Review Article

Genetically Modified Foods and Social Concerns

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Abstract

Biotechnology is providing us with a wide range of options for how we can use agricultural and commercial forestry lands. The cultivation of genetically modified (GM) crops on millions of *hectares* of lands and their injection into our food chain is a huge global genetic experiment involving all living beings. Considering the fast pace of new advances in production of genetically modified crops, consumers, farmers and policymakers worldwide are challenged to reach a consensus on a clear vision for the future of world food supply. The current food biotechnology debate illustrates the serious conflict between two groups: 1) Agri-biotech investors and their affiliated scientists who consider agricultural biotechnology as a solution to food shortage, the scarcity of environmental resources and weeds and pests infestations; and 2) independent scientists, environmentalists, farmers and consumers who warn that genetically modified food introduces new risks to food security, the environment and human health such as loss of biodiversity; the emergence of superweeds and superpests; the increase of antibiotic resistance, food allergies and other unintended effects. This article reviews major viewpoints which are currently debated in the food biotechnology sector in the world. It also lays the groundwork for deep debate on benefits and risks of Biotech-crops for human health, ecosystems and biodiversity. In this context, although some regulations exist, there is a need for continuous vigilance for all countries involved in producing genetically engineered food to follow the international scientific biosafety testing guidelines containing reliable pre-release experiments and post-release track of transgenic plants to protect public health and avoid future environmental harm.

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Introduction

Genetically Modified Organisms (GMOs) are being made by inserting a gene from an external source such as viruses, bacteria, animals or plants into usually unrelated species. Biotechnology has granted us the ability to overcome insurmountable physiological barriers and to exchange genetic materials among all living organisms.

The use of recombinant DNA technology has the potential to allow the creation of an organism which is desired and designed by human. Genetically Modified Food (GMF) means any food containing or derived from a genetically engineered organism [(1)]. Describing biotechnology methods is beyond the scope of this paper however, it is informative

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to only name some of the vastly used techniques in creating GM crops: *Agrobacterium* has been used as an intermediate organism for transferring a desirable gene into plants [2]. This has been a successful method for modification of trees and cereal crops. Biolistic transformation is a physical method by which the genes of interest are bombarded into the plant cells and DNA-coated beads are usually used as carriers [3].

Another technique which facilitates the incorporation of genes into the host genome is called Electroporation. This is a suitable method for plant tissues without cell walls. DNA enters the plant cells through minute pores which are temporarily caused by electric pulses [4]. These holes can be also created by microscopic crystals. Another recent method consists of Microinjection which is direct introduction of DNA into genome [5]. Antisense technology is also a useful method for deactivation of specific genes such as those responsible for softening of fruits and fighting against plant viral infections [6].

With currently available techniques the favorite DNA are inserted to only a few numbers of the treated cells. Therefore, in order to detect whether the incorporation of the gene to the cell has taken place, the desired DNA are generally attached to marker gene before their transfer. These marker genes allow researchers to verify whether transfer of the desired DNA has properly occurred. However, after the successful gene transfer, important factors that have triggered debates over the safety of GM crops are the genotypic and phenotypic stability and permanence inheritance [7].

The majority of the Biotech-crops available on the global market have been genetically manipulated to express one of these basic traits: resistance to insects or viruses, tolerance to certain herbicides and nutritionally enhanced quality. At present, more than 148 million *hectares* of farmland are under cultivation for biotech crops throughout the world [8]. There has been a 60-fold rise in the application of Agri-biotechnology since 1996, when the first biotech-crop was commercially produced [9]. Major producers of GM crops include USA, Argentina, Canada, and China [10]. In the US, about 80% of maize, cotton and soya are biotech varieties [11]. In Canada Genetically Engineered (GE) ingredients are used in more than 70% of the processed food products [12]. The current rate of biotech crop adoption is remarkably higher in developing versus industrialized countries (21% *vs.* 9%) [9]. Developing countries are rapidly accepting the technology with the hope of alleviating hunger and poverty. These countries account for 40% of the global farmlands used for GM crop cultivation [9]. It is predicted that, by 2015, more than 200 million *hectares* of lands will be planted by biotech crops in about 40 countries [9].

The emergence of agricultural biotechnology has created social and ethical contradictions. The widespread debate exists as to how biotechnology can be used for planting high quality high yield crops while protecting ecosystem and human health.

