

Genetically Modified Food Controversies: A Review

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ABSTRACT

This study was conducted at University of Gujrat during 2014-2015 as a term paper for Master of Philosophy. The data regarding genetically modified food controversies reviewed and compiled as a review paper from more than 40 published articles of international reputed journals, Annual / Environmental Reports of recognized organization and e-books. The study was carried out with the objectives to examine some reasons that are behind the genetically modified controversies and provide a better idea of what a genetically modified food is and how it affects human beings. This review paper includes various controversies regarding genetically modified food, positive and negative impacts of GM food towards mankind and environment, consumer attitudes to genetically modified food and its future prospects. It was exposed that food produced by conventional means or through genetic modification, is never assured to be completely safe. Just as with traditionally produced food, genetically produced food could be dangerous and risky due to inappropriate conduct or storage, environmental contamination, and deterioration. It is hard to give statements about the genetically modified foods because they are created in many different ways and using many different methods. In all aspects of safety a genetically modified food is either equal to or safer for human consumption than foods produced using conventional means and therefore should not be regarded hazardous to human health. The recommendations were that there is a need for accurate assessment of each crop for possible negative outcomes. Communication and networking amongst researchers and corporations is necessary and technology should to be properly conducted to become effective.

Key Words: Genetically modified food, Genetic modification, Conventional means, Environmental contamination, Transgenic, Controversies

1) INTRODUCTION:

Genetically engineered (GE) or genetically modified (GM) foods is hot issue after nearly 20 years on the market. Genetic engineering allows the gene transfer from one organism to another and also transfers between different kingdoms like bacteria to plants [51].

With the help of Biotechnology we have the ability to exchange genetic materials and to overcome physiological barriers. Genetically Modified Food (GMF) is that food derived from a genetically engineered organism [39].

The first genetically modified food appeared in market during 1960s. Lenape potato that was a new form of potato introduced in 1967. After Two years, a toxin was developed in this new potato variety named solanine. Therefore it was removed by the USDA from the market. The incident revealed that genetic alteration might show adverse effects in plants or even in animals [65].

Genetic engineering has many health benefits and important for world growing population that was six billion at present [41], [85], and will possibly become double in coming years. Therefore, genetic engineering is the only way to solve hunger problems of an overpopulated world [56].

Growing demands for food are the major challenges to humankind. There is an on-going discussion among researchers on the best approach to keep pace with increasing food demand and population growth. One strategy favors the use of genetically modified (GM) crops, while another strategy focuses on agricultural biodiversity. Shortage of research funds will be provided for agricultural biodiversity solutions in comparison with funding for research in genetic modification of crops. It was concluded that the research funding currently available for the development of GM crops would be much better spent in other research areas of plant science, e.g., nutrition, policy research, governance, and solutions close to local market conditions if the objective is to provide enough food for the world's growing population in a sustainable way [44].

According to some researchers genetic engineering products are easier to control and handled than those producing from conventional breeding methods. Genetically modified foods are nontoxic. Life will be easy by using genetic engineering products carefully as it will improve our health, environment and save money and time. Generally, the genetically modified foods benefits are greater than its risk [99].

2) GENETICALLY MODIFIED FOOD: HOW IS IT PRODUCED?

The term GM food refers to crop plants that are created by using the latest molecular biology techniques for human or animal consumption. Plant Genetic modification occurs in following steps:

1. Identify an organism with desired characteristic and the specific gene for this character is located and then cut off the DNA.
2. Attached the gene to a carrier (mostly plasmid act as a carrier) in order to introduce the gene into the cells of the plant to be modified.
3. Promoter is also added with the gene and carrier to confirm that the gene works effectively when it is introduced into the plant.
4. The gene of interest along with carrier and promoter is then inserted into bacterium, and create many copies of the gene by reproduction which is then transferred into the plant being modified.

5. Then examined the plants to ensure that either they show desired physical characteristic that are conferred by the new gene or not.

6. The genetically modified plants are bred with the same variety of conventional plants to produce seed for further analysis and possibly for future commercial use.

The entire process can take up to ten years or more from the initial gene selection to commercial production [13].

