Genetically modified food

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Genetically modified foods or **GM foods**, also known as **genetically engineered foods**, are foods produced from organisms that have had changes introduced into their DNA using the methods of genetic engineering. Genetic engineering techniques allow for the introduction of new traits as well as greater control over traits than previous methods such as selective breeding and mutation breeding.[1]

Commercial sale of genetically modified foods began in 1994, when Calgene first marketed its unsuccessful Flavr Savr delayed-ripening tomato.[2][3] Most food modifications have primarily focused on cash crops in high demand by farmers such as soybean, corn, canola, and cotton. Genetically modified crops have been engineered for resistance to pathogens and herbicides and for better nutrient profiles. GM livestock have been developed, although as of November 2013 none were on the market.[4]

There is a scientific consensus[5][6][7][8] that currently available food derived from GM crops poses no greater risk to human health than conventional food,[9][10][11][12][13] but that each GM food needs to be tested on a case-by-case basis before introduction.[14][15][16] Nonetheless, members of the public are much less likely than scientists to perceive GM foods as safe.[17][18][19][20] The legal and regulatory status of GM foods varies by country, with some nations banning or restricting them, and others permitting them with widely differing degrees of regulation.[21][22][23][24]

However, there are ongoing public concerns related to food safety, regulation, labelling, environmental impact, research methods, and the fact that some GM seeds are subject to intellectual property rights owned by corporations.[25]

Contents

Definition

Genetically modified foods, GM foods or genetically engineered foods, are foods produced from organisms that have had changes introduced into their DNA using the methods of genetic engineering as opposed to traditional cross breeding.[26][27] In the US, the Department of Agriculture (USDA) and the Food and Drug Administration (FDA) favor the use of "genetic engineering" over "genetic modification" as the more precise term; the USDA defines genetic modification to include "genetic engineering or other more traditional methods."[28][29]

According to the World Health Organization, "Genetically modified organisms (GMOs) can be defined as organisms (i.e. plants, animals or microorganisms) in which the genetic material (DNA) has been altered in a way that does not occur naturally by mating and/or natural recombination. The technology is often called 'modern biotechnology' or 'gene technology', sometimes also 'recombinant DNA technology' or 'genetic engineering'. ... Foods produced from or using GM organisms are often referred to as GM foods."[26]

History

Human-directed genetic manipulation of food began with the domestication of plants and animals through artificial selection at about 10,500 to 10,100 BC.[30]:1 The process of selective breeding, in which organisms with desired traits (and thus with the desired genes) are used to breed the next generation and organisms lacking the trait are not bred, is a precursor to the modern concept of genetic modification (GM).[30]:1[31]:1 With the discovery of DNA in the early 1900s and various advancements in genetic techniques through the 1970s[32] it became possible to directly alter the DNA and genes within food.

The first genetically modified plant was produced in 1983, using an antibiotic-resistant tobacco plant.[33] Genetically modified microbial enzymes were the first application of genetically modified organisms in food production and were approved in 1988 by the US Food and Drug Administration.[34] In the early 1990s, recombinant chymosin was approved for use in several countries.[34][35] Cheese had typically been made using the enzyme complex rennet that had been extracted from cows' stomach lining. Scientists modified bacteria to produce chymosin, which was also able to clot milk, resulting in cheese curds.[36]

The first genetically modified food approved for release was the Flavr Savr tomato in 1994.[2] Developed by Calgene, it was engineered to have a longer shelf life by inserting an antisense gene that delayed ripening.[37] China was the first country to commercialize a transgenic crop in 1993 with the introduction of virus-resistant tobacco.[38] In 1995, *Bacillus thuringiensis* (Bt) Potato was approved for cultivation, making it the first pesticide producing crop to be approved in the USA.[39] Other genetically modified crops receiving marketing approval in 1995 were: canola with modified oil composition, Bt maize, cotton resistant to the herbicide bromoxynil, Bt cotton, glyphosate-tolerant soybeans, virus-resistant squash, and another delayed ripening tomato.[2]

With the creation of golden rice in 2000, scientists had genetically modified food to increase its nutrient value for the first time.[40]

By 2010, 29 countries had planted commercialized biotech crops and a further 31 countries had granted regulatory approval for transgenic crops to be imported.[41] The US was the leading country in the production of GM foods in 2011, with twenty-five GM crops having received regulatory approval.[42] In 2015, 92% of corn, 94% of soybeans, and 94% of cotton produced in the US were genetically modified strains.[43]

The first genetically modified animal to be approved for food use was AquAdvantage salmon in 2015.[44] The salmon were transformed with a growth hormone-regulating gene from a Pacific Chinook salmon and a promoter from an ocean pout enabling it to grow year-round instead of only during spring and summer.[45]

In April 2016, a white button mushroom (*Agaricus bisporus*) modified using the CRISPR technique received *de facto* approval in the United States, after the USDA said it would not have to go through the agency's regulatory process. The agency considers the mushroom exempt because the editing process did not involve the introduction of foreign DNA.[46]

The most widely planted GMOs are designed to tolerate herbicides. By 2006 some weed populations had evolved to tolerate some of the same herbicides. Palmer amaranth is a weed that competes with cotton. A native of the southwestern US, it traveled east and was first found resistant to glyphosate in 2006, less than 10 years after GM cotton was introduced.[47][48][49]

Process

Genetically engineered organisms are generated and tested in the laboratory for desired qualities. The most common modification is to add one or more genes to an organism's genome. Less commonly, genes are removed or their expression is increased or silenced or the number of copies of a gene is increased or decreased.

Once satisfactory strains are produced, the producer applies for regulatory approval to field-test them, called a "field release." Field-testing involves cultivating the plants on farm fields or growing animals in a controlled environment. If these field tests are successful, the producer applies for regulatory approval to grow and market the crop. Once approved, specimens (seeds, cuttings, breeding pairs, etc.) are cultivated and sold to farmers. The farmers cultivate and market the new strain. In some cases, the approval covers marketing but not cultivation.

