Understanding Precision Fermentation

Discussion Paper

SF&F
Exploring Southland's *food and fibre opportunities*

THRIVING SOUTHLAND

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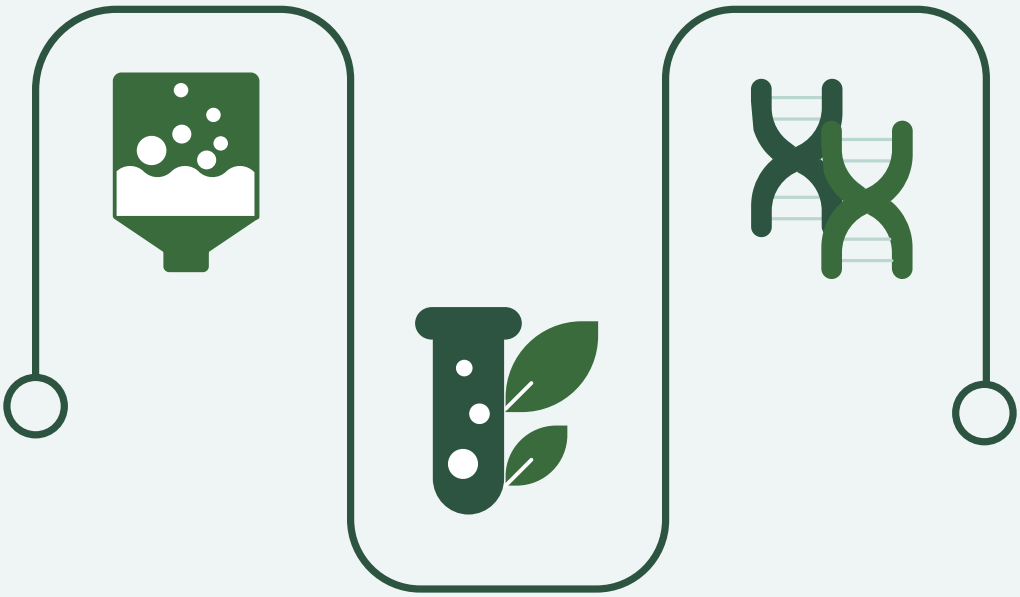
Contents

Technology to create alternative proteins: precision fermentation

- **Precision fermentation is one method of making alternative proteins.**
- **Alternative proteins is the name given to products brought to market as an alternative to animal-sourced proteins. Alternative proteins are also referred to as 'emerging proteins'.**
- **It's widely agreed that precision fermentation is the alternative protein technology most likely to impact New Zealand and its farming systems first, at scale.**



This paper aims to inform Southland farmers about precision fermentation. It provides a high-level summary of the technology, shares insights and directs readers to sources with more detailed information, including recently published New Zealand studies and scenarios. We also present the varied opinions of different stakeholders.

This paper is an introductory resource, therefore it doesn't offer any new research findings.

Thriving Southland has invested in this work to help make southern farmers more aware of the technology. Although the future impacts of precision fermentation remains uncertain, Thriving Southland hopes this resource will encourage thinking and debate, grow awareness of the varying opinions on this topic and inform readers' own thinking.

This work has been funded by the Ministry of Business, Innovation and Employment (MBIE) through the Southland Just Transition. Thriving Southland explored Southland's future food and fibre opportunities as a part of the Just Transition initiative, including consulting with the Southland community. From this work, we identified the need for a simple resource on precision fermentation.

Summary of key points

Investment into precision fermentation to produce alternative proteins **will continue to grow globally.** The dairy sector is currently more vulnerable to disruption from **this technology, than the red meat sector.**

Should regulations change, we have existing science, research and development (R&D), and engineering/processing capabilities that could be applied to precision fermentation. We also have a strong inventory of facilities that could be repurposed and a reliable hydro-energy supply (fermentation at commercial scale requires energy). **Opportunities may arise if we look hard enough.**

New Zealand's **current regulatory settings will not incentivise** rapid growth of investment into commercial scale precision fermentation facilities onshore.

The use of other biomass/ waste streams as a feed source for commercial scale fermentation (instead of sugar) **is something New Zealand could invest in,** as a long-term R&D play.

Commercial scale up of new precision fermentation products remains challenging. It takes time, requires **deep expertise and ongoing investment of significant** sums of capital.

There are significant uncertainties around the actual level of disruption precision fermentation will cause in the future (its scale and speed). **Disruption to the dairy sector will not be total nor immediate.**

Disruption will come from offshore precision fermentation activities, especially from the B2B (business-to-business) ingredients model. Our overseas customers that currently use New Zealand dairy ingredients in product formulation will have increased access to alternative ingredients, which will likely offer a compelling range of supply chain benefits (cost, consistency, environmental impacts).

Opinions seem loosely divided between two camps. How much do we invest in preparing for disruption that may not happen? Versus, **can we afford not to?**

We need to pro-actively consider how we differentiate and compete in a global protein supply landscape. Fonterra will remain deeply engaged in precision fermentation technology. It's to our national advantage that they are 'inside the tent' and have strong capabilities and knowledge of the technology.