3) THE GM FOOD CONTROVERSY:

Genetically modified food has become the controversial topics from beginning. The aim of Genetic engineering is to provide benefit to human beings. Therefore intentionally a known allergen or toxin would never be used by the food manufacturers as it is not in manufacture's interest. Additionally, genetically modified products refer to more rigorous testing as compared to conventionally bred fruits and vegetables. Several controversial debates provoke on genetic engineering [4], [50] since after the cloning of Dolly the sheep [101]. Some people scare that in future genetic engineering would ultimately lead to the human cloning that is prohibited in the Great Britain and US [62], [102].

The supporters of this technology declare that genetic engineering of food is safe and not different from conventional agriculture for decades. From these method undesirable characteristics also transferred. Hence, to remove undesirable trait it requires several generations as it is slow process. Though modern technologies cross natural reproductive barriers [61].

Opponents of GMF believe that there is no similarity between genetic engineering and traditional breeding as it combines the genes of unrelated species forcefully [55]. According to the Agri-biotech companies these recombinant DNA techniques enhance nutritional values and yield of plants like cotton and pharmaceuticals [9]. But, independent scientists warn that the success of genetic modification is not depending on scientific standards.

Drug studies that were sponsored by pharmaceutical companies got positive in their favor than independently funded studies [19]. Thus, strict precautionary approach is required in designing experiments on GMF by independent scientists. Before introducing in the market GM plants have to meet the guideline criteria. However, it is needed to build the regulatory and scientific measurements to implement such guidelines worldwide specifically in developing countries [88].

According to Social activists biotech companies produce genetically modified crops because it was their private property not a natural property [78]. Like, Monsanto is the largest Agri-biotech company by taken authority over small seed companies in last 10 years. Farmers are affected by patent right as they have to sign contract for saving and replanting the seeds and have to pay for it each year [61].

Some critics wanted GMF to be completely banned as they are frightened and have many questions. Should humans have the right to play with nature for any reason [90]? Should scientists are certified to clone different organisms? [102]? Groups that oppose genetic engineering include health advocacy groups, grain importers, farmers, scientists and environmentalists, ethicists, and food advocacy groups.

For critics religious and environmental issues are more essential as compared to food quality and production. According to these opponents genetically modified food

should cover some aspects like food should be label, its impact on biodiversity should be known and other possible negative and positive impacts [31], [32], [82].

Groups that support GMF include private industries, food technologists, distributors, retailers, scientists, nutritionists, and regulatory agencies. According to them this technique is nontoxic, more appropriate and nutritious [16], [27]. They believed that genetically modified food has the ability to solve agriculture and health issues and show limitless benefits. They also consider that opponents of GMF show unreasoned doubts rather than sincere concerns about health and environment [99].

3.1) Controversy in Europe:

In Europe genetically modified food are strongly opposing by environmental organizations and NGOs and was noticed by public by recent controversies [59], [34], [70]. Consumers not accept GM products in market due to health issues [60]. The European government set regulations and gives guidelines about GMF labeling and provides protection towards health and economic interest [64], [79].

3.2) Controversy in United States:

In US three different agencies have authority on genetically modified food. First is the Food and Drug Administration (FDA) investigate either the plant is good to eat or not; Second is the U.S. Environmental Protection Agency (EPA) that investigate environmental protection regarding genetically modified plant, and third one is the United States Department of Agriculture (USDA) which investigate whether the plant that has to grow be safe or not [74], [95]. The USDA has several partitions that include Animal Health and Plant Inspection Service (APHIS), the Agricultural Research Service and the Cooperative State Research, Education and Extension Service which perform field tests, internal research and risk evaluation program respectively. It is calculated that 85% corn, 91% soybeans and 88% cotton have genetically modified constituents [100].

3.3) In Developing Countries:

In developing countries people are starving due to seasonal changes, their main aim is to feed people either with GM food or traditional bred food. These countries also have GMO regulations, but their rules are not important than saving people life when food aid is coming [3].

4) POTENTIAL ADVANTAGES OF GM FOOD:

Some benefits of genetically modified crops towards humans are pest resistance, cold tolerance, herbicide tolerance, nutrition, pharmaceuticals and environment monitoring that are discussed in detail below.