According to the USDA, the number of field releases for genetically engineered organisms has grown from four in 1985 to an average of about 800 per year. Cumulatively, more than 17,000 releases had been approved through September 2013.[50]

Crops

Fruits and vegetables

Papaya was genetically modified to resist the ringspot virus. 'SunUp' is a transgenic red-fleshed Sunset papaya cultivar that is homozygous for the coat protein gene PRSV; 'Rainbow' is a yellow-fleshed F1 hybrid developed by crossing 'SunUp' and nontransgenic yellow-fleshed 'Kapoho'.[51] The New York Times stated, "in the early 1990s, Hawaii's papaya industry was facing disaster because of the deadly papaya ringspot virus. Its single-handed savior was a breed engineered to be resistant to the virus. Without it, the state's papaya industry would have collapsed. Today, 80% of Hawaiian papaya is genetically engineered, and there is still no conventional or organic method to control ringspot virus."[52] The GM cultivar was approved in 1998.[53] In China, a transgenic PRSV-resistant papaya was developed by South China Agricultural University

3 views of the Sunset papaya cultivar, which was genetically modified to create the SunUp cultivar, resistant to PRSV.[51]

and was first approved for commercial planting in 2006; as of 2012 95% of the papaya grown in Guangdong province and 40% of the papaya grown in Hainan province was genetically modified.[54]

The New Leaf potato, a GM food developed using naturally occurring bacteria found in the soil known as *Bacillus thuringiensis* (Bt), was made to provide in-plant protection from the yield-robbing Colorado potato beetle.[55] The New Leaf potato, brought to market by Monsanto in the late 1990s, was developed for the fast food market. It was withdrawn in 2001 after retailers rejected it and food processors ran into export problems.[56]

As of 2005, about 13% of the Zucchini (a form of squash) grown in the US was genetically modified to resist three viruses; that strain is also grown in Canada.[57][58]

In 2011, BASF requested the European Food Safety Authority's approval for cultivation and marketing of its Fortuna potato as feed and food. The potato was made resistant to late blight by adding resistant genes blb1 and blb2 that originate from the Mexican wild potato Solanum bulbocastanum.[59][60] In February 2013, BASF withdrew its application.[61]

Plums genetically engineered for resistance to plum pox, a disease carried by aphids.

In 2013, the USDA approved the import of a GM pineapple that is pink in color and that "overexpresses" a gene derived from tangerines and suppress other genes, increasing production of lycopene. The plant's flowering cycle was changed to provide for more uniform growth and quality. The fruit "does not have the ability to propagate and persist in the environment once they have been harvested," according to USDA APHIS. According to Del Monte's submission, the pineapples are commercially grown in a "monoculture" that prevents seed production, as the plant's flowers aren't exposed to compatible pollen sources. Importation into Hawaii is banned for "plant sanitation" reasons.[62]

In 2014, the USDA approved a genetically modified potato developed by J.R. Simplot Company that contained ten genetic modifications that prevent bruising and produce less acrylamide when fried. The modifications eliminate specific proteins from the potatoes, via RNA interference, rather than introducing novel proteins.[63][64]

In February 2015 Arctic Apples were approved by the USDA,[65] becoming the first genetically modified apple approved for sale in the US.[66] Gene silencing is used to reduce the expression of polyphenol oxidase (PPO), thus preventing the fruit from browning.[67]

Corn

Corn used for food and ethanol has been genetically modified to tolerate various herbicides and to express a protein from Bacillus thuringiensis (Bt) that kills certain insects.[68] About 90% of the corn grown in the U.S. was genetically modified in 2010.[69] In the US in 2015, 81% of corn acreage contained the Bt trait and 89% of corn acreage contained the glyphosate-tolerant trait.[43] Corn can be processed into grits, meal and flour as an ingredient in pancakes, muffins, doughnuts, breadings and batters, as well as baby foods, meat products, cereals and some fermented products. Corn-based masa flour and masa dough are used in the production of taco shells, corn chips and tortillas.[70]

Soy

Genetically modified soybean has been modified to tolerate herbicides and produce healthier oils.[71] In 2015, 94% of soybean acreage in the U.S. was genetically modified to be glyphosate-tolerant.[43]

Derivative products

Corn starch and starch sugars, including syrups

Starch or amylum is a polysaccharide produced by all green plants as an energy store. Pure starch is a white, tasteless and odourless powder. It consists of two types of molecules: the linear and helical amylose and the branched amylopectin. Depending on the plant, starch generally contains 20 to 25% amylose and 75 to 80% amylopectin by weight.[72]

Starch can be further modified to create modified starch for specific purposes,[73] including creation of many of the sugars in processed foods. They include:

- Maltodextrin, a lightly hydrolyzed starch product used as a bland-tasting filler and thickener.
- Various glucose syrups, also called corn syrups in the US, viscous solutions used as sweeteners and thickeners in many kinds of processed foods.
- Dextrose, commercial glucose, prepared by the complete hydrolysis of starch.
- High fructose syrup, made by treating dextrose solutions with the enzyme glucose isomerase, until a substantial fraction of the glucose has been converted to fructose.
- Sugar alcohols, such as maltitol, erythritol, sorbitol, mannitol and hydrogenated starch hydrolysate, are sweeteners made by reducing sugars.

Lecithin

Lecithin is a naturally occurring lipid. It can be found in egg yolks and oil-producing plants. it is an emulsifier and thus is used in many foods. Corn, soy and safflower oil are sources of lecithin, though the majority of lecithin commercially available is derived from soy.[74][75][76] Sufficiently processed lecithin is often undetectable with standard testing practices.[72] According to the FDA, no evidence shows or suggests hazard to the public when lecithin is used at common levels. Lecithin added to foods amounts to only 2 to 10 percent of the 1 to 5 g of phosphoglycerides consumed daily on average.[74][75] Nonetheless, consumer concerns about GM food extend to such products.[77] This concern led to policy and regulatory changes in Europe in 2000, when Regulation (EC) 50/2000 was passed[78] which required labelling of food containing additives derived from GMOs, including lecithin. Because of the difficulty of detecting the origin of derivatives like lecithin with current testing practices, European regulations require those who wish to sell lecithin in Europe to employ a comprehensive system of Identity preservation (IP).[79][80]

