Genetically Engineering Our Future Food Security

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Scientia

GENETICALLY ENGINEERING OUR FUTURE FOOD SECURITY

Genetically modified crops can offer a range of environmental and health benefits, such as reduced usage of chemical pesticides, improved farm efficiency and crop yields, and an enhanced nutritional profile. Despite this, fears surrounding genetic modification have led to a lack of acceptance of these foods by many consumers, regulators, and governmental organisations. **Dr Richard Goodman** from the Food Allergy Research and Resource Program at the University of Nebraska–Lincoln, is helping to shift the narrative around genetically modified crops, through his extensive work evaluating their safety.

The Genetic Basis of Life

DNA acts as the master blueprint for all plants and animals, instructing their growing tissues to develop into, for instance, a heart, or eyes, or leaves. Differences in the genes inherited from each parent account for the wide variety of characteristics seen within some species. For example, the variation in eye and hair colours, heights, facial features, and even physiological characteristics in humans are a result of the unique combination of genes we each possess.

Small changes in the DNA – or genetic 'mutations' – can lead to the development of novel and beneficial characteristics. In plants, genetic mutations arising over millions of years of evolution have allowed them to exploit a range of climates, adapt to differing levels of water availability, and resist emergent diseases.

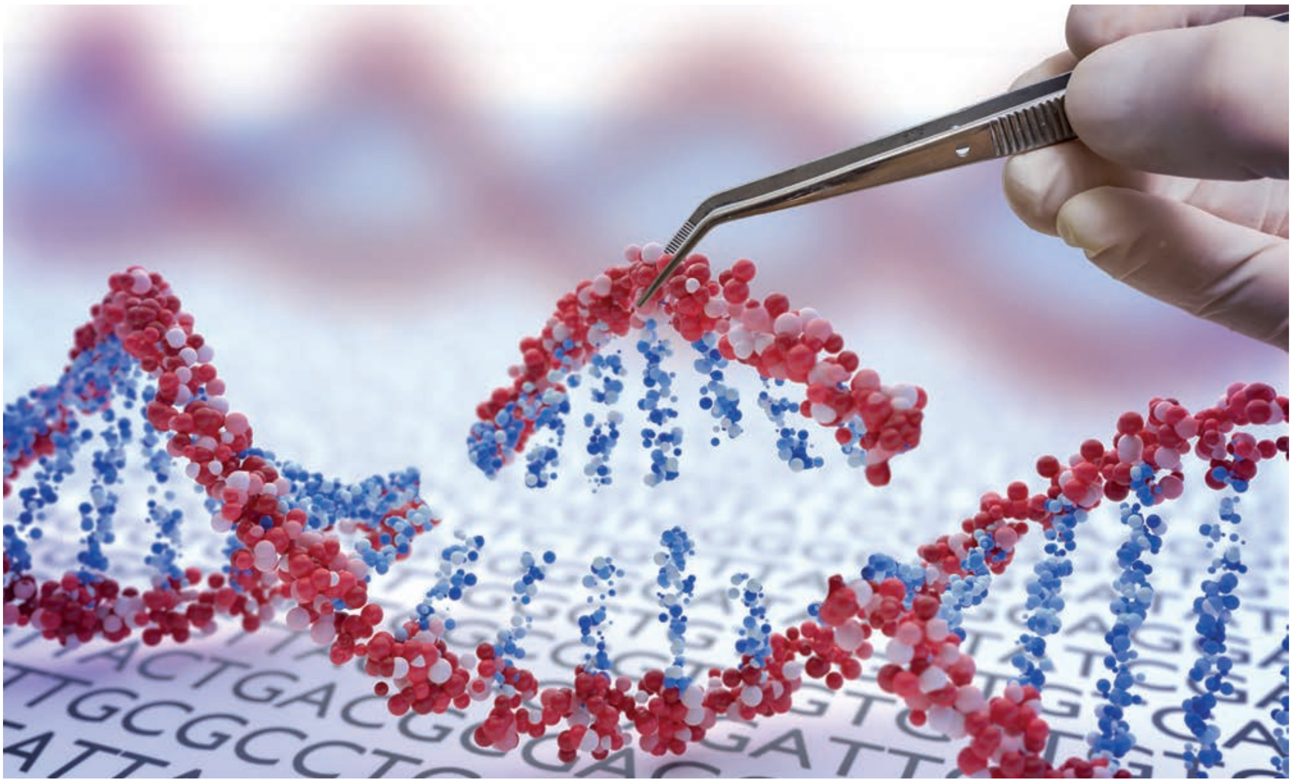
For the last few thousand years, humans have been manipulating the development of plant characteristics by selectively breeding plants with desirable traits. In some cases, whole genomes have been added in this way, for example in wheat and triticale. However, some plants including potato are rarely bred, and introducing new traits for fungal and insect resistance is very slow. The process of selective breeding has provided us with crop plants that are tastier, have enhanced nutritional benefits, achieve higher yields, and flourish in a range of climatic conditions.