4.1) Pest Resistance:

The basic purpose of genetic modification in crops is to provide protection against insect pests. Notably, in the developing world this crop trait could significantly improve yields where pest damage is rampant and reduce use of chemical pesticides. The *Bacillus thuringiensis* (soil bacterium) in Bt corn produces crystal proteins that are toxic to some insects but usually harmless to non-lepidopteran insects and vertebrates [33]. Monsanto developed a very renowned genetically modified crop is Bt cotton that creates an insect control protein (Cry1Ac) by naturally present soil bacterium, *Bacillus thuringiensis* subsp. *kurstaki*. It provides protection against Lepidopteran pests (cotton and pink bollworm) in the cotton plant [15]. Bollgard cotton has several benefits it control insect pests, enhanced yield, save money, and increase profit [23], [30].

4.2) Herbicide Tolerance:

Some times for certain eradication of weeds become difficult by different physical process like tilling, so large quantity of herbicides were often sprayed by farmers to eradicate these weeds but it was prolonged and costly. Genetically engineered crops are resistant to herbicides and though protect environment by reducing the use of required herbicides. These crops tolerate the application of powerful herbicides using genes from soil bacteria. The herbicides to which the GM crops are tolerant are 'broad spectrum' weed-killers, which mean they can be sprayed over the entire field, killing all plants apart from the GM crop. Herbicide-tolerant crops include transgenes providing tolerance to the herbicides glyphosate or glufosinate ammonium. These herbicides kill nearly all kinds of plants except those that have the tolerance gene. Commonly known as Roundup, glyphosate is made by Monsanto and is the world's best-selling herbicide. Another important benefit is that this class of herbicides breaks down quickly in the soil, eliminating residue carryover problems and reducing adverse environmental impacts [21].

4.3) Temperature Tolerance:

Unpredicted coolness damage sensitive seedlings. Certain crops are difficult to grow in particular climates for different reasons. For example, strawberries are difficult to grow in cold climate as they are not very frost hardy. Recently researchers have discovered that the arctic flounder produces an anti-freeze protein to protect itself in arctic waters. Genetically engineered strawberries or soybeans expressing this anti-freeze gene can protect themselves against the damaging effects of the frost, thereby sustaining under environmental constraints [92]. Moreover, plants like tobacco build an ability to tolerate low temperature by introducing an antifreeze gene that was obtained from cold water fishes [48].

4.5) Improve Nutrition:

In developing countries malnutrition is very common as they usually rely on single crop. As rice is their basic diet, sufficient nutrients are not present in rice that prevents them from malnutrition. Future GM crops could also have substantial direct nutritional or medicinal benefits to consumers. Genetically modified crops add pivotel

micronutrients to human diet. One type of such crop is “golden rice,” produce beta-carotene by genetically modification; the precursor to vitamin A. Genetically modified ‘golden rice’ is one of the promising strategies to solve the vitamin A deficiency. This type of crop can be potentially beneficial among Asian and African populations that suffer from malnutrition. Canola, too, can be genetically modified to enhance vitamin E content or to better balance fatty acids [21] while cereals on the other hand have been modified for specific starch or protein content [68]. Other efforts are aimed at modifying rice to increase the iron content in order to reduce anemia. Plant oils are also being modified to adjust cholesterol levels. GM food containing sweet proteins like thaumatin may be helpful to diabetics [45]. Genetic engineering also enhances protein quality [28], [84].

Pharmaceuticals:

For producing biopharmaceuticals such as enzymes, vaccines, antibodies and blood proteins therapeutic proteins are needed. By genetically modified plant safe, effective and pure therapeutic proteins are obtained. In near future tomatoes and potatoes are produced that contain edible vaccines that are easy to transport and store. Transgenic (i.e., GM) bananas containing inactivated viruses protecting against common developing-world diseases, such as cholera, hepatitis B, and diarrhea, have been produced [21]. Because they would produce only the necessary antigens, these types of vaccine-producing GM crops may be safer than traditional vaccines whose additional materials often cause harmful side effects [5].