Sugar

The US imports 10% of its sugar, while the remaining 90% is extracted from sugar beet and sugarcane. After deregulation in 2005, glyphosate-resistant sugar beet was extensively adopted in the United States. 95% of beet acres in the US were planted with glyphosate-resistant seed in 2011.[81] GM sugar beets are approved for cultivation in the US, Canada and Japan; the vast majority are grown in the US. GM beets are approved for import and consumption in Australia, Canada, Colombia, EU, Japan, Korea, Mexico, New Zealand, Philippines, Russian Federation and Singapore.[82] Pulp from the refining process is used as animal feed. The sugar produced from GM sugarbeets contains no DNA or protein—it is just sucrose that is chemically indistinguishable from sugar produced from non-GM sugarbeets.[72][83] Independent analyses conducted by internationally recognized laboratories found that sugar from Roundup Ready sugar beets is identical to the sugar from comparably grown conventional (non-Roundup Ready) sugar beets. And, like all sugar, sugar from Roundup Ready sugar beets contains no genetic material or detectable protein (including the protein that provides glyphosate tolerance).[84]

Vegetable oil

Most vegetable oil used in the US is produced from GM crops canola,[85] corn,[86][87] cotton[88] and soybeans.[89] Vegetable oil is sold directly to consumers as cooking oil, shortening and margarine[90] and is used in prepared foods. There is a vanishingly small amount of protein or DNA from the original crop in vegetable oil.[72][91] Vegetable oil is made of triglycerides extracted from plants or seeds and then refined and may be further processed via hydrogenation to turn liquid oils into solids. The refining process[92] removes all, or nearly all non-triglyceride ingredients.[93] Medium-chain triglycerides (MCTs) offer an alternative to conventional fats and oils. The length of a fatty acid influences its fat absorption during the digestive process. Fatty acids in the middle position on the glycerol molecules appear to be absorbed more easily and influence metabolism more than fatty acids on the end positions. Unlike ordinary fats, MCTs are metabolized like carbohydrates. They have exceptional oxidative stability, and prevent foods from turning rancid readily.[94]

Other uses

Animal feed

Livestock and poultry are raised on animal feed, much of which is composed of the leftovers from processing crops, including GM crops. For example, approximately 43% of a canola seed is oil. What remains after oil extraction is a meal that becomes an ingredient in animal feed and contains canola protein.[95] Likewise, the bulk of the soybean crop is grown for oil and meal. The high-protein defatted and toasted soy meal becomes livestock feed and dog food. 98% of the US soybean crop goes for livestock feed.[96][97] In 2011, 49% of the US maize harvest was used for livestock feed (including the percentage of waste from distillers grains).[98] "Despite methods that are becoming more and more sensitive, tests have not yet been able to establish a difference in the meat, milk, or eggs of animals depending on the type of feed they are fed. It is impossible to tell if an animal was fed GM soy just by looking at the resulting meat, dairy, or egg products. The only way to verify the presence of GMOs in animal feed is to analyze the origin of the feed itself."[99]

A 2012 literature review of studies evaluating the effect of GM feed on the health of animals did not find evidence that animals were adversely affected, although small biological differences were occasionally found. The studies included in the review ranged from 90 days to two years, with several of the longer studies considering reproductive and intergenerational effects.[100]

Proteins

Rennet is a mixture of enzymes used to coagulate milk into cheese. Originally it was available only from the fourth stomach of calves, and was scarce and expensive, or was available from microbial sources, which often produced unpleasant tastes. Genetic engineering made it possible to extract rennet-producing genes from animal stomachs and insert them into bacteria, fungi or yeasts to make them produce chymosin, the key enzyme.[101][102] The modified microorganism is killed after fermentation. Chymosin is isolated from the fermentation broth, so that the Fermentation-Produced Chymosin (FPC) used by cheese producers has an amino acid sequence that is identical to bovine rennet.[103] The majority of the applied chymosin is retained in the whey. Trace quantities of chymosin may remain in cheese.[103]

FPC was the first artificially produced enzyme to be approved by the US Food and Drug Administration.[34][35] FPC products have been on the market since 1990 and as of 2015 had yet to be surpassed in commercial markets.[104] In 1999, about 60% of US hard cheese was made with FPC.[105] Its global market share approached 80%.[106] By 2008, approximately 80% to 90% of commercially made cheeses in the US and Britain were made using FPC.[103]

In some countries, recombinant (GM) bovine somatotropin (also called rBST, or bovine growth hormone or BGH) is approved for administration to increase milk production. rBST may be present in milk from rBST treated cows, but it is destroyed in the digestive system and even if directly injected into the human bloodstream, has no observable effect on

humans.[107][108][109] The FDA, World Health Organization, American Medical Association, American Dietetic Association and the National Institutes of Health have independently stated that dairy products and meat from rBST-treated cows are safe for human consumption.[110] However, on 30 September 2010, the United States Court of Appeals, Sixth Circuit, analyzing submitted evidence, found a "compositional difference" between milk from rBGH-treated cows and milk from untreated cows.[111][112] The court stated that milk from rBGH-treated cows has: increased levels of the hormone Insulin-like growth factor 1 (IGF-1); higher fat content and lower protein content when produced at certain points in the cow's lactation cycle; and more somatic cell counts, which may "make the milk turn sour more quickly."[112]

Livestock

Genetically modified livestock are organisms from the group of cattle, sheep, pigs, goats, birds, horses and fish kept for human consumption, whose genetic material (DNA) has been altered using genetic engineering techniques. In some cases, the aim is to introduce a new trait to the animals which does not occur naturally in the species, i.e. transgenesis.

A 2003 review published on behalf of Food Standards Australia New Zealand examined transgenic experimentation on terrestrial livestock species as well as aquatic species such as fish and shellfish. The review examined the molecular techniques used for experimentation as well as techniques for tracing the transgenes in animals and products as well as issues regarding transgene stability.[113]

Some mammals typically used for food production have been modified to produce non-food products, a practice sometimes called Pharming.

