Genetically Modified Foods – Boon or Bane

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Abstract: The fast growing population of the world needs to be fed properly with nutritious food. This is one of the major concerns still although we are in the highly advanced 21st century. A highly debatable issue is if genetically modified (GM) foods can solve the starvation problem to a certain extent. The other side of the story is whether it is safe for consumption or not? This article discusses the current status and importance, and various other aspects of GM foods. Efforts have been taken to discuss a few of the available GM crops. The advantages and disadvantages of GM foods has been discussed in detail. Finally the regulations of using GM foods has been examined with references to a few countries of the world.

1. Introduction

Years before, men have tried to visualise and portray organisms in epics and fictions having resemblance to more than one type of organisms known to them. Most of them were pictured as giants or monsters with superhuman traits. So for centuries, it was a myth that one type of organisms can have the features of another organism and mixed creatures known as chimeras were possible. It is in this context, that our genetically modified organisms need to be introduced although at least they do not visually appear as scary or terrific as the epical or fictional chimeras.

When it comes to the case of plants, for millennia, humans have modified plant genes in order to develop crops best suited for food, fibre, feed, and energy production. The earliest efforts were by manipulating the techniques involved in traditional plant breeding, but with the advent of recombinant DNA technology, there was a revolution in agriculture with the help of genetic engineering. Genetic engineering helped the design and development of transgenic plants especially edible ones which were notoriously known as ‘Frankenfoods’ reminding the fictional giant Frankenstein who was the product of an unorthodox scientific experiment.

This article aims to throw light on the importance of Genetically Modified (GM) foods and also examines the beneficial and hazardous effects of GM foods by discussing a few among those.

Genetically Modified Organisms

Genetically Modified organisms (GMOs) are those organisms whose genes have been altered or modified to enhance desirable traits. In this, the natural genetic machinery of the organism is altered and the resulting organisms are known as Genetically modified, Genetically Engineered or Transgenic. When it comes to plants, modification of crops have been taking place through processes like traditional breeding, interspecific crosses but genetic modification was not initiated until 20th century. The first GM plant was produced in 1983, using an antibiotic-resistant tobacco plant.

Why do we go for genetic modification?

Genetic modification introduces new traits which are not naturally present in a plant. It also enhances and upgrades desirable traits in a particular plant. The enhancement of desired traits has traditionally been undertaken through breeding, but conventional plant breeding methods can be very time consuming and are often not very accurate. Genetic engineering, on the other hand, can create plants with the exact desired traits very rapidly and with great accuracy [13]. These traits include improved nutritional content, increased resistance to herbicides, insecticide resistance, and disease resistance, tolerance to drought and salinity and enhanced phytoremediation.

As mentioned, Genetic engineering unlike other techniques can create plants with the exact desired trait very rapidly and with great accuracy and reliability. Therefore it is a technique which can revolutionise food production by enhancing productivity and GM foods are gaining popularity these days. Studies say that by 2050, we will need to feed 9.3 billion people and so food production has to be multiplied and it is one of the challenges going to be faced.

GM foods

These days several GM crops are used as sources of food. Till now there are no GM animals approved so far to be consumed as food but the possibility is not too far away. The GM food products are either directly consumed as foods or sometimes modified crops are processed into food ingredients. China was the first country to commercialise a transgenic crop in 1990, a virus resistant tobacco. In 1994, US-FDA approved ‘Flavr-
Savr’ Tomato for marketing and consumption. A few other transgenic crops were approved in 1995. Some of them were canola with modified oil composition (Calgene), Bacillus thuringiensis (Bt) corn/maize (Ciba-Geigy), cotton resistant to the herbicide bromoxynil (Calgene), Bt cotton (Monsanto), Bt potatoes (Monsanto), soybeans resistant to the herbicide glyphosate (Monsanto), virus-resistant squash (Asgrow) and additional delayed ripening tomatoes (DNAP, Zeneca/Peto, and Monsanto) [5]. According to USDA, 40 plant varieties have completed all the federal requirements for commercialisation. A total of 35 approvals had been granted to commercially grow 8 transgenic crops and one flower crop of carnations with 8 different traits in 6 countries plus the EU till 1996. Reports say that GM crops are grown over 160 million hectares in 29 countries, and imported by countries (including European ones) that don’t grow them. In 2000, 68% of all GM crops were grown by U.S. farmers. In comparison, Argentina, Canada and China produced only 23%, 7% and 1%, respectively. Other countries that grew commercial GM crops in 2000 are Australia, Bulgaria, France, Germany, Mexico, Romania, South Africa, Spain, and Uruguay. Soybeans and corn are the top two most widely grown crops (82% of all GM crops harvested in 2000), with cotton, rapeseed (or canola) and potatoes trailing behind. 74% of these GM crops were modified for herbicide tolerance, 19% were modified for insect pest resistance, and 7% were modified for both herbicide tolerance and pest tolerance. Globally, acreage of GM crops has increased 25-fold in just 5 years, from approximately 4.3 million acres in 1996 to 109 million acres in 2000 - almost twice the area of the United Kingdom. Approximately 99 million acres were devoted to GM crops in the U.S. and Argentina alone.

