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Food Biotechnology and its Impact on Our Food Supply

Mohammad B. Habibi-Najafi

Department of Food Science and Technology, Faculty of Agriculture,
Ferdowsi University of Mashhad, P.O. Box 91775-1163, Mashhad, Iran

Abstract: Genetically Modified (GM) plants are rapidly entering the food system in the world. These modifications, which are intended to enhance plant productivity and product quality, make use of genetic engineering. This technology offers enormous potential for creation of plants optimized for food and fiber production in support of human needs. However, there is increasing concern about the use of genetic engineering for plant improvement, particularly about possible deleterious effects on human health and about the impacts of the widespread deployment of genetically modified plants in the environment. Different policies are governed this issue around the world. While several European countries have developed positions that do not welcome genetically modified food products in their fields or markets, one may find more flexibility in North America. However, restrictive planting or food labeling requirements are being introduced or considered in both Europe, North America and elsewhere. Governments and regulatory agencies face significant challenges in providing consumers with unbiased information and maintaining consumer confidence in the food supply. The impact of different aspects of GM on our food system will be discussed in detail.

Key words: Food biotechnology · GM foods · food systems.

INTRODUCTION

Food biotechnology is defined as the application of biological techniques to food crops, animals and microorganisms with the aim of improving the attributes, quantity, safety, ease of processing and production economics of our food. It thus includes the traditional food manufacturing processes used for bread, pickles and cheese and indeed all crops and animals for food or feed since agriculture was first practiced [1]. The most recent application of biotechnology to food is Genetic Modification (GM), also known as genetic engineering, genetic manipulation and gene technology and/or recombinant DNA technology. The collective term "Genetically Modified Organisms" or GMOs is used frequently in regulatory documents and in the scientific literature to describe plants, animals and microorganisms which have had DNA introduced into them by means other than by combination of an egg and a sperm or by natural bacterial conjugation. Agricultural GMOs have increasingly been the subject of controversy in scientific and public discussion [2]. International consensus has been reached on the principles regarding evaluation of the food safety of genetically modified organisms. Unbiased information will be given in this review considering the benefits and risks of GMOs from food Science and technology perspective.

Historical background: There are virtually no food products on supermarket shelves that have not been improved by plant breeders. Most wild forms of the plants we consume daily are significantly different from what is currently commercialized. Both yield and food quality have been improved since the transition from hunter-gatherer societies to farming societies where farmers selected and collected seed from the best plants in their fields. Wild lettuce is bitter and unpalatable, wild tomatoes are not nearly as sweet as current varieties and most consumers would reject them. The yield of corn has almost doubled in the last 40 years and almost tripled in the last 100 years. World food production has doubled since 1960 while productivity (amount of food per hectare) has tripled [3]. This somewhat parallels the growth in population over the same time period. To create such plant varieties, plant breeders have until recently crossed plants with interesting characteristics (yield, quality...) and examined the progeny for plants which combined as many favorable characteristics as possible from the

Corrsponding Author: Dr. Mohammad B. Habibi-najafi, Department of Food Science and Technology, Faculty of Agriculture, Ferdowsi University of Mashhad, P. O. Box 91775-1163, Mashhad, Iran

parents. Several such individuals were then tested for performance under field conditions. Genes transferred by the pollen from one plant to the other control these favorable characteristics. This approach relied on chance to generate the right combination of characteristics and required several years of effort to create a new variety. Plant breeding has significantly contributed to our current standard of living. Food products are generally available year-round and food prices and quality generally meet consumer demands. Approximately 30 years ago, several research groups discovered that soil bacteria could transfer genes from bacteria to plant cells. The bacteria (several species of *Agrobacteriu*m) have all the "machinery" for naturally transferring segments of DNA to a plant. Genetic engineers take advantage of this capacity of bacteria to transfer genes to introduce new genes into plant cells. In this way, genetic engineering makes it possible to introduce foreign genes into plants, eliminating the fertility barrier that separated most plants from each other and from animals and microbes. In theory, any segment of DNA from any living cell can be inserted and the trait for which it codes can be expressed in plant cells [4]. The first plant product derived from biotechnology to be put on supermarket shelves was the FlavrSavr tomato (in 1995, developed by Calgene Co.). This tomato variety was created to satisfy consumer demand for a flavorful product year round. By increasing the tomato's firmness, it could be left to ripen on the vine and still be transported to market without the losses associated with a soft ripe tomato [5, 6].