Given the importance of the dairy sector to New Zealand, we need more national and regional discussions about how we improve our resilience to disruption. Several pieces of New Zealand research in recent years share similar conclusions – **'doing nothing is not an option'.**

> *As a family business, we're aware of precision fermentation and the pace of change occurring out there in the world.*
>
> *We're trying to spread our business risk as much as we can – without leveraging more debt on the business."*
>
> - Dairy Farmer

Preparing for disruption aligns with a need to **improve our farm systems'** resilience, to a range of existing headwinds (market, consumer, regulatory, climate). Improving efficiencies, income diversification, and supporting and simplifying land use change will be key.

We're not aware that the government has developed a strong position on how we better **prepare for disruption** from precision fermentation.

What is precision fermentation?

There are three main methods of creating alternative proteins:

1 Fermented protein

Proteins are produced by genetically engineered host microorganisms, grown in a controlled environment (a special tank called a bioreactor) using a sugar-based feedstock. This method is commonly referred to as 'precision fermentation'. Precision fermentation makes many other products besides proteins, including enzymes, fats, flavouring agents and vitamins.

2 Plant-based protein

Proteins are extracted from plants, legumes and grains, and used to create alternative meat-free or dairy-free food products, or to replicate ingredients traditionally sourced from animals (for example, aquafaba from chickpeas is used as an egg white replacement, because it has similar properties).

3 Cell-cultured protein

Cells extracted from animals (e.g. muscle or fat cells) are replicated in a controlled environment. Harvested cells are constituted into meat products or used as an ingredient in other products. This is also referred to as 'cellular agriculture' or 'lab-based meat'. It is awaiting more widespread regulatory approval. Singapore was the first mover in the regulatory space to approve food product for sale.

Precision fermentation is an 'acellular' technology

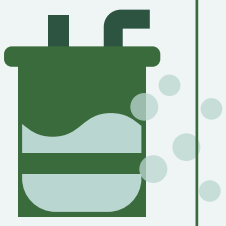
- **Cellular technologies** use controlled environments to create products made of living or once living cells. Cell-cultured proteins are an example of cellular technology.
- **Acellular technologies** use controlled environments to produce non-living cells, such as proteins or fat molecules.

The Precision fermentation process

Precision fermentation makes single ingredients (e.g. whey or casein).

It uses microbial hosts as 'cell factories'. Microorganisms are programmed, using DNA sequences, to produce specific proteins, enzymes, flavour molecules, vitamins, pigments or fats. The target compound (e.g. the protein or fat) is isolated and extracted from the host microorganisms and used as ingredients which improve the sensory characteristics and functional attributes of products.

The extracted products (e.g. proteins or fats) are the very same as those harvested from the animal or plant whose DNA sequence was used. The only difference is how they were made.



Bioengineering techniques are used to programme the host microorganisms. Specific genetic codes direct the microorganisms to produce a desired outcome, when they're fermented under precise conditions. The genetic code is taken from a relevant DNA sequence, which can be sourced freely from existing open-source databases of animal or plant DNA sequences. Therefore, animal or plant DNA is not necessary to start the precision fermentation process – you just need the DNA sequence.

Because DNA is the universal language of life, microorganisms recognise DNA regardless of its origin. When scientists insert the relevant DNA sequence into an organisms' genome, the organism recognises it and attempts to adopt it using a natural DNA repair process. Scientists will isolate those microorganisms that successfully undergo the DNA repair process. At this point, scientists know the new DNA is permanently incorporated into the microorganism's genome.

Precision fermentation uses genetic engineering techniques, but many countries do not classify end products as genetically modified. The modified host organisms are not used after the fermentation takes place. The target compound (e.g. a protein, enzyme or flavour molecule) is extracted and becomes the valuable ingredient that is sold. Because the compound is identical to the same compound harvested from the 'DNA mothership' animal or plant, the ingredient product is not required to be labelled as a GMO (genetically modified organism).

Regulatory settings in New Zealand differ. New Zealand's regulations apply to the process, not the product. If a genetically edited organism is used to produce a product, and is extracted and used as an ingredient, the final food product is classed as genetically modified even though no part of the original genetically modified organism is present in the final food product.

To produce a dairy-free milk product from precision fermentation, the different compounds (e.g. proteins and fats) must be produced separately, then combined to create a new product. Therefore, undesired compounds (e.g. lactose) can be left out.

Conversely, a specific product created by precision fermentation does not include the complete nutritional profile of the conventional whole food produced by the animal, from which a DNA sequence has been taken (e.g. whole milk).

Food products formulated with precision fermentation ingredients require the addition of other ingredients, vitamins or minerals, to be comparable nutritionally to conventional animal products.

The most common microorganisms used in precision fermentation are bacteria and fungi. For example, 80% of global rennet supply is made using a bacteria-based precision fermentation process.