Assessment of GM foods

It is very important to know about the advantages and disadvantages of GM food, especially with respect to its safety. Because these foods are made by inserting genes of other species into their DNA. Though this kind of genetic modification is used both in plants and animals, it is found more commonly in the former than in the latter. GM foods have lot of advantages, one of the main being reduced use of pesticides.

Types of GM foods

In this section a few varieties of genetically modified crops will be discussed with emphasis to its modification and also throwing light to the major advantages and disadvantages associated.

1) GM Tomatoes

The most preferred and widely marketed GM tomatoes are the ‘Flavr-Savr’ tomatoes. It has a gene modification which helps delaying ripening after plucking so it facilitates transport through long distances. It was considered substantially equivalent (SE) to natural tomatoes as there are no significant alterations in the total proteins, vitamins or mineral contents. They are produced by inserting Kanamycin resistance genes by antisense method.

2) GM maize

It is an herbicide resistance plant expressing the gene of phosphinothricin acetyltransferase (PAT). It has altered carbohydrates and fat content when compared with the parent, non-GM variety.

3) GM soyabean

It is an herbicide resistance soybeans which has the gene of 5-enolpyruvylshikimate-3-phosphate synthase from Agrobacterium. There is also another variety which is Glyphosate resistance. The latter showed a substantially different outcome when compared to the non-GM variety as there was a considerable difference in contents of isofolavone and increase in trypsin inhibitor [9].

4) GM potatoes

They express soyabean glycinin gene and was SE to the non-GM variety. Another variety of GM potato had Bt kurstaki Cry 1 toxin gene from Bacillus thuringenesis, but caused villus epithelial cell hypertrophy and multinucleation, disrupted microvilli, mitochondrial degeneration, increased numbers of lysosomes and autophagic vacuoles when given to mice [14]. The results showed Cry1 toxin which was stable in the mouse gut. A third variety of GM potato has snow drop bulb lectin gene and it showed significant increase in the mucosal thickness of the stomach and the crypt length of the intestines of rats fed with the same.

5) GM rice

This modified type of rice has soyabean glycinin gene as mentioned in the case of potatoes. It was claimed to contain 20% more protein. However, later it was found that the increased protein content was found probably due to a decrease in moisture rather than true increase in protein.

6) GM cotton

Although GM cotton is not edible and does not belong to GM food category, it requires special mention. Several lines of GM cotton plants have been developed using a gene from Bacillus thuringenesis subsp. kurstaki providing increased protection against major lepidopteran pests. They were claimed to be SE to parental varieties in levels of macro nutrients and gossypol. But cyclopropenoid fatty acids and...
GM peas
They express α-amylase inhibitor gene. Nutritional value of α-amylase inhibitor expressing GM peas was shown to be similar to parental peas [10].