Advantages and potential benefits of genetic modification: For the development of improved food materials, GM has the following advantages over traditional selective breeding [7, 8].

- Allows a much wider selection of traits for improvement: e.g. not only pest, disease and herbicide resistance achieved to date in plants but also potentially drought resistance, improved nutritional content and improved sensory properties.
- It is faster and lower in cost.
- Desired change can be achieved in very few generations.
- Allows greater precision in selecting characteristics.
- These advantages could, in turn, lead to a number of benefits, especially in the longer term, for the consumer, industry, agriculture and the environment:
- Improved agricultural performance (yields) with reduced use of pesticides.
- Ability to grow crops in previously inhospitable environments (e.g. *via* increased ability of plants to grow in conditions of drought, salinity, extremes of temperature, consequences of global warming, etc.) leading to improved ability to feed an increasing world population at a reduced environmental cost.
- Improved sensory attributes of food (e.g. flavor, texture, etc.).
- Improved nutritional attributes, e.g. combating anti-nutritive and allergenic factors and increased vitamin A content in rice helping to prevent blindness in Southeast Asia.
- Improved processing characteristics leading to reduced waste and lower food costs to the consumer.

GM has huge potential for mankind in medicine, agriculture and food [2]. In food, the real benefits are not the early instances that have been appearing so far, but its longer term benefit to the world -and especially the third world-its potential for contributing to elimination of hunger and malnutrition. Even today, there are 800 million people in the third world who regularly do not receive enough food to alleviate hunger, still less provide adequate nutrition; and this will be greatly worsened as a result of the world's escalating population over the coming decades. It is frequently argued by some that there is more than enough food to feed the world and all that is needed is "fairer distribution" (which so far mankind has signally failed to achieve)-or a variant of that, "the real problem is not shortage of food, it is poverty". Whatever may be done by way of improved yields through conventional methods, attempted population control and fairer distribution would, however, be inadequate for the future. The important point is not only how to feed the world now but also addressing and trying to solve the problem of "How mankind shall feed the world in a few decades when the world's population has doubled, with most of the increase in the poorest parts of the world?" Food science cannot by itself solve a problem that has such huge political and economic dimensions. However, it will not be solved without food science. It also stressed that this is something that should not be left to commercially oriented R&D but must be progressed by governments and international agencies.

Potential risks and concerns regarding genetic engineering:

Human health concerns: One question, which remains largely unanswered in the opinion of many, is whether the new food products pose any threat to human health.

The ingestion of foreign DNA is an unlikely source of risk, as we ingest DNA daily as part of our regular diet of plant, animal and microbial products. In addition to inserting genes, most genetic manipulations also introduce an antibiotic resistance gene as a "marker," to discriminate transformed from un-transformed plants in the course of experimentation. The ability of transformed plants to resist antibiotics is useful as un-transformed plants die in the presence of the antibiotic, thereby simplifying the task of identifying transformed plants. The presence of the proteins conferring antibiotic resistance in the foodstuff is considered unlikely to affect human therapeutic treatments that use the corresponding antibiotic since the protein will be inactivated and digested in the digestive tract [9]. However, more experimentation is required on a broader range of antibiotics. Although generally regarded as possible, the transfer of the antibiotic resistance genes from plant material to gut or soil bacteria is probably inconsequential. Antibiotic resistance genes occur naturally and are transferred naturally between. GM plants will not contribute much to the spread of antibiotic resistance in nature. Proponents of GM food suggest that a canola plant that is resistant to herbicides should produce the same oil as a non-GM canola plant. Others state that this can not be assumed to be the case since it has not been established scientifically. This is perhaps the crux of the battle behind whether the "precautionary principle" should be used by regulatory agencies instead of the principle of "substantial equivalence". Most regulatory agencies have so far operated using the principle of substantial equivalence. These two approaches will be described later in detail. The possibility that GM foods could induce allergic reactions has been widely mentioned [10]. This issue should normally be addressed during the safety assessment of a food produced from GM. Protocols exist for testing some allergic reactions, but more research is needed to standardize and implement them [11]. One of the most widely criticized GM plants is the result which has been found from project attempts to produce high methionine content soybean by a gene transfer from a brazil nut. This modification was found also to transfer protein involved in allergenicity (these plants have never been put on supermarket shelves). In many cases, more experimental analyses are needed [1].

