

Analysis

Insight into the Genetically Modified Foods: From the Concerns of Safety to Food Development (Part I)

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SUMMARY

Genetic engineering is the name of a process in which we add new DNA to an organism manually. The primary purpose is to add some features that are not present in the particular organism. We know that genetically modified crops can help increase the production, and food accessibility can increase multiple folds. There is a scientific concord that genetically manufactured foods presently available in the market are not harmful and are safe to be consumed. They not only increase the food production but also help in increasing the nutritional content. Although there are benefits of genetically modified foods, this technology faces a lot of controversies. Critics include consumer and health groups, importers of grain from European countries, organic farmers, scientists and environmentalists, religious groups, food advocacy groups and ethicists, politicians and traders. Some fears associated are alteration in nutritional quality of food, toxicity, antibiotic resistance, allergy and carcinogenicity. Other concerns are environmental pollution; transfer of genes to plants unintentionally, development of some viruses and toxins, some ethical as well as cultural concerns and fear of the unknown. Supporters of genetic technology are private industrialists, research scientists, a portion of users and farmers and the regulatory authorities.■

KEYWORDS Genetic engineering; Foods; Population health; Toxicity; Genetic pollution

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Genetic engineering is the name of a process in which we add new DNA to an organism manually. The primary purpose is to add some features that are not present in the particular organism. Some examples of transgenic organisms presently in the market include the plants that resist insects, tolerate herbicides and crops that have oil content modified.

On one end, genetic engineering transfers the genes manually from one organism to the other. On the other end, traditional breeding transfers the genes with the help of mating and crossing the organisms with high hopes of obtaining offspring with the desired features. Traditional breeding is just like picking up two cookbooks and then combining recipes into one cookbook. The product will be a new cookbook that has half recipes from each of the original. Thus, half of genes in offspring of a cross inherit from each of the parent.

Traditional breeding is somehow effective in improving the traits, but when we compare it with genetic engineering, it is not as much advantageous. We know that breeding relies heavily upon the ability to mate two organisms for the transfer of genes. In this manner, the trait improvement limits only to those traits that are present already within the species. On the other hand, genetic engineering physically removes genes from one organism and places them into the other. The need for mating is eliminated in this way and movement of genes is allowed between organisms of any specie. Hence, the potential traits are virtually unlimited.

Moreover, breeding is not as much precise as genetic engineering is. Half of the genes pass from each parent to the offspring in breeding that may also comprise of undesirable genes for the traits not wanted in the new organism. Genetic engineering is helpful here as it allows only the movement of a single or a few desirable genes.

Genetically modified (GM) crops are a threat to food security or they are not harmful for public health is a subject where we can find a large difference in opinion. We know that genetically modified crops can help increase the production and food accessibility can increase multiple folds. The quality of foods and the combination of nutrients may also be disturbed. Finally, GM crops also lead to make a sound impact on the income of farmers and hence their access to needs of livelihood. Farmers owning small-based plots of land compose an outsized proportion of the ill-fed folks worldwide. We will focus on this side and analyze the food security impacts of GM crops at the root level. Let's consider cotton genetically modified whose adoption has dominantly improved the calorie consumption and the quality of diet as the earning of farmer also increased. This technology reduced the food insecurity up to 20% in cotton producing houses. It is to be noted that GM crops cannot fight alone against the plague of hunger; but still a major component in the food security strategy.

The branch of science dealing with the deliberate modification in genetic material of animals or plants is called

Genetic Engineering. It is not a very new concept but is an old agricultural practice since historical times. However, it is improved a lot in the present times due to technology. Although there are benefits of genetically modified foods, this technology faces a lot of controversies. Critics include consumer and health groups, importers of grain from EU countries, organic farmers, scientists and environmentalists, religious groups, food advocacy groups and ethicists, politicians and traders. Some fears associated are alteration in nutritional quality of food, toxicity, antibiotic resistance, allergy and carcinogenicity. Other concerns are environmental pollution; transfer of genes to plants unintentionally, development of some viruses and toxins, some ethical as well as cultural concerns and fear of the unknown. Supporters of genetic technology are private industrialists, research scientists, a portion of users and farmers and the regulatory authorities.

