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A US Perspective

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The Nuts and Bolts of Genetically Engineered (Modified) Foods

A US Perspective

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Abstract: The bulk of consumed Genetically Modified (GM) foods, in the United States (US), come from corn, soybeans and their products (corn syrup, tofu, popcorn, oils, tortillas, etc.). Some other GM crops and foods or foods containing GM components are cotton (cottonseed oil), canola, genetically engineered rennin cheese, “light beer” and papayas. During the genetic engineering of an organism, “foreign” genetic material is spliced (inserted) into a recipient, which becomes transgenic. The DeoxyriboNucleic Acid (DNA), the blue print of life, carries the universal genetic code. Each gene (basic hereditary unit) on the DNA consists of codons. Amino acids, the building blocks of proteins, are coded for by codons. During gene expression, the genetic code is transcribed into a Ribonucleic Acid (RNA) molecule, which in turn is translated into a protein. One or more proteins may govern a trait. A disarmed plant pathogen bacterium, *Agrobacterium tumefaciens*, and the "Gene Gun" are some methods used in the making of transgenic food plants**.** Some Methods to genetically engineer food animals are the Embryonic Stem Cell mediated gene transfer and the Pronucleus DNA microinjection. The making of food related GM crops, GM animals and processing aids address economical, nutritional-health and environmental issues. “Fitness” related genes such as insect, herbicide and disease resistance are found in most “deregulated” (approved) GM food crops. Other food crops and animals may be modified to be more nutritious (“Golden Rice”) or protein fortified (cow milk for cheese-making). The agencies regulating GM food related plants, animals and microorganisms are the US Department of Agriculture (USDA), the Food & Drug Administration (FDA) and the Environmental Protection Agency (EPA). GM foods may be labeled on a voluntary basis. Educational programs to inform consumers about GM foods are a necessary step toward establishing

confidence-building measures.

Keywords: Genetically Modified Foods, Genetic Engineering, DNA Technology, Food Safety

This paper focuses on the US and discusses the availability and acreage of genetically modified food crops, the genetic modification of food related plants, animals and microorganisms, safety and labeling issues and the need to inform the public in the US and elsewhere about genetically modified foods.

Genetically Modified (GM) Foods in US Markets

Recent estimates show that 60 to 70% of foods in the US contain a small quantity of GM ingredients (GEO-PIE Project 2001). This is mainly due to corn and soybean. Adding foods containing oil from canola and cotton covers nearly 100% of the GM plant food ingredients in the American diet. The increase in planted acreage of GM food crops in the US may have contributed to the rise in the amounts of GM ingredients in foods.

The US and Global Acreage of GM Crops

The US has experienced an increase in acreage of GM varieties of corn, cotton and soybeans (Reifschneider and Vogel 2002) from 1996 (below 20%) to 2002 (34, 71 and 75%, respectively). Some of the GM varieties of these three crops are characterized with "fitness" related genes such as Insect Resistance (IR) and Herbicide Resistance (HR). Corn is high with IR varieties while cotton and soybeans are high with HR varieties. During 2002, IR and HR varieties of corn and cotton accounted for 22 & 9% and 13 & 36%, respectively of their total respective acreage. The GM soybeans in 2002 were all HR varieties.

The estimated global planted area of GM crops in 2002 is 145 million acres. It represents a 35-fold increase over the 1996 acreage. Globally, the principal 2002 GM crops (as percent of global acreage) were soybeans (62%), corn (21%), cotton (12%), and canola (5%). During the period between 1996 and 2002, HR varieties have consistently

been the dominant trait with IR varieties second (Clive 2003). The yield gains from GM crops in developing countries are much higher than what has been reported for other countries where GM crops were used mostly to replace and enhance chemical pest control (Qaim and Zilberman 2003).

Genetic Engineering (Modification) is paramount to the making of GM food related products.

