

Genetically modified food: a review on mechanism of production and labeling concern

Abstract

Development of modern biotechnological achievements resulted in the Genetic modification or genetic engineering in the form of genetically modified plants and genetically modified organisms and ultimately the outcomes in the form of genetically modified food, which can be a key point to eradicate hunger, poverty and malnutrition from the country, however some labeling issues, mis and myth conceptions resulted in the failure of all biotechnological advancement. This review indicate the mechanism of group of actions with various biotechnological tool utilize to carry out genetic modification, their benefits, labeling issues etc. India has approved cultivation of some GM crops but due to lack of proper knowledge and religious factors lead to stunted outcomes ignoring environment cleanliness and hunger of malnourished segments. So more attention still needed for its adoption globally by ensure its safety for human utilization.

Keywords: *bacillus Thuringiensis*, genetically modified crops, genetically modified foods, genetically modified organisms

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Abbreviations: Bt, *Bacillus thuringiensis*; GMC, genetically modified crops; GMF, genetically modified foods; GMO, genetically modified organisms; GBSS, granule bound starch synthase; Psy, phytoene synthase; Lyc, lycopene cyclase; hp, high pigment; AmA, amaranth seed albumin; PLU, price look up

Introduction

For years, farmers have been selecting for certain features in crops producing plants that are easier to grow, tastier and bigger without knowing the exact mechanism of how this occurs. Recognizing valuable traits and incorporating them into future generations is very important in plant breeding. Advances in plant biotechnology have made it possible to identify and modify genes controlling specific characteristics.

Now a day scientists can transfer genes from one organism to another unrelated organism, producing what is now known as “genetically modified organism” or “transgenic animal/plant”. Any food produced this way is called Genetically Modified food. In India, a total area of 8.4million hectares is used in the production of GM crop especially cotton.¹ The foods obtained by added or deleted gene sequence is called genetically modified foods. Supplement of essential nutrients in diet is called Nutrition. The Purpose of this issue is to provide an independent analysis of the scientific basis for assessing the benefits of most of GM foods. In this paper, the section deals with the various GM Foods. In addition, it also indicates current needs, benefits and limitations that hamper further developments in the area of GMF production and their usage.

Essential amino acids which are deficient in cereals are Lys, Trp, Thr and pulses for sulfur containing amino acids like Met, Cys and Trp.² Nutritional deficiency causes many diseases like kwashiorkor, sterility, blindness, anemia and abnormal child birth. In order to full-fill the basic needs; many scientists have made attempts to improve the nutritional value of food crops through genetical modification. Two Scientist, Watson and Crick discovered the double helix structure

of DNA which is the basis for biological revolution. Other Scientist made the transgenic modification in plants and animals food possible.

Why genetically modified plants?

By genetically modifying the plant in the laboratory it is possible to have stricter control over the genes. With GM, the desirable genes can be separated from the undesirable genes. It is also possible by GM to cross species that would not breed together naturally (Figure 1). The following are some reasons for genetic modifications:

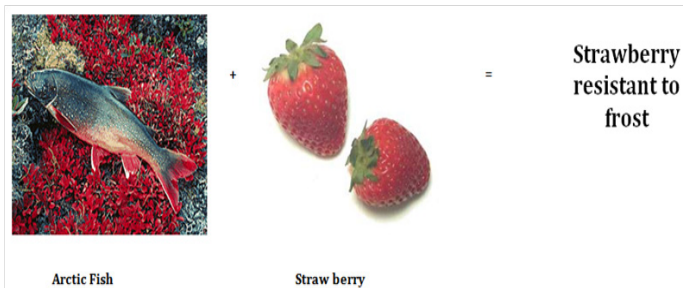


Figure 1 Involves the insertion of DNA from one organism into another (OR) Modification of an organism's DNA in order to achieve a desired trait.

- Improved yields
- More resistant to disease
- Less likely to be damaged by insect
- Tolerance to herbicides
- Better nutritional value
- Increased shelf life
- Better climatic survival by increasing tolerance to draught, flood or frosty conditions to allow the use of previously inhospitable land
- Higher crop yields

- Reduced farm costs
- Increased farm profit
- Improvement in health and environment

What is genetically modified food?

- Food that contain an added gene sequence
- Food that have a deleted gene sequence
- Animal products from animals fed GM Feed.
- Products produced by GM organisms.

Why produce GM food?