While it is claimed that food biotechnology, by improvement of the plant productivity and developing nutrient-fortified staple food, is the promising solution to malnutrition and food shortage, the accumulating evidence over 20 years of GMF introduction to the market does not fully support these claims. The consumers are mainly concerned about the long term human health effects of the biotech crops such as antibiotic resistance, allergenicity, unnatural nutritional changes and toxicity. Furthermore, Agri-biotech companies and their affiliated scientists present GM food as an environmentally friendly crop.

It is excessively stated over the media and through their dependent scientific publications that GM crops containing genes expressing herbicide tolerance and pest resistance lead to reduction of broad spectrum pesticides and herbicide use. Also, they profess that GM crops help diminishing greenhouse global emissions by reducing needs for plowing (replacement of energy-intensive by low-till agriculture). On the other hand, environmen-

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talists believe that engineering of the genetic materials could deeply transform the global ecosystem from all possible aspects [13]. They are concerned about the long term consequences of GM agriculture on biodiversity as it may create superweeds and superpests which can potentially disturb the balance of nature and cause serious hazards for beneficial insects. In this article, different views on agricultural biotechnology which has given rise to debates between advocated and opponents of GM crop are provided.

The information presented in this review was collected through extensive web searches of databases such as Regulatory Framework on Food Biosafety implemented by UNEP-GEF; guidelines of European Parliament's committee on the Environment, Public Health and Food Safety; Food and Agriculture Organization of the United Nations, biosafety guidelines for crop production and food labeling and also scientific data presented by independent scientists of non-profit international organizations and many others.

Major Concerns

Much of the current debates on agricultural biotechnology have focused on the potential risks of GM crops for human health. Some of the health risks pertinent to unapproved GMFs include antibiotic resistance, allergenicity, nutritional changes and the formation of toxins [14]. To address the possible drawbacks of biotechnology application in engineered foods, we point out some of the problems stemming out from genetic modification techniques.

GE Techniques

GE techniques have been used to transfer single gene traits such as herbicide tolerance from soil microbes into plant cells. However, recent studies in higher eukaryotic cells have shown that genes do not function independently from each other. For example, it has been discovered that human genome is not a simple collection of independent genes. Genes, instead of being constant and static, are dynamic and operate in an interactive system and intertwined with one another. Furthermore, proteins do not function separately; rather they behave in interactive network systems. Gene traits work in the cell by intercommunication and reciprocity [15]. Hence, one gene might not determine one trait, be it herbicide tolerance, or resistance to pest. Therefore, the genetic engineering techniques seem to be imprecise and must include gene optimization steps to minimize this concern. The new understanding of genome function has changed the genetic concept which launched biotech industry a couple of decades ago [16].

To make a GM crop, the gene of interest is inserted into the crop's genome using a vector. This vector might contain several other elements, including viral promoters, transcription terminators, antibiotic resistance and marker genes. The genes incorporated into a genome, could reside anywhere, cause mutation in the host genome, and move or rearrange after insertion or in the next generations. Transgenic DNA might break up and reintegrate into the genome again (recombination) leading to chromosomal rearrangement in successive generations and could potentially change the transgenic crops in a way to produce proteins that are allergic or cause other health problems [17,18].

As DNA does not always fully defragment in the digestive system, human gut microflora and pathogens can take up GM materials including antibiotic resistance genes [19]. This may cause the reduction of the effectiveness of antibiotics and therefore increasing the risk of antibiotic-resistant diseases. Some scientific advices have proposed that such markers should be replaced by non-antibiotic marker system in GMF production [20]. In this regard, the Food Safety Unit of WHO has been assessing the safety of antibiotic resistance marker genes [21]. However, the proponent of commercial production of GMF believe that DNA are abundant in all the foods we eat, but there has not been any evidence of the gene transfer from the food source to gut bacteria.

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However, there is a concern that the existence of viral promoters in the vectors carrying the foreign genes might expose the consumer to the viral infection. For example: the *Cauliflower Mosaic* Virus (CaMV) promoter is exploited to induce the expression of transgenes in almost all GM crops commercially released- in Round Up ready soy of Monsanto, Bt-maize of Novaris, and GM cotton and canola. It is of concern that this promoter could potentially becomes activated in human and animal cells [22,23].

Seed companies argue that viruses have been engineered to be dormant in plant cells and therefore they are safe. Contrary to these claims, studies have shown that viruses, lacking the gene needed for movement, can easily gain it from neighboring genes [24,25].

