Future of Food

Gene genius

How gene technology is changing the future of food

Powered by FoodHQ

Powered by

food HQ
Shaping the Future of Food

Future of Food series
Issue 01

Published March 2024

Written by Vincent Heeringa based on interviews with:

Grasslanz Technology Ltd

- John Caradus FRSNZ, CEO

Plant & Food Research

- Professor Richard Newcomb, Chief Scientist
- Dr Revel Drummond, Scientist
- Dr Peter Cook, General Manager, Business Development

Massey University

- Professor Joanne Hort, Fonterra Riddet Chair in Consumer and Sensory Science, Food Experience and Sensory Testing (Feast) Lab

Dr Victoria Hatton • CEO

+64 27 538 5338

victoria@foodhq.com

FoodHQ Innovation Limited

21 Dairy Farm Road
PO Box 1210
Palmerston North 4440
New Zealand

www.foodhq.com

Gene genius

How gene technology is changing the future of food

New Zealand's food and fibre industry is built on generations of selective breeding – from ryegrass and cows to kiwifruit and apples. But recent improvements in gene technologies offer a step-change in how we can create new resilient and productive varieties. Will New Zealand seize the opportunity or be left flatfooted in a race to the future?

Threat: Restrictive regulations on the use of gene editing technology are hampering New Zealand's efforts to invent, test and deploy new breeds and varieties that are suited to our changing climate and consumer demand.

Opportunity: Smart and ethical use of genetic technologies could accelerate the adoption of new crops and animals for improved health, resilience and productivity.

Key points:

- Genetic technologies have experienced a step change in recent years
- CRISPR in particular is a powerful new technique for gene editing – gene editing techniques allow for more precise and accurate changes to a plant or animal's own DNA
- New Zealand's regulatory framework (the HSNO Act) has not kept up with the changes in genetic technologies
- New Zealand's food and fibre sector is in danger of becoming uncompetitive and unable to adapt, without access to these genetic tools
- Rapid development of new livestock and crop plants is critical in the response to climate change
- But it's not as simple as changing the regulations: buy-in must be gained from Māori, industry and the public
- Changes to the regulations must be through informed, nationwide discussion.

The story of New Zealand's primary industry is a story of genetics.

Consider 'Scifresh', known by consumers as the brand Jazz™ apple, a derivative of the Royal Gala and Braeburn varieties. Jazz™ was selectively bred to deliver a superior crunch and bright red skin and is now one of the world's most popular apples.

Or take the humble kiwifruit. Originally known as the Chinese gooseberry, decades of traditional breeding by New Zealand means our yellow-fleshed kiwis dominate the trade.

Fruit, sheep, grasses, dairy, beef, berries and barley – the list of primary products that have benefited from generations of selective breeding is huge.

In the pastural sector it's hard to overstate just how important the improvement in ryegrass to suit New Zealand conditions is worth. "Without the breeding programme... we would not have ryegrass growing in the North Island and large parts of the South Island. Same with white clover. So, if you're talking about economic impact, you're talking billions of dollars," says John Caradus, Chief Executive of Grasslanz Technology Ltd, a subsidiary of AgResearch.

Over the last 10 years in the livestock sector, the accumulated value of genetic gain or improvement *for a single dairy herd alone* is more than $250,000 according to Livestock Improvement Corporation[1] (LIC). Genetic gain or improvements are achieved by selecting individual animals with the most desirable traits, such as higher milk production in dairy cattle, and breeding them with each other to create offspring with superior genetic characteristics. A higher rate of genetic gain means that the population will produce more offspring with the desired traits in a shorter period. This can lead to higher productivity, increased profitability, and improved sustainability of the production system.