Genetic Engineering (Modification) of Organisms

For the purpose of this article, genetic engineering (modification) may be defined as a molecular based transfer of "foreign" genetic material (natural or synthetic) to a recipient. In the process, the recipient becomes transgenic. The inserted genetic material (transgene or transgenes) may come from either a related or unrelated organism (plant, animal, bacterium etc.). For example, Insect Resistant or Bt Soybeans that produce their own biopesticide contain a transgene from the bacterium *Bacillus thuringiensis*. Any organism containing a transgene is often called transgenic, genetically modified (GM) or genetically engineered (GE). These three terms will be used interchangeably in this article. Genetic engineering is part of a sequence of scientific techniques used over a period of about 10,000 years to improve traits of food related organisms (NRC 1989).

Improving Traits of Food Organisms - A Historical Perspective

Some of the techniques that have been used and are still in use to ameliorate traits of some food related organisms such as plants, animals and yeast are selective breeding, hybridization, mutations and fusion technology (IFT 2000).

Selection has been used for the enhancement of economical traits. For example, faster growing and high yielding plants, plants with larger or less scattering seeds, increased

milk production, and adaptation to certain environmental conditions, to mention a few. It has dramatically changed both plant and animal species compared to either their wild relatives or ancestors. Selective breeding brought about enrichment of the genetic make up of both plants and animals with economic and fitness attributes. In other words, selective breeding brought about genetic modification in its most primitive form.

Hybridization or crossbreeding between closely related species might lead to organisms with desirable traits. For example, the cross between wheat, *Triticum aestivum*, and rye, *Secale cereale* (members of two different genera) produced the grain triticale - a wheat-rye hybrid - containing the whole genomes (the totality of the genetic material) of both parents. Corn, as we know it, is the result of decades of self-pollination followed by cross-pollination to produce vigorous hybrid plants. While most breeders cross-pollinate plants of a single species, some breeding methods rely on crosses that can be made between two species within the same genus. For example, a cross between *Musa acuminata* and *Musa balbisiana*, both members of the genus *Musa*, produced the bananas of today. Varieties of tomato, soybean, and canola, to mention a few, were formed containing a single genome and randomly acquired genes (sometimes thousand of genes) from either parent (IFT 2000). The products of naturally occurring interspecies crosses have been employed for thousands of years, and many of current foods (tomato, soybean, canola, and oil from cotton) are derived from such crosses. They are all products of extensive genetic modification and selection.

Mutations (spontaneous or induced) are changes in the genetic make up of an organism. These changes may lead to improved agricultural and cultivation attributes. For example, a spontaneous mutation in nature that would prevent the dispersal of wheat grains may

have led to the selection of these varieties, which enabled farmers to collect the grains rather than pick them up from the ground. During "Mutation Breeding" plants are exposed to either radiation (such as gamma rays) or chemicals (such as sodium azide) to induce mutations of economical value.

Protoplast (cell-wall free cell) fusion is a technique in which cells from different species of plant, bacteria or yeast are treated to remove the cell wall so that they can fuse. Fusion results in the recombination (genetic modification) of parental genetic material and the production of superior cross-species hybrid cells. The production of rapid rising Baker's yeast and dextrin digesting Brewer's yeast for the manufacturing of "light" (low-calorie) beers are examples of protoplast fusion derived food related products (Spencer et al 1985; Janderova et al 1990).

The previous examples demonstrated that during the process of improving economical traits of food related organisms genetic modification took place. Thus, one may conclude that from a genetic modification aspect, genetic engineering is another trait improving technique. Any genetic modification of an organism starts at the cell level.

The Genetic Material of the Cell

The genetic material of the cell includes two nucleic acids: DNA (Deoxyribonucleic Acid**)** and RNA (Ribonucleic Acid). The DNA molecule is a polynucleotide. Each nucleotide is made up of a sugar (deoxyribose) molecule, a phosphate group and one of four (nitrogenous) bases (Adenine, Cytosine, Guanine and Thymine). The DNA molecule is usually double stranded. The strands run antiparallel to each other. They are attached to one another through hydrogen bonds between complementary bases. Complementary bases pair according to the "base pairing principle" where Adenine pairs with Thymine

and Cytosine pairs with Guanine. The antiparallel arrangement of the DNA strands allows for the base pairing principle to take effect.