Salmon

A GM salmon, awaiting regulatory approval[114][115][116] since 1997,[117] was approved for human consumption by the American FDA in November 2015, to be raised in specific land-based hatcheries in Canada and Panama.[118]

Recombinant food-grade organisms for healthcare

The use of genetically modified food-grade organisms as recombinant vaccine expression hosts and delivery vehicles can open new avenues for vaccinology. Considering that oral immunization is a beneficial approach in terms of costs, patient comfort, and protection of mucosal tissues, the use of food-grade organisms can lead to highly advantageous vaccines in terms of costs, easy administration, and safety. The organisms currently used for this purpose are bacteria (Lactobacillus and Bacillus), yeasts, algae, plants, and insect species. Several such organisms are under clinical evaluation, and the current adoption of this technology by the industry indicates a potential to benefit global healthcare systems.[119]

Health and safety

There is a scientific consensus[120][121][122][123] that currently available food derived from GM crops poses no greater risk to human health than conventional food,[124][125][126][127][128] but that each GM food needs to be tested on a case-by-case basis before introduction.[129][130][131] Nonetheless, members of the public are much less likely than scientists to perceive GM foods as safe.[132][133][134][135]

Opponents claim that long-term health risks have not been adequately assessed and propose various combinations of additional testing, labeling[136] or removal from the market.[137][138][139][140] The advocacy group European Network of Scientists for Social and Environmental Responsibility (ENSSER), disputes the claim that "science" supports the safety

of current GM foods, proposing that each GM food must be judged on case-by-case basis.[141] The Canadian Association of Physicians for the Environment called for removing GM foods from the market pending long term health studies.[137] Multiple disputed studies have claimed health effects relating to GM foods or to the pesticides used with them.[142]

Testing

The legal and regulatory status of GM foods varies by country, with some nations banning or restricting them, and others permitting them with widely differing degrees of regulation.[143][144][145][146] Countries such as the United States, Canada, Lebanon and Egypt use *substantial equivalence* to determine if further testing is required, while many countries such as those in the European Union, Brazil and China only authorize GMO cultivation on a case-by-case basis. In the U.S. the FDA determined that GMO's are "Generally Recognized as Safe" (GRAS) and therefore do not require additional testing if the GMO product is substantially equivalent to the non-modified product.[147] If new substances are found, further testing may be required to satisfy concerns over potential toxicity, allergenicity, possible gene transfer to humans or genetic outcrossing to other organisms.[26]

Regulation

Government regulation of GMO development and release varies widely between countries. Marked differences separate GMO regulation in the U.S. and GMO regulation in the European Union.[148] Regulation also varies depending on the intended product's use. For example, a crop not intended for food use is generally not reviewed by authorities responsible for food safety.[149]

Green: Mandatory labeling required; Red:Ban on import and cultivation of genetically engineered food.

United States Regulations

In the U.S., three government organizations regulate GMOs. The FDA checks the chemical composition of organisms for potential allergens. The United States Department of Agriculture (USDA) supervises field testing and monitors the distribution of GM seeds. The United States Environmental Protection Agency (EPA) is responsible for monitoring pesticide usage, including plants modified to contain proteins toxic to insects. Like USDA, EPA also oversees field testing and the distribution of crops that have had contact with pesticides to ensure environmental safety.[150] In 2015 the Obama administration announced that it would update the way the government regulated GM crops.[151]

In 1992 FDA published "Statement of Policy: Foods derived from New Plant Varieties." This statement is a clarification of FDA's interpretation of the Food, Drug, and Cosmetic Act with respect to foods produced from new plant varieties developed using recombinant deoxyribonucleic acid (rDNA) technology. FDA encouraged developers to consult with the FDA regarding any bioengineered foods in development. The FDA says developers routinely do reach out for consultations. In 1996 FDA updated consultation procedures.[152][153]

Labeling

As of 2015, 64 countries require labeling of GMO products in the marketplace.[154]

US and Canadian national policy is to require a label only given significant composition differences or documented health impacts, although some individual US states (Vermont, Connecticut and Maine) enacted laws requiring them.[155][156][157][158] In July 2016, Public Law 114-214 was enacted to regulate labeling of GMO food on a national basis.

In some jurisdictions, the labeling requirement depends on the relative quantity of GMO in the product. A study that investigated voluntary labeling in South Africa found that 31% of products labeled as GMO-free had a GM content above 1.0%.[159]

In Europe all food (including processed food) or feed that contains greater than 0.9% GMOs must be labelled.[160]

Detection

Testing on GMOs in food and feed is routinely done using molecular techniques such as PCR and bioinformatics.[161]

In a January 2010 paper, the extraction and detection of DNA along a complete industrial soybean oil processing chain was described to monitor the presence of Roundup Ready (RR) soybean: "The amplification of soybean lectin gene by end-point polymerase chain reaction (PCR) was successfully achieved in all the steps of extraction and refining processes, until the fully refined soybean oil. The amplification of RR soybean by PCR assays using event-specific primers was also achieved for all the extraction and refining steps, except for the intermediate steps of refining (neutralisation, washing and bleaching) possibly due to sample instability. The real-time PCR assays using specific probes confirmed all the results and proved that it is possible to detect and quantify genetically modified organisms in the fully refined soybean oil. To our knowledge, this has never been reported before and represents an important accomplishment regarding the traceability of genetically modified organisms in refined oils."[162]

According to Thomas Redick, detection and prevention of cross-pollination is possible through the suggestions offered by the Farm Service Agency (FSA) and Natural Resources Conservation Service (NRCS). Suggestions include educating farmers on the importance of coexistence, providing farmers with tools and incentives to promote coexistence, conduct research to understand and monitor gene flow, provide assurance of quality and diversity in crops, provide compensation for actual economic losses for farmers.[163]

Controversies

The genetically modified foods controversy consists of a set of disputes over the use of food made from genetically modified crops. The disputes involve consumers, farmers, biotechnology companies, governmental regulators, non-governmental organizations, environmental and political activists and scientists. The major disagreements include whether GM foods can be safely consumed, harm the environment and/or are adequately tested and regulated.[138][164] The objectivity of scientific research and publications has been challenged.[137] Farming-related disputes include the use and impact of pesticides, seed production and use, side effects on non-GMO crops/farms,[165] and potential control of the GM food supply by seed companies.[137]

The conflicts have continued since GM foods were invented. They have occupied the media, the courts, local, regional and national governments and international organizations.