Advancements in genetic technologies over the last few decades have allowed scientists to begin adding new genes from different species or altering genes directly, offering greater efficiency than traditional breeding methods. By using genetic modification, or 'genetic engineering' (GE), genes conferring a benefit, such as disease resistance, can be transferred from one plant species to another.

Inserting novel DNA into a plant is called 'transformation', and is followed by rigorous testing and breeding programs to ensure the transformed plants have two copies of the new gene, and that they are stable, functional, and safe. GE crops undergo extensive food safety testing to establish whether they produce any potential allergens – compounds in food that can cause an allergic reaction in some individuals – as a result of the inserted gene.

Dr Richard Goodman and his team at the Food Allergy Research and Resource Program at the University of Nebraska–Lincoln are committed to continually improving the tools and techniques used to assess the safety of novel crop varieties, including GE crops. The producers of GE crops and regulatory organisations are focused on preventing an increase in avoidable risk of allergic reaction, especially where the transferred gene may lead to production of an allergen in a food crop where it was previously absent.

In an effort to facilitate robust and comprehensive food safety assessments, Dr Goodman manages the publicly available AllergenOnline, an extensive database of searchable amino acid sequences for suspected and proven food allergens. This resource allows food producers to identify potential allergens in newly developed crops and food products



based on matching sequences, improving the accuracy and efficiency of the evaluation process. If significant matches are identified, regulators expect detailed tests using blood serum samples from allergic individuals.

Benefits of GE Crops

The development of GE crops began during the 1980s, when beneficial genes from the bacteria *Bacillus thuringiensis* were inserted into crops including maize, soybean, and aubergine. These bacteria have been used extensively by organic farmers to prevent caterpillars and other pest insects from destroying their crops, without relying on chemical pesticides. Because many chemical pesticides harm the surrounding ecosystems by leaching into soils and waterways, switching to other methods of pest control can offer improved environmental outcomes and sustainability in farming.

Similarly, other intensive agricultural practices can degrade natural ecosystems and harm farm productivity. For example, fertilisers, herbicides, and high tillage practices – which involve turning the soil over to disrupt weeds before sowing crops – are often used to create the weed-free growing environment required to produce high crop yields. However, these practices also reduce soil fertility by damaging the bacterial, fungal, and invertebrate communities that contribute to soil health. As a result, more fertilisers are required to maintain the same crop yields in subsequent years.

Growing GE crops transformed to be tolerant to a single or small number of herbicides allows farmers to switch to no-tillage or low-tillage practices, preserving the delicate soil ecosystem and allowing yields to be maintained with a lower input of fertiliser and herbicide. By reducing agricultural inputs and increasing yields, herbicide-tolerant GE crops have contributed to significant economic improvements. Herbicide-tolerant soybean alone contributed an extra $54.6 billion USD to farm income between 1996 and 2016.

Many GE crops are intended to reduce crop losses by insects, bacteria, and fungi. In some cases, GE technology may provide the only solution to a devastating problem. Citrus Greening Disease, a bacterial disease of citrus trees, was previously addressed with pesticides to control populations of the insect vector that carries the disease between trees. However, pesticide resistance emerging in the insect pest has reduced the efficacy of this approach.

Since no natural varieties of citrus that can resist the bacterial disease have been discovered, GE technology may offer the only solution. 'There are ongoing studies to determine which GE genes, events and methods are most useful,' says Dr Goodman. He has been working with developers, using AllergenOnline and other databases, to ensure that the novel proteins produced by the transformed citrus plants to resist the bacteria do not have similarities to any known food allergens.

The ancient plant pathogen, *Phytophthora infestans*, that was responsible for the Irish potato famine in the middle of the 19th century is still common worldwide, affecting both potatoes and tomatoes. The most common method of controlling this fungal pathogen is the use of chemical fungicides, but these can be toxic to humans. Therefore, some

crop developers have transferred three simple genes from a wild potato species with natural resistance. Since resistance in potato varieties cannot be developed using traditional plant breeding, genetic engineering provides the most efficient method of maintaining potato production.

Similarly, bananas are a stable food crop in Africa that is limited by a variety of plant diseases including Xanthomonas bacterial blight. By transferring two genes from commonly consumed pepper into banana plants, researchers in Kenya have developed a new variety of banana that exhibits sustainable resistance. 'We evaluated potential risks of food allergy and toxicity using bioinformatics and found that these proteins do not present risks of food allergy or toxicity,' says Dr Goodman.

GE Crops: Food Safety Assessments

As mentioned, a key concern surrounding GE crops is the potential risk of the transferred gene leading to the production of an allergen in a food where it was not previously present. 'Protecting people with food allergies against accidental exposure to allergens has become an important focus for food manufacturers and regulators responsible for all food safety,' explains Dr Goodman.