Traditionally, combining the desirable genes in one plant is a tough task that utilizes longer time and so much attention, involving crossing one plant to another plant of the same species or related species. From economical and agricultural standpoints, it is advantageous to grow crops that have higher yield or improved quality, pest or disease resistance, or tolerance to heat, cold and drought. Desirable genes may provide means for plants to combat these conditions. The development of transgenic technology allows useful genes from various living sources to be brought together in a relatively simple manner.

How is genetic modification possible?

The component of DNA is same in all organisms in the form of amino acid sequence that are responsible for genetic make-up of the organism. This amino acid sequence can be altered or moved from one organism to another by recombinant technology, molecular cloning and genetic engineering (Figure 2). There are two enzymes which play major role in the process:

1. Restriction Enzyme: are used to "CUT" DNA Segment from one Genome.
2. DNA Ligases: are used to "PASTE" them into another genome.

Shifting of DNA from one organism to other

- Find an Organism with the desired trait.
- Isolate the gene sequence that Code for the desired trait.
- Insert the gene sequence into the genome of the plant cell.
- Allow the genetically engineered cell to grow into a plant.
- Allow the Plant to propagate.
- A vector can carry DNA. The vector can be a gene gun, viruses and bacteria also can be utilized to transfer gene (Figure 3).

Transformation method

Transformation system should allow for stable integration of DNA into the host genome without structural alteration and the whole process comprises of three basic steps as follows:

- Integration of a distinct number of copies of the transforming DNA
- Stability of the new phenotype over several generations
- Character regulation of the inserted gene

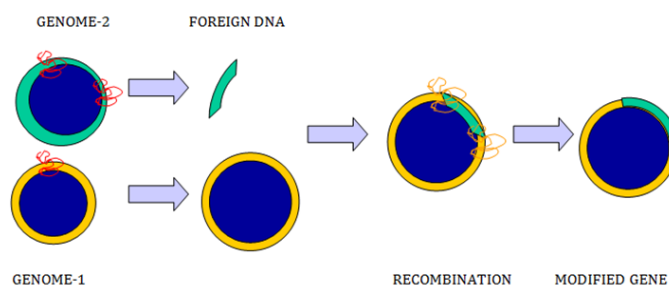


Figure 2 Genetic modifications.

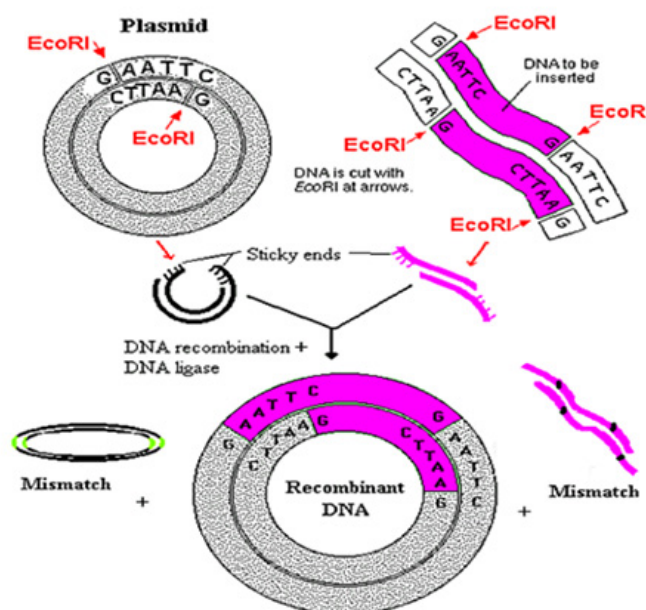


Figure 3 Shifting of DNA from one organism to other.

Methods of transformation:

1. *Agrobacterium tumefaciens*
2. Electroporation
3. Polyethylene Glycol
4. Silicon carbide fiber
5. Gene Gun
6. Microinjection

Agrobacterium tumefaciens:³ Plant transformation mediated by *Agrobacterium tumefaciens* Virulent Strain of *Agrobacterium tumefaciens* & *Agrobacterium rhizo* genes contains a large plasmid known as Ti plasmid. These bacteria possess the ability to transfer T-DNA, Causing the Crown of Gall Disease & Hairy root (Figure 4). The initial results of T-DNA transfer process to plant cells demonstrate three important features:-

- Tumor formation is the results of the integration of T-DNA into plant cells.
- The T-DNA genes are transcribed only in plant cells.