In this discussion only chromosomal and plasmid DNA will be included. Chromosomal DNA can be either circular as in bacteria or linear (chromosome) as in yeast, molds, plants and animals. The circular plasmid DNA is found in some microorganisms such as bacteria. Plasmid DNA is smaller than the chromosomal DNA and is mobile. The mobility of plasmids allows them to move in and out of cells. The mobility of plasmids makes them ideal shuttles for carrying "foreign" DNA into cells.

Genes make up the DNA. A gene is a sequence of nucleotides including a promoter sequence, a coding region and a termination sequence. The promoter initiates and enhances gene expression (see below), the coding region codes for a specific protein and the termination sequence marks the end of the gene.

Codons make up a gene. A codon (or trinucleotide) is made up of three nucleotides such as Cytosin-Cytosin-Guanine (or CCG). The codons specify the genetic code for particular amino acids in a protein and the start and stop of the translation process of the genetic code into a protein.

The RNA molecule is also a polynucleotide. Each nucleotide is made up of a sugar (ribose) molecule, a phosphate group and one of four (nitrogenous) bases (Adenine, Cytosine, Guanine and Uracil). The RNA molecule is usually a single strand. For genetic engineering purposes one should be aware of three types of RNA molecules: the messenger RNA (mRNA), the transfer RNA (tRNA) and the ribosomal RNA (rRNA). All three types of RNA are transcribed from DNA. The mRNA carries the genetic code of a gene (Drlica 2004).

Gene Expression

Gene Expression is the process of assembling a protein based on the genetic code of a gene. In general, gene expression includes two major steps: transcription and translation. During transcription mRNA is formed using the gene in question as a template. mRNA is both the messenger and the message (an RNA "version" of the gene). Translation takes place at the ribosomes (small cellular components composed of rRNA and protein; sites of protein assembly) and it involves the assembly of a protein based on the genetic code carried by the mRNA. The tRNA assists the mRNA during translation. The rRNA is a component of the ribosomes (Drlica 2004).

The Making of a Transgenic Organism -General Considerations

A transgenic organism is one that carries a transgene or transgenes that have been inserted into its genome. The followings are general considerations in the making of a transgenic organism (Wong 1997):

1. The gene of interest, the transgene, is isolated.
2. The gene construct is assembled:
    a. Both promoter and termination sequences are added to the transgene.
    b. A reporter gene (such as antibiotic or herbicide resistance genes) is added to the transgene.
3. The gene construct is spliced into an organism.
4. Genetically transformed cells or organisms are selected.
5. When needed, whole organisms are regenerated.

Isolation of the gene of interest may be a limiting step in the process. Progress has been made to make this step less restrictive. Once the gene is isolated, promoter and termination sequences are added in the build up of the gene construct. Next, a reporter gene is added to complete the gene construct. The reporter gene helps in the identification of cells or organisms that have successfully integrated the transgene. Splicing the transgene into organisms may be done in different ways depending on the organism to be genetically engineered.

Transformation is a common method of transferring or acquiring DNA. Usually during transformation cells take-up "foreign" DNA (chromosomal DNA or plasmid DNA). After the "foreign" DNA integrates into the chromosomal DNA of a recipient cell, the genetic make-up of that cell is genetically transformed.

Methods to genetically engineer food related bacteria, plants and animals would be briefly described.

The Making of Genetically Engineered Food Related Bacteria

Genetically modified bacteria are used, for example, as food processing aids (Dairy and Meat industries), for making food-processing aids (Rennin - the cheese-making enzyme) and in the *Agrobacterium* method to genetically engineer plants.

