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Milk Without a Moo

What's the Risk to the New Zealand Dairy Industry?

Kellogg Rural Leadership Programme

Course 43 2021

Anna Benny

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TABLE OF CONTENTS

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EXECUTIVE SUMMARY

The NZ primary industry is no stranger to disruption and has adapted over the years to deal with changing market, environmental and economic conditions. There is a new threat on the horizon: alternative protein, sometimes called lab grown, cultured or synthetic food. Alternative protein is not a new term and has not impacted the NZ primary industry in any major way so far. It would be easy to dismiss as a phenomenon that will happen elsewhere, that it won't affect the pasture raised, free range, high quality products from New Zealand. Having researched this topic for a year, I do not believe this is the case – here's why:

Dairy is the low hanging fruit for alternatives. Risk to the NZ primary industry from alternative protein is often considered in relation to the meat industry. Meat is a complex product, with many structural, textural, inconsistent aspects – different animals, cuts, types of protein etc. In contrast, milk is a homogenous product – it's always a liquid consisting of 87% water and 13% solids. The complexity of meat will be very complicated to replicate successfully using alternative technologies, but this is not the case for milk. Dairy, and particularly dairy ingredients, are seen as the 'low hanging fruit' for disruption.

New Zealand dairy exports are mostly used as ingredients in other foods. New Zealand is the largest dairy exporter in the world, growing from $2 billion of exports to $20 billion in just thirty years. A large proportion of NZ dairy products are used as ingredients in processed food. In 2021, Fonterra made 74% of the milk they processed into ingredients. New Zealand provides 60% of the world's whole milk powder exports, with a large proportion of this going to China to supplement their domestic milk production. The retail market for milk powder pales in comparison to the demand for drinking yoghurt, shelf stable milk and flavoured milk drinks which are most likely what Chinese food manufacturers produce with NZ milk powder.

When dairy products become ingredients in processed food items, they are treated as commodities, comparable with the same product specification (i.e. milk powder) made all over the world and competing only on price. They lose their origin story which is what New Zealand prides itself on. Consumers don't value the fact that the milk powder in their processed food such as a chocolate bar is made with NZ milk powder, so any competitive story associated with NZ production methods is lost.

Some of NZ's highest earning exports are first in line for replacement. Plant-based liquid dairy alternatives