Every DNA sequence can be transferred to plant cells

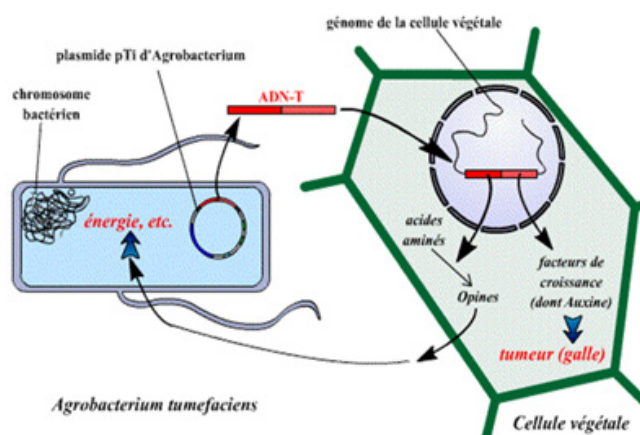


Figure 4 Agrobacterium tumefaciens.

Electroporation:⁴ In this, Material is incubated in a buffer solution containing DNA and subjected to high voltage electric pulses. DNA migrates through high voltage, introduces pores in the plasma membranes & integrates into the genome. Mainly Used for: - Rice, Wheat and Maize.

Polyethylene glycol: Plant Protoplast can be transformed with naked DNA by treatment with Polyethylene Glycol in the presence of divalent Cation (Ca^{2+}). They both help in destabilizing the plasma membrane of plants and make it convenient for DNA penetration. Once the DNA enters the nucleus, it gets integrated into the genome.

Silicon carbide fiber:⁵ In this, plant material is introduced into a buffer containing DNA and silicon carbide fibers. The fibers penetrate the cell wall and plasma membranes allowing the DNA to gain access to inside of the cell.

Gene gun method:⁶ A particle gun is used to shoot small bits of metals coated with the gene into the plant (Figure 5).

Microinjection:⁷ This method involves the use of a fine needle to inject the DNA material in the form of a solution into developing embryo.

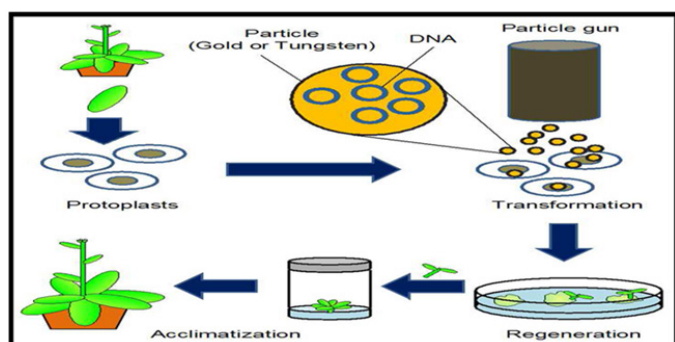


Figure 5 Plant transformation process using particle bombardment includes following steps:

(1) Isolate protoplasts from leaf tissue. (2) Inject DNA-coated particles into protoplasts using particle gun. (3) Regenerate into whole plants. (4) Acclimate the transgenic plants in a greenhouse.

Uses of genetic modification

Genetic modification in the laboratory was first reported in the early 1970s. Since then, there has been a wide range of research

and applications of genetic engineering in agriculture, medicine, the environment, food production and the manufacturing industry. A number of examples are listed below:

In agricultural area:

- Herbicide tolerant crops
- Insect resistant crops
- Virus resistant crops

In the field of medicine:

- Insulin to treat diabetic mellitus
- Production of human growth hormone
- Production of blood clotting factors VIII and IX
- The treatment of cystic fibrosis
- Research into human and animal diseases

In other areas:

- Environmental clean-up of soil spills
- Treatment of contaminated land and water
- Manufacture of useful chemicals such as enzymes
- Plants providing renewable sources of industrial chemicals

Crops under development

- Sweet potato resistant to the feathery mottle virus.
- Further development of golden rice to increase levels or bioavailability of iron, zinc, vitamin E, vitamin A and improve the quality of protein.
- Maize with increased levels of the amino acid lysine and protein for animal feeds.
- Transgenic rice has been developed by a California company to improve oral rehydration therapy for diarrhea. In sub-Saharan Africa and parts of Latin America and Asia, diarrhea is the second highest infectious killer of children under the age 5.