Isolated DNA from donor and recipient bacterial cells are separately treated with the enzyme restriction endonuclease, which cuts the DNA at certain locations based on recognition of a specific DNA base-sequence. Chromosomal DNA is cut into a number of fragments of different lengths. Plasmid DNA subjected to a restriction endonuclease cleaves open. In the process, single strands of DNA are formed at both ends of a fragment of chromosomal DNA and at both ends of the cleaved-open plasmid. These

single strands of DNA are also known as “sticky ends”. Since “sticky ends” are complementary, they pair (DNA base-pairing principle) forming a recombinant DNA made of the recipient DNA and some of the donor DNA. The cleaved-open plasmid serves as the recipient of a fragment from a donor DNA. Once the plasmid acquired a donor DNA fragment it becomes a recombinant plasmid. The recombinant plasmid is reintroduced into a bacterial cell via Transformation. At this point the cell, which acquired the recombinant plasmid, becomes transgenic (recombinant or genetically engineered) as a portion of its DNA was obtained from a donor. The reporter gene, in the gene construct, helps identifying recombinant cells. The selected recombinant cells are propagated and tested for the expression of the transgene (Atlas 1996).

In those instances where it is difficult to isolate the desired gene, reverse transcription is used. This process involves the assembly of a gene using the respective mRNA as a template. The mRNA in question is isolated from an organ or tissue specializing in the production of the protein coded for by the desired gene. A case in point is the production of the cheese-making enzyme, Rennin (Chymosin). The mRNA is isolated from cells of the gastric mucosa of an unweaned calf. The isolated mRNA serves as a template for the assembly of the gene in question. The newly formed gene is spliced into a plasmid, which is reintroduced into a bacterial cell via Transformation. The process proceeds as described above (FDA 1990). The production of Rennin via genetic engineering alleviated an acute shortage of the enzyme and stabilized its price. It is estimated that nowadays the recombinant Rennin is used in more than 80% of cheeses manufactured in the US and Canada (IFT 2000).

In those cases where neither the desired gene nor the respective mRNA is available,

reverse translation is used. This process involves the assembly of a mRNA using as a guide the sequence of amino acids in the respective protein. Once the mRNA is obtained the gene is assembled via reverse transcription. A case in point is the production of the sweetener Nutrasweet (Aspartame). No gene coding for Aspartame is known to occur in nature. Since Aspartame is made up of two amino acids (aspartic acid and phenylanaline) it was relatively easy to construct a mRNA and subsequently the respective gene. The artificial gene was constructed to code for a "super" molecule made up of multiple Aspartame molecules. After translation, the "super" molecule is enzymatically broken down into individual Aspartame molecules (Murata et al 1993).

Some Methods to Genetically Engineer Food Plants

A number of methods are used to genetically engineer or genetically transform food plants. Two of these methods, the *Agrobacterium* method and the "Gene Gun" method, will be described. Using either method one obtains a transgenic food plant.

The *Agrobacterium* method exploits the natural infection process of the "Crown Gall" disease causing bacterium *Agrobacterium tumefaciens*. This bacterium possesses a plasmid known as Ti-plasmid. A segment of the Ti-plasmid, the T-DNA, carries oncogenes controlling tumor formation in plants during the Crown Gall disease. In the course of the natural infection of a plant, the T-DNA region detaches itself from the Ti-plasmid and incorporates itself into the chromosomal DNA of the host plant. Biotechnologists use the T-DNA region as a shuttle for desired genes to be spliced into a plant. The *Agrobacterium* method was originally designed for dicotyledonous species such as soybeans & tomatoes. This method is characterized by a high frequency of single-site insertions of donor DNA. In the process of genetically engineering the T-DNA

region, the oncogenes are disarmed and a desired gene construct (including coding sequence, a promoter and a reporter gene) is inserted into that region. The resulting recombinant Ti-plasmid is reintroduced into *Agrobacterium tumefaciens* cells via Transformation. The recombinant cells of *Agrobacterium tumefaciens* containing the desired gene are used to infect leaf discs (Wong 1997). As the infection of the leaf discs progresses the recombinant T-DNA region of the Ti-plasmid incorporates itself into the chromosomal DNA of the plant. The leaf discs are regenerated into plants using plant tissue culture techniques (Trigiano and Gray 1996). The regenerated recombinant plants may contain a reporter gene conferring resistance to the antibiotic Kanamycin. In this case, the regenerated recombinant plants survive the presence of Kanamycin. The survivor-regenerated plants are selected and after seeds are produced the progeny is tested for expression of the desired gene. In the same manner, genes from the bacterium *Bacillus thuringiensis* known to confer resistance to insects can be spliced into the T-DNA region of *Agrobacterium tumefaciens* and used as described above to make, for example, insect resistant transgenic tomato or soybean plants.