Precision fermentation technologies have been in use for decades and already create a range of products used by millions of people worldwide, e.g. insulin, vanilla essence, many vitamins (such as B2 and B12), and numerous enzymes used in food manufacturing.

Precision fermentation can be used to produce minor ingredients which improve the functionality of other hero ingredients (e.g. plant proteins) in a formulated food product.

- **Precision fermentation is different to traditional fermentation and biomass fermentation processes.**

- **Traditional fermentation uses microbial anaerobic digestion to change a food, i.e. converting ingredients into something else. This process has been used for centuries to make beer, wine, yogurt, vinegar and cheese.**

- **Biomass fermentation is used to efficiently make large amounts of microbes. The microbes are the valuable product, e.g. yeast.**

Global examples of companies using precision fermentation

Alternative protein ventures raised USD $1.6B in 2023. The total investment in alternative protein start-ups since 2015 sits at USD $15.8B. As at the end of 2022, there were 136 companies active in precision fermentation technology globally[1].

Daisy Lab is an Auckland based start-up seeking to produce dairy proteins by precision fermentation.

Perfect Day is a US company focused on whey protein. In only eight years, they have multiple products on shelves via several different B2B partners. They have teamed up with Nestlé to create a milk-like beverage from proteins identical to those from cows, and with Starbucks to trial a precision fermented milk.

Remilk in Israel is scaling-up its facility to the equivalent of a 50,000-cow production operation. The company already produces cheese, yogurt and icecream.

Nourish Ingredients is an Australian biotech pioneer in the emerging animal-free speciality fat segment. They're using precision fermentation and fungal strains to create meat and dairy fats without the animal. Its Creamilux (dairy mouthfeel, taste and function) and Tastilux (meaty flavour and aroma) products are low-inclusion lipids that recreate the emulsification properties of animal fat. Added to plant-based products, they provide consumers with a more authentic eating experience. They can also be added to conventional food products to help companies provide consumers with 'cleaner labels'. The company is aiming to take both products to market in 2025.

A selection of others include:

USA:	New Culture, Change Foods, Geltor
Israel:	ImaginDairy
Germany:	Formo
Belgium:	Those Vegan Cowboys
France:	Bon Vivan, Standing Ovation
Australia:	Eden Brew
India:	Zero Cow Factory
Spain:	UK-based Better Dairy
South Africa:	De Novo Foodlabs

Examples of products made by Perfect Day's B2B partners.

1 The Good Food Institute. 2022 State of the Industry report on fermentation. 2023. View it here.

Precision fermentation is creating products to disrupt dairy

Precision fermentation companies in several countries are producing dairy ingredient products 'without the cow'. Dairy ingredients products are used in a vast range of processed food (chocolate, biscuits, potato chips, instant noodles, baked goods etc.).

Importantly, replacing dairy ingredient products with alternatives made from precision fermentation doesn't alter the consumer's experience eating the processed food product. It is likely consumers will remain unaware of ingredients in processed foods created by precision fermentation.

Milk is a homogenous product: always a liquid comprising of 13% solids and 87% water. Of the 13% solids, 3% is protein. 80% of the protein is casein and 20% is whey. Milk's homogeneity makes it easier to replicate its constituent components (e.g. proteins) using alternative protein technologies (such as precision fermentation), making it more vulnerable to disruption than meat.

Precision fermentation has the potential to disrupt the dairy ingredients market. This is an important distinction because most of New Zealand's dairy exports are sold as dairy ingredients across a range of market segments.

Fonterra's *Path to 2030* report (2021) forecasts that by 2030, approximately two-thirds of milk solids will be made into core ingredients. In May 2024, Fonterra announced a strategic decision to explore partial divestment of some of its core consumer brands (e.g. Anchor, Mainland and Fernleaf), as it commits to deepening its position as a world-leading provider of high-value dairy ingredients.

> ***From talking to banks, levy bodies, Federated Farmers etc, there seems to be limited understanding of precision fermentation and a perception that we won't experience disruption based on the lack of success some start-up alternative food companies have experienced (e.g. Beyond Burger).***
>
> **- Dairy Farmer**

> ***It's important that all stakeholders in the dairy system have their eyes wide open to the potential disruption that could be caused by precision fermentation. While it sounds like scaremongering and there isn't a nice tidy answer about what to do about it, the solution is not to bury our heads in the sand.***
>
> **- Dairy Farmer**

"New Zealand needs to develop knowledge and capability in fermentation to remain a competitive international food-producing nation. To date, achieving scale has been a major limiting factor for precision fermentation, but several observers predict significant disruption of the dairy sector within a decade. It is expected that the dairy ingredients market will be affected more than whole milk[2]."

2 L. Day et al. Fermentation for future food systems – What are the opportunities for New Zealand? 2022. The White Paper and other information on AgResearch's activities in precision fermentation can be found here.