We often prefer to eat fresh foods instead of processed food. Fresh GM foods are eaten throughout the world on regular basis in large quantity. No proven side effect is observed. The developed and industrialized countries are meeting their population's needs through GM foods.

The "Nutrition and the Cancer Patient" sheds light on a lot of issues that are discussed in details, but does not comment on GM foods to be a cause of cancer (1). In a changing ecosystem, plants born and survive via sudden genetic mutations. Humans harvest the food for their consumption from the survivors.

Humans tried to selectively breed plants and animals since antediluvian. It benefitted mankind. However, the process was slow and it did take many generations to become successful as genomics and the biotechnology has made the genetic mutations faster than ever before. The crop yields become better in quality as well as the quantity increases when proper genetic engineering is applied.

Recently, research suggested that genetically modified foods are somehow causally linked with carcinogenesis (2). From the implications of the research, we can guess that when genetically engineered foods are shunned, cancer will not develop. Cancer can be cured by prophylactic selection of diet. Other medical practices are filled with myths to cure; unproven whatsoever, most publicized as the ultimate medications (3). By means of modern therapy, some cancers have changed into chronic diseases and cancer survival rates have improved in a last few score years. But some cancers such as pancreatic and liver cancers still need a lot of research to be cured.

Many GMFs are not taken directly by us; almost 90% are to be used by industry from which derivatives of foods are made. Let's take the example of maize. It is used for the production of ethanol and to manufacture edibles such as fructose, which is used extensively in many foods and drinks.

From the commercialization of genetically modified crops, no health or ecological effect has been observed.

There is a scientific concord that genetically manufactured foods presently available in the market are not harmful and are safe to be consumed. 15 years have passed and 2 billion acres planted but no harmful health or environmental effect has been seen from commercializing GM crops (4). We know that some cancers can be cured since their causes are well known, most of the cancers cause are yet unknown (5).

Once the neoplastic change takes place, unfortunately there is no cure except the whole surgical removal or replacement of cancerous cells (like in leukemias or lymphomas). Chemotherapy and radiation therapy are no doubt life-increasing treatments but they are not the cures. Virally induced cancers can be reduced by promoting and enhancing vaccination strategies. Screening by health care workers is used to quicken detection, diagnosis and therapy with reasonable outcomes (6).

Billions of people used GM foods, decades passed by and their health wasn't devastated. GM foods have a sound contribution to the supply of food and have stabled the markets providing them with enough food for all (7). Plants with some favorable characteristics have been produced by conventional breeding methods for thousands of years. The advantageous traits are selected and combined and are cultivated by repeating sexual crossings over and over throughout generations. It's a long process and may take around 15 years to produce new varieties (8). The genetic engineering enables this process to efficiently accelerate this process in a well-targeted manner through the introduction of some genes. Moreover, it surpasses the hurdle of sexual incompatibility among plant species and thus increases the available gene pool.

Transgenic plants are genetically modified utilizing recombinant DNA technology. The protein in gene gives a unique trait to the plant. In 2007, global area of biotech crops continued to increase for the twelfth consecutive year, with the growth rate 12% in 23 countries; major crops grown being soybean, maize, cotton, canola and rice respectively (9). However, GM crops grown in EU make up a few thousand hectares (around 0.03% of production of world) which makes sense of European opposition to the particular technology. Many animal feeds used in Europe made from imported plant materials constitute GM products. In USA, however, GM plants provide food in abundance.

GENETIC MODIFICATION OF A PLANT

GM plants can be produced through a variety of different techniques. Two most common practices are:

- Bacterium *Agrobacterium tumefaciens* which enable plants to transfer DNA
- Gene gun which is a device for injecting cells with the genetic data; the inserted genetic materials are termed transgenes.

- Commonly, plant cells are targeted individually and regenerated into whole genetically engineered plants via techniques of tissue culture. The three important aspects of the procedure are discussed in relation to human health.
- Selectable markers used to identify the transformed cells
- Extraneous DNA transferred into the plant's genome
- Possible increase in mutations in GM plants as compared to that of non-GM as tissue culture process is used in their production and DNA rearranges around the insertion sites of foreign genes.

Plant transformation procedure is criticized as unnecessary DNA transfers into plant genome as a result of engineering and the transfer process (10). Off course DNA process is not harmful; humans intake GM foods. But plant technologists' reply to the criticism by calling minimal cassettes' through which only gene of our interest is transferred (11).

