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What is genetically modified food, why is it controversial and how do I know if I'm eating it?

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Abstract

Genetically modified (GM) crops were first grown commercially in 1996. This paper explores what genetic modification is, which crops are GM and the traits that these crops have. It also explores how GM crops are tested, regulated and monitored in the United States of America (US) and in Australia. It details some of the scientific controversy about GM and clarifies how GM food is labelled in Australia.

What is genetic modification?

Most organisms inherit information from their parents via chromosomes that are partially made up of deoxyribonucleic acid (DNA). Sections of this DNA are called genes. With plants, genetic modification (GM) alters DNA by inserting new genes in a 'gene cassette' to alter how a plant functions. The inserted material can consist of genes and genetic information from bacteria, viruses, plants and animals or be synthetic or chimeric genes that have never existed before.

The two main ways to insert this material into a plant cell are:

- to use a bacterium to 'infect'
- to use particle bombardment to 'shoot' the GM material into the existing DNA of the host plant.

This is different to traditional crossbreeding, which has been used for thousands of years.

Food crops that have been genetically modified

Australia

The GM crops approved by Food Standards Australia New Zealand (FSANZ) for consumption in Australia are soy, corn (maize), canola, sugar beet, cotton—which we eat as cottonseed oil—and alfalfa (lucerne), which is mainly an animal feed (Food Standards Australia New Zealand, 2013a). Soy, corn, canola, cotton and sugar beet constitute the vast majority of GM crops grown worldwide. They are used as ingredients in processed food, as biofuels or as animal feed.

Three types (events) of GM potato and one of GM rice have also been approved by FSANZ, but these particular GM events are not grown commercially anywhere. Australia grows two GM crops—cotton, which is over 90% of the crop and canola, which is less than 10% the crop.

Other countries

GM papaya, rice, zucchini, yellow squash, tomato, capsicum and garlic are reported to be on sale in a handful of countries. These crops have not yet been approved by FSANZ and so should not be on sale in Australia. However, in the absence of GM testing, monitoring and certifying of imported produce, Australian consumers cannot be certain that these products are not being imported in some form.

Contamination

GM research and field trials have created contamination of ordinary crops even though the GM crops being trialled have never been commercially released. GM contamination by unapproved GM events has been found in Canadian flax, in US wheat and corn, and in rice from the US, India, China, Hong Kong and Pakistan (MADGE Australia, 2013).

Europe has a Rapid Alert System for Food and Feed known as the RASFF Portal. It has a searchable database and shows when unauthorised GM food, feed and novel foods have been detected, where they came from and what country they were found in. Australia has no comparable system of detection.

What do GM crops do?

Herbicide and insecticide resistance

GM crops have two main traits (GMO Compass, 2007):

- The most common is herbicide resistance. This means the GM plants can survive being sprayed with weed killer. The intention is for the weeds to die but the GM crop to survive.

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- The second trait is insect resistance. The GM plant produces toxins to kill certain insects that eat them. The toxins cannot be washed off.

An increasing trend is for GM crops to have both herbicide tolerance and insect resistance (ISAAA, 2013). For example, Smartstax corn has eight GM genes, six to produce insect toxins and two so that it can be sprayed with two weed killers: Roundup and Liberty (Monsanto, 2012–2013).

Development of beneficial traits

There also very small amounts of GM crops that use a controversial 'gene silencing' technique to provide virus resistance, or to alter the oil composition to create high oleic acid soy (Ruanjan, Kertbundit, & Juříček, 2007; Food Standards Australia New Zealand, 2013b).

> "Drought-tolerant GM corn…provided only modest benefit in moderate drought conditions, and little or no benefit in severe drought conditions"

One drought-tolerant GM corn event is grown commercially, but as noted by the Union of Concerned Scientists (2013), it has '*provided only modest benefit in moderate drought conditions, and little or no benefit in severe drought conditions*'. GM crops engineered to increase the use of nitrogen fertiliser have not reached market yet. There is no GM crop that increases yield.

GM golden rice is being developed with the intention to reduce vitamin A deficiency (IRRI, 2013). However, there are no published data on beta-carotene levels (the precursor to vitamin A) in the GM rice, the amount of beta-carotene at harvest and after storage or the presence of potentially harmful metabolites. Given that vitamin A deficiency in the Philippines has been greatly reduced since 2000 by a combination of a campaign of vitamin A supplementation, food fortification and a campaign to promote consumption of fruit and vegetables (Hansen, 2013), questions the need for GM rice to reduce vitamin A deficiency.

Can non-GM breeding produce the same results?

