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Genetic Modification in Plants and Food: Human Health; Risks and Benefits

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Abstract

Genetically modified (GM) foods are items that had their deoxyribsoe nucleic acid (DNA) altered through genetic engineering. Unlike conventional genetic modification that is carried out through time-tested conventional breeding of plants and animals. Combining genes from different organisms is known as recombinant DNA technology (RDT), and the resulting organism is said to be "genetically modified", "genetically engineered" or "transgenic". GM products include medicines and vaccines, foods and food ingredients, feeds, and fibers. Apart from the advantages of the GM food consumption, there are also various perils associated it their consumption that may prove a threat to humankind.

Keywords: Genetic Modification; Genetic Engineering; Recombinant Technology; Food

Introduction

The region around the globe under genetically modified (GM) crops shows growth enhancement from 1.7 million hectares in 1996 to 134 million hectares in 2009. Today, 14 million farmers worldwide have grown GM crops in 25 countries; including 16 developing countries [1]. Nearly fifteen years have passed after the introduction of genetic modifications (GM) in food and new GM food are added to the existing list of foods. Is GM safe for human health? There are still few studies available for the safety related issues along with toxicity studies that must accompany the application of any novel drug for approval by the corresponding drug administration. In the absence of adequate safety studies, the lack of evidence that GM food is unsafe cannot be considered as safe for consumption. Furthermore, if they are not considered safe for human consumption why should they be approved for animals? One has to wonder what will happen if we start consuming food crops contaminated by GM crops containing genes for the production of drugs and industrial chemicals that have never been assessed for their toxicity [2]. The European Food Safety Authority and each individual member state have detailed the requirements for a full risk assessment of GM plants and derived food and feed (In the USA, the Food and Drug Agency, the Environmental Protection Agency and the US Department of Agriculture are all involved in the regulatory process for GM crop approval [3]. The controversies of GM are always in debate, but there is always something new to add.

Origin of genetically modified Food

Between 1997 and 1999, gene modification (GM) ingredients suddenly in 2/3^{rds} of all US processed foods. It is allowed, for the first time, the patenting of life forms for commercialization. Since then thousands of applications for experimental GM organisms have been filed with the US patent Office alone, and many abroad. Tomato known as Flavr Savr was the first commercially grown genetically modified whole food, which was made more resistant to rotting by Californian Company Calgene. The grand releasing of these tomatoes brand was done officially in 1994 to markets without specific labels. In February 1996, J Sainsbury and Safeway Stores (UK) launches Europe's first genetically modified food product. A variant of the Flavr Savr was used by Zeneca to produce tomato paste which was sold in Europe during summer of 1996.

Following GM crops included insect resistant cotton and herbicide-tolerant soybeans both of which were commercially available in 1996.

In 2003, 99% of the GM food cultivation was contribute by the United States (63%), Argentina (21%), Canada (6%), Brazil (4%), China (4%), and South Africa (1%) and today the grocery manufacturers of America estimate that 75% of all processed foods in the U.S contain a GM ingredient. Between 1995 and 2005, the total surface area of land cultivated with GMOs had increased by a factors of 50, from 17,000 km^2 (4.2 million acres) to 900,000 km^2 (222 million acres), of which 55 percent were in Brazil. In the US, by 2006 89% of the planted area of soyabeans, 83% of cotton, and 61% maize were genetically modified varieties.

Several techniques exist for the development of GM plants. The commonly employed are the bacterium Agrobacterium tumefaciens, which is naturally able to transfer DNA to plants, and the “gene gun”, which shoots microscopic particles coated with DNA into the plant cell [4]. The following given aspects of this transfer have raised concern of human health (Table 1).

- The use of selectable markers to identify transformed cells.
- Transfer of external DNA into the plant genome (i.e. genes other than those being studied)
- The possibility of increased mutations in GM plants compared to non GM, arising due to process of tissue culture for their production and rearrangement of DNA in the vicinity of the insertion site of foreign genes.

How a plant is genetically modified?

Food	Properties of the genetically modified variety	Modification	% Modification in US	% Modified in World
Soyabean	Resistance to glyphosate or glufosinate herbicides	Herbicide resistant gene taken from bacteria inserted into soybean	93 %	77 %
Corn,field (Maize)	Resistant to gylphosate or glufosinate herbicides. Insect resistance via producing Bt proteins, some previously used as pesticides in Organic crop production. Vitamin enriched corn derived from South African white corn variety M37W has bright orange kernels, with 169X increase in the beta carotene , 6x the vitamin C and 2x folate (Shaista et al. 2009).	New genes, some from the bacterium Bacillus thruringiensis, added/transferred into plant genome	86%	26%
Cotton (Cottonseed oil)	Pest resistant cotton.	Bt crystal protein gene added/transferred into plant genome.	93%	49%
Alfalfa	Resistant to glyphosate or glufosinate herbicides.	New genes added/transferred into plant genome.	Planted in the US from 2005-2007;banned until Jan 2011 and presently deregulated	
Hawaiian papaya	Variety is resistant to the papaya ring spot virus	New gene added/transferred into the plant genome.	80%	
Tomatoes	Variety in which the production of the enzyme polygalacturonase (PG) is suppressed retarding fruit softening after harvesting.	A reverse copy (an antisense gene) of the gene responsible for the production of PG enzyme added into plant genome.	Taken off the market due to commercial failure.	Small quantities grown in China