Finally, it is said that GM plants have more mutations than untransformed as a consequence of production method. Plants can be produced with the tissue culture process generating somaclonal variations and some endogenous DNA rearrangements can also occur around the integrated transgene. It means that plants may be produced with reduced level of nutrients or increased allergens/toxins. Lathem et al stated that the mutations around foreign gene insertion sites are fully characterized experimentally or through commercialized GM plants. As a result, these authors proposed a lot of suggestions to improve molecular analysis before commercializing GM crops in future (12). It must be noted that GM crops grown till now have been produced under regulations and passed through safety tests before commercializing them.

FOOD APPLICATIONS FOR GENETICALLY MODIFIED PLANTS

In the underdeveloped world, more than 840 million people are chronically ill-fed and survive on less than 8000 KJ/day or 2000 Kcal/day (13). In the whole world, 20% of the population is living on less than a dollar per day. It equals 1.2 billion people who are surviving through difficult time and do not have fair access to food and water. Most of them are rural people mostly small-scale farmers. They cannot afford to irrigate their crops and use pesticides, which results in a low crop growth (14). Moreover, the population of world is expected to double over the next forty years with 95% increase in developing countries that are already fighting the plague of poverty. To meet the increasing needs, the food production must at least increase by 40% (15). Genetic engineering of foods is one of the various approaches that can help us in future. Research is being done on increasing the

crop yields a great extent and to improve the nutritional content directly.

INCREASING THE NUTRITIONAL CONTENT

Nutritional content is not an issue in the developed world as people have access to a variety of foods that meets the nutritional needs. However, in the underdeveloped countries, most of the population relies on a single major crop to fulfill their hunger. Genetic engineering enables us to palliate such problems by producing plants with extra products to stand against malnutrition. Let's consider "Golden Rice Project". Deficiency of Vitamin A is responsible for an estimated 2 million children's death every year (16).

Children who survive are often found blind. Humans are able to produce vitamin A from β -carotene found commonly in plants but not in cereals. With the Golden Rice Project, metabolic steps were introduced into rice endosperm allowing β -carotene synthesis. In 2000, ye et al produced rice with moderate levels of β -carotene and then high yielding "Golden Rice 2" have been produced. An estimate says that 72g of dry Golden Rice 2 provide 50% of RDA of Vitamin A needed for a child of 1-3-year (17).

Golden Rice was introduced to help farmers and local population in the developing world. Hence, the aim of scientists was to provide this assistance free of cost. It is supposed to be given to farmers without any extra conditions and is a perfect example of health solutions offered by biotechnology.

INCREASING THE FOOD PRODUCTION

Parasites, pesticides, pathogens and herbivorous insects reduce the crop yield significantly throughout the world (18). There are two examples of commercial GM crop's growth:

- Insect resistant crops that express the "BT gene" (*Bacillus Thuringiensis*)
- Virus resistant papaya

Former has been successful in particular. Let's talk about USA where the insect resisting genetically engineered maize covers a large area of 10.6 million hectares and constitutes 35% of all the maize (GM & non-GM) grown in the country. In laboratory, bacterial and fungal plant's pathogens are resisted (19). Abiotic stress is a basic parameter to the plant loss globally; salinity, temperature extreme and drought in particular (20). As the water resources will shorten in future and the fertile land would turn into desert (desertification would intensify), crops shall be effected brutally. Serious salinization is expected, unfortunately, of all arable area by 2050 due to extensive droughts and salinity. The need of new technologies to overcome the situation is inevitable. Research is still at the laboratory level for manufacturing abiotic stress-tolerating GM plants such as the study by Shou et al showing that enzyme in genetically

modified maize activates oxidative signal cascade which tolerates cold, heat and salinity.

GM FOODS – SAFE TO EAT OR NOT?

Several government bodies regulate GM crops. European Food Safety Authority (EFSA) has made a detailed list of requirements for full risk assessment of genetically engineered foods (21). In USA, Food and DRUG Agency, Environmental Protection Agency and US Department of Agriculture, Animal and Plant Health Inspection Service help regulate GM crops' approval (22). As a result, GM plants pass through several safety testing before commercialization.