As noted above, reduction of vitamin A deficiency can be achieved by other means. Similarly, non-GM breeding has produced virus and disease resistant plants, higher yields (GM Watch, 2013a), high oleic acid soy (Pham, Lee, Shannon, & Bilyou, 2010) and drought resistance (GM Watch, 2013b).

How are GM crops tested, regulated and monitored in the US and Australia?

Food plants do not generally undergo toxicological testing. The concept of substantial equivalence was created as the basis for the assessment of GM foods worldwide, whereby '*Substantial equivalence is meant not to establish absolute safety but that it is as safe as its traditional counterpart, where such a counterpart exists*' (FAO/WHO Expert Consultation on Foods Derived from Biotechnology, 2000).

Substantial equivalence means that GM food is compared with its conventional counterpart in its agronomic, genetic and chemical aspects. Additional testing and animal feeding trials may be used if thought necessary. No regulatory agency has required long-term feeding trials, with most feeding trials being 90 days or less. Reproductive and multi-generational feeding trials are not required.

United States of America

The US was the first country to commercialise a GM crop and grows roughly 40% of the world's transgenic crops (James, 2012). A US company, Monsanto, owns about 90% of GM crops. Therefore it is important to know the type of pre-market scrutiny of GM crops performed in the US.

The US Food and Drug Administration (FDA) has a voluntary consultation process for companies wishing to release a GM food. The FDA does no independent testing, instead relying on information provided by the company wishing to release the crop (Food and Drug Administration, 1997). The consultation ends with the FDA sending a letter to the company saying there is no need for the FDA to do a pre-market review or approval.

For example, the FDA sent a letter to Du Pont/Pioneer on 25 March 2013 about its GM corn event 4114. This is a stacked event, meaning the GM corn produces three toxins to kill insects and can be sprayed with the weedkiller glufosinate (International Service for the Acquisition of Agri-Biotech Applications, 2013).

> *Based on the safety and nutritional assessment Pioneer has conducted, it is our understanding that Pioneer has concluded that food and feed derived from event 4114 corn are not materially different in composition, safety, and other relevant parameters from corn-derived food and feed currently on the market, and that event 4114 corn* ***does not raise issues that would require premarket review or approval by FDA*** *(US Food and Drug Administration, 2013).* (Emphasis added).

Australia

In Australia, Food Standards Australia New Zealand (FSANZ) relies on the data provided by the companies wishing to release a GM food. It does no independent testing and requires no animal feeding trials. FSANZ has approved every GM crop application they have received (Food Standards Australia New Zealand, 2013c).

In 2010, FSANZ allowed what many would consider to be a GM corn, Smartstax, into the food supply without any assessment or notification. Smartstax has six GM genes to kill insects and two to allow it to survive being sprayed by weedkillers. However, because the plant was bred conventionally from GM parents and because the GM parents had been individually approved previously, FSANZ decided Smartstax corn did not require a safety assessment. FSANZ also did not notify the public of the crop's approval (MADGE, 2010). This ignores the potential for reactions between the GM genes.

There are currently no official mechanisms for monitoring the long-term impacts of GM foods in Australia, or in fact anywhere in the world. In Australia, FSANZ expects the GM companies to '… *monitor for existing and emerging risks*' of their products (Food Standards Australia New Zealand, 2013c).

How do I know if I'm eating GM food? Labelling in Australia

The FSANZ website states that there are mandatory labelling requirements for GM food. Most people reading that would assume all GM-derived food is labelled. In fact, there are almost no GM labels. This is despite the Australian Food and Grocery Council saying that if all ingredients derived from GM needed labelling, nearly every processed food would have one (Australian Food and Grocery Council, 2010).

Under current labelling laws only ingredients with detectable levels of GM DNA or protein within them require labelling. FSANZ's position is that these are not detectable within refined products such as oils, sugars and starches. GM crops such as corn, soy, canola, sugar beet and cotton are transformed into oils, sugars and starches and therefore escape labelling. However, there is evidence that proteins do exist in refined oils and can trigger reactions in susceptible people (Awazuhara, Kawai, Baba, Matsui, & Komiyama, 1998). This also overlooks the possibility that ds RNA created by GM crops may be having unknown effects on health. GM labels are also not required for food from animals fed GM feed and food containing GM enzymes and additives. Since most GM ingredients enter the food chain in these forms, most GM food remains unlabelled in Australia.