The "Gene Gun" method uses microprojectile “bombardment” of DNA-coated gold, tungsten or plastic microscopic particles. The particles penetrate the wall of plant cells and into their cytoplasm. The DNA is released from the particles, finds its way into the nucleus and integrates into the DNA of plant cells (Klein et al 1987). Originally, the gene gun has been especially useful to genetically transform monocotyledonous species like corn and rice. The gene gun may be used to either genetically modify leaf discs or intact plants (Helenius et al 2000).

Further developments allowed the application of each of the two described methods to

some mono- and dicotyledonous species of plants. “Golden Rice” and the Ringspot Virus Resistant Papaya are some examples of genetically modified food plants made using the *Agrobacterium* method and the "Gene Gun" method, respectively.

The rational for the development of “Golden Rice” stems from the fact that rice is either a major food staple or the only food staple to many around the globe. No cultivars of rice are known naturally to produce in the endosperm neither vitamin A nor its precursor (β carotene). Vitamin A deficiency causes symptoms ranging from night blindness to total blindness. In Southeast Asia, it is estimated that annually a quarter of a million children go blind because of this nutritional deficiency. Vitamin A deficiency may also exacerbate diarrhea, respiratory and childhood diseases. It is estimated that 124 million children worldwide are deficient in vitamin A and that improved nutrition could prevent 1 to 2 million deaths annually among children (Beyer et al 2002). To alleviate the deficiency in vitamin A, rice was genetically transformed to produce β carotene. An *Agrobacterium*-mediated genetic transformation was used to introduce the genes (from the Daffodil and a soil bacterium) into the rice endosperm that control the entire β carotene biosynthetic pathway resulting in “Golden Rice” (Beyer et al 2002).

Since 1992, papaya ringspot virus (PRSV) has destroyed over 35% of the papaya acreage in the Puna district of Hawaii where 95% of Hawaii's papayas are grown. Using the gene gun method, papaya plant cells were genetically transformed with a gene coding for the PRSV coat protein. Transgenic resistance was found to be a practical solution to the PRSV problem in Hawaii. This genetic modification gave the $45 million Hawaiian papaya industry a second chance (Gonsalves 1998).

Some Methods to Genetically Engineer Food Animals

A number of methods are used to genetically engineer or genetically transform food related animals. The Embryonic Stem Cell Method and the Pronucleus Method will be discussed. Since mice were the first animals to be genetically engineered they are used as a model. Stem cells are undifferentiated cells that have the potential to differentiate into any type of cell either somatic or germ cells and therefore to give rise to a complete organism. A pronucleus is the nucleus of the egg or the sperm after fertilization but before the two sets of chromosomes have united to form the nucleus of the original cell of the embryo. Either method leads to a transgenic animal.

The Embryonic Stem (ES) Cell Method involves exposure of ES cells, in an vitro culture, to a gene construct to allow for genetic transformation. Cells expressing the desired gene are selected with the help of the reporter gene in the gene construct. The selected ES cells are injected into an embryo at the blastocyst stage of development. The blastocysts are implanted into the uterus of a pseudopregnant (a female who mated with a vasectomized male) mouse. The DNA of the newly born pups is examined for the desired gene. Further selection and mating lead to the transgenic strain (Gossler et al 1986).

The Pronucleus Method involves the direct microinjection of a gene construct into the pronucleus of a fertilized egg. The genetically altered fertilized egg is implanted into the uterus of a pseudopregnant mouse. The DNA of newly born pups is examined for the desired gene (Gordon and Ruddle 1981).