Common genetically modified food

- Soybean, Corn & sugar-beet:- resistant to glyphosate by inserting herbicide resistant gene
- Cottonseed oil:- by inserting pest resistant Bt crystal protein gene
- Tomato:- by removing the gene that codes for polygalacturonase, responsible for softening of fruits after harvesting
- Potatoes:- Amylopectin rich variety by switching off of GBSS (granule bound starch synthase) gene, responsible for amylose production.
- Rapeseed (canola):- with high oleic acid content by adding new gene
- Rice:- with high Vitamin A by inserting gene from daffodils

Golden rice

It was created by Ingo Potrykus. Golden rice is a variety of rice produced through genetic modification to biosynthesize the

precursors of beta-carotene (pro-vitamin A) in the edible parts of rice (endosperm).

More than 120 million children in the world suffer from vitamin A deficiency. Golden Rice has the potential to help prevent the 1 to 2 million deaths each year caused by a deficiency in this vitamin (Figure 6).



Figure 6 Golden rice.

In the part of rice that people eat the endosperm, the rice plant can naturally produce beta-carotene, which is a carotenoid pigment that occurred in the leaves and involved in the photosynthesis. However, the plant does not normally produce the pigment in the endosperm since photosynthesis does not occur in the endosperm.

Golden rice was created by incorporating rice with two beta carotene biosynthesis genes.

- i. Psy (Phytoene synthase)
- ii. Lyc (lycopene cyclase)

The psy and lyc genes were transformed into the rice nuclear genome and placed under the control of an endosperm specific promoter, so that they are only expressed in the endosperm. The end product of the engineered pathway is lycopene, but if the plant accumulated lycopene the rice would be red. Recent analysis has shown that the plant's endogenous enzyme process the lycopene to beta carotene in the endosperm, giving the rice the distinctive yellow colors for which it is named.

In 2005, a new variety called golden rice-2 was announced which produces up to 23 times more beta carotene than the original variety of golden rice (Figure 7).

Iron enriched rice

As cereal grains are deficient in certain essential mineral nutrients, including iron, several approaches have been used to increase the iron accumulation and alter iron metabolism. Since ferritin is a general iron storage protein in all living organisms, the ferritin genes has been added to rice and wheat plants to increase their iron content.

Cold tolerant tomato

Scientists have created a frost resistant tomato plant by adding an antifreeze gene from a cold water fish to it. The antifreeze genes come from the cold water flounder, a fish that can survive in very cold conditions (Figure 8).

The flounder has a gene to make chemical antifreeze. This is removed from the antifreeze DNA and is joined onto a piece of DNA called a plasmid. This hybrid DNA, which is a combination of DNA from two different sources, is known as recombinant DNA.

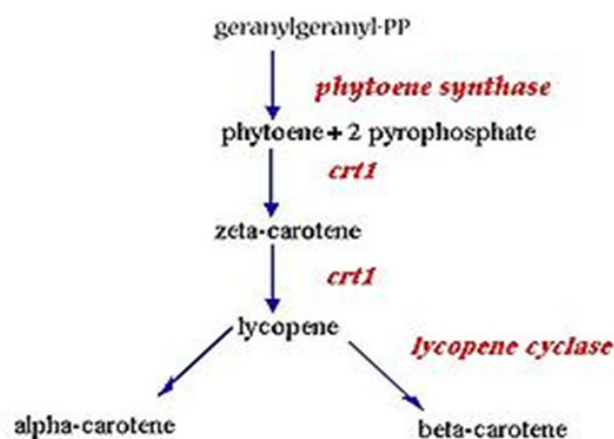


Figure 7 Process flow diagram for development of golden rice.

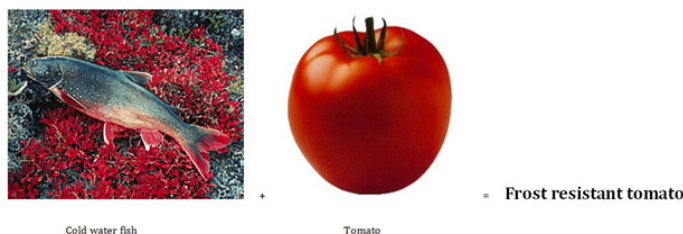


Figure 8 Cold tolerant tomato.