Meat, in comparison to milk, is an inconsistent and more complex product, with different textures and structures [bone/muscle/fat], different cuts and different types of proteins. It's harder to replicate via alternative protein technologies.

Consumers have complex demands for alternative meat products, as we expect an authentic eating experience. We want the taste, texture and feel of alternative products to closely replicate that of meat products.

There have been some high-profile failures of start-up companies taking alternative protein meat products to market (created by other technologies – not precision fermentation).

The challenges in alternative protein meat have been driven by the challenge of creating an authentic eating experience, but also by a crowded market where numerous start-ups have competed for market share.

Government investment into alternative proteins around the world

Research has suggested that, globally, governments must collectively invest $3.4B GDP annually, to ensure we can produce the volume of alternative proteins needed to feed our global population by 2050[3].

The European Union has invested USD $155M into cellular agriculture.

The Netherlands has supported one of the world's largest protein facilities.

The United Arab Emirates has supported a precision fermentation facility in Dubai.

A report on government investment into alternative proteins[4] assessed the commitment of 10 governments to the alternative protein sector. The weighted assessment methodology considered national food strategies, levels of investment, timelines, regulatory environments, partnerships, infrastructure and facilities, aligned initiatives, and talent and capability. The results were:

★★★★★
Singapore
The Netherlands

★★★★
Australia
Canada
Denmark

★★★
Israel
United Kingdom

★
Ireland
New Zealand
Sweden

The Singapore Government has invested over $220M SGD in agrifood. There are over 60 alternative protein start-ups in Singapore, employing over 700 people[5]. Their level of investment in alternative proteins reflects their ambition to produce 30% of the food consumed in their country on and around Singapore Island by 2030.

> ***Precision fermentation technology is not going to go away. Food security will become increasingly important to governments and precision fermentation will be a key tool in their toolbox.***
>
> **- Dairy Farmer**

3 United Kingdom Foreign, Commonwealth and Development Office & ClimateWorks Foundations. 2021. Global Innovation Needs Assessment: Protein Diversity. https://www.climateworks.org/wp-content/uploads/2021/11/GINAs-Protein-Diversity.pdf.

4 Emerging Proteins NZ/ FoodHQ/ AGMARDT. 2022. Government Investment in the Opportunities of Alternative Proteins. Access the report here.

5 Singapore's Economic Development Board. 2024. Report here.

Why the resilience of our dairy sector is crucial to New Zealand

Dairy generates more than one in every four dollars of New Zealand's foreign exchange receipts from goods and services exports. It is New Zealand's largest goods exporter by a significant margin, accounting for 35% of goods exports[6]. The dairy sector directly employs over 50,000 New Zealanders.

Only around 7-8% of global dairy production is traded across borders, with most dairy produced and consumed in the country of origin. New Zealand is the world's fifth largest producer of milk overall, but the largest single-country exporter of milk products. Statistics vary year on year, but we are responsible for approximately 60% of the world's whole milk powder (WMP) exports and 12% of the world's skimmed milk powder (SMP) exports[7].

In the year to end of June 2023, dairy exports earned $26,008M NZD. Across all segments, China is our largest export market, but the table below highlights other key markets in individual dairy segments (note: not all segments are included in the table)[8].

Dairy product	Earnings $NZD (M) to the end of June 2023	Top three export markets
Whole milk powder	8274	China 31%, Algeria 12%, UAE 6%
Casein and other proteins	3320	USA 28%, China 23%, Japan 13%
Skim milk and butter milk powder	2673	China 32%, Indonesia 16%, Thailand 8%
Infant formula	1915	China 70%, Hong Kong 11%, Australia 8%

Our whole milk powder exports alone are worth $8.2B per annum.

If precision fermentation disrupts New Zealand's whole milk powder export market by 7% (for example) that's a $574M disruption.

If our processors can't find alternative markets and the market disruption equates to an equivalent loss in GDP, that 7% disruption to whole milk powder exports would be equivalent to losing our entire aquaculture sector ($528M). Some of the scenarios modelled in New Zealand research stretch to 20%+ levels of disruption.

The export of casein and other dairy proteins alone is worth over $3.3B to New Zealand per annum.

Our largest export market for these products is the USA, where companies such as Perfect Day are actively expanding their whey product range with several B2B partners.

Put into perspective, caseins and other dairy proteins (viewed as a distinct export industry, at $3.3B), is larger than our wine sector ($2.2B), seafood sector ($1.9B), or kiwifruit sector ($2.6B).

6 DairyNZ, 2023. Solid Foundations: Dairy's Economic Contribution to New Zealand. (Produced by Sense Partners). Access the report here.

7 Te Puna Whakaarounui. WELL_NZ: Alternative Protein 2022 – establishing a fact-base. 2022. Access the report here

8 MPI Situation and Outlook, December 2023. Access the report here.

Of course, all our exporting food and fibre sectors constantly face shifting headwinds, tailwinds and commodity cycles. Disruption over the next 10-20 years will come from several corners, including government strategies to improve national food security.