For more than 15 years, foods derived from genetically engineered crops are in use by millions of people all over the world with no reported harmful effects. There is a small documented proof of GM crops being toxic. A scandalous study claimed that the rats that were fed with GM potatoes, expressed the gene for lectin *Galanthus Nivalis* suffered through a disaster to gut mucosa. It was published in 1999 (23). However, the paper was published only after one of the authors named Arpad Pusztai who announced the finding on TV (24).

Royal Society called the study to be flawed with errors. Hence no conclusion can be derived. For example, only a few rats were tested, so the information is just merely insignificant to be trusted. Presence of foreign DNA sequences indicates no intrinsic risk towards human health (25). All the foods contain a significant amount of DNA as well as RNA; consumed amid 0.1 and 1 g/day (26).

The possibility of protein produced from transgene being toxic is a concern. Potential allergenicity to novel gene products is also a common issue. Allergies to non-GM foods like fleshy fruits, vegetables and soy are widespread. It is clear that the new varieties of crops produced through GM techniques as well as through conventional methods has a chance to be allergic. The two major concerns are:

- Possibility of genes from known allergens to be inserted into the crops that are associated with allergenicity.
- Possibility of creation of new and unknown allergens either by inserting novel genes into the crops or by changing the nature of endogenous proteins.

Assessing the allergenic potentials of different compounds is difficult and various bodies have given guidelines and decision trees to evaluate experimentally the allergenic potential (27).

They are useful in assessing the components that are harmful by determining if:

- The source of induced gene belongs to an allergenic plant
- GM foods react with the antibodies in patients with some known allergies.

- Product encoded by the new gene shows same properties with the known allergens.

Moreover, animal models are used for screening GM foods. No tests are made to assess the risks presented by the pollens and dust inhaled. This is also not used for the conventionally grown foods and no allergies are linked with commercially grown GM pollen as well. Two examples often quoted with GM crops allergenicity are:

- Genetically engineered peas produced by adding protein from beans granting resistance to weevils was discarded when it showed GM peas to cause lung allergy in mice (28).
- Soya bean was engineered to express a Brazil nut protein was removed from production when it showed allergenicity in tests (29).

People who oppose GM technology are often found citing these examples as proofs although another interpretation is to state safety testing as ineffective in both cases; allergenic potential was identified before releasing of both the products into market. If conventional breeding techniques were used, no legal requirements would have been necessary to assess the allergenicity and different plant varieties could have been commercialized without in vivo testing. At the same time, GM technology can also be used to lower the allergen's level in plants reducing the expression level of related genes. An example is the research made recently to identify a particular allergen in soybeans and its removal by GM means (30). ■

ARTICLE INFORMATION

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REFERENCES

1. Del Fabbro E, Bruera E, Demark-Whanefried W, Bowling T, Hopkinson JB, Baracos VE, editors. Nutrition and the Cancer Patient. New York, NY: Oxford University Press; 2010.
2. de Vendômois JS, Roullier F, Cellier D, Séralini GE. A comparison of the effects of three GM corn varieties on mammalian health. *Int J Biol Sci* 2009; 5:706-726.
3. Touyz LZG. Alternate and orthodox medicine and the "odd" principle. *Curr Oncol* 2012; 19:64-65.
4. Ronald P. Scientific American. Guest Blog New York, NY: Scientific American; 2011. Genetically engineered crops—what, how and why [blog entry] [Available at:<http://blogs.scientificamerican.com/guest->
[blog/2011/08/11/geneticallyengineered-crops/](http://blogs.scientificamerican.com/guest-blog/2011/08/11/geneticallyengineered-crops/); December 20, 2015]
5. Touyz LZG. Politics, health, and mesothelioma: when it comes to cancer, none is one too many. *Curr Oncol* 2012; 19:e374-e375.
6. Touyz LZG. Mixing drinks and concocting troubles. *Curr Oncol* 2011; 18:262-263.
7. Kloor K. No, genetically modified corn won't give you cancer. *National Post* 2012; A11.
8. Southgate EM, Davey MR, Power JB, Merchant R. Factors affecting the genetic engineering of plants by micro-projectile bombardment. *Biotechnol Adv* 1995; 13:631-657.
9. ISAAA Briefs No. 37. Ithaca, NY: ISAAA; 2007. Executive summary of Global Status of Commercialised Biotech/GM crops: 2007.
10. Wu HX, Sparks CA, Jones HD. Characterization of T-DNA loci and vector backbone sequences in GM wheat produced by Agrobacterium-mediated transformation. *Mol Breed* 2006; 18:195-208.
11. Fu XD, Duc LT, Fontana S, Bong BB, Tinguangjun P, Sudhakar D, Twyman RM, Christou P, Kohli A. Linear transgene constructs lacking vector backbone sequences generate low-copy-number GM plants with simple integration patterns. *Transgenic Res* 2000; 9:11-19.
12. Latham JR, Wilson AK, Steinbrecher RA. The mutational consequences of plant transformation. *J Biomed Biotech* 2006; 2006(2):25376.
13. Pinstrip-Anderson P, Pandra-Lorch R, Rosegrant MW. World food prospects: critical issues for the early twenty-first century. 1999 Food policy report.