The horticultural sector has benefited too, with New Zealand known to be the home of fruit varieties that consumers love and that command a premium in overseas markets. Every year, horticulture exports more than $4 billion of produce to countries across the world. "The economic gain that genetics has provided is sizable and it's all come off the back of the fact that we've already got the base genetics here in the country," says Plant & Food Research chief scientist Dr Richard Newcomb. "We have collections of material and we've been able to shuffle those genetics by using selective breeding to select for the ideal combinations of genes in those cultivars."

But will our success in the past be sufficient for the future?

No, say a growing number of leaders, including geneticists, food scientists and politicians. Traditional breeding techniques may have got us this far, but they may be insufficient for the challenges ahead, such as climate change.

"With climate change comes a new set of challenges: increased threat of disease, extreme weather, the need for closed growing systems. We need to ensure we can respond, and we need to be able to respond quickly," says Newcomb.

It's not just climate change. Consumer preferences in food are following the same trajectory as fashion: fast-changing, global and based on convenience. Tastes change and so do health and consumer regulations.

1 www.lic.co.nz/news/value-genetic-improvement

We've tried and it doesn't work.

To meet consumer demand New Zealand food producers, need to adapt at scale and at pace.

"If we're going to be an agricultural, biological economy, we need to have the [full] biological toolkit available to us," Sir Peter Gluckman, the former chief scientist told RNZ[2].

Question is, do we?

Hand brakes on development

Under the current rules, the answer is no. The 1996 Hazardous Substances and New Organisms Act (HSNO), which regulates the use of all genetically modified organisms, severely restricts the application of genetic technologies in plant and animal breeding. Strictly speaking, there is no ban on the use of genetically modified or gene edited plants and animals in NZ's primary production. However, not a single GMO plant or animal has been grown commercially in New Zealand, ever. This is despite 17 million farmers growing more than 2.7 bln hectares of GMO crops worldwide since 1996.

When is a ban not a ban?

For staff at AgResearch, it feels very much like one. They say the regulations have curtailed the further development of ryegrasses and clover – the staple of New Zealand sheep and cows.

Traditional breeding techniques have limitations. They're slow and, in some cases, unable to deliver the improvements that are now available through gene editing techniques. Of special focus for Caradus is the relationship between naturally occurring fungi and the ryegrass they inhabit. "Having screened thousands of these combinations we've started to realize that, in fact, we can manipulate the chemical pathways in these fungus using gene editing and knock out some of the genes that are producing chemistry that cause things like ryegrass staggers or summer fescue toxicosis, which is a heat stress-related problem."

Another breakthrough has been the discovery that genetically modified (transgenic) ryegrass can dramatically reduce methane from cows – the single biggest source of agricultural emissions. So-called High Metabolisable Energy[3] (HME) ryegrass is the result of adding and modifying two plant genes to increase lipid content in the leaf and enhance photosynthesis in the plant under some conditions.

Neither of these improvements are possible without modern genetic technologies, says Caradus. "We've tried and it doesn't work."

While the lab-based genetic modification work has been performed here, New Zealand's restrictive regime means field trials are far more easily done offshore, in Australia and the USA. The costs and hurdles the HSNO Act presents are too great. Says Caradus: "The regulations are restricting the opportunities to bring in traits or have traits expressed that will help us overcome some of the environmental and production issues that we have in both agriculture and horticulture. We are being left behind."

New Zealand's regulatory settings restrict development and use of genetically modified plants and animals, but our food regulations allow many GM foods to be sold and consumed. The commonly found GMO-derived canola and soy oils do not require GMO labelling nor does the standard emulsifier soy lecithin. Almost all cheese is made with GMO-derived rennet, but as the

2 www.rnz.co.nz/news/national/491825/changes-to-genetic-modification-rules-would-benefit-the-economy-national
3 www.agresearch.co.nz/news/pasture-biotechnology-update1/

We need to make the regulation proportionate to risk

rennet isn't an ingredient of the final product, cheese is exempt from GM regulation and labelling. The Impossible Burger is labelled as GM and available from your local supermarket.