Transgenic food animals such as lambs, goats, cows, fish, pigs and chickens have been developed. Transgenic lambs, goats, and chicken have been obtained using the pronucleus method to express pharmaceutical human proteins in either milk or eggs

accordingly. Transgenic fish (Fletcher et al 2000) and pigs (Young 2002) were made to either increase or modify muscle-food production. A spider gene and a gene for a recombinant pharmaceutical protein were introduced separately into all the cells of goats including the mammary gland (Karatzas et al 1999; Wang et al 2002).

Transgenic chickens were obtained by direct injection of gene constructs before the first embryonic cell division. The first commercial application of genetic modification technologies in poultry will be the production of pharmaceutical proteins in the egg whites. A longer-term aim is increasing avian disease resistance (Love et al 1994). Transgenic lambs, with a human gene, expressed the coded protein in large quantities in their milk (Schnieke et al 1997)**.**

A number of transgenic food fish species such as carp, tilapia, salmon and channel catfish have been developed (Hew et al 1995; Fletcher and Davies 1991). Gene constructs using the ocean pout antifreeze proteins (AFP) promoter linked to the Chinook salmon growth hormone were injected into fertilized eggs of either Atlantic salmon or tilapia fish. In the case of Atlantic salmon, approximately 40% of the founder transgenic fish exhibited growth rates that were, on average, 3 to 6 times that of non-transgenic salmon over a 30-month period. The growth of transgenic salmon was most rapid during the first year reaching market size (about 3 to 4 Kilograms) a year earlier than do non-transgenic salmon grown commercially in Atlantic Canada (Fletcher et al 2000). A different approach to produce growth-enhanced tilapia was achieved by rearranging the genome of the tilapia fish so it is transgenic solely with respect to DNA sequences of tilapia origin. In other words, no non-tilapia genetic material was introduced (Rahman 1998; Maclean et al 1992). Most world fisheries are over exploited and many are in

danger of commercial extinction. As the world population continues to grow exponentially, aquaculture in combination with transgenesis may become a major means of meeting demands for fish in the future (Fletcher et al 1999). Biotechnology may provide a significant contribution in alleviating the problem. Regarding the hazards associated with release or escape of transgenic fish, containment by sterility is probably the most promising. This can be achieved either by triploidy or by transgenic methods (Maclean and Laight 2000).

Cows genetically modified to produce high-protein milk for the cheese industry have been obtained in New Zealand. The cows possess additional copies of genes for two milk proteins, beta and kappa casein. As a result, their milk contains between up to 20 per cent more beta-casein and twice the amount of kappa-casein as milk from ordinary cows. This should allow cheese-makers to produce more cheese from the same volume of milk and faster due to rapid clotting times associated with the higher protein levels in the milk (Brophy et al 2003).

Aggressive behavior of pigs is being genetically addressed. A swine lean-growth model has been developed to examine genetic-nutrition interactions and to optimize lean production efficiency. The more pigs in a pen, the slower their growth rate due to stress and aggression (competing and fighting for food). The goal is to find genes in pigs that also influence behavior. This eventually may lead to less aggressive animals and to a growth increase of 20 to 25 percent. Increasing pork production by just 20 percent in the United States would mean an additional $2 billion annually for pork producers (Purdue University News 2001). Transgenic pigs with spinach genes have been produced (Young 2002). The genes control the conversion of saturated fat into unsaturated fat. It is reported

that the transgenic pigs contain 20 per cent less saturated fat than normal pigs and thus could be healthier to eat (Young 2002). Pecking and other aggressive behavior is economically taxing the poultry industry. Two kinds of birds were developed using traditional breeding practices: kinder-gentler and “mean” birds. The hope is to use these birds to study genes that may lead to harmful or aggressive behavior and in turn use this new knowledge to alleviate the problem (Muir and Craig 1998).

Regulation and Safety of GM Foods in the US

The Agencies primarily responsible for regulating biotechnology in the United States are the US Department of Agriculture (USDA regulates plant pests, plants and veterinary biologics), Environmental Protection Agency (EPA regulates microbial/plant pesticides, new uses of existing pesticides and novel microorganisms), and the Food and Drug Administration (FDA regulates food, feed, food additives, veterinary drugs, human drugs and medical devices). Products are regulated according to their intended use, with some products being regulated under more than one agency. For example, the USDA, EPA and FDA conduct the regulatory review of viral resistance and herbicide tolerance in food crops in terms of safety to grow, safety to the environment, new use of companion herbicide, and safety to eat.