For example, a USD $3.5B investment (backed by Qatar) will create a new dairy system in Algeria (our second largest whole milk powder market), comprising 270,000 animals on 117,000 hectares. It's forecast to produce 1.7B litres of milk per annum and meet 50% of Algeria's powdered milk demand[9].

Some stakeholders feel it is unwarranted to put a spotlight on precision fermentation as a key potential disruptor, as market, consumer, regulation, climate and competitor driven disruption is 'always on our doorstep'. Other stakeholders feel its growth is another compelling reason to talk more, at a national level, about the resilience of our dairy sector.

Why this is important for Southland's dairy sector

The dairy sector is an important land use in Southland and a key contributor to the regional economy.

1 in 5 jobs in Southland is in the dairy sector.	Southland produces approximately 12% of New Zealand's dairy output.	Southland is home to over half a million dairy cows, spread across over 980 herds.	Southland produces approximately 265M kilograms of milksolids per annum.	Dairying is a key land use – over 220,000 hectares.

> *It feels like lots of discussion about intensity and efficiency is being aimed at dairy farmers, but there is less discussion happening about the long-term resilience of our industry.*
>
> **- Dairy Farmer**

> *There's a cost associated with building resilience and preparing for disruption. We need to talk through what all this means with our processers. We need to be more open with them about the guidance we need to position ourselves going forward. The problem is, the industry outside the farm gate is leveraged on volume.*
>
> **- Dairy Farmer**

> *Will we survive disruption? We're not sure. If the dairy industry 'takes a hit,' the hit will be felt at farm gate prices and in our margins. Even minor disruption will be untenable for dairy farmers carrying especially high levels of debt.*
>
> **- Dairy Farmer**

9 Qatari dairy developing record milk powder plant in Algeria. https://www.dairyglobal.net/dairy/milking/qatari-dairy-developing-record-milk-powder-plant-in-algeria/

Stakeholder insights

We asked **Jeremy Hill, Fonterra's chief science and technology officer,** for his thoughts.

Jeremy Hill MNZM has a PhD in biochemistry and has worked in the field of precision fermentation since the research and technology was emerging. Jeremy has worked in the dairy sector for over 30 years and is also an Adjunct Professor at Massey University.

Jeremy provided us with the following text:

- "The potential to produce analogue milk proteins using modified microorganisms and fermentation, otherwise known as precision fermentation, is a technology currently under development by a growing number of start-up companies, including Vivici BV, a start-up venture in The Netherlands spun-out of a collaboration between Fonterra and DSM. *(Jeremy is chair of the Vivici Scientific Advisory Board, having acted as its first chief technology officer).*
- Fonterra has been active in researching precision fermentation since 2018, including a minor investment in Motif, a Boston USA-based start-up looking to produce ingredients using precision fermentation.
- Fonterra has also undertaken a wide range of collaborations and contract research in precision fermentation with other research organisations. This includes VTT Technical Research Centre of Finland and jointly published research into the International Journal of Lifecyle Assessment, on a comparison of the carbon and water footprints of milk protein analogues produced by precision fermentation and milk proteins extracted from milk. The research showed that, contrary to claims by some start-ups and others, when appropriate and internationally accepted methodology is used, the footprints of protein from precision fermentation are not considerably lower than protein extracted from milk, and in fact could be higher.
- Fonterra's investments and collaborations have taught us that, although scaling precision fermentation to industrial scale is possible, numerous challenges must be overcome for precision fermentation to produce proteins at similar costs to those sourced from milk.
- Some of the claims being made about precision fermentation's superior economic or environmental performance still need to be validated.
- The technology is specialised and requires deep expertise to develop and commercialise. Getting the genetically transformed organisms to produce the right type of protein, in high amounts, then cost effectively separating them from the rest of the fermentation including the microbial cells (biomass), at a scale that is economically viable, is very challenging.

Milk will remain clearly differentiated from the alternative protein products made from precision fermentation. Crucially, milk is much more than just protein and contains a wide range of essential nutrients. Work undertaken by the Sustainable Nutrition Initiative at Massey University has found that milk's nutrient richness (range of essential nutrients in milk) and nutrient density (amount of those nutrients) means milk makes a disproportionate contribution to global nutrient provision.

Milk is 8% of total food biomass yet, in terms of global nutrient availability, provides 49% of food calcium, 24% of vitamin B2, 18% of lysine and contributes more than 10% for a further five indispensable amino acids, vitamins A, B5 and B12, phosphorous, and potassium.

Precision fermentation will not substitute the role played by milk in the short to medium term. It is very likely this will remain the case in the longer-term.

Precision fermentation technology will be complementary to milk-sourced protein. It will provide new options for consumers with specific preferences, and new ingredients food companies can use to formulate foods.

Fonterra plans to remain deeply engaged with the technology."

We asked **Paul Melville, Federated Farmers GM of policy and advocacy,** for his thoughts on precision fermentation.

