for sale have been documented, although two products failed initial safety testing and were discontinued, due to allergic reactions (Leary, 1999). Most feeding trials have observed no toxic effects and saw that GM foods were equivalent in nutrition to unmodified foods, although a few reports attribute physiological changes to GM food. However, some scientists and advocacy groups such as Greenpeace and World Wildlife Fund consider that the available data do not prove that GM food does not pose risks to health, and call for additional and more rigorous testing before marketing genetically engineered food (Martieau, 2001).

Safety assessments

The starting point for the safety assessment of genetically engineered food products is to assess if the food is "substantially equivalent" to its natural counterpart. To decide if a modified product is substantially equivalent, the product is tested by the manufacturer for unexpected changes in a limited set of components such as toxins, nutrients or allergens that are present in the unmodified food. If these tests show no significant difference between the modified and unmodified products, then no further food safety testing is required. The manufacturers data is then assessed by an independent regulatory body, such as the Nigeria Food, Drug Administration and Control (NAFDAC).

However, if the product has no natural equivalent, or shows significant differences from the unmodified food, then further safety testing is carried out. A 2003 review identified 7 main parts of a standard safety test:

i. Study of the introduced DNA and the new proteins or metabolites that it produces;

ii. Analysis of the chemical composition of the relevant plant parts, measuring nutrients, anti-nutrients as well as any natural toxins or known allergens;

iii. Assess the risk of gene transfer from the food to microorganisms in the human gut;

iv. Study the possibility that any new components in the food might be allergens;

v. Estimate how much of a normal diet the food will make up;

vi. Estimate any toxicological or nutritional problems revealed by this data;

vii. Additional animal toxicity tests if there is the possibility that the food might pose a risk (NRC, 2004).

Control of the market

Patent holder companies use their control of their own GMO to corner the market and gain profit. However, other companies often compete for the little market share available to GM foods worldwide. Detractors such as Greenpeace say that patent rights give corporations a dangerous amount of control over their product while corporations claim that they need product control in order to prevent seed piracy, fulfill financial obligations to shareholders and invest in further GM development.

Contamination Issues

In the 1990s, genetically modified Flax tolerant to herbicide residues in soil was developed by the Crop Development Centre (CDC) at the University of Saskatchewan in Canada. Named Flax variety FP967, but commonly called *CDC Triffid*, research was controversially halted following protests from Canadian farmers who stood to lose up to 70% of their traditional export markets if it was introduced. GM Flax was deregistered, its sale was criminalized and in 2001 all modified seeds were destroyed. No modified crops had been planted and no seed had been sold, but GM industry proponent Alan McHughen controversially passed out sample packets of seeds at presentations. In early September 2009, Flax imported into Germany was found to be contaminated with *CDC Triffid* causing the price of Canadian Flax to fall 32%. By mid November 35 countries reported contamination of imported Canadian Flax which has now been banned by the European Union. Canadian farmers are expected to be responsible for the cost of the cleanup and testing of future crops.

Public perception

Research by the Pew Initiative on Food and Biotechnology has shown that in 2005 Americans' knowledge of genetically modified foods and animals continues to remain low, and their opinions reflect that they are particularly uncomfortable with animal cloning. In one instance of consumer confusion, DNA Plant Technology's Fish tomato transgenic organism was conflated with Calgene's Flavr Savr transgenic food product. The Pew survey also showed that despite continuing concerns about GM foods, American consumers do not support banning new uses of the technology, but rather seek an active role from regulators to ensure that new products are safe.

Only 2% of Britons were said to be "happy to eat GM foods", and more than half of Britons were against GM foods being available to the public, according to a 2003 study. However, a 2009 review article of European consumer polls concluded that opposition to GMOs in Europe has been gradually decreasing (MBOGMC, 2003).

Approximately half of European consumers accepted gene technology, particularly when benefits for consumers and for the environment could be linked to GMO products. 80 % of respondents did not cite the application of GMOs in agriculture as a significant environmental problem. Many consumers seem unafraid of health risks from GMO products and most European consumers did not actively avoid GMO products while shopping.

In Australia, GM foods that have novel DNA, novel protein, altered characteristics or has to be cooked or prepared in a different way compared to the conventional food have, since December 2001, had to be identified on food labels. However, multiple surveys have shown that while 45% of the public will accept GM foods, some 93% demand all genetically modified foods be labelled as such. A 2007 survey by the Food Standards Australia and New Zealand found that 27% of Australians looked at the label to see if it contained GM material when purchasing a grocery product for the first time. Labelling legislation has been introduced and rejected several times since 1996 on the grounds of "restraint of trade" due to the cost of labelling. The controversy erupted again in 2009 when Graincorp, the nations largest grain handler, announced it would mix GM Canola with its unmodified grain. Traditional growers, who largely rely on GM-free markets, have been told they will now need to pay to have their produce certified GM free. Critics such as Greenpeace and the Gene Ethics Network have renewed calls for labelling.

Opponents of genetically modified food often refer to it as "Frankenfood", after Mary Shelley's character Frankenstein and the monster he creates, in her novel of the same name. The term was coined in 1992 by Paul Lewis, an English professor at Boston College who used the word in a letter he wrote to the *New York Times* in response to the decision of the US Food and Drug Administration to allow companies to market genetically modified food. The term "Frankenfood" has become a battle cry of the European side in the US-EU agricultural trade war.

Religious views on genetically modified foods

As of yet, no GM foods have been designated as unacceptable by religious authorities.

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