It's very frustrating for scientists like Caradus - as they perceive a double standard at work. "You know, it's very interesting. If you go on the Food Standards Australia and New Zealand (FSANZ) website, which regulates what can be eaten in New Zealand, there are 90 foods listed there that are derived from transgenic or gene edited plants. And yet our farmers cannot grow any of them in New Zealand. Now, from my perspective, that just doesn't add up."

The last time is was fully calculated, in 2019, some 17 million farmers had grown a cumulative 2.7 billion hectares of GM crops[4]. In 2018 alone, 28 countries grew GM crops, accounting for 10% of the world's arable land, covering 191 million hectares[5]. By 2023 an amazing 440 GM events were recorded in the ISAAA database[6] with some GM crops reaching near saturation uptake in GM accepting countries.

"Every time I give a talk on the subject, I must check if there's something else that I now need to mention. Because every week somebody's published another product announcement, often with plants ready to go" says Dr Revel Drummond, a geneticist with Plant & Food Research.

"We need to make the regulation proportionate to risk," says Drummond who specialises in indoor growing systems. "Transgenic plants have been in the ground since the 1980s. So, we're talking nearly 40 years of use. I think we've [humans] fed more than a trillion meals to livestock of GMO products. They seem to have all grown healthily and turned into food for all of us to eat."

That confidence has changed the way GMOs are regulated overseas. Countries such as Australia, USA, China, Canada, Brazil, Argentina and Singapore are among several which regulate GMOs based on product traits, rather than process. Many countries have also simply excluded simple gene edited plants (SDN-1) from regulation as GMOs entirely. More are moving to deregulate gene editing processes and products, including a dramatic review by the European Union.

Rush to conclusion?

Slam dunk then? Change the rules, liberate the genetic engineers.

It's not quite that simple, warns Dr Peter Cook, General Manager Business Development with Plant & Food Research, and the convenor of a recent forum about the future of selective breeding and genetic modification in horticulture. Facilitated by futurist Melissa Clark-Reynolds, the group recommended a more nuanced approach. There are many considerations.

Not the least are Māori perspectives to genetic technologies, which themselves include a wide range of views. The group broadly summed up such views as 'preserving whakapapa'. The concern here is the damage that could occur to taonga species through irresponsible modification, or the wholesale exploitation of native characteristics or the theft of IP. At the heart of Māori concern is the motivation of the scientists: to exploit or to improve? Tikanga matters.

A 2019 survey of Māori views concluded: "That while Māori informants were not categorically opposed to new and emerging gene editing technologies, they suggest

4 www.isaaa.org/resources/infographics/doyouknowwherebiotechcropsaregrown/default.asp
5 www.isaaa.org/resources/publications/briefs/54/infographics/default.asp
6 www.isaaa.org/resources/infographics/gmapprovaldatabase/default.asp

...to exploit or to improve? Tikanga matters.

a dynamic approach to regulation is required where specific uses or types of uses are approved on a case-by-case basis."

New gene technologies could be deployed to address a range of challenges our food and natural ecosystems face and deliver a more regenerative future. The group highlighted the importance for the industry to "identify opportunities to clearly align precision breeding with movements supporting the regeneration of the planet/nature/soils/Papatūānuku (e.g. improving carbon sequestration, improving efficiency of biofertilizers, improving no-till systems, decarbonizing, improving water utility)."

Another consideration is that the science, though quickly advancing, is not settled. It's too glib to say, 'oh let's just edit for this trait or that.' Cook points out that, significant research and knowledge is required to develop a gene edited product. Hence there are only a few examples of gene edited products on the market. But the ability to readily use these leading-edge genetic breeding technologies in New Zealand will enable our sectors to start the journey should they want to.

What's more, New Zealand's primary sector has made a virtue of its non-GMO stance and its clean, green image. We mess with that at our peril. Conversely, as the tech advances and international regulations loosen, it's possible that our food multinationals move production to countries with a more welcoming stance. New Zealand may become too hard to grow food in.