Advantages of GM Foods
1) Enhancing nutrition: Malnutrition is common in third world countries where impoverished people rely on a single crop such as rice for the main staple of their diet. However, rice does not contain adequate amounts of all necessary nutrients to prevent malnutrition. If rice could be genetically engineered to contain additional vitamins and minerals, nutrient deficiencies could be alleviated. For example, blindness due to vitamin A deficiency is a common problem in third world countries. Researchers at the Swiss Federal Institute of Technology, an Institute for Plant Sciences have created a strain of "golden" rice containing an unusually high content of beta-carotene (vitamin A). Since this rice was funded by the Rockefeller Foundation, a non-profit organization, the Institute hopes to offer the golden rice seed free to any third world country that requests it. Plans were underway to develop a golden rice that also has increased iron content. However, the grant that funded the creation of these two rice strains was not renewed, perhaps because of the vigorous anti-GM food protesting in Europe, and so this nutritionally-enhanced rice may not come to market at all.

2) Pest resistance: Crop losses from insect pests can be staggering, resulting in devastating financial loss for farmers and starvation in developing countries. Farmers typically use many tons of chemical pesticides annually. Consumers do not wish to eat food that has been treated with pesticides because of potential health hazards, and run-off of agricultural wastes from excessive use of pesticides and fertilizers can poison the water supply and cause harm to the environment. Growing GM foods such as Bt corn can help eliminate the application of chemical pesticides and reduce the cost of bringing a crop to market. A study assessing the global economic and environmental impacts of biotech crops for the first seventeen years (1996-2012) of adoption showed that the technology has reduced pesticide spraying by 503 million kg and has reduced environmental footprint associated with pesticide use by 18.7%. The technology has also significantly reduced the release of greenhouse gas emissions from agriculture equivalent to removing 11.9 million cars from the roads [4]. The technology has also facilitated a significant reduction in the release of greenhouse gas emissions from this cropping area, which, in 2011, was equivalent to removing 10.22 million cars from the roads.

3) Herbicide tolerance: For some crops, it is not cost-effective to remove weeds by physical means such as tilling, so farmers will often spray large quantities of different herbicides (weed-killer) to destroy weeds, a time-consuming and expensive process that requires care so that the herbicide doesn't harm the crop plant or the environment. Crop plants genetically-engineered to be resistant to one very powerful herbicide could help prevent environmental damage by reducing the amount of herbicides needed. This reduces the usage of pesticides which is definitely environment friendly. For example, Monsanto has created a strain of soybeans genetically modified to be not affected by their herbicide product Roundup®. A farmer grows these soybeans which then only require one application of weed-killer instead of multiple applications, reducing production cost and limiting the dangers of agricultural waste run-off.

4) Disease resistance: There are many viruses, fungi and bacteria that cause plant diseases. Plant biologists are working to create plants with genetically-engineered resistance to these diseases.

5) Cold tolerance: Most of the plants cannot tolerate cold conditions and unexpected frost can destroy sensitive seedlings. An antifreeze gene from cold water fish has been introduced into plants such as tobacco and potato [16]. With this antifreeze gene, these plants are able to tolerate cold temperatures that normally would kill unmodified seedlings [6].

6) Drought tolerance/salinity tolerance: Creating plants that can withstand long periods of drought or high salt content in soil and groundwater will help people to grow crops in formerly inhospitable places.

7) Pharmaceuticals: Medicines and vaccines often are costly to produce and sometimes require special storage conditions not readily available in third world countries. Researchers are working to develop edible vaccines in tomatoes and potatoes. These vaccines will be much easier to ship, store and administer than traditional injectable vaccines.

8) Phytoremediation: Phytoremediation is the direct use of living green plants for in situ, or in place, removal, degradation, or containment of contaminants in soils, sludge, sediments, surface water and groundwater. Not all GM plants are grown as crops. Soil and groundwater pollution continues to be a problem in all parts of the world. Plants such as Poplar trees have been genetically engineered to
clean up heavy metal pollution from contaminated soil.