Health Risks Associated with GM Food Consumption

Many scientific data indicate that animals fed by GM crops have been harmed or even died. Rats exposed to transgenic potatoes or soya had abnormal young sperm; cows, goats, buffalo, pigs and other livestock grazing on Bt-maize, GM cottonseed and certain biotech corn showed complications including early deliveries, abortions, infertility and also many died [26-30]. However, this is a controversial subject as studies conducted by company producing the biotech crops did not show any negative effects of GM crops on mice [31]. Although Agri-biotech companies do not accept the direct link between the GMFs consumption and human health problems, there are some examples given by the opponents. For example: The foodborne diseases such as soya allergies have increased over the past 10 years in USA and UK [32] and an epidemic of Morgellons disease in the US [33]. There are also reports on hundreds of villagers and cotton handlers who developed skin allergy in India [34,35]. Recent studies have revealed that *Bacillus thuringiensis* corn expresses an allergenic protein which alters overall immunological reactions in the body [36,37].

The aforementioned reports performed by independent GM researchers have lead to a concern about the risks of GMFs and the inherent risks associated with the genetic technology. It is therefore essential that the safety and long-term effects of GM crops should be examined before their release into the food chain by all organizations responsible to produce GMFs.

In order to give the public the option of making informed decision about the consumption of GMF, enough information on the safety tests of such product is required. Unfortunately, such data are scarce due to a number of factors. For example it is hard to compare the nutritional contents of GM crops with their conventional counterparts because the composition of crops grown in different areas might vary depending on the growth and agronomic conditions. At the present there is no peer-reviewed publication on clinical studies of GMF effects on human health.

Current testing methods being used in biotech companies appear to be inadequate. For instance, only chemical analysis of some nutrients are reported and generally consider the GM crops equal to its conventional crops when no major differences are detected between the compound compositions in both products. Such approach is argued to guarantee that the GM crop is safe enough to be patented and commercially produced [38,39]. It is strongly believed that animal trials should be used to evaluate the probable toxic effects of genetically modified foods [38,40]. Herbicide and glyphosphate resistant soybeans [41-43] as well as GM cotton resistant to insects are claimed to be substantially equal to conventional soybeans or cotton [43]. However, in these studies other than the use of inappropriate statistics, instead of comparing GM crops with the control grown at same locations, samples from different areas were measured, while it is known that environmental conditions could have major effects on the components levels [41,44,45]. Another example are from the results of toxicological studies con-

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ducted on a variety of animals fed with glyphosate-resistant soybean (GTS) which were shown to be similar for GTS fed and control group. However, these experiments were not scientifically sound since high dietary protein concentration and very low level of GTS have hidden any real effects of GM and basically these experiments were more a commercial and not scientific studies [46]. Also, there are some false claims on the improvement of the protein content of GM crops expressing the desired protein from an inserted gene. For example, studies on GM potato and containing soybean glycine gene did not show considerable increase in the protein content or even amino acid profile and as for GM rice the rise in protein content was due to the decline in moisture rather than the increase in protein content [28,47].

Also, there are some difficulties with assessing the allergenicity of GM crops. When the gene causing allergenicity is known, such as the gene for the alpha-amylase trypsin inhibitors, or cod proteins, it is easier to recognize whether the GMF is allergenic by using *in vitro* tests [48-51]. Of course to test the stability of GMF products in the digestive systems, human/animal trials are required and data bank studies are effective. Since insertion of a non-allergenic gene might cause over expression of already existing minor allergen, it is difficult to specifically identify whether a new GM crop with a gene transferred from a source with unknown allergenicity is allergenic before its introduction to the food chain.

GM Food Labelling

In order to verify whether people have been harmed over the years by consuming GMF, specifically in countries like the US where people's dietary are mainly composed of such products, the law for mandatory labeling is highly required. However, the labeling is not just about health issue rather, it is about consumer rights to make an informed choice on GMF. Although a consensual system on GMF labeling is crucial, it seems unlikely that an internationally agreed labeling system can be set up in proximate future. Nevertheless, different GMF labeling schemes have been established in different countries, ranging from stringent to extremely lenient or even non existent legislations [52]. While the EU has established strict GMF labeling regulations, in the US, Canada and Argentina, three big producers of GM food, such laws have been put forward but not enacted by these governments [53].