The recombinant DNA, including the antifreeze gene, is placed in a bacterium. The bacterium is allowed to reproduce many times producing lots of copies of the recombinant DNA (Figure 9).

Tomato plant cells are infected with the bacteria. As a result, the antifreeze gene in the plasmids in the bacteria becomes integrated into the tomato plant cell DNA. Tomato cells are placed in the growth medium that encourages the cells to grow into plants. Now these tomato plant seedlings are planted.

In tomato, beta-carotene expressing gene called hp (high pigment) gene and OG-c (crimson) gene which is antagonistic to hp gene are present naturally.

If hp gene is expressed, the fruit gets a red color and beta-carotene content increases by 40%. If OG-c gene is also expressed, the fruit gets a crimson color and beta-carotene content is decreased by 40%.

Vitamin rich tomato

The *Agrobacterium* naturally infects the plants by causing various diseases, so by replacing that gene with desirable ones results into the new genetic makeup with advantageous traits. The bright orange color of carrots comes from beta-carotene, which works as the precursor for the synthesis of vitamin A in our body. So by inserting this color gene into the tomato enhance its appearance as well as its vitamin A level to the desired level (Figure 10).

Protein enriched sweet potato for NASA

Dr. Marceline Egnin and her colleagues at Tuskegee University have developed a protein enriched sweet potato by incorporating a synthetic protein storage gene. To provide sufficient protein and amino acids to astronauts with their complete nutritional requirements, NASA is looking for such nutritionally rich crops. Sweet potato is a good source of energy because it has high level of carbohydrates and minerals.

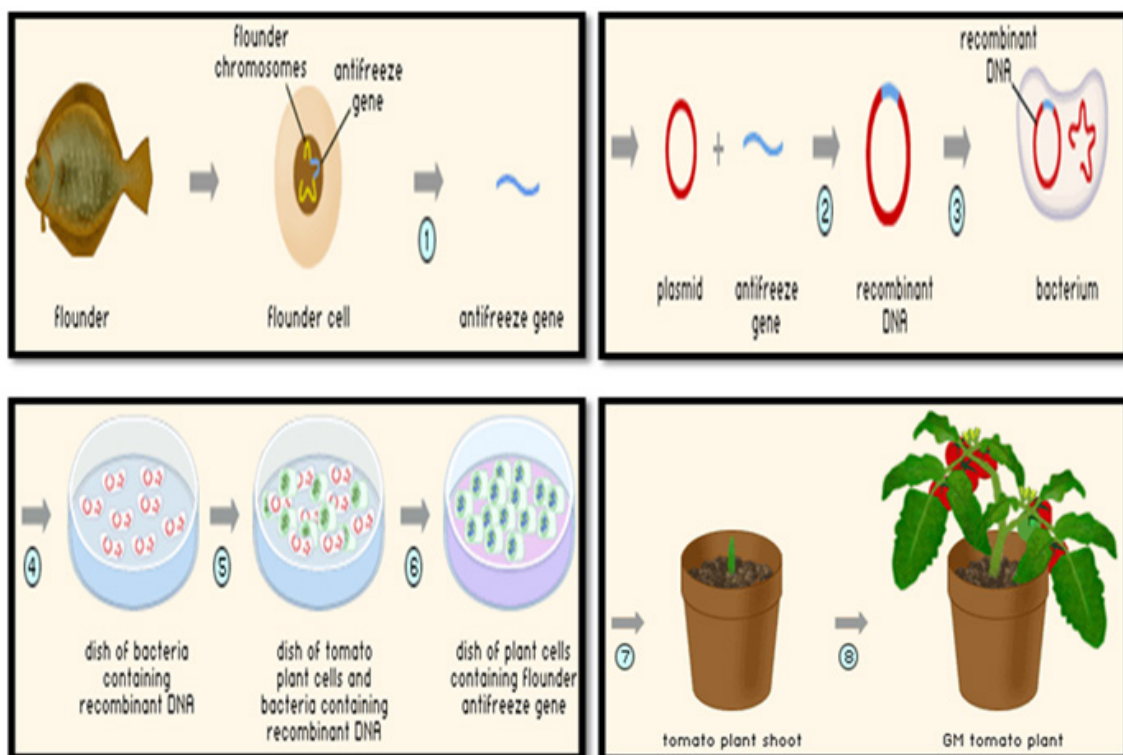


Figure 9 Tomato plant by adding an antifreeze gene from a cold water fish.