Paul provided us with the following text:

"There are a number of hurdles to overcome before precision fermentation begins to impact New Zealand farmers.

For example, precision fermentation isn't yet cost competitive with pastoral agriculture, but even if it was cost-competitive in the future, there are hurdles around consumer acceptance of both the technology and the use of the feedstocks, such as sugar or maize, that would be needed.

If we did get to a point where precision fermentation was commercially competitive, I don't see a situation where precision fermentation is a big opportunity for New Zealand. Precision fermentation would require large quantities of sugar-based feedstocks and then obviously a large market of people who want the product. These sugar-based feedstocks are typically grown in tropical places like India, Brazil and Queensland.

New Zealand produces milk and meat because of our ability to grow grass and graze animals, and export this beyond our shores. If precision fermentation was commercially competitive, it would likely happen in a place that can grow huge quantities of sugar-based feedstocks or a place that has a large market of people, neither of which is New Zealand.

Ultimately, the way precision fermentation may impact New Zealand farmers is with a possible change in demand and price for the milk and meat we currently produce. However, precision fermentation is only one of a number of technologies or trends that could impact global food prices.

It's not possible for farmers or the government here in New Zealand to predict what the price of meat, milk or any other food type will be in 20 years' time, and we shouldn't try to. Today dairy is our biggest export earner, in 1990 it was meat, and in 1960 it was wool. Rather than predict what our biggest export earner will be in 2050, we should aim to provide the mechanisms needed for farmers to adapt to change as it occurs.

So rather than try to predict the future, in the face of this uncertainty we should aim to allow farmers to be productive, competitive, to change land use when they need to, and to have access to good bank finance to invest in new production systems. This way farmers have the power to adapt to change as it occurs.

Unfortunately, these things are all under threat by poor regulation holding farmers back."

We asked **Anna Benny, a food technologist and dairy farmer,** for her thoughts on precision fermentation.

Anna provided us with the following text:

"The New Zealand dairy industry is exposed because our distance to market, seasonal production variation, and the huge disparity between level of production and size of our local population means we need to process dairy into products that have a long shelf life and are tradeable, which means we produce huge amounts of powdered dairy ingredients.

Although precision fermentation only makes single components and is a very long way from replicating the nutritional and functional complexity of milk, it does pose a disruption threat to New Zealand. Unlike the rest of the world, in New Zealand we separate milk into its constituent parts and sell them as ingredients – 80% of Fonterra's milksolids go into the core ingredients stream.

The risk is not equal across the agricultural sector – the dairy sector is uniquely exposed. While meat is a complex product with different textures and structures which will be incredibly complex to successfully replicate, milk is always a homogenous liquid consisting of 87% water.

Individual protein powders are the lowest hanging fruit for precision fermentation to produce. Nestlé is an example of a key New Zealand ingredients customer with explicit goals around replacing animal-sourced ingredients with plants to help reduce their Scope 3 emissions (emissions from value chain activities, rather than emissions from their own assets). Nestlé's aims include 'leveraging our expertise in plant proteins to expand our dairy-alternative offerings' and 'constantly assessing opportunities to reduce our products' footprint, through changing recipes and by using alternative ingredients'.

How will we differentiate New Zealand milk from lab-produced substitutes? How will we compete in a world where our milk products can be made cheaper and more consistently in a different way, which also eliminates many production-related issues associated with dairy farming systems (e.g. animal welfare, methane production, nitrogen run-off, water consumption etc.)."

> ***The challenge – first of all – is collectively acknowledging that disruption is coming.***
>
> ***Then we need to make a collective plan around how we'll manage it. Our story lies in our natural product and our natural production processes, but is that differentiation going to be enough?***
>
> ***We can't drive our production systems harder to remain cost competitive, as that will undercut our point of difference***
>
> **- Dairy Farmer**

> ***As dairy farmers, carrying significant levels of debt, we have limited options when it comes to preparation for disruption. Our number one priority is paying down as much debt as possible, as soon as possible. Options for diversification are limited while the milk price is so good and we have so much debt to repay, but we are definitely considering our options.***
>
> ***We supply a dairy company that adds value to milk, have an A2 herd and try to exceed all environmental targets, so we can stay ahead of the curve.***
>
> **- Dairy Farmer**

We asked **Dr. Nikki Freed, Daisy Lab co-founder and chief science officer,** some questions.

We asked Nikki the following questions:

What key messages about precision fermentation would you like to share?

"Precision fermentation produces high quality, dairy-identical proteins with significantly less environmental impact compared to traditional animal farming. This innovation not only meets the growing global demand for protein but also aligns with a commitment to a more sustainable and ethical food system."

Should we be doing more to prepare for the potential impacts of precision fermentation?

"As precision fermentation technology advances, it has the potential to disrupt traditional agricultural and food production sectors.

New Zealand is particularly exposed to this disruption, as the New Zealand economy is heavily reliant on products that have the most potential to be impacted by precision fermentation – milk powder and dairy protein powder are bulk commodity ingredients with the potential to be most impacted by precision fermentation.