Effective and scientifically sound premarket evaluation of GE foods is the most effective tool to protect the public. Dr Goodman, along with his team, has been developing assessment protocols to determine the safety of GE foods. Following criteria described by the food safety organisation, the Codex Alimentarius Commission, AllergenOnline uses peer-reviewed scientific publications to evaluate amino acid sequences from proteins that are known or suspected allergens. The evidence is judged by an expert panel associated with AllergenOnline, while advanced computational tools are used to determine allergy risks for novel and GE foods.

To date, no cases of proven adverse health effects have been recorded from approved GE crops. 'The premarket screening process helps to avoid possible severe reactions in unsuspecting allergic consumers and also prevents subsequent costly food and seed recalls that would be needed to prevent additional reactions,' explains Dr Goodman. As new scientific evidence is gathered, the screening process and AllergenOnline are refined and improved. However, fears surrounding the safety of GE crops, and the persistence of outdated guidance on screening methods, have prevented or delayed many of them from reaching the market.

Regulatory scientists in each country set their own testing requirements for bringing new food varieties, including GE foods, to the market. In some cases, regulators have continued to base their requirements on non-validated tests, such as studies using animal models, or even rejected tests. 'Demanding inclusion of such non-validated tests can lead to the rejection of safe and beneficial products, excessive costs and, potentially, disruption of trade without any further reduction of risk,' says Dr Goodman. 'Many regulatory scientists have rarely studied food safety and food allergy, and they are often unfamiliar with the extensive evaluations used to assess GE crops. Unfortunately, many African and Asian countries have not adopted science-based food safety procedures that allow screening and acceptance of new GE crops for food use.'

GE canola that produces Omega-3 fatty acid was developed by the company Nuseed, to replace fish as the primary source of this healthy oil, offering an alternative to the overfishing that has depleted many of the ocean's tuna, mackerel and salmon populations. Regulatory studies based on the Codex Alimentarius guidelines, conducted to gain approval for these GE plants in Australia, New Zealand, and the USA in 2018, demonstrated no known risks. Despite this, some regulators have demanded much more extensive testing and evaluations before they will grant market approval for GE canola, many of which have not been validated for predicting risks to humans or the environment.

Navigating the regulatory requirements for international trade can sometimes delay the approval of GE crops to more than 12 years and require more than $150 million USD to get them to the market. With GE crops often being developed to address an urgent need, such as the emergence of a new plant disease, human malnutrition, or changing climatic conditions, delays of this magnitude can have significant consequences for farmers, consumers and the environment.

Conclusion

Although there is some way to go before GE crops gain widespread acceptance and trust by the public, governments, and regulatory bodies, their utility continues to expand as genetic technologies improve. As new evidence arises, tools like Dr Goodman's AllergenOnline continue to be updated and developed, further improving the safety evaluations of GE crops reaching the market.

Environmental degradation, climate change, and emergent plant diseases are making it increasingly difficult for agriculture to meet the food demands of a rapidly expanding human population. GE crops may provide solutions to many of these issues. In some instances, such as the case of Citrus Greening Disease, GE crops may provide the only available solution to a devastating problem.

Meet the researcher

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Dr Richard E. Goodman earned his PhD in Molecular Biology and Physiology in the Department of Dairy Science at The Ohio State University. He currently holds the position of Research Professor within the Food Allergy Research and Resource Program at the University of Nebraska–Lincoln. His research interests include refining and developing methods to assess the allergenicity of foods, and in particular, examining the food safety of new crop varieties and genetically engineered food varieties. Additionally, he manages AllergenOnline, which provides allergen lists and a searchable database intended to aid identification of proteins in novel food varieties that may pose a risk of reaction in allergic individuals. Dr Goodman also participates in international workshops on allergenicity assessment tools and genetically engineered crop safety, and supervises PhD research students.

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FURTHER READING

Y Jin, RE Goodman, AO Tetteh, M Lu, L Tripathi, Bioinformatics analysis to assess potential risks of allergenicity and toxicity of HRAP and PFLP proteins in genetically modified bananas resistant to Xanthomonas wilt disease, Food and Chemical Toxicology, 2017, 109, 81.

RE Goodman, M Ebisawa, F Ferreira, HA Sampson, R van Ree, S Vieths, JL Baumert, B Bohle, S Lalithambika, J Wise, SL Taylor SL, AllergenOnline: a peer-reviewed, curated allergen database to assess novel food proteins for potential cross-reactivity, Molecular Nutrition & Food Research, 2016, 60, 1183.

RE Goodman, S Vieths, HA Sampson, D Hill, M Ebisawa, SL Taylor, R van Ree, Allergenicity assessment of genetically modified crops—what makes sense?, Nature Biotechnology, 2008, 26, 73.

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