See also

- California Proposition 37 (2012)
- Chemophobia
- Genetic engineering
- Genetically modified crops
- Genetically modified food controversies
- Genetically modified organisms
- List of genetically modified crops
- Pharming (genetics) – use of genetically modified mammals to produce drugs
- Regulation of the release of genetic modified organisms
- Starlink corn recall

References

(July 2003). Chairman Professor Sir David King, Chief Scientific Advisor to the UK Government, P 9
2. James, Clive (1996). "Global Review of the Field Testing and Commercialization of Transgenic Plants: 1986 to 1995" (PDF). The International Service for the Acquisition of Agri-biotech Applications. Retrieved 17 July 2010.
3. Weasel, Lisa H. 2009. *Food Fray.* Amacom Publishing
4. "Consumer Q&A". Fda.gov. 2009-03-06. Retrieved 2012-12-29.
5. Nicolia, Alessandro; Manzo, Alberto; Veronesi, Fabio; Rosellini, Daniele (2013). "An overview of the last 10 years of genetically engineered crop safety research" (PDF). *Critical Reviews in Biotechnology*. **34**: 1–12. doi:10.3109/07388551.2013.823595. PMID 24041244. "We have reviewed the scientific literature on GE crop safety for the last 10 years that catches the scientific consensus matured since GE plants became widely cultivated worldwide, and we can conclude that the scientific research conducted so far has not detected any significant hazard directly connected with the use of GM crops."

   "The literature about Biodiversity and the GE food/feed consumption has sometimes resulted in animated debate regarding the suitability of the experimental designs, the choice of the statistical methods or the public accessibility of data. Such debate, even if positive and part of the natural process of review by the scientific community, has frequently been distorted by the media and often used politically and inappropriately in anti-GE crops campaigns."

6. "State of Food and Agriculture 2003–2004. Agricultural Biotechnology: Meeting the Needs of the Poor. Health and environmental impacts of transgenic crops". Food and Agriculture Organization of the United Nations. Retrieved February 8, 2016. "Currently available transgenic crops and foods derived from them have been judged safe to eat and the methods used to test their safety have been deemed appropriate. These conclusions represent the consensus of the scientific evidence surveyed by the ICSU (2003) and they are consistent with the views of the World Health Organization (WHO, 2002). These foods have been assessed for increased risks to human health by several national regulatory authorities (inter alia, Argentina, Brazil, Canada, China, the United Kingdom and the United States) using their national food safety procedures (ICSU). To date no verifiable untoward toxic or nutritionally deleterious effects resulting from the consumption of foods derived from genetically modified crops have been discovered anywhere in the world (GM Science Review Panel). Many millions of people have consumed foods derived from GM plants - mainly maize, soybean and oilseed rape - without any observed adverse effects (ICSU)."
7. Ronald, Pamela (May 5, 2011). "Plant Genetics, Sustainable Agriculture and Global Food Security". *Genetics*. **188**: 11–20. doi:10.1534/genetics.111.128553. PMC 3120150. PMID 21546547. "There is broad scientific consensus that genetically engineered crops currently on the market are safe to eat. After 14 years of cultivation and a cumulative total of 2 billion acres planted, no adverse health or environmental effects have resulted from commercialization of genetically engineered crops (Board on Agriculture and Natural Resources, Committee on Environmental Impacts Associated with Commercialization of Transgenic Plants, National Research Council and Division on Earth and Life Studies 2002). Both the U.S. National Research Council and the Joint Research Centre (the European Union's scientific and technical research laboratory and an integral part of the European Commission) have concluded that there is a comprehensive body of knowledge that adequately addresses the food safety issue of genetically engineered crops (Committee on Identifying and Assessing Unintended Effects of Genetically Engineered Foods on Human Health and National Research Council 2004; European Commission Joint Research Centre 2008). These and other recent reports conclude that the processes of genetic engineering and conventional breeding are no different in terms of unintended consequences to human health and the environment (European Commission Directorate-General for Research and Innovation 2010)."
8. But see also:

   Domingo, José L.; Bordonaba, Jordi Giné (2011). "A literature review on the safety assessment of genetically modified plants" (PDF). *Environment International*. **37**: 734–742. doi:10.1016/j.envint.2011.01.003. PMID 21296423. "In spite of this, the number of studies specifically focused on safety assessment of GM plants is still limited. However, it is important to remark that for the first time, a certain equilibrium in the number of research groups suggesting, on the basis of their studies, that a number of varieties of GM products (mainly maize and soybeans) are as safe and nutritious as the respective conventional non-GM plant, and those raising still serious concerns, was observed. Moreover, it is worth mentioning that most of the studies demonstrating that GM foods are as nutritional and safe as those obtained by conventional breeding, have been performed by biotechnology companies or associates, which are also responsible of commercializing these GM plants. Anyhow, this represents a notable advance in comparison with the lack of studies published in recent years in scientific journals by those companies."

   Krimsky, Sheldon (2015). "An Illusory Consensus behind GMO Health Assessment" (PDF). *Science, Technology, & Human Values*. **40**: 1–32. doi:10.1177/0162243915598381. "I began this article with the testimonials from respected scientists that there is literally no scientific controversy over the health effects of GMOs. My investigation into the scientific literature tells another story."

   And contrast:

Panchin, Alexander Y.; Tuzhikov, Alexander I. (January 14, 2016). "Published GMO studies find no evidence of harm when corrected for multiple comparisons". *Critical Reviews in Biotechnology*: 1–5. doi:10.3109/07388551.2015.1130684. ISSN 0738-8551. PMID 26767435. "Here, we show that a number of articles some of which have strongly and negatively influenced the public opinion on GM crops and even provoked political actions, such as GMO embargo, share common flaws in the statistical evaluation of the data. Having accounted for these flaws, we conclude that the data presented in these articles does not provide any substantial evidence of GMO harm."

"The presented articles suggesting possible harm of GMOs received high public attention. However, despite their claims, they actually weaken the evidence for the harm and lack of substantial equivalency of studied GMOs. We emphasize that with over 1783 published articles on GMOs over the last 10 years it is expected that some of them should have reported undesired differences between GMOs and conventional crops even if no such differences exist in reality."

and

Yang, Y.T.; Chen, B. (2016). "Governing GMOs in the USA: science, law and public health". *Journal of the Science of Food and Agriculture*. **96**: 1851–1855. doi:10.1002/jsfa.7523. PMID 26536836. "It is therefore not surprising that efforts to require labeling and to ban GMOs have been a growing political issue in the USA *(citing Domingo and Bordonaba, 2011)*."

"Overall, a broad scientific consensus holds that currently marketed GM food poses no greater risk than conventional food... Major national and international science and medical associations have stated that no adverse human health effects related to GMO food have been reported or substantiated in peer-reviewed literature to date."