- Washington DC: International Food Policy Research Institute; 1999.
14. <http://www.un.org/en/globalissues/briefingpapers/food/vitalstats.shtml>
 15. Byerlee D, Helsey P, Pingali PL. Realising yield gains for food staples in developing countries in the early 21st century: prospects and challenges. In: Chang BM, Colombo M, Soronolo M, editors. *Food Needs of the Developing World in the 21st Century*. Vatican City: Political Academy of Sciences; 2000. pp207-pp50.
 16. Christou P, Twyman RM. The potential of genetically enhanced plants to address food insecurity. *Nut Research Rev* 2004;17:23-42
 17. Paine JA, Shipton CA, Chaggar S, Howells RM, Kennedy MJ, Vernon G, Wright SY, Hinchliffe E, Adams JL, Silverstone AL, Drake R. Improving the nutritional content of Golden Rice through increased provitamin A content. *Nat Biotechnol* 2005; 23:482-487.
 18. Anderson PK, Cunningham AA, Patel NG, Morales FJ, Epstein PR, Daszak P. Emerging infectious diseases of plants: pathogen, pollution, climate change and agrotechnology drivers. *Trends Eco Evol* 2004; 19:535-544.
 19. Peschen D, Li HP, Fischer R, Kreuzaler F, Liao YC. Fusion protein comprising aFusarium- specific antibody linked to antifungal peptides protect plants against a fungal pathogen. *Nat Biotech* 2004; 22:732-738.
 20. Vinocur B, Altman A. Recent advances in engineering plant tolerance to abiotic stress: achievements and limitations. *Curr Op Biotech* 2005; 16:123-132
 21. Guidance document of the genetically modified organisms for the risk assessment of genetically modified plants and derived food and feed. *EF-SA J* 2004; 99:1-94.
 22. McKeon TA. Genetically modified crops for industrial products and processes and their effects on human health. *Trends Food Sci Tech* 2003; 14:229-241
 23. Ewen SWB, Pusztai A. Effects of diets containing genetically modified potatoes expressing *Galanthus Nivalis* lectin on rat small intestine. *Lancet* 1999;354:1353-1354.
 24. Burke DM. GM Food and Crops: what went wrong in the UK? *EMBO Reports* 2004; 5:432-436.
 25. FAO/WHO. Evaluation of Allergenicity of Genetically Modified Foods, Report of a joint FAO/WHO Expert Consultation on Allergenicity of Foods derived from Biotechnology. Geneva: FAO/WHO; 2001.
 26. Doerfler W, Schubert R, Fremde DNA im Sciugersystem. *Deutsches Arzteblatt* 1997; 94:51-52.
 27. WHO/FAO. Strategies for assessing the safety of foods produced by biotechnology. Report of the Joint WHO/FAO Consultation. Geneva: FAO/WHO; 1991.
 28. Prescott VE, Campbell PM, Moore A, Mattes J, Rothenberg ME, Foster PS, Higgins TJ, Hogan SP. Transgenic expression of bean α -amylase inhibitor in peas results in altered structure and immunogenicity. *J Agric Food Chem* 2005; 53:9023-9030.
 29. Nordlee JA, Taylor SL, Townsend JA, Thomas LA, Bush RK. Identification of a brazil-nut allergen in GM soybeans. *N Engl J Med* 1996; 334:688-692.
 30. Herman E. Soybean allergenicity and suppression of the immunodominant allergen. *Crop Sci* 2005; 45:462-467.