Scientific debates over GM

Safety

There has been controversy over the science and safety of GM foods from the beginning. A lawsuit brought in the US by the Alliance for Bio-Integrity in 1998 revealed internal documents of the Food and Drug Administration showing that the FDA's own scientists believed that GM foods pose unique health risks. Documents that came to light during the lawsuit revealed that '*The processes of genetic engineering and traditional breeding are different, and according to the technical experts in the agency, they lead to different risks*' (Kahl, 1992). In 2000 the judge determined that the FDA was not regulating GM foods, that the FDA's bureaucratic staff disregarded the advice of the scientific staff and that there was disagreement on the safety of GM food. However, she said that because she was specifically reviewing an FDA policy decision of May 1992, she was restricted to consider only the information the FDA had before it at that time. She then ruled that based on that information, the FDA administrators had reasonable grounds to presume there was an overwhelming consensus about safety as of May 1992. This is despite a 1991 memo from a FDA biotechnology co-ordinator saying: '*As I know you are aware, there are a number of specific issues addressed in the document for which a scientific consensus does not exist currently, especially the need for specific toxicology tests. … I think the question of the potential for some substances to cause allergenic reactions is particularly difficult to predict*' (Alliance for Bio-integrity, 2003).

GM supporters claim that scientific bodies and numerous research papers show that GM food is safe (Tribe, 2013). Careful reading shows endorsements by bodies such as the WHO and the National Academy of Sciences are less than might be expected. The WHO states GM foods undergo a safety assessment and that while no effects on the population have been seen from GM foods, there has been no post-market surveillance (World Health Organization, 2013). The National Academy of Sciences notes there are sizeable gaps in the knowledge and understanding of how these crops function and may affect health (Committee on Identifying and Assessing Unintended Effects of Genetically Engineered Foods on Human Health, 2004). These statements fall short of affirming there is scientific proof of the safety of GM crops.

> *"There are currently no official mechanisms for monitoring the long-term impacts of GM foods in Australia"*

"*Independent research papers on GM crops and methods… often provoke controversy*"

Independence of testing

The testing of GM crops is inhibited because they are patented and the companies that own the GM patents have restricted independent testing (Waltz, 2009). A 2011 review of GM safety studies noted their limited number, that most reporting favourable findings had been conducted by the GM companies and that the safety debate remains open at all levels (Domingo & Bordonaba, 2011).

When independent research papers on GM crops and methods are produced, they often provoke controversy. The best known of these is the paper *'Long term toxicity of a Roundup herbicide and a Roundup-tolerant genetically modified corn.'* (Séralini et al., 2012). The following is a summary of the controversy.

The paper is a peer-reviewed paper published in the journal *Food and Chemical Toxicology*. The paper explained that, during a two-year study, rats were fed GM corn NK603 and/or its weedkiller, Roundup, in levels permitted in US crops and drinking water. Male rats in the Roundup/NK603 groups developed liver and kidney disease and female rats developed mammary tumours. The study was criticised for several reasons, including the use of the tumour-prone Sprague-Dawley rats and the size of each test group. However, Sprague-Dawley rats are the standard rat used for long-term carcinogenicity or toxicity trials. Séralini et al. (2012) used the same number of rats that Monsanto analysed in its 90-day trial of GM corn. The authors have responded to all the criticisms of their study (GMO Séralini, 2012a). Numerous scientists showed their support for the research in individual and open letters (GMO Séralini, 2012b). The Belgian Biosafety Advisory Council supported the most important elements of the study (GM Watch, 2013c), as did some Brazilian regulators (GM Watch, 2013d). In 2013 expert witnesses in a Philippine court failed to rebut the Séralini study (GMO Seralini, 2013a). Since the study, *'(t)he European Food Safety Authority (EFSA) has issued guidelines for two-year whole food feeding studies to assess the risk of long-term toxicity from GM foods … which largely validates the methodology and choices of Prof Gilles-Eric Séralini in his 2012 study on GM maize NK603—methodology and choices that EFSA and countless other critics previously attacked him for'* (GMO Séralini, 2013b).[1]

FSANZ approved GM corn NK603 in 2002. This was based on a 9-day acute toxicity trial where mice were given single doses of a purified GM protein. It was assumed that because the GM protein did not appear similar to known allergens it would not be allergenic. It was also assumed that although there were differences in the GM corn's fatty acids and amino acids it was '*compositionally equivalent to unmodified corn varieties*' (Food Standards Australia New Zealand, 2001).

Other studies showing adverse outcomes from GM have also been attacked. Unfortunately, these attacks appear to be motivated to discredit rather than to expand scientific knowledge and discussion.