The USDA Animal and Plant Health Inspection Service (APHIS) is responsible for permits or for providing notifications, prior to "introducing" a regulated article in the United States. Regulated articles are considered to be organisms and products altered or produced through genetic engineering. Once a determination of nonregulated status has been made, the product (and its offspring) no longer requires APHIS review for movement or release in the US (Federal Register 1997).

The BioPesticides and Pollution Prevention Division of the Office of Pesticide Programs (OPP) uses the authority of the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) to regulate the distribution, sale, use and testing of plants and microbes producing pesticidal substances (US Code Collection Title 7). Under the Federal Food, Drug and Cosmetic Act (FFDCA) EPA sets tolerance limits for substances used as pesticides on and in food and feed, or establishes an exemption from the requirement of a tolerance.

FDA regulates foods and feed derived from new plant varieties under the authority of the Federal Food, Drug, and Cosmetic Act. The FDA 1992 policy (Federal Register 1992) requires that genetically engineered foods meet the same rigorous safety standards as is required of all other foods. In practice, the regulatory paradigm used by the FDA is "substantial equivalence". This means that the allergen, nutrient and toxin content of a new GE food must fall within the normal range of the equivalent, conventional food. If so, the FDA does not regulate the GE food any differently than others. If however, the FDA determines that a GE food is not equivalent to a conventional product (if, for example, it is more likely to cause allergies), then the GE food must be either labeled or, if health concerns are serious enough, not allowed to be marketed at all. The FDA publishes a list of deregulated GM foods (FDA 2002). The FDA biotechnology policy treats substances intentionally added to food through genetic engineering as food additives and examines if they are significantly different in structure, function, or amount than substances currently found in food. According to the regulatory agencies, many of the food crops currently being developed using biotechnology do not contain substances that are significantly different from those already in the diet and thus do not require pre-

market approval. An example of a product that its development was discontinued is a soybean variety genetically modified with a gene from the Brazil nut to improve its nutritional quality (adding the amino acid methionine). The soybean was found allergenic to people who had allergic reactions to Brazil nuts. As a result, the development of this transgenic soybean was abandoned (Nordlee et al 1996).

The National Research Council (NRC) in its 2002 report stated that food products from transgenic animals might not be safe. The uncertainty surrounding new proteins and potential impact on consumers is serious enough to cause concern. In transgenic animals developed for human consumption, there is a low probability that a few new proteins may trigger allergic or hypersensitive reactions. In addition, bioactive protein (for example those conferring resistance to a disease) and other proteins may either retain their activity after being digested or cause unintended and unexpected toxic reactions (NRC 2002).

The "StarLink" incident involving the contamination of the human food chain with transgenic animal feed corn brought about safety concerns in terms of separating transgenic products for human consumption from those that are for animal consumption (EPA 2001). StarLink corn was genetically engineered to be insect resistant. Tests on the (Bt Cry9C) protein used in StarLink corn showed several similarities to allergens. Concern about the possibility of allergic responses led US regulators to approve StarLink corn for animal feed or for non-food purposes.

Most of the gene-based modifications of animals for food production fall under the FDA Center for Veterinary Medicine regulation as new animal drugs. For example, fish that was genetically altered to produce extra growth hormone is classified as a new animal drug, for which FDA oversight is mandatory. It is similar to the way the agency regulates

bovine somatotropin, the genetically engineered bovine growth hormone that makes cows produce more milk. The logic is that genetic modification provides another means to add growth hormone to an animal (Lewis 2001). Transgenic fish production has the goal of producing food for human consumption; thus the design of gene constructs must take into consideration the potential risks to consumer health, as well as marketing strategies and product acceptance in the market. For example, the FDA evaluation of an application for permission to sell transgenic Atlantic salmon in the US seeks answers to four fundamental questions (NRC 2002): Is the animal safe to eat? Does the genetic change do what it's supposed to do? Is the modification safe for the fish themselves? Does the animal endanger the environment?