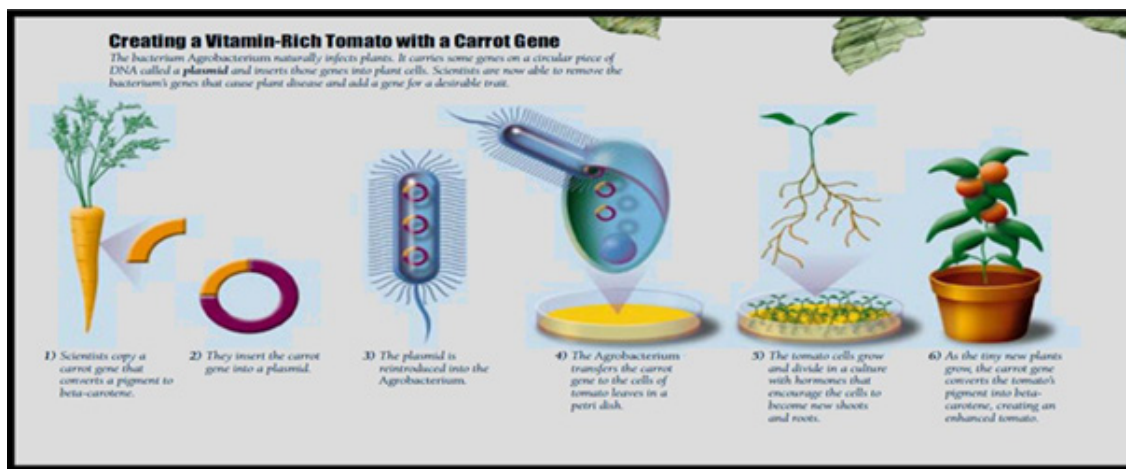


Figure 10 Creating a vitamin rich tomato with a carrot gene.

Amflora potatoes

The gene for granule bound starch synthase (GBSS) (the key enzyme for the synthesis of amylose) was switched off by inserting antisense copy of the GBSS gene.

Rotein modified potato

- The Potato is a non-cereal food crop limited in the amount of lysine, tyrosine, methionine and cysteine.
- A tuber-specific protein amaranth seed albumin (AmA1) has been used to transform potatoes.
- The AmA1 protein has a well-balanced amino acid profile. In fact its amino acid composition exceeds values recommended by the

W.H.O. for a nutritionally rich protein.

- This protein was used due to its non-allergenicity in its purified form. When the AmA1 gene was inserted into a potato 2.5 to 4 fold increases in lysine, tyrosine, methionine and cysteine content and 35 to 45% increases in total protein content was reported in transgenic tubers.

Bt soybean

The two target insects for insect-resistant, transgenic soybeans are the velvet bean caterpillar and the soybean looper. These pests feed on the leaves of the soybean plant and can severely limit yield. Velvet bean caterpillar populations can reach damaging levels rapidly. Many producers in areas where velvet bean caterpillar is a significant

problem apply a preventive treatment of Dimilin when plants are in full bloom. Scientist have incorporated *Bacillus thuringiensis* gene into soybean which has insecticidal protein that maintains the yield of the crop. *Bacillus thuringiensis*, a ubiquitous soil bacterium is the source of the gene for insect resistance (Figure 11).

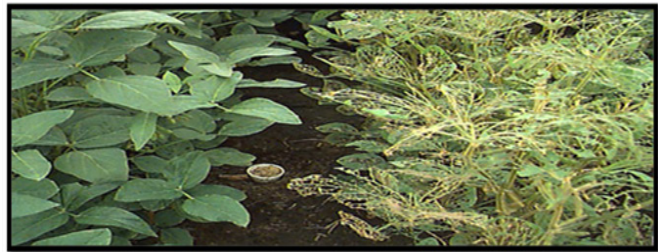


Figure 11 Infestation of a transgenic Bt soybean with velvet bean caterpillar. The non transgenic control on the right shows extensive defoliation.