4.6) Environmental Monitoring and Remediation:

Environmental pollution is the main problem all over the world now genetically engineered products are used to remove pollution such as genetically modified plants that remove heavy metal from polluted soil [17]. Also used as pollution indicator [67]. Rugh (2004) [86] observed that plants also have the ability for metal phyto-extraction or phyto-degradation of organic compounds. For this objective, many plants like *Arabidopsis thaliana* and *Tobacum nicotiana* engineered with transgenes of non-plant to boost phytoremediation efficiency against many pollutants such as organomercurials, nitroaromatic explosives and trichloroethylene solvents [18], [35], [29]. In addition, plants could be engineered to produce industrial raw materials that are biodegradable (e.g., bioplastics) and thus reduce loading of non-degradable plastics in the environment. Heavy metal pollutants can also be managed through bioremediation using GM trees.

5) POTENTIAL HEALTH RISKS OF GM FOOD:

All technologies have their own risk and benefit same the case with genetic modification techniques [37]. Some of the toxic effects caused by genetically modified crops are being discussed in detail below [1].

5.1) Food Allergenicity:

One of the adverse effects of GM food is to increase the food allergies through food chain in the human population. Mostly food allergy is mediated by immunoglobulin

E (IgE) antibodies¹ it show immediate reaction as its symptoms occur in minutes after ingestion. According to FAO and WHO (2001) allergenicity caused by genetically modified foods or crops should be evaluated by identifying the sequencing of amino acids, its characterization, and using models of animals that diagnose food allergens same as in human disease [7], [47].

Other factors include the molecular mass range of glycoproteins that is usually from 10,000 to 80,000 Da [54], heat and processing stability, pH and gastric juices [10]. According to Prescott *et al.*, (2005) [77] a product without allergenicity may not be produced by introducing non allergenic protein like GM field pea, that express alpha-amylase inhibitor-1. A GM plant such as Brassica juncea, show low IgE response in mice expressing choline oxidase gene [94]. Farmers who are exposed to Bt pesticide show skin sensitization [14]. From Brazil nuts methionine-rich 2S albumin storage protein was introduced in soybean to increase the methionine content. That protein contains allergen. Plant breeding program was stopped as there is no guarantee that genetically modified soya would not introduce in human food chain [97], [14], [24].

The labeling issue is also important. GM food should be labeled properly so that costumer who has allergies avoids buying foods they is harmful towards them [66]. Now, allergenic potentials of GM food studied by using several animal species included Balb/cmice [47], [53], pigs [40], brown Norway rats [49].

5.2) Antibiotic Resistance:

Antibiotic resistance occur when an organism is unaffected by the antibiotic. When foreign gene is inserted in plant it often link to another gene known as antibiotic resistance marker gene (arm). If an antibiotic resistance gene is present in food it might cause harmful effects. Power of antibiotics that fight bacterial diseases is reduced by consuming these foods that contain such antibiotics [12]. The growing public health danger of antibiotic resistance may be because of these new combinations German researchers have found antibiotic resistant bacteria in the guts of bees feeding on gene-altered rapeseed (canola) plants. Ampicillin resistance gene is present in genetically engineered Bt corn from Novartis [22] due to which European countries rejected the growth of Novartis Bt corn [42].

5.3) GE Superweeds and Superpests:

Herbicide resistance genes transfer weeds into superweeds. Some genetically engineered crops (rapeseed) spread Herbicide resistance characters to related weeds like mustard plant. It was estimated by different tests that cotton bollworms will soon turn in to superweeds by living under GE crops. This is a danger for organic farmers whose management practices will not compete with increasing numbers of superpests and weeds. In crops like *Medicago sativa*, *Brassica napus*, *Brassica rapa*, *Helianthus annuus* and *Oryzae sativa* show some characteristics that are weed-like will soon become weedier [80], [81]. Insect pests that are resistant towards transgenic proteins might decrease the duration that an insecticidal transgenic variety can be easily grown. Such as,

the diamond black moth, that is pest to Brassica crops showed resistance against Bt toxins applied as microbial formulations in field populations [96].

5.4) Adverse Effects on Non-Target Species:

Non target species might affect by genetically modified crops that contain insecticidal transgenes and was used to control agricultural pests [43], [89]. Species that used pesticidal gene product of the transgenic crops might be toxic to them; for example, toxic effects of Bt endotoxins in non-target species have been observed [15]. This toxicity was limited to certain species or insect group that includes Lepidoptera, Coleoptera or Diptera. While plant species are not affected by Bt genes [71], [76].