"I think we need to consider many factors," says Cook. "What's right for our country at a national level is to have the best science working for the best outcome. We may not want to miss capturing the significant opportunities that a disruptive technology like precision breeding could offer to our primary sectors. There will be some markets that will pay a premium for a product that's labelled as non-GMO. Other segments won't care and just go for the lowest price. Others might pay a premium for a crop edited to grow indoors with minimal inputs."

The full biological toolkit

When Gluckman talks about the full toolkit he's most likely referring to the biggest change in genetic research since 1996: CRISPR-Cas9. It's a method of genetic editing discovered by Emmanuelle Charpentier and Jennifer Doudna, who shared the Nobel Prize in Chemistry in 2020. The science can be mind-bending but one way to understand it is that CRISPR allows scientists to modify the genetics without the need for foreign DNA – what is commonly referred to as genetic modification*.

Essentially, CRISPR[7] in the lab speeds up what happens in nature.

"Typically, a breeding cycle for us in, say, apples or kiwifruit is 20 to 25 years," says Newcomb. "In fact, we've had one apple programme going as long as I've been at Plant & Food Research, since 2000. This is the time it takes from the initial cross through to an elite cultivar that we can confidently deploy."

Using genetic technologies, Plant & Food Research scientists have been able to create an apple that flowers every three months. "Normally we have to wait for the plant to mature before it starts flowering. But if we get it flowering straight out of tissue culture, then we can do a cross.

7 www.youtube.com/watch?v=sweN8d4_MUg

How am I supposed to deliver public good when my research can only go so far?

"And if it's flowering quickly, it's also fruiting quickly, so we can check for the attributes we are seeking. We can, using gene technologies, do multiple crosses even within a year."

This matters for climate resilience. "We're struggling with a breeding cycle that lasts for 25 years and climate change that's happening in front of our eyes. We really need to make some changes to our growing systems and genetics to make our crops more resilient," says Newcomb.

Plant & Food Research is exploring the potential of growing fruit and vegetables indoors – sometimes called controlled environment agriculture (CEA)[8]. As the Earth heats and weather becomes more extreme, traditional growing methods are becoming less reliable. Currently, indoor growing works only for certain crops such as leafy greens, strawberries and mushrooms. Growing fruit trees, wheat or corn is more complicated.

"What if you wanted to grow something like apples or kiwifruit or tamarillos, all of which are big plants and need a lot of space?, " asks Drummond. "And rather annoyingly you sometimes need a boy plant and a girl plant and pollinators. None of which is sustainable in an indoor system. Plus you've got to have year-round productivity."

At least part of the answer is to select for favourable traits via gene editing.

Drummond is working on two projects to understand if it's possible to miniaturise apples, kiwifruit, tamarillos and blueberries suitable for a CEA facility and make them economically and environmentally viable.

Under the current rules, Drummond can conduct both CRISPR and transgenic experiments. And new rules proposed by the Ministry for the Environment will make it easier to conduct these experiments in the lab.

But research is only the beginning of the process. Without changes to the HSNO Act, the D of R&D is throttled.

"We don't have enough money to fund the process. Frankly, the amount of time it takes even to get a lab approval through the Environmental Protection Agency (EPA) is years. Trying to apply for anything beyond this through the EPA is unbearably slow and very expensive. How am I supposed to deliver public good when my research can only go so far?"

Drummond believes New Zealand needs to be prepared for increasing demand. "Singapore has decided they would like to be 30% self-sufficient in food production, but they have no outdoor space to be able to achieve that. So, imagine if we could take some of our crops to Singapore and grow them in the basement of their high-rise buildings and everybody in the building gets fresh fruit every day. That's a win for everyone."

8 en.wikipedia.org/wiki/Controlled-environment_agriculture

...buckle up. This could take some time.

What next

As hinted at above, a simple change to the HSNO Act will not 'solve' the issue. There's a lot to address.