Labeling and Naming Genetically Modified Foods in the US

In the US, a "guided" voluntary system exists (FDA 2001). Two attempts by states to mandatory label GM foods were not successful. The Colorado Citizens' Initiative in 2000 did not make it to the ballot and in 2002 Oregon Proposition 27 failed.

The European Union (EU) mandates labeling foods as GM if they contain 0.9 % GM ingredients (EC Council 2003).

The FDA in its 1992 policy advised that labeling requirements that apply to foods in general also apply to GM foods. According to FDA (1992) the following are general guidelines regarding naming, use, and nutritional and allergenic properties:

If a GM food is significantly different from its conventional counterpart such that the usual name no longer adequately describes the new food, the name must be changed to describe the difference. For example, if soybean oil contains more oleic acid than the conventional counterpart, the term "soybean oil" no longer adequately describes the

nature of the product. A phrase like “high oleic acid” would be required to appear as part of the name as follows: “This product contains high oleic acid soybean oil from soybeans developed using biotechnology to decrease the amount of saturated fat”.

If an issue exists for a GM food or a constituent of that food regarding how the food is used or consequences of its use, a statement must be made on the label to describe the issue.

If a GM food has a significantly different nutritional property, its label must reflect the difference.

If a new GM food includes an allergen that consumers would not expect to be present based on the name of the food, the presence of that allergen must be disclosed on the label.

As far as label statements about GM foods are concerned, consumers favor statements that disclose and explain the goal of the technology. Consumers also expressed some preference for the term "biotechnology" over such terms as "genetic modification" and “genetic engineering”. For example, "This product contains cornmeal that was produced using biotechnology" is preferred.

Statements about non-GM foods or foods not containing GM ingredients must avoid misleading accounts. For example, the term "Genetically Modified Organisms (GMO) free" may be misleading because consumers may assume that "free" of GM material means “zero”. Practically, “zero” level cannot be measured. By the same token, a label statement that expresses or implies that a food is superior (e.g., safer or of higher quality) because it is not genetically modified would be misleading. Thus, the FDA suggests for both cases using something like "This oil is made from soybeans that were not

genetically engineered".

If no GM green beans were being marketed, it would be misleading to state on the label of green beans, "not produced through biotechnology".

A manufacturer who claims that a food or its ingredients, including foods such as raw agricultural commodities, are not genetically modified should be able to substantiate through testing that the claim is truthful and not misleading.

In the US, the Produce Electronic Identification Board assigns Price Look Up (PLU) codes among others to fruits and vegetables. Retail tellers, to look up the price of unpackaged fruits and vegetables, use the PLU codes. Most standardized codes are four digits, but if the product is GM an 8 precedes the four digits code. For example, the PLU code for a conventional banana is 4011 and that of a GM banana would be 84011 (Calvin et al 2001)**.** The PLU system may become an indirect method of labeling GM fruits and vegetables.

If the recent estimates that 60 to 100% of foods in the US contain a small quantity of GM ingredients (GEO-PIE Project 2001) hold true the question of labeling foods containing GM ingredients becomes a moot point.

The Need to Inform the Public

The public may have a certain amount of uncertainty as far as biotechnology and the genetic modification of foods. A possible scenario is the making of cold resistant transgenic strawberries using ”Antifreeze” protein coding gene from the Arctic Flounder. It may be perceived, by some, that the product may change appearance into something that looks like a strawberry fish - a “Fishberry”. This may be an extreme example but it relays the need for developing extensive educational opportunities to both inform the

public and develop a general understanding of transgenic foods and how are they made. This may lead to building confidence measures toward GM foods. Such an effort may be coordinated among government, industry and academia.

Summary

This article concentrated on the US in terms of the acreage and availability of GM foods, the basic science related to the making of genetically engineered food related plants, animals and microorganisms. The issues of safety, labeling, naming and informing the public in the US and elsewhere about genetically modified foods were also discussed.

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