5.5) Increase in Antinutrients:

Current levels of anti-nutrients can be increased by the insertion of a new gene, which cannot be eradicated by heat [11]. Glyphosate-resistant Roundup Ready soybean, are the commercial genetically modified products that show an increase in anti-nutrients [73]. Infertility problem is caused by heat-stable anti-nutrients like phytoestrogens, glucinins, and phytic acid in sheep and cattle [58], [2]. Consumption of GM food as raw material makes the rise in anti-nutrient level objectionable.

6) GM FOOD AND ENVIRONMENT:

Genetically modified crops have an adverse impact on non-target species like soil microorganisms which play a vital role in degradation of crop residues and in biogeochemical cycles cause main environmental risk [36]. Similarly, plants that genetically modified by *Bacillus thuringiensis* (Bt) is risk factor for other plants as the Bt toxin in pollen could be deposited on other nearby plants and affect non-target species [103]. According to Losey *et al.*, (1999) GM crop cultivation might have negative impact on environment [59].

7) GM FOOD AND ECONOMIC ISSUES:

Introducing genetically modified food in market is prolonged and costly process. Bringing a GM food to market is a lengthy and costly process, and investor wished to get profit on what they have invested. Farmers and developing countries are worried as seed price is rise due to patenting and not in their reach due to which the gap between rich and poor will increase. Large companies might offer seed to third world countries at low cost. Otherwise, it will be a financially difficult for farmers to get seed as it is only viable for one season and they have to buy fresh seed every year [3].

8) ETHICAL ISSUES ABOUT GM FOODS:

GM foods create specific ethical problems for those of various faiths. For example, religious vegetarians, such as Hindus and Buddhists, want to be able to avoid fruits and vegetables with insect, animal or humans genes in them. Similarly, Jews and Muslims not eat grains that may contain pig genes, and generally wanted Halal foods [25]. Because almost all genetically engineered foods are not labeled, most people are not

aware that they are probably already consuming them. So labeling should be a right of citizens in a free society.

9) ATTITUDES TOWARD GENETICALLY MODIFIED FOODS:

Attitudes toward genetically modified foods have varied widely. Opponents of genetically modified foods claim that, because these products have not been adequately tested, their long-term effects on human health remain unknown, particularly because interaction between genes is not yet fully understood [6], [20]. Some of the potential risks that are related to genetically modified food that are explained by critics include nutritional alteration, resistance to antibiotics, Potential toxicity and Environmental concerns threat to crop genetic diversity. While, some supporters believed that it will improve crop yield and food and give some potential benefits that include improved quality of protein, less risk of allergies, and provide protection against diseases and pests [99].

Consumer attitudes toward GM food products on developed countries are highly negative as its use was controversial [52]. Consumers in United States are profound to genetically modified food as compared to Europe. A Canadian study found that consumers were willing to purchase genetically modified potatoes if offered at equal or slightly discounted prices [8].

In developing countries little research conducted on attitudes of for genetically modified foods. But, recent studies in China and Columbia found similar results. Li *et al.*, (2002) concluded that on average Chinese customers, were ready to pay a 16% premium for GM soybean oil and a 38% premium for rice that are genetically modified over the non-GM alternatives [57]. As well as, pay a 35% premium for genetically modified processed potato products such as French fries, mashed potatoes, and potato chips [26]. Pachico and Wolf (2002) found that 66% of the survey respondents in Colombia were willing to try a genetically modified food, that was high among those who thought that they did not have high quality and sufficient amount food at home [72].

The potential benefits like improved crop yield and dietary supplements generally contributed to show positive attitudes in lesser developing countries. Still, the risks must be carefully assessed. Rissler and Mellon (1996) argued that the United Nations should develop international biosafety protocols to confirm that developing countries secure the danger of natively engineered crops endangering domestic crop diversity [83]. Nelson (2001) concluded that public evaluation of GM organisms that considers the costs and benefits with a special preference for public health safety is important prior to future development [69].

Among all genetically modified crops cultivated worldwide, only four rule the market: soybean, cotton, corn and rape. Regarding the cultivated surface, soybean is more spread. In 2009 soybeans was cultivated (77%) from the 90 million hectares worldwide were genetically modified, while for cotton, (49%) from the 33 million hectares were genetically modified. And, (26%) from the 158 million hectares cultivated worldwide with corn were genetically modified and 21% of the 31 million hectares of rape cultivated worldwide were genetically modified [46].