"Despite various concerns, today, the American Association for the Advancement of Science, the World Health Organization, and many independent international science organizations agree that GMOs are just as safe as other foods. Compared with conventional breeding techniques, genetic engineering is far more precise and, in most cases, less likely to create an unexpected outcome."

9. "Statement by the AAAS Board of Directors On Labeling of Genetically Modified Foods" (PDF). American Association for the Advancement of Science. October 20, 2012. Retrieved February 8, 2016. "The EU, for example, has invested more than €300 million in research on the biosafety of GMOs. Its recent report states: "The main conclusion to be drawn from the efforts of more than 130 research projects, covering a period of more than 25 years of research and involving more than 500 independent research groups, is that biotechnology, and in particular GMOs, are not per se more risky than e.g. conventional plant breeding technologies." The World Health Organization, the American Medical Association, the U.S. National Academy of Sciences, the British Royal Society, and every other respected organization that has examined the evidence has come to the same conclusion: consuming foods containing ingredients derived from GM crops is no riskier than consuming the same foods containing ingredients from crop plants modified by conventional plant improvement techniques."

   Pinholster, Ginger (October 25, 2012). "AAAS Board of Directors: Legally Mandating GM Food Labels Could "Mislead and Falsely Alarm Consumers" ". American Association for the Advancement of Science. Retrieved February 8, 2016.

10. "A decade of EU-funded GMO research (2001–2010)" (PDF). Directorate-General for Research and Innovation. Biotechnologies, Agriculture, Food. European Commission, European Union. 2010. doi:10.2777/97784. ISBN 978-92-79-16344-9. Retrieved February 8, 2016.
11. "AMA Report on Genetically Modified Crops and Foods (online summary)". American Medical Association. January 2001. Retrieved March 19, 2016. "A report issued by the scientific council of the American Medical Association (AMA) says that no long-term health effects have been detected from the use of transgenic crops and genetically modified foods, and that these foods are substantially equivalent to their conventional counterparts. *(from online summary prepared by ISAAA)*" "Crops and foods produced using recombinant DNA techniques have been available for fewer than 10 years and no long-term effects have been detected to date. These foods are substantially equivalent to their conventional counterparts. *(from original report by AMA: [1] (http://www.ama-assn.org/ama/pub/about-ama/our-people/ama-councils/council-science-public-health/reports/reports-topic.page?))*"

    "REPORT 2 OF THE COUNCIL ON SCIENCE AND PUBLIC HEALTH (A-12): Labeling of Bioengineered Foods" (PDF). American Medical Association. 2012. Retrieved March 19, 2016. "Bioengineered foods have been consumed for close to 20 years, and during that time, no overt consequences on human health have been reported and/or substantiated in the peer-reviewed literature."

12. "Restrictions on Genetically Modified Organisms: United States. Public and Scholarly Opinion". Library of Congress. June 9, 2015. Retrieved February 8, 2016. "Several scientific organizations in the US have issued studies or statements regarding the safety of GMOs indicating that there is no evidence that GMOs present unique safety risks compared to conventionally bred products. These include the National Research Council, the American Association for the Advancement of Science, and the American Medical Association. Groups in the US opposed to GMOs include some environmental organizations, organic

farming organizations, and consumer organizations. A substantial number of legal academics have criticized the US's approach to regulating GMOs."

13. "Genetically Engineered Crops: Experiences and Prospects". The National Academies of Sciences, Engineering, and Medicine (US). 2016. p. 149. Retrieved May 19, 2016. "*Overall finding on purported adverse effects on human health of foods derived from GE crops:* On the basis of detailed examination of comparisons of currently commercialized GE with non-GE foods in compositional analysis, acute and chronic animal toxicity tests, long-term data on health of livestock fed GE foods, and human epidemiological data, the committee found no differences that implicate a higher risk to human health from GE foods than from their non-GE counterparts."
14. "Frequently asked questions on genetically modified foods". World Health Organization. Retrieved February 8, 2016. "Different GM organisms include different genes inserted in different ways. This means that individual GM foods and their safety should be assessed on a case-by-case basis and that it is not possible to make general statements on the safety of all GM foods."

    "GM foods currently available on the international market have passed safety assessments and are not likely to present risks for human health. In addition, no effects on human health have been shown as a result of the consumption of such foods by the general population in the countries where they have been approved. Continuous application of safety assessments based on the Codex Alimentarius principles and, where appropriate, adequate post market monitoring, should form the basis for ensuring the safety of GM foods."

15. Haslberger, Alexander G. (2003). "Codex guidelines for GM foods include the analysis of unintended effects". *Nature Biotechnolgy*. **21**: 739–741. doi:10.1038/nbt0703-739. PMID 12833088. "These principles dictate a case-by-case premarket assessment that includes an evaluation of both direct and unintended effects."
16. Some medical organizations, including the British Medical Association, advocate further caution based upon the precautionary principle:

    "Genetically modified foods and health: a second interim statement" (PDF). British Medical Association. March 2004. Retrieved March 21, 2016. "In our view, the potential for GM foods to cause harmful health effects is very small and many of the concerns expressed apply with equal vigour to conventionally derived foods. However, safety concerns cannot, as yet, be dismissed completely on the basis of information currently available."

    "When seeking to optimise the balance between benefits and risks, it is prudent to err on the side of caution and, above all, learn from accumulating knowledge and experience. Any new technology such as genetic modification must be examined for possible benefits and risks to human health and the environment. As with all novel foods, safety assessments in relation to GM foods must be made on a case-by-case basis."

    "Members of the GM jury project were briefed on various aspects of genetic modification by a diverse group of acknowledged experts in the relevant subjects. The GM jury reached the conclusion that the sale of GM foods currently available should be halted and the moratorium on commercial growth of GM crops should be continued. These conclusions were based on the precautionary principle and lack of evidence of any benefit. The Jury expressed concern over the impact of GM crops on farming, the environment, food safety and other potential health effects."

    "The Royal Society review (2002) concluded that the risks to human health associated with the use of specific viral DNA sequences in GM plants are negligible, and while calling for caution in the introduction of potential allergens into food crops, stressed the absence of evidence that commercially available GM foods cause clinical allergic manifestations. The BMA shares the view that that there is no robust evidence to prove that GM foods are unsafe but we endorse the call for further research and surveillance to provide convincing evidence of safety and benefit."