Canola	Resistance to herbicides (glyphosate or glufosinate), high laurate canola.	New genes added/transferred into plant genome.	93%	21%
Sugar cane	Resistance to certain pesticides, high sucrose content.	New gene added/transferred into plant genome.		
Sugar beet	Resistance to glyphosate, glufosinate herbicides.	New genes added/transferred into plant genome.	95 %(2010); planting in 2011 under controlled conditions.	9%
Rice	Golden Rice: genetically modified to contain beta carotene (a source of vitamin A).	Current version of Golden Rice under development contains genes from maize and a common soil microorganism Previous prototype version contained three new genes: two from daffodils and the third from a bacterium.	Forecast to be on the market in 2013.	
Squash(Zucchini)	Resistance to watermelon, cucumber and zucchini yellow mosaic viruses.	Contains coat protein genes of viruses.	13%	
Sweet Peppers	Resistance to virus.	Contains coat protein genes of the virus		Small quantities grown in china.

Table 1: List of Genetically Modified Food Species (percent modified are mostly 2009/2010 data). (Ronald et al, 2010, Wright et al, 2010).

To facilitate the transformation process, a selectable marker gene conferring, for example resistance to an antibiotic (e.g. kanamycin, which kill a normal non GM plant cell), is often co-transferred with the gene of interest to differentiate between GM tissues and regeneration of GM plants. Criticism behind this technology quoted that there is a risk of the spread of antibiotic resistance to the bacterial population either in the soil or in the human gut after ingestion of the GM food derived from the GM plant. Kanamycin itself has GRAS (Generally Regarded as Safe). Studies have shown that the probability of transmission of antibiotic resistance genes from plants to bacteria is extremely low and that the hazard occurring from any such transfer is at worst, slight [5].

Health peril of genetically modified food

Probable menace of genetically modified food consumption in animals comprise of pleiotropic and insertional effects, on animal and human health resulting from the increase of anti-nutrients, potential effects on human health resulting from the application of viral DNA in plants, possible transfer of antibiotic resistant genes to bacteria in gastrointestinal tract, and possible effects of GM foods on allergic responses. Multiple animal studies, indicate serious health risks associated with the GM food Consumption [6-8].

The potential for pleiotropic and insertional effects

The above cited effects cause the silencing of genes, changes in their level of expression or, potentially, the turning on of existing genes that were not previously being expressed [9]. This interference with the expression of the existing genes and biochemical pathways of plants, may lead to destruction of metabolism in erratic ways and to the formation of new toxic compounds or an enhance production of already existing ones as it occurs in two genetically produced foods, tryptophan and g-linolenic acid [10]. The possibility that an unidentified compound may be present in the GM food makes a significant issue that each transgenic food as a whole food and not as a single protein should be tested directly for toxicity in animals [11].

Probable influence on animal health resulting from the increase ofa-nutrients

The introduction of new genes can sometimes lead to increase in existing levels of anti-nutrients, some of which cannot be reduced with heat treatment [12].One of the most widely available commercial GM products nowadays glyphosate-resistant Roundup Ready soybean may display an increase in anti-nutrients. Heat stable anti-nutrients such as phytoestrogens, glucinins, and phytic acid were also found to cause infertility problems in sheep and cattle [13].

Potential effects on human health on implementation of viral DNA in Plants

Cauliflower mosaic Virus 35S promoter is widely using promoter in the manipulated crops, for switching on the introduced gene. Application of this virus promoter is controversial with its highly infectious disposition, that CaMV35S upon horizontal transfer causes, carcinogenesis, mutagenesis, reactivation of dormant viruses and even generation of new viruses [14]. CaMV found in normal foods is not highly infectious and cannot be absorbed by mammals. In contrast others believe that although human have been ingesting CaMV and its 35S promoter at high levels it has never been shown to cause disease in human or to recombine with human viruses [15]. The transient expression of transgenes in mammalian cells transcribed from the CaMV35S promoter raised the possibility that genes regulated by the 35S promoter have the potential for expression in animals. On the contrary, recent studies failed to show presence of DNA transfer in mice and CaMV35S transcriptional activity with real time polymerase chain reaction (PCR), although they do emphasize the need for further studies [16].