10) SCIENTIFIC CONCLUSIONS ON THE SAFETY OF GENETICALLY MODIFIED FOOD:

The most significant proof to Americans that in the short-term genetically modified foods are safe should be the fact that Americans have been eating them for the

last ten years without any evident ill effects. Though the long term effects of genetically modified food are unknown, it has been concluded by the FDA that genetically modified food poses no threat to human health, either in the short or long-term [97]. The FDA Commission Jane E. Henney M.D. states that genetically modified foods appear to have no ill effects on humans and that all GMF currently on the market are nontoxic, rapidly digestible, and non-allergenic [38],[97]. The FDA as well as the biotechnology companies completes hundreds of tests to ensure food safety, because the worst thing a biotechnology company could do is create a product that is unsafe for the consumer. The average time between the creation of a transgenic plant and that plant reaching the market is over ten years. During this time extensive laboratory tests as well as field tests are performed on the transgenic plant. Monsanto, one of the largest biotechnology companies, ran over eighteen hundred analyses and tests on its Round-Up Ready soybeans. The tests compared the transgenic soybean to a traditionally produced soybean and concluded that the soybeans, safety wise and nutritional, did not differ. These analyses were sent to the FDA for evaluation like other test done by biotechnology companies [75].

Another impressive study was conducted by Chinese researcher Zhang-Liang Chen of Beijing University. He conducted forty studies proving that no damage occurred when rats were fed transgenic foods [98], [75]. In each experiment one hundred mice were fed transgenic foods and over six months were examined. Examination compared the mice fed genetically modified food to mice that had eaten only conventionally grown food. The comparison revealed no differences between the two sets of mice. After the study it was concluded that genetically modified foods had no ill effects on the mice and that they were therefore unlikely to cause health problems in humans [75], [87]. By the findings of the FDA and other scientific studies, genetically engineered foods have been judged to be completely safe. It is only the public perception of genetic modification that makes the technology seem dangerous.

11) FUTURE PROSPECTS:

Although technology and science play a vital role in debates regarding to genetically modified food but it should be admit that alone they cannot alleviate it. Transgenic crops cause revolutionary change in many fields like agriculture industry, nutrition, and medicine. With this revolt in molecular biology, biotechnology and genomics human health will improve. By combining medical science and plant physiology cheap pharmaceutical products are produced [63]. Nutritionally-enhanced and bio-fortified crops have the potential to control malnutrition but further research needed to ensure that by using same crops multiple mal-nutritional deficiencies are controlled [13].

Now especially in Europe, researchers have been searching for new techniques that are used to enhance crop production as genetically modified food is surrounded by many controversies. The latest technique is called marker-assisted selection (MAS). This technique combines both traditional genetics and molecular biology. MAS select genes that control desired traits. It has the potential of becoming a valuable tool in selecting desired organisms. Because this process uses existing DNA, not transgenic DNA, to select desired traits, MAS stands to be less controversial then other genetically modified techniques [91].

12) CONCLUSION:

The variety of foods consumed by humans has changed greatly over the centuries, altering the balance of nutrients in the diet. Such changes may have a more profound impact on the health of the population. Genetically modified products give benefits and adverse effect in two specific areas that include health and the environment. Every new technology has some adverse effects. The same is true for GM food. Controversies continue to arise regarding their risks on health of humans and threat to biodiversity GM food might be toxic to human health. Therefore, these food items need to be carefully examined before they can be used in the food supply, to ensure their safety.

13) RECOMMENDATIONS:

GM production and its impact on consumers should be fully understood before being made commercially viable. Impact of genetically modified food on environment and human health should be observed. Since genetically modified food is not inherently unsafe it is necessary to address public concern about the technology and give them reliable information that allows them to come to an accurate judgment on the safety of genetically modified food. For happening this biotechnology companies must first gain the trust of consumers, and then the fright encouraging messages of anti-GM organization must be opposed with actual scientific indication that allows consumers to come to their own conclusion about genetically modified foods. After both these things happen, hopefully a majority of the public, will be able to get an accurate picture of genetically modified foods and begin to accept genetically modified food as a useful and safe technological advancement.

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