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    "The literature about Biodiversity and the GE food/feed consumption has sometimes resulted in animated debate regarding the suitability of the experimental designs, the choice of the statistical methods or the public accessibility of data. Such debate, even if positive and part of the natural process of review by the scientific community, has frequently been distorted by the media and often used politically and inappropriately in anti-GE crops campaigns."

121. "State of Food and Agriculture 2003–2004. Agricultural Biotechnology: Meeting the Needs of the Poor. Health and environmental impacts of transgenic crops". Food and Agriculture Organization of the United Nations. Retrieved February 8, 2016. "Currently available transgenic crops and foods derived from them have been judged safe to eat and the methods used to test their safety have been deemed appropriate. These conclusions represent the consensus of the scientific evidence surveyed by the ICSU (2003) and they are consistent with the views of the World Health Organization (WHO, 2002). These foods have been assessed for increased risks to human health by several national regulatory authorities (inter alia, Argentina, Brazil, Canada, China, the United Kingdom and the United States) using their national food safety procedures (ICSU). To date no verifiable untoward toxic or nutritionally deleterious effects resulting from the consumption of foods derived from genetically modified crops have been discovered anywhere in the world (GM Science Review Panel). Many millions of people have consumed foods derived from GM plants - mainly maize, soybean and oilseed rape - without any observed adverse effects (ICSU)."
122. Ronald, Pamela (May 5, 2011). "Plant Genetics, Sustainable Agriculture and Global Food Security". *Genetics*. **188**: 11–20. doi:10.1534/genetics.111.128553. PMC 3120150. PMID 21546547. "There is broad scientific consensus that genetically engineered crops currently on the market are safe to eat. After 14 years of cultivation and a cumulative total of 2 billion acres planted, no adverse health or environmental effects have resulted from commercialization of genetically engineered crops

(Board on Agriculture and Natural Resources, Committee on Environmental Impacts Associated with Commercialization of Transgenic Plants, National Research Council and Division on Earth and Life Studies 2002). Both the U.S. National Research Council and the Joint Research Centre (the European Union's scientific and technical research laboratory and an integral part of the European Commission) have concluded that there is a comprehensive body of knowledge that adequately addresses the food safety issue of genetically engineered crops (Committee on Identifying and Assessing Unintended Effects of Genetically Engineered Foods on Human Health and National Research Council 2004; European Commission Joint Research Centre 2008). These and other recent reports conclude that the processes of genetic engineering and conventional breeding are no different in terms of unintended consequences to human health and the environment (European Commission Directorate-General for Research and Innovation 2010)."

123. But see also:

Domingo, José L.; Bordonaba, Jordi Giné (2011). "A literature review on the safety assessment of genetically modified plants" (PDF). *Environment International*. **37**: 734–742. doi:10.1016/j.envint.2011.01.003. PMID 21296423. "In spite of this, the number of studies specifically focused on safety assessment of GM plants is still limited. However, it is important to remark that for the first time, a certain equilibrium in the number of research groups suggesting, on the basis of their studies, that a number of varieties of GM products (mainly maize and soybeans) are as safe and nutritious as the respective conventional non-GM plant, and those raising still serious concerns, was observed. Moreover, it is worth mentioning that most of the studies demonstrating that GM foods are as nutritional and safe as those obtained by conventional breeding, have been performed by biotechnology companies or associates, which are also responsible of commercializing these GM plants. Anyhow, this represents a notable advance in comparison with the lack of studies published in recent years in scientific journals by those companies."

Krimsky, Sheldon (2015). "An Illusory Consensus behind GMO Health Assessment" (PDF). *Science, Technology, & Human Values*. **40**: 1–32. doi:10.1177/0162243915598381. "I began this article with the testimonials from respected scientists that there is literally no scientific controversy over the health effects of GMOs. My investigation into the scientific literature tells another story."

And contrast:

Panchin, Alexander Y.; Tuzhikov, Alexander I. (January 14, 2016). "Published GMO studies find no evidence of harm when corrected for multiple comparisons". *Critical Reviews in Biotechnology*: 1–5. doi:10.3109/07388551.2015.1130684. ISSN 0738-8551. PMID 26767435. "Here, we show that a number of articles some of which have strongly and negatively influenced the public opinion on GM crops and even provoked political actions, such as GMO embargo, share common flaws in the statistical evaluation of the data. Having accounted for these flaws, we conclude that the data presented in these articles does not provide any substantial evidence of GMO harm."

"The presented articles suggesting possible harm of GMOs received high public attention. However, despite their claims, they actually weaken the evidence for the harm and lack of substantial equivalency of studied GMOs. We emphasize that with over 1783 published articles on GMOs over the last 10 years it is expected that some of them should have reported undesired differences between GMOs and conventional crops even if no such differences exist in reality."

and

Yang, Y.T.; Chen, B. (2016). "Governing GMOs in the USA: science, law and public health". *Journal of the Science of Food and Agriculture*. **96**: 1851–1855. doi:10.1002/jsfa.7523. PMID 26536836. "It is therefore not surprising that efforts to require labeling and to ban GMOs have been a growing political issue in the USA *(citing Domingo and Bordonaba, 2011)*."

"Overall, a broad scientific consensus holds that currently marketed GM food poses no greater risk than conventional food... Major national and international science and medical associations have stated that no adverse human health effects related to GMO food have been reported or substantiated in peer-reviewed literature to date."

"Despite various concerns, today, the American Association for the Advancement of Science, the World Health Organization, and many independent international science organizations agree that GMOs are just as safe as other foods. Compared with conventional breeding techniques, genetic engineering is far more precise and, in most cases, less likely to create an unexpected outcome."

124. "Statement by the AAAS Board of Directors On Labeling of Genetically Modified Foods" (PDF). American Association for the Advancement of Science. October 20, 2012. Retrieved February 8, 2016. "The EU, for example, has invested more than €300 million in research on the biosafety of GMOs. Its recent report states: "The main conclusion to be drawn from the efforts of more than 130 research projects, covering a period of more than 25 years of research and involving more than 500 independent research groups, is that biotechnology, and in particular GMOs, are not per se more risky than e.g. conventional plant breeding technologies." The World Health Organization, the American Medical Association, the U.S. National Academy of Sciences,

the British Royal Society, and every other respected organization that has examined the evidence has come to the same conclusion: consuming foods containing ingredients derived from GM crops is no riskier than consuming the same foods containing ingredients from crop plants modified by conventional plant improvement techniques."