Possible transfer of antibiotic resistant genes to bacteria in the GI tract and absorption of introduced genes in a GM plant from the Gut

As it is known that antibiotic resistance genes used as markers in transgenic crops may be horizontally transferred to pathogenic gut bacteria, thereby reducing the effectiveness of several antibiotics [17]. Even though this probability is considered to be low other marker genes, such as jellyfish green fluorescent protein (GFP) genes have been utilized. The only study depicting toxicity and allergenicity of GFP in male rats for 26 d, concluded that GFP exhibit low allergenicity risk [18]. Another aspect of this coin is stated that there is possibility that genes introduced in a GM plant absorbed from the Gut. In recent studies abortive results has been found in the detection of fragments of the glyphosate resistant in a variety of tissue samples from pigs, fed glyphosate-tolerant soybeans and of transgenic and endogenous plant DNA in the chicken breast muscle [19]. On the other hand the orally administered naked M13 phage DNA was detected in the mice blood [20] and also short DNA fragments of GM plants have been detected in white blood cells and in milk of cows and in chicken and mice tissues that had been fed GM corn and soybean, respectively [21]. Moreover fragments of recombinant cry1 Ab gene were detected in the gastrointestinal tract of *Bacillus thuringiensis* (BT) 11 corn fed pigs, but not in blood. The chaos remains in mind that whether the GM DNA is safe or unsafe. In the unlikely event that the DNA is recombined into the host chromosome, the probability that it will exert any biological effect on those cells remains unknown.

Possible Effects of GM Foods on Allergic Responses

A potentially harmful immunological response, including allergic hypersensitivity mechanism has been noticed on the application of novel proteins into foods [22] such as a GM soybean variety expressing methionine from Brazil nut [23] and a genetically engineered corn variety modified to produce a bit endotoxin, Cry9c [24]. However the introduction of gene expressing non allergenic protein such as GM field pea, expressing alpha-amylase inhibitor-1, may not always result in a product without allergenicity. *Brassica juncea*, another GM plant, expressing choline oxidase gene caused low IgE response in mice and a cross-reactive epitope search showed a stretch similar to Hev b 6 having some antigenic properties, although it had no allergenicity [25]. As for BT expressed in many crops, farm workers exposed to BT pesticide may develop skin sensitization and Ig antibodies to the Bt spore extraction. This allergenicity study necessitates the evaluation of all GM products on an individual observation basis and to improve the screening requirement for GM products.

Other Side of the coin: Beneficial aspect of genetically engineered products to Human Health

Developing world comprises of 840 million chronically undernourished people, surviving on less than 8000 KJ/day (2000 Kcal/day) [26]. Approximately 1.3 billion people are living on less than US dollar 1/day [27] and do not access to food. Most of the farmers can't afford to irrigate their crops and to make their livings [28]. Genetic engineering is one of the most suitable approaches to combat these problems of the developing countries. Particularly, studies are under way for genetically modified plants to increase crop yields, or to directly improve nutritional content.

Enhancing nutritional content

The problem of nutrition is not a major issue with the developed countries, as every individual is fulfilling its nutritional requirement. But for the individuals in developing countries, a great concern is required; most of the population of developing nations is undernourished. The people relying on single staple food crop for their energy intake. GM technology inviting a hope to cope up with this drastic issue of malnutrition. “Golden Rice Project” is the finest citation for this technology. Vitamin A deficiency is widespread in the developing world and is estimated to account for the deaths of approximately 2 million children per year. In surviving children it has been identified as the leading cause of blindness. The strategy of genetic engineering in Gloden Rice Project for the Humans is to fulfill the requirement of β-carotene (precursor of vitamin A). In 2003, genetically modified variety of rice has been made [29] having moderate level of β-carotene and since then researchers have produced the much improved variety of rice having more content of β-carotene “Golden Rice 2” [30]. It is estimated that 72g of dry Golden Rice 2 will provide 50% of the RDA of vitamin A for a 1-3 year old child. Golden Rice was made by the researchers for the farmers of developing world and will be given to subsistence farmers with no additional conditions. This is serving as a health solution that can be made available with the tool of genetic engineering.

Scale up of food production

Crops are the major target of parasites, pathogens and herbivorous insects that reduces the yield worldwide [31]. Two examples of commercial GM crop emerging in this area are the insect resistant crops expressing the *bt* gene (from the bacterium *Bacillus thuringiensis*) and virus resistant GM papaya [32, 33]. In USA insect resistant GM maize is successfully cultivated within an area of 10.6 million hectares and comprises 35% of all maize (GM and non GM) grown in the country. A primary cause of crop yield worldwide is abiotic stress, particularly salinity, drought, and temperature extremes [34]. These basic problems will become chaos for the farmers and requiring the implementation of new technologies for their eradication.

Conclusion

GM technology is not a magic stick against all problems of the developing world, but it hold a prominent role in the contribution to poverty reduction, better nutrition and health, and sustainable overall development of the mankind. Some of these potential have already materialized. This article has reviewed the dilemma of genetically modified products with respect to their hazardous and beneficial effects. However it always a debatable topic in research, but still science in ahead of GM. This review will also examine how GM plants may impact on human health and toxicity assessment of GM food in order to fully evaluate any potential disruptions in biochemical parameters and to evidence possible pathological signs on their application. The above results also evaluate that many GM food have some common toxic effects. Although intensive scientific effort is currently in progress to thoroughly understand and forecast possible consequences on human health. It is anticipated that many efforts are needed in relation to GM product in order to accomplish their complete assessment.

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