9) Economic benefits -: Genetically engineered crops have enhanced productivity and thereby increase crop yield. Bt crops have had a positive impact on farm income worldwide due to enhanced productivity and efficiency gains. In 2012, direct global farm income benefit was $18.8 billion. Over the period of 17 years, between 1996 to 2012, farm incomes have increased by $116.6 [2]. The impact of Bt cotton on cotton farming industry in India is encouraging. Activists strongly opposed Bt cotton in India, and published reports claiming that the crop had failed in the field. Cotton is a very important crop for India, accounting for 30% of its agricultural GDP. However, due to the high incidence of pests, especially the cotton bollworms, India falls short of the world’s average yield of cotton by 48%, an equivalent of 280 kg/ha². Indian farmers often lose up to 50-60% of their crop to the cotton bollworm. With the commercialization of Bt cotton in India in 2002, the cyclic infestation of bollworms has been suppressed. The farmers soon learned from experience that Bt cotton was very profitable, and 30 million rushed to adopt it. In consequence, India’s cotton production doubled and exports zoomed, even while using much less pesticide. In 2013, India ranks first in biotech cotton production worldwide [7]. The adoption of insect-resistant Bt cotton resulted in a 50 percent increase in profit per hectare and an 18 percent increase in expenditures [8].

Disadvantages of GM foods

There are lot of controversies regarding GM crops especially edible ones. The main concern is with respect to environmental toxicity and risk threats posed to human health upon consumption. Economic considerations are also there. Some people think creating GM foods involves tampering with Mother Nature as there is alteration of genetic composition to meet our needs.

1) Environmental hazards

1) Unintended harm to other organisms -: The main concern regarding this aspect is whether GM crop affects non-targeted organisms apart from the targeted species, especially if it is a harmless but beneficial one. It is possible that it can reach human beings even without direct consumption as it would be cycled through food web [3]. The case study regarding targeting harmless organisms comes from Bt corn. The pollen from Bt corn caused high mortality rates in monarch butterfly caterpillars. Monarch caterpillars consume milkweed plants, not corn, but the fear is that if pollen from Bt corn is blown by the wind onto milkweed plants in neighbouring fields, the caterpillars could eat the pollen and perish. Although the Nature study was not conducted under natural field conditions, the results seemed to support this viewpoint. Unfortunately, Bt toxins kill many species of insect larvae indiscriminately; it is not possible to design a Bt toxin that would only kill crop damaging pests and remain harmless to all other insects. In 2001, a study published in PNAS concluded that the impact of Bt corn pollen on Monarch butterfly populations is negligible [12]. But still there are no solid evidences for this issue and is thus still a topic of debate. Some people are concerned that the soil in which the Bt crops are grown would contain residues of the Bt toxin and can harm the other biota in future.

2) Reduced effectiveness of pesticides -: Just as some populations of mosquitoes developed resistance to the now-banned pesticide DDT, many people are concerned that insects will become resistant to Bt or other crops that have been genetically modified to produce their own pesticides.

3) Gene transfer to non-target species -: Another concern is that crop plants engineered for herbicide tolerance and weeds will cross-breed, resulting in the transfer of the herbicide resistance genes from the crops into the weeds. These “superweeds” would then be herbicide tolerant as well. Other introduced genes may cross over into non-modified crops planted next to GM crops. Gene exchange from crop to wild could also result in extinction of rare plants and support weedy relatives. Besides ‘Super weeds’ there is also concern about ‘Superbugs’ which could be antibiotic resistant. There is also fear that antibiotic resistance may spread from the crop plant to intestinal or soil microorganisms. But this issue of ‘superweeds’ can be addressed using several methods. For say, production of pollen which is supposed to transfer can be prevented by making sterile male GM plants. Another possible solution is to create buffer zones around fields of GM crops. For example, non-GM corn would be planted to surround a field of Bt GM corn, and the non-GM corn would not be harvested. Beneficial or harmless insects would have a refuge in the non-GM corn, and insect pests could be allowed to destroy the non-GM corn and would not develop resistance to Bt pesticides. Gene transfer to weeds and other crops would
supermarkets are offering both GM foods and testing of GM foods is voluntary. Japanese foods will be mandatory as of April 2001. Currently, and Welfare has announced that health testing of GM supermarkets yet. In Japan, the Ministry of Health Cotton and no edible GM foods are available in only available commercial GM crop in India is Bt a great supporter of transgenic plant research, but the different governments are different. For e.g., India is country and therefore so far the responses from they have commissioned mandatory labelling of GM