Pinholster, Ginger (October 25, 2012). "AAAS Board of Directors: Legally Mandating GM Food Labels Could "Mislead and Falsely Alarm Consumers" ". American Association for the Advancement of Science. Retrieved February 8, 2016.

125. "A decade of EU-funded GMO research (2001–2010)" (PDF). Directorate-General for Research and Innovation. Biotechnologies, Agriculture, Food. European Commission, European Union. 2010. doi:10.2777/97784. ISBN 978-92-79-16344-9. Retrieved February 8, 2016.
126. "AMA Report on Genetically Modified Crops and Foods (online summary)". American Medical Association. January 2001. Retrieved March 19, 2016. "A report issued by the scientific council of the American Medical Association (AMA) says that no long-term health effects have been detected from the use of transgenic crops and genetically modified foods, and that these foods are substantially equivalent to their conventional counterparts. *(from online summary prepared by ISAAA)*" "Crops and foods produced using recombinant DNA techniques have been available for fewer than 10 years and no long-term effects have been detected to date. These foods are substantially equivalent to their conventional counterparts. *(from original report by AMA: [2] (http://www.ama-assn.org/ama/pub/about-ama/our-people/ama-councils/council-science-public-health/reports/reports-topic.page?))*"

    "REPORT 2 OF THE COUNCIL ON SCIENCE AND PUBLIC HEALTH (A-12): Labeling of Bioengineered Foods" (PDF). American Medical Association. 2012. Retrieved March 19, 2016. "Bioengineered foods have been consumed for close to 20 years, and during that time, no overt consequences on human health have been reported and/or substantiated in the peer-reviewed literature."

127. "Restrictions on Genetically Modified Organisms: United States. Public and Scholarly Opinion". Library of Congress. June 9, 2015. Retrieved February 8, 2016. "Several scientific organizations in the US have issued studies or statements regarding the safety of GMOs indicating that there is no evidence that GMOs present unique safety risks compared to conventionally bred products. These include the National Research Council, the American Association for the Advancement of Science, and the American Medical Association. Groups in the US opposed to GMOs include some environmental organizations, organic farming organizations, and consumer organizations. A substantial number of legal academics have criticized the US's approach to regulating GMOs."
128. "Genetically Engineered Crops: Experiences and Prospects". The National Academies of Sciences, Engineering, and Medicine (US). 2016. p. 149. Retrieved May 19, 2016. "*Overall finding on purported adverse effects on human health of foods derived from GE crops:* On the basis of detailed examination of comparisons of currently commercialized GE with non-GE foods in compositional analysis, acute and chronic animal toxicity tests, long-term data on health of livestock fed GE foods, and human epidemiological data, the committee found no differences that implicate a higher risk to human health from GE foods than from their non-GE counterparts."
129. "Frequently asked questions on genetically modified foods". World Health Organization. Retrieved February 8, 2016. "Different GM organisms include different genes inserted in different ways. This means that individual GM foods and their safety should be assessed on a case-by-case basis and that it is not possible to make general statements on the safety of all GM foods."

    "GM foods currently available on the international market have passed safety assessments and are not likely to present risks for human health. In addition, no effects on human health have been shown as a result of the consumption of such foods by the general population in the countries where they have been approved. Continuous application of safety assessments based on the Codex Alimentarius principles and, where appropriate, adequate post market monitoring, should form the basis for ensuring the safety of GM foods."

130. Haslberger, Alexander G. (2003). "Codex guidelines for GM foods include the analysis of unintended effects". *Nature Biotechnolgy*. **21**: 739–741. doi:10.1038/nbt0703-739. PMID 12833088. "These principles dictate a case-by-case premarket assessment that includes an evaluation of both direct and unintended effects."
131. Some medical organizations, including the British Medical Association, advocate further caution based upon the precautionary principle:

    "Genetically modified foods and health: a second interim statement" (PDF). British Medical Association. March 2004. Retrieved March 21, 2016. "In our view, the potential for GM foods to cause harmful health effects is very small and many of the concerns expressed apply with equal vigour to conventionally derived foods. However, safety concerns cannot, as yet, be dismissed completely on the basis of information currently available."

    "When seeking to optimise the balance between benefits and risks, it is prudent to err on the side of caution and, above all, learn from accumulating knowledge and experience. Any new technology such as genetic modification must be examined for possible benefits and risks to human health and the environment. As with all novel foods, safety assessments in relation to GM foods must be made on a case-by-case basis."

"Members of the GM jury project were briefed on various aspects of genetic modification by a diverse group of acknowledged experts in the relevant subjects. The GM jury reached the conclusion that the sale of GM foods currently available should be halted and the moratorium on commercial growth of GM crops should be continued. These conclusions were based on the precautionary principle and lack of evidence of any benefit. The Jury expressed concern over the impact of GM crops on farming, the environment, food safety and other potential health effects."

"The Royal Society review (2002) concluded that the risks to human health associated with the use of specific viral DNA sequences in GM plants are negligible, and while calling for caution in the introduction of potential allergens into food crops, stressed the absence of evidence that commercially available GM foods cause clinical allergic manifestations. The BMA shares the view that that there is no robust evidence to prove that GM foods are unsafe but we endorse the call for further research and surveillance to provide convincing evidence of safety and benefit."

132. Funk, Cary; Rainie, Lee (January 29, 2015). "Public and Scientists' Views on Science and Society". Pew Research Center. Retrieved February 24, 2016. "The largest differences between the public and the AAAS scientists are found in beliefs about the safety of eating genetically modified (GM) foods. Nearly nine-in-ten (88%) scientists say it is generally safe to eat GM foods compared with 37% of the general public, a difference of 51 percentage points."
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143. "Restrictions on Genetically Modified Organisms". Library of Congress. June 9, 2015. Retrieved February 24, 2016.
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148. http://www.cfr.org/agricultural-policy/regulation-gmos-europe-united-states-case-study-contemporary-european-regulatory-politics/p8688
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External links

- Library resources in your library (https://tools.wmflabs.org/ftl/cgi-bin/ftl?st=wp&su=Genetically+modified+food) and in other libraries (https://tools.wmflabs.org/ftl/cgi-bin/ftl?st=wp&su=Genetically+modified+food&library=0CHOOSE0) about Genetically modified food
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