To manage these changes, we should prioritise the following collective actions:

- we need to provide economic incentives and support to farmers and industries affected by this transition, helping them adapt and integrate precision fermentation technologies
- we need to develop clear regulatory frameworks that ensure the use of precision fermentation is possible in New Zealand at scale
- we need to increase public awareness about the safety of precision fermentation, including the benefits from an ethical and sustainability standpoint to build consumer trust and acceptance.
- we need government and private investment in R&D to enhance precision fermentation efficiency, foster innovation, and broaden its applications to ensure New Zealand is at the forefront of this technology."

What could individual businesses do to prepare?

"Prepare by being informed. Individuals should learn about precision fermentation and explore the potential risks and benefits. Individuals can help shape policies that support both traditional and innovative dairy practices.

Dairy producers can focus on producing high-quality, specialty dairy products that cannot be easily replicated by precision fermentation. This includes artisanal cheeses, organic dairy products, and other niche items that emphasise New Zealand's clean, green image and the product's local origins.

Dairy farmers can explore diversification of income streams by investing in or partnering with precision fermentation technology companies. This could involve co-producing or processing of precision fermentation products alongside traditional dairy products."

‘Beyond Meat and Milk’ – protein future scenarios research

WELL_NZ: Alternative Protein 2022 – establishing a fact-base[10]

Te Puna Whakaaronui is the Food and Fibre Think Tank formed to support delivery of the Government’s *Fit For A Better World* programme. This Te Puna Whakaaronui report aims to ‘ground-truth’ the potential impact of alternative protein on conventional production in New Zealand, by understanding if and how it might disrupt New Zealand’s export profile. The report explores the impacts of alternative proteins replacing conventional dairy and meat to varying degrees.

The report includes some useful scenario modelling. In considering what the future scenarios might mean, the research notes a range of relevant factors: consumer willingness to try; consumer willingness to buy; environmental and climate regulation; geopolitics; commercial pressures; price parity with conventional protein; technical barriers; scaling of facilities; availability of operating inputs.

Summary points, paraphrased from the report, are:

- **there is consensus that any significant impact on conventional farming has the potential to create social and economic pain for New Zealand**
- **the work undertaken for the report cannot, and does not predict if, when or by how much, alternative proteins will disrupt conventional meat and dairy. But it does demonstrate that disruption is plausible**
- **managing global technological development and the speed that it will impact our conventional food production sectors, is beyond New Zealand’s control – but we can manage how well-prepared we are. ‘New Zealand simply cannot risk taking a reactive approach and waiting until disruption is a certainty.’**
- **Te Puna Whakaaronui’s view is that by 2030-2035 ‘it is plausible that there will be milk powders produced by precision fermentation on the market, able to be sold in commodity ingredient quantities’.**
- **the business model likely to impact New Zealand is the business-to-business sales of key dairy proteins as food product ingredients**
- **Te Puna Whakaaronui’s view is that disruption, if it occurs, won’t be total. ‘This is a question of how New Zealand stakes out and maintains a value proposition alongside the development of alternative proteins, should alternative proteins prove to be a significant challenge to conventional food production. Improving primary sector resilience to global shocks and significant change is critical.’**

10 Te Puna Whakaarounui. :WELL_NZ: Alternative Protein 2022 – establishing a fact-base. 2022. Access the report here

Unleashing Aotearoa New Zealand's Next Protein Revolution July[11]

This report was published by Emerging Proteins NZ and FoodHQ, and includes useful analysis of 10 major emerging protein sources, including precision fermentation. The report notes that:

- innovation in the protein supply market is rapidly expanding. We have been at the forefront of grass-fed, high-quality protein production but are in the backseat in the merging proteins race
- due to our limited resources, we need to make informed choices about where we invest into the development of emerging proteins
- plant-based milks – as we have seen in recent years, will compete with each other for market share. However, precision fermented milk is simply a different way to produce cow's milk and may prove to be more disruptive to conventional dairy production.

The report concludes there are four emerging protein sources that New Zealand may be best placed to explore further – hemp, seaweed, fungi, and grass and leafy greens. Changes to our regulatory settings are needed to make investment into precision fermentation in New Zealand more attractive. It also notes that, as a dairy producing nation, we need to remain aware of the investment in precision fermentation in other countries.

11 NZ Emerging Proteins / Food HQ, Unleashing Aoteroa New Zealand's next protein revolution, 2023. Access the report here

‘Beyond Meat and Milk’ – protein future scenarios research[12]

This research was commissioned by the My Land and Water National Science Challenge.

Key messages from this research are:

- we need to prepare for significant changes to our key food export markets
- alternative proteins are likely to significantly affect the global market for proteins, as food technology improves and diets change in response to concerns about climate change and animal welfare
- as technology improves, countries dependent on importing food from New Zealand will increasingly be able to produce more of their own alternatives to animal protein
- the dairy sector in New Zealand is more threatened by the development of new proteins, than our meat producers.