Environmental issues: The large majority (>92 %) of GM crops planted in 2000 were modified for only two characteristics: either herbicide resistance or insect resistance. Despite research efforts, relatively few genes are available for genetic engineering. Genetic engineers still do not know which DNA sequences code for the vast majority of traits of economic importance (such as yield and quality) and modification of those traits has so far largely been out of the reach [1, 3].

Herbicide resistance: Herbicide resistance, which is conferred by introducing a gene encoding an enzyme metabolizing and thus detoxifying the herbicide or by introducing a gene coding for the target enzyme insensitive to the herbicide, is an indispensable part of modern agriculture. Proponents of GM crops show field data, which suggest that use of herbicide-resistant GM plants can lead to reduced herbicide use in the field and ultimately increased yields and reduced costs. Tolerant to glyphosate (Roundup Ready) and glufosinate (BASTA), respectively, are the commercially most relevant applications [3]. It also reduces the need for farmers to till the soil, thus reducing erosion. It is now possible to sow herbicide-tolerant soybean directly into undisturbed soil and apply a post-emergence herbicide, thus conserving soil moisture, improving crop performance and reducing water and wind erosion. On the other hand, others believe that GM soybean allows farmers to substitute Roundup for more hazardous and long-lasting herbicides such as acetochlor. However, herbicide-resistant plants are grown on 75% of the global area of transgenic crops particularly soybean [12].

Insect resistance: The natural insecticidal protein (δ-endotoxin) produced by a soil bacterium *(Bacillus thurigiensis*; Bt) has been used for decades by organic food producers as well as by conventional producers to control crop-damaging insects. In cotton for instance, the use of GM plants (made resistant to insects by transferring to them the gene that produces the Bt insecticide) on close to one million hectares in 1998 has lead to reduced chemical pesticide used by over 12 percent. Cotton farmers who used the technology increased their income (after the fees paid to biotechnology companies) by nine percent. Major benefits exhibited by Bt-resistant plants comprise improved crop yields, reduced use of chemical insecticides, reduced level of fungal toxins and preservation or enhancement of populations of beneficial insects [13]. Some fear that deployment of insect-resistant plants on large surfaces will accelerate the appearance of insects capable to resisting the insecticide. All pest control methods, whether from biotechnology or the traditional chemical industry, will increase the incidence of pests able to resist the control method. Strategies have been devised to slow the spread of insecticide-resistant insects and new Bt protein versions are being designed to replace the versions that have become obsolete because of widespread resistance (the same strategy to combat resistance was used by the chemical insecticide industry). However, pest control will be necessary as long as high yields of insect-free and cheap crops are expected from agricultural producers. A report by Losey *et al.* [14], raised fears about potential environmental damage to non-pest insects. The pollen of Bt corn was suspected to adversely affect the monarch butterfly. However, it was shown that crops distribute Bt-containing pollen at significant levels only a few meters away from the field and there is dispute as to whether the amount of Bt insecticide on surrounding fields is sufficient to affect non-pest insects. Data from different research groups indicate a range of effects on non-target organisms (the monarch butterfly among others).