And arguably the biggest challenge will be what ordinary people think. Despite genetic technology moving on since 1996, there's little public understanding of the science - even if we're eating GMOs already.

It doesn't help that there's little consensus on what the terms mean, with gene editing, precision breeding, selective breeding, genetic engineering, genetic modification and genetically modified organisms used interchangeably (see the glossary).

One of the recommendations from Cook's forum is to stop confusing the terms. "Agree standardised language e.g. "precision breeding techniques (or alternatively advanced breeding, advanced selective breeding) and use it consistently in all narratives," concludes the report.

Professor Joanne Hort is a specialist in consumer science at Massey University. She says consumers are not rational when it comes to food. Despite GMOs being used in medicine and in ingredients, local advocates of GMOs need to bring consumers along.

"Handled correctly, there's a possibility that we can educate consumers around the benefits and the risks of these technologies.

"I think it's very important that as scientists we need to bring the consumer with us. It only takes a couple of statements that consumers don't understand or that are not backed by evidence for the consumer to put up a brick wall."

Does the advent of CRISPR make that conversation easier?

Hort laughs. "Well, I don't understand it yet because it's not my field, so I doubt the consumer will."

In other words, buckle up. This could take some time.

* While this article has been written the Environmental Protection Agency[9] (EPA) has released a clarification that certain organisms, known as null segregants, are not considered GMO's under the HSNO Act. The application was led by AgResearch and 14 other research or industry organisations. While it doesn't change how GMO's are used in research, it does give 'clarity on the use of organisms that we saw as being a grey area within the regulations," says AgResearch science team leader Richard Scott.

9 www.epa.govt.nz/news-and-alerts/latest-news/epa-clarifies-gmo-definition

Glossary of terms

Genetic technologies

Traditional/conventional breeding – a technique where two organisms are crossed to produce offspring for commercial (or other) reasons. Includes:

- **Selective breeding** – a breeding technique where the parents and/or offspring are selected specifically for their known genetic characteristics

Mutagenesis – a technique where the DNA of an organism is permanently altered by the application of a chemical or physical agent (such as radioactivity or UV radiation).

Genetic modification (GM) / genetic engineering (GE) – techniques where the DNA of an organism is altered by scientists through the permanent addition of DNA from another source. Includes:

- **Transgenic** – modifying an organism with DNA from another species
- **Cis-genic** – modifying an organism with DNA from its own species

Null segregant – the offspring of a genetically modified organism that does not carry the modified and/or foreign DNA in its genome.

New breeding techniques (NBTs) / precision breeding – techniques where the DNA of an organism is altered by scientists in a targeted and precise way. *Classified as genetic modification under New Zealand regulations.* Includes:

- **Gene editing / genome editing** – a technique where a change to the DNA of an organism is triggered at a very specific point in the DNA by causing a cut in the DNA. The most common technology is known as CRISPR-Cas9.

- In some regions (including Australia), products of gene editing are classified as:
  - **SDN-1**, where a small change DNA occurs at a targeted point in the genome, with no external DNA inserted
  - **SDN-2**, where an existing gene is replaced with a new gene with a similar DNA sequence (for example, from the same or related species) and the new template DNA is physically inserted at the targeted point
  - **SDN-3**, a new gene (from any species) is added at a targeted point in the genome and the new DNA is physically inserted
- Newer techniques fall outside these categories as they do not (completely) cut the DNA
  - **Base editing** – a technique that where a change to the DNA sequence of an organism is targeted at a single targeted point, without the permanent addition of DNA from another source
  - **Prime editing** – a technique where a targeted point in the DNA sequence is rewritten using a temporary primer/template, without the permanent insertion of DNA from another source.

01

Future of Food series

FoodHQ is the New Zealand hub of leading food and food production researchers that advocates for collaboration, food innovation and investment among researchers, industry, and policymakers to tackle challenges to advance the food industry.

www.foodhq.com

Shaping the Future of Food