Other controversies

The debate over the methods of developing GM crops and effects of GM is ongoing. The following is a sample of contentious issues:

- The process of genetic engineering deletes and scrambles parts of the existing plant DNA (Latham, Wilson, & Steinbrecher (2006). The results of this are poorly understood.
- In 2012, it was discovered that a commonly used viral promoter that 'turns on' the GM gene in plants, has a significant fragment of a viral gene within it (Podevin & du Jardin, 2012). The contention is that this '*might not be safe for human consumption. It also may disturb the normal functioning of crops, including their natural pest resistance*' (Latham & Wilson, 2013a; 2013b).
- ds RNA has the potential to silence genes both within the plants and within animals that eat them (Heinemann, Carman, & Agapito, 2013). There are few GM crops designed specifically to silence genes; however, it may be that all GM crops could potentially create some ds RNA that could silence genes. FSANZ's failure to have any formal assessment of these risks has been criticised in a peer-reviewed paper (Heinemann, Agapito-Tenfen, & Carman, 2013). FSANZ has responded saying it will continue to monitor the literature on ds RNA (Food Standards Australia New Zealand, 2013d). This is a rapidly evolving and little explored area (National Institute of General Medical Sciences, 2013). RNA from plants, bacteria and fungi are found in human plasma and may affect human health (Wang, Li, Yuan, Etheridge, Zhou, Huang … Galas, 2012).

1. On 28 November 2013, while this article was in press, the Seralini (2012) paper was retracted by the journal, *Food and Chemical Toxicology*. The reasons given for this were concern about the number of animals used and the type of rat selected, and that the results of the study are inconclusive in regards to overall mortality and tumour incidence. The retraction was despite there being no evidence that the paper should be retracted based on the grounds for retraction according to the Committee on Publication Ethics (COPE), of which the Journal of Food and Chemical Toxicology is a member. Please refer to European Network of Scientists for Social and Environmental Responsibility. ENSSER Comments on the Retraction of the Séralini et al. 2012 Study retrieved 7 December 2013 from http://www.ensser.org/democratising-science-decision-making/ensser-comments-on-the-retraction-of-the-seralini-et-al-2012-study/ for further discourse on this controversial retraction.

Media coverage

Scientific debates can be confusing to the public. This is especially so when many scientists and their detailed research remain unheard while simplistic messages receive wide coverage.

Mark Lynas received an unusually large amount of media attention for a GM activist (*The Economist*, 2013; Walker, 2013; Gillespie, 2013; Storr, 2013; Business Standard, 2013) earlier this year in his worldwide tour that encompassed Australia, India, the Philippines and Africa. This began after a speech in Oxford where he said he was a leader in the anti-GM movement but changed his mind when he read the science and realised that GM is the way to feed the world (Lynas, 2013). However, his claims to be a leading anti-GM protestor have been disproved (GM Watch, 2013e). Scientists, including Professor John Vandermeer from the Department of Ecology and Evolutionary Biology at the University of Michigan, have challenged his understanding of the science (Vandermeer, 2013). His actions and motivations have been questioned in a series of detailed articles (Matthews, 2013a, 2013b, 2013c).

In contrast, the views of genetic engineer and soil biologist Dr Thierry Vrain (Vrain, 2013) are not brought to widespread public attention. Vrain, now retired, worked for Agriculture Canada for 30 years. He changed from being a supporter of GM to giving talks on his concerns about the technology.

The general public is also mainly unaware of a statement signed in October 2013 by over 230 scientists (European Network of Scientists for Social and Environmental Responsibility, 2013a). The statement states that there is no consensus on the safety of GM crops, and that there are no epidemiological studies investigating the effects of GM food on health. It goes on to say that claims that scientific and governmental bodies endorse GM safety are exaggerated or inaccurate and that the EU research project does not provide reliable evidence of GM food safety. It contends that a list of several hundred studies does not show GM food safety and there is no consensus on the environmental risks of GM crops. There is widespread recognition of the risks posed by GM foods and crops in international agreements. One of the signatories is the developer of the world's first whole GM food, the Flavr Savr tomato that is no longer grown (European Network of Scientists for Social and Environmental Responsibility, 2013b).

Conclusion

GM is a new form of plant breeding that presents new risks. The main traits of GM crops are herbicide tolerance, insect resistance or a combination of both. Promises of beneficial traits in GM crops have either not yet materialised or are already achievable by non-GM breeding. The science on which GM crops have been brought to market is contested. The ability of the current regulation to protect public health is contested. The claims that GM foods are labelled in Australia are misleading.

This article has attempted to clarify the issues of GM crops and food that are of immediate relevance for the Australian eater. The wider issues of the effect of GM crops on human, animal, soil and plant health, biodiversity, chemical use, farmer independence, agricultural monopolies and patent control have been left untouched. These are complex and require space to be examined.

> "*Many scientists and their detailed research remain unheard while simplistic messages receive wide coverage*"

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