II) Risks to Human Health

1) Allergenicity :: It is feared that consumption of GM foods elicits immune response resulting in allergy in human beings. There is a possibility that introducing a gene into a plant may create a new allergen or cause an allergic reaction in susceptible individuals. A proposal to incorporate a gene from Brazil nuts into soybeans was abandoned because of the fear of causing unexpected allergic reactions. Extensive testing of GM foods may be required to avoid the possibility of harm to consumers with food allergies. There is no evidence that a transgenic gene has introduced allergenicity into a crop or caused the endogenous allergenicity of the crop to increase [15].

2) Unknown effects on human health :: There is a growing concern that introducing foreign genes into food plants may have an unexpected and negative impact on human health. For e.g. the case studies in animals have been discussed above with regards to GM potatoes.

III) Economic concerns

Bringing a GM food to market is a lengthy and costly process, and of course agri-biotech companies wish to ensure a profitable return on their investment. Another major concern is regarding patenting and Intellectual property. The problem is that patenting these new plant varieties will raise the price of seeds so high that small farmers and third world countries will not be able to afford seeds for GM crops, thus widening the gap between the wealthy and the poor.

Regulation of GM foods

Different regulatory processes to monitor the cultivation and distribution of GM crops is very important. This depends upon the political, social and economic conditions in a particular country and therefore so far the responses from different governments are different. For e.g., India is a great supporter of transgenic plant research, but the only available commercial GM crop in India is Bt Cotton and no edible GM foods are available in supermarkets yet. In Japan, the Ministry of Health and Welfare has announced that health testing of GM foods will be mandatory as of April 2001. Currently, testing of GM foods is voluntary. Japanese supermarkets are offering both GM foods and unmodified foods, and customers are beginning to show a strong preference for unmodified fruits and vegetables. Europe is another continent where there is large hue and cry over GM foods and as a result they have commissioned mandatory labelling of GM foods before making them available in markets for consumption. EC claims that the people have the right to know what they are eating, argue the interest groups, and historically industry has proven itself to be unreliable at self-compliance with existing safety regulations. In the United States, the regulatory process is confused because there are three different government agencies that have jurisdiction over GM foods. To put it very simply, the EPA evaluates GM plants for environmental safety, the USDA evaluates whether the plant is safe to grow, and the FDA evaluates whether the plant is safe to eat. The EPA is responsible for regulating substances such as pesticides or toxins that may cause harm to the environment. GM crops such as Bt pesticide-laced corn or herbicide-tolerant crops but not foods modified for their nutritional value fall under the purview of the EPA. The USDA is responsible for GM crops that do not fall under the umbrella of the EPA such as drought-tolerant or disease-tolerant crops, crops grown for animal feeds, or whole fruits, vegetables and grains for human consumption. The FDA historically has been concerned with pharmaceuticals, cosmetics and food products and additives, not whole foods. Under current guidelines, a genetically-modified ear of corn sold at a produce stand is not regulated by the FDA because it is a whole food, but a box of cornflakes is regulated because it is a food product. The FDA's stance is that GM foods are substantially equivalent to unmodified, "natural" foods, and therefore not subject to FDA regulation.

Conclusion

Throughout the years there has been great debate on the issue of GM foods and the main concern is if it is safe to be grown and consumed. But the truth lies in the fact that the GM foods have the potential to solve many of the world’s hunger and malnutrition problems, and to help protect and preserve the environment by increasing yield and reducing reliance upon synthetic pesticides and herbicides. But the challenges ahead lie in many areas viz. safety, testing, regulation, policies and food labelling [1]. Proper research and understanding of the hazardous effects of GM foods have to be conducted and evaluated for their safety. In any case, we need novel methods and concepts to probe into the compositional, nutritional, toxicological and metabolic differences between GM and conventional crops and into the safety of the genetic techniques used in developing GM crops if we want to put this technology on a proper scientific foundation and allay the fears of the general public. Considerable efforts should also be taken in the direction of making the public aware of the immense potentials of GM foods as studies so far show that their beneficial effects are more prominent than their hazardous nature.
References