Gene escape or genetic pollution does raise some concerns. Transgenic plants could transfer their transgene to wild relatives through pollen. The thus modified wild relatives could become “superweeds.” This concern only applies to plants that have wild relatives around the field where they are cultivated and which flower at the same time and rely on cross-pollination. Corn, for example, does not have any wild relatives to which it could hybridize in Canada. Canola, on the other hand, can hybridize to wild relatives of the mustard family. Gene transfer to wild relatives has been observed and we must study the environmental risks more thoroughly. The two genetic modifications used (so far) on large surface areas in agriculture herbicide and insect resistance are the result of research work performed in the late 1980s and early 1990s. Consumers have seen little benefit from the use of these modifications. Once the majority of farmers have adopted the technology, it is likely that savings on production costs, if any, will be passed on to consumers since the most cost-efficient farmers will drive down the price of the commodity. Use of less persistent and less toxic pesticides (decreased health concerns) and improved agricultural practices (improved sustainability) are benefits that can be substantial but are not passed on directly to the consumer. Products with more direct consumer benefits will likely be developed. An example is the introduction of genes that produce beta-carotene (the precursor of vitamin a) in rice. GM rice now has a light golden-yellow color and contains sufficient beta-carotene to meet human vitamin A requirements from rice alone. In order to convince the consumer on the advantage of genetic engineering and thus to increase the advantage of GM foods, “obvious” traits such as sensory or nutritional properties have to be improved [15].

Safety and regulation of GM foods: In recent years, two contrasting approaches to evaluating the safety of GM foods have been developed. They are respectively called the method of substantial equivalence and the precautionary principle.

Substantial equivalence: The essence of the substantial equivalence approach to evaluating the safety of a new food product is to compare the new product to a familiar or traditional product. If it can be demonstrated that the new product will not affect human health or the environment differently from its traditional counterpart, then the new product is considered "substantially equivalent" to the existing product. Historically, the substantial equivalence approach was originally developed in the context of medical device evaluation in the USA and was later adapted to the evaluation of new foods [16]. The selection of which specific characteristics to include in the comparison and exactly how to compare them can be important topics of discussion and perhaps generate disagreement. Even so, the substantial equivalence approach has been generally accepted by several national and international organizations. Differing interpretations of the purpose and basis of the substantial equivalence approach have resulted in an ongoing debate about its adequacy. Critics have attacked the motivation and procedures of the substantial equivalence approach as inherently suspect. Proponents have just as fervently defended it. A possible future dilemma is whether reliance on the substantial equivalence approach for purposes of safety determination will undermine marketing goals of product differentiation and identity preservation. In other words, can a food manufacturer have both substantial equivalence and a product that is sufficiently distinctive from others to market it successfully? Further experience with the application of substantial equivalence in the food industry should help to illuminate some of these questions [17, 18].

The precautionary principle: Another approach to the safety evaluation of GM foods is the precautionary principle. Historically, it originated in Germany in the 1970s in the context of environmental and sustainability issues. The precautionary principle can be stated in non-technical language as follows: "When a product or activity raises threats of harm to human health or the environment, precautionary measures should be taken even if some cause and effect relationships are not fully established scientifically." The precautionary principle has stimulated a great deal of discussion and debate. Critics argue that the precautionary principle challenges scientific reliance on experiment, theory falsification, verification, consistency and predictability. Proponents argue that the precautionary principle represents an attempt to take science seriously, not to discard or revise it. Others charge that decisions based on the precautionary principle are veiled forms of trade protectionism. Recent examples include bans on US and Canadian beef because of the use of growth hormones and delays in the approval of GM crops in European markets. It will probably take some time for the scientific and legal arguments engendered by the precautionary principle to be resolved [19, 20].

CONCLUSIONS

Genetic engineering and biotechnology will undoubtedly have a profound effect on agricultural and food production in coming years. There is enough potential synergism in the application of biotechnology and GM to food and agricultural production to ensure that farmers, consumers and companies have meaningful choices and a chance to realize true benefits. At the same time, as with most new Technologies, there is a remote but real possibility of unintended effects of GM in food and agricultural production on health and the environment if the technology is not managed properly. These unintended effects have the potential to be perceived as negative for the future of the technology if they are not offset by benefits elsewhere in the social system. With adequate patience and foresight, scientists should be able to develop adequate public policies to monitor, control and minimize potential risks of biotechnology and any possible adverse impacts on public health, the environment and society at large.

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