A proper labeling represents the "GM" word, along with additional information on changed characteristics and the external source of the inserted gene (*i.e.* GM soya bean with gene from X source). Negative labeling such as "GM free" is not suggested, because it might give the wrong impression to the consumers. The law for compulsory labeling of genetically modified food products has been established in more than 40 countries [54]. Surveys commissioned by different organizations have shown that people across the world are seeking for transparency and consumer choice and believe that compulsory labeling scheme on GM ingredients is highly required: 88% Canadians, 92% Americans and 93% French [54,55]. However, the opponents of GMF labeling believe that such a tag resembles a skull and cross bones on a food which makes consumers reluctant in using any bio-engineered products. On the other hand they are concerned that obligatory labeling holds back the progress of Agri-biotechnology [52] and also it would lead to extra costs and logistical difficulties.

Current Debates

The genetic modification of crops has been a controversial issue since the first commercial production of GMF. The proponents of such technologies claim that bio-engineering of food is absolutely safe and it is similar to what has been happening through traditional agriculture for thousands of years. However, in selective breeding when two parental plants are crossed to obtain a desirable trait, it is likely that other unpleasant characteristics are transferred as well. Therefore, taking out the

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undesirable traits is a slow process and requires trial and errors through several generations of plants breeding. In this context, modern biotechnology has allowed us to go beyond natural physiological reproductive barriers in a manner that gene transfer among evolutionarily divergent organisms is now possible and therefore, individual genes expressing certain traits in animals or microorganisms can be precisely incorporated to the plant genome.

GM advocates believe that conventional breeding can achieve similar results using transferred gene but only within related species and in a lengthy and imprecise process. However, GMF opponents explain that genetic engineering bears no resemblance to natural breeding as it forcibly combines genes from unrelated species together; species that were perfectly separated over billions of years of evolution [56]. They believe that the genetic engineering is not an alternative to traditional breeding as natural crossing of plants contributes thousands of genes to the offspring through the elegant dance of life.

Agri-biotech companies claim that recombinant DNA techniques can bring advantages for consumers such as nutritional enhancement as well as improving the quality and yield of food and non-food plants such as cotton and pharmaceuticals [57,58]. Most of the claims about the benefits of GMF have been proposed by the seed industry. However, independent scientists warn that the publications on the success of the GM in offering more nutritious and safe food is not based on expected scientific standards.

Drug studies funded by pharmaceutical companies are more likely to report positive result in favor of the sponsor than independently funded studies [59]. The biased results might be achieved by the type of experiment design, selection of data and briefing the actual findings to what is expected. The same might be happening with researches conducted by the seed industry. The majority of research experiments on transgenic plants are being performed by the private sector and those carried out in universities are funded by the industry [60]. Therefore, independent scientists should urgently follow strict precautionary approach in designing experiments on GMF. GM plants have to meet the criteria of the guidelines in order to get approval for entering the market. However, the regulatory and scientific capacities to implement such guidelines need to be built up worldwide specifically in developing countries.

Intellectual Property Rights (IPR) are one of the important factors in the current debate on GMF. The GM crops are patented by Agribusiness companies leading to monopolization of the global agricultural food and controlling distribution of the world food supply. Social activists believe that the hidden reason why biotech companies are eager to produce GM crops is because they can be privatized, unlike ordinary crops which are the natural property of all humanity [57,61]. It is argued for example that to achieve this monopoly, the large Agri-biotech company, Monsanto, has taken over small seed companies in the past 10 years and has become the biggest Agri-biotech Corporation in the world. The patent right for vegetable forms of life also affect the livelihoods of family farmers as they are required to sign a contract preventing them from saving and re-planting the seeds, thus they have to pay for seeds each year [62].

Conclusion

Taking everything into consideration, GM crops are alive; they can migrate and spread worldwide. In this regard, clear signals should be sent to biotech companies to proceed with caution and avoid causing unintended harm to human health and the environment. It is widely believed that it is the right of consumers to demand mandatory labeling of GM food products, independent testing for safety and environmental impacts, and liability for any damage associated with GM crops. We are aware that many regulatory laws already exist for risk assessments which are performed on three levels of impacts on Agriculture (gene flow, reducing biodiversity), Food and Food

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safety (allergenicity, toxicity), and Environment (including non target organism); And at the same time, in recent years Cartagena protocol has created laws and guidelines and has obliged countries and companies to obey them for production, handling and consumption of GM materials. In this article, we have not reviewed the regulatory issues involved in GMFs production. However, we are certain that the interested readers will follow the debates on GMFs and the related regulatory issues in the years to come.

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