Roundup ready soybean

The Roundup Ready soybean is a transgenic soybean that has been immunized to the Roundup herbicide. Since the soybean's natural trypsin inhibitors provide protection against pests, the only major problem in soybean farming was weeds, thus making soybean revolutionary. The glyphosate in the herbicide would inhibit the soybean plant's ESPSP gene, which is involved in the maintenance of the "biosynthesis of aromatic metabolites," and cause the plant to die along with the weeds for which the herbicide was meant. A plasmid which was transferred to the soybean cells through the cauliflower mosaic virus was soon developed to provide immunity to glyphosate-containing herbicides, and, after this process was perfected, the Roundup Ready soybean was ready, first hitting the US market in 1996.⁸

Genetically modified maize (corn)

Corn has been deliberately genetically modified (GM) to have agronomically desirable traits. Traits that have been engineered into corn include resistance to herbicides and resistance to insect pests, the latter being achieved by incorporation of a gene that codes for the *Bacillus thuringiensis* (Bt) toxin. Transgenic maize was grown commercially in 11 countries, including the United States (where 85% of the maize crop was genetically modified), Brazil (36% GM), Argentina (83% GM), South Africa (57% GM), Canada (84% GM), the Philippines (19% GM) and Spain (20% GM) (<https://www.google.com>).⁹

Corn varieties resistant to glyphosate herbicides (Liberty and Roundup) have been produced. Pioneer Hi-Bred has marketed corn hybrids with tolerance to imidazoline herbicides under the trademark "Clearfield" - though in these hybrids, the herbicide-tolerance trait was bred without the use of genetic engineering (Figure 12).

Consequently, the regulatory framework governing the approval, use, trade and consumption of transgenic crops does not apply for imidazoline-tolerant corn. Herbicide-resistant GM corn is grown in the United States.¹⁰

Canola

The name "canola" was derived from "Canadian oil, low acid" in 1978.¹¹ Rapeseed oil had a distinctive taste and a disagreeable greenish color due to the presence of chlorophyll. It also contains a high concentration of erucic acid. Experiments on animals have

pointed to the possibility that erucic acid, consumed in large quantities, may cause heart damage. Feed meal from the rapeseed plant was not particularly appealing to livestock, due to high levels of sharp-tasting compounds called glucosinolates, and they would not eat it.¹² A variety developed in 1998 is considered to be the most disease and drought-resistant Canola variety of rapeseed to date.¹³

Canola oil: Approximately 43% of canola seed is oil¹⁴ that remains is a rapeseed meal that is tolerated by livestock and has become a high quality animal feed. 22.68kilograms of rapeseed makes approximately 10 liters of canola oil. Canola oil is a key ingredient in many foods. Its reputation as a healthy oil has created high demand in markets around the world.

Canola oil is low in saturated fat (less than 7%), is high in monounsaturated fat, and has a beneficial omega-3 fatty acid profile (which has well established heart benefits) and is recognized by many health professional organizations including the American Dietetic Association, and American Heart Association. Although wild rapeseed oil contains significant amounts of erucic acid, a known toxin, the cultivar used to produce commercial food-grade canola oil was bred to contain less than 2% erucic acid, levels that are not believed to cause harm in humans and no ill health effects has been associated with consumption by humans of the genetically modified oil.¹⁵



Figure 12 Genetically modified maize (corn).

Papaya

Papaya cultivation is threatened by papaya ring spot virus, a disease that sharply lowers the fruit yield. The University of Hawaii developed a ring spot virus disease resistant papaya. To do this, certain viral genes encoding capsid proteins were transferred to the papaya genome. These viral capsid proteins elicit something similar to an "immune response" from the papaya plant. The first resistant papaya varieties were grown commercially in 1999 in Hawaii. These genetically modified papayas are approved for consumption both in US and in Canada.¹⁶

Labeling of genetically modified food

The Price look up (PLU) code mentioned on fruits help you identify if the fruit was genetically modified, organically grown or produced with chemical fertilizers, fungicides, or herbicides. For fruits grown with chemicals, the PLU code on the sticker consists of four numbers.

Organically grown fruit has a five-numeral PLU prefaced by the number 9. Genetically engineered fruit has a five-numeral PLU prefaced by the number 8.

For example, a conventionally grown banana would be: 4011. An

organic banana would be: 94011. A genetically engineered banana would be: 84011.

Federal regulations

The FDA has the primary responsibility for regulating food additives except for meat and poultry products, which are regulated by the USDA. The FDA, USDA work together along with Environment protection agency on food safety matters like deciding various tolerance pesticides residues limits in foods.