The research includes the modelling of four scenarios. One is a baseline scenario and the other three are a mix of rapid, conservative or stalled growth across precision fermentation, plant-based proteins and cellular proteins. They model impacts on variables such as land use, the economy, employment and greenhouse gas emissions.

We encourage readers to read the scenarios in full. Some of the headline metrics are confronting when viewed in isolation (e.g. a scenario where precision fermentation reaches price parity with dairy by 2025 leads to a 9% reduction of the New Zealand economy by 2035).

However – as always, with scenario forecasts – individual metrics need to be read within the context of modelling assumptions and methodologies. The three non-baseline scenarios forecast a range of reductions in our dairy, sheep and beef stock numbers, some very sizeable (two of the scenarios predict a reduction in dairy land use across New Zealand of over 700,000 hectares). Some scenarios of regional impacts are also provided.

Researchers call for a national policy or strategy to help New Zealand prepare for the risks and new opportunities associated with alternative proteins.

> **“We are already 3-5 years behind in some product classes [in the emerging protein sector] and do not have the resources to compete in many of these categories. Understanding where New Zealand can compete and create long-term value is critical.[13]”**

> **The possibility for New Zealand to add value to its land and traditional protein industries is attractive, exciting even, especially for existing sectors to apply their capability and infrastructure to build resilient, diversified landscapes and commercialise new products in new markets.**

> **Consequently, if we do not diversify our proteins sector, New Zealand risks losing the opportunity to develop new export markets to meet growing consumer demand seeking new food choices.[12]**

12 A collaborative research project undertaken by multiple providers for the My Land and Water National Science Challenge. 2024. https://ourlandandwater.shorthandstories.com/beyond-meat-and-milk/index.html

13 Te Puna Whakaaronui. 2022. WELL_NZ - Reframing New Zealand’s food sector opportunities. https://fitforabetterworld.org.nz/assets/Te-Puna-Whakaaronui-publications/Reframing-New-Zealands-Food-Sector-Opportunities.pdf

Ongoing challenges for the scale up of precision fermentation

Technology

Precision fermentation is an established technology and generally doesn't require new, major technical breakthroughs.

Previous R&D has focused on a small number of strains and target products. Commercialising new precision fermentation products will require time and capital to develop new strains, reduce production costs and scale-up production, rather than step-change technological innovation.

Although precision fermentation technology has existed for decades, the start-up, scale up and commercialisation steps remain challenging and will take time to perfect (although none are viewed as insurmountable).

- **Identifying and selecting the target product, e.g. identifying which of the hundred or so proteins in milk are the appropriate proteins to replicate.**
- **Selecting and developing the right strain of host micro-organism.**
- **Developing the right feedstock. Sugar is the preferred food of most strains used, but is expensive and not produced in the quantities needed for major scaling-up. Alternative feedstocks are being investigated but are not currently as efficient.**
- **The customising and scaling of extraction and purification processes must be perfected for each new target product/strain combination.**
- **Formulating end products/building recipes with ingredients made from precision fermentation[14]**

Capital investment

Commercial facilities that could produce 10,000+ annually are estimated to cost NZ$238-636M for new facilities or NZ$159-413M utilising repurposed fermenters[15].

14 Te Puna Whakaarounui. WELL_NZ: Alternative Protein 2022 – establishing a fact-base. 2022. Access the report here

15 NZ Emerging Proteins / Food HQ, Unleashing Aoteroa New Zealand's next protein revolution. 2023. Access the report here

Regulation

Compared to many other countries, New Zealand has more restrictive regulations. Precision fermentation is covered by novel food regulation, which regulates the importation of micro-organisms to produce a target product and approves the use of resulting products as a food ingredient (e.g. the soy-based 'heme' soy leghemoglobin has been approved as a food additive to the Impossible Burger).

New Zealand's stringent regulatory environment does not permit the domestic production of food from precision fermentation[16 17].

Although New Zealand's more complex regulatory regime may slow down precision fermentation start-ups onshore, the disruption from precision fermentation will be influenced by other countries and how they accelerate or hinder global trends in precision fermentation product substitution.

16 NZ Emerging Proteins / Food HQ, Unleashing Aoteroa New Zealand's next protein revolution. 2023. Access the report here

17 For more information, see Te Puna Whakaaronui. WELL_NZ: Modern genetic technology - what it is and how it is regulated. 2023. https://fitforabetterworld.org.nz/assets/Te-Puna-Whakaaronui-publications/WELL-NZModern-genetic-technology-2023.pdf

Thriving Southland wishes to acknowledge the valuable input from the stakeholders we approached to contribute. We offered stakeholders the option to contribute anonymously if they wished, and some opted to do this.

Thriving Southland – community-led, supporting 37 catchment groups with a dedicated team of coordinators. We provide free resources, support great events and empower farmers to take ownership of local issues so they can be addressed and resolved.

Our mission is for the Southland Community to work together for a better future for all.

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