The FDA released the guidelines that help the companies to decide whether they need FDA approval of a genetically engineered food product. The FDA determined that a special review of a genetically engineered food product would be needed only when specific safety issues were raised, such as if the gene for peanut protein, to which some people are allergic, was inserted into a different food like a tomato.

Current labeling policy

The U.S. Food & Drug Administration announces the policy for labeling of GM/GE foods.

- i. We do not use ingredients produced using biotechnology.
- ii. Genetically engineered.
- iii. This oil is made from soybeans that were not genetically engineered
- iv. This product contains cornmeal, produced using biotechnology.
- v. High oleic acid soybean oil developed using biotechnology to decrease the amount of saturated fat in soybeans.

Conclusion

Genetically modified food is still a new concern in few countries and its acceptance restricted mainly due to the mis and myth conceptions ignoring valuable benefits. India is the second most populated country, so to feed the large hungry and malnourished population is also a challenge. Biotechnological advancement is the ultimate option that has the capacity to build a stronger nation with healthier people. GM crop propagation proves to be a good alternate for revenue generation in the form of high yield, nutritious grain with less reliance on pesticides and herbicide which has no threat to our agriculture and environment. Despite all these positive attributes this technology still lies in its embryonic stage. Awareness programmes at village level for farmers to adopt newest technologies in field farming viz. crop rotation, organic farming and genetic modification results in increase in production per area with healthy crop. These technologies have great potential rather than relying on traditional approaches to meet the global future food demands.

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Conflict of interest

The author declares no conflict of interest.

References

1. Sheweta B, Deepak M, Singh KB. Genetically modified food: benefits, safety aspects and concerns. *As J Food Ag-Ind.* 2010;3(6):548–560.
2. Ufaz S, Galili G. Improving the content of essential amino acids in crop plants: goals and opportunities. *Plant Physiol.* 2008;147(3):954–961.
3. Pitzschke A, Hirt H. New insights into an old story: *Agrobacterium*-induced tumour formation in plants by plant transformation. *EMBO J.* 2010;29(6):1021–1032.
4. Hjouj M, Rubinsky B. Magnetic resonance imaging characteristics of non-thermal irreversible electroporation in vegetable tissue. *J Membr Biol.* 2010;236(1):137–146.
5. Kaeppler HE, Gu W, Somers DA, et al. Silicon carbide fiber-mediated DNA delivery into plant cells. *Plant Cell Rep.* 1990;9(8):415–418.
6. Oneto CD, Gonzalez G, Lewi D. Biolistic maize transformation: improving and simplifying the protocol efficiency. *African J Agricultural Research.* 2010;5(25):3561–3570.
7. Korzh V, Strahle U. Marshall Barber and the century of microinjection: from cloning of bacteria to cloning of everything. *Differentiation.* 2002;70(6):221–226.
8. Bomgardner MM. Replacing Trans Fat: New crops from Dow Chemical and DuPont target food makers looking for stable, heart-healthy oils. *Chemical and Engineering News.* 2012;90(11):30–32.
9. <https://www.princeton.edu/~achaney/tmve/wiki100k/docs/Transgenic-maize.html>
10. Gerald MD, Claire AJ, Stephen RP. Glyphosate resistant crops: adoption, use and future considerations. *Pest Manag Sci.* 2008;64(4):326–331.
11. Turchini GM, Francis DS, Senadheera SP, et al. Fish oil replacement with different vegetable oils in Murray cod: Evidence of an “omega-3 sparing effect” by other dietary fatty acids. *Aquaculture.* 2011;315(3–4):250–259.
12. Cecil HV, Melvin ED, Iwan AW. Natural glucosinolates (thioglucosides) in foods and feeds. *J of agriculture and food chemistry.* 1969;17(3):483–491.
13. Enami HR, Safaar H. Evaluation of adding canola meal to diet on growth performance of male wistar rats. *J Anim Vet Adv.* 2010;9(6):1073–1076.
14. Lee KH, Olomu JL, Sim JS. Live performance carcass yield, protein and energy retention of broiler chickens fed canola and flax full fat seeds and the restored mixtures of meal and oil. *Can J Anim Sci.* 1991;71(3):897–903.
15. Harvey BL, Downey RK. The inheritance of Erucic acid content in rapeseed (*Brassica napus*). *Can J Plant Sci.* 1963;44(1):104–111.
16. Nap JP, Metz PLJ, Escaler M, et al. The release of genetically modified crops into the environment. *Plant J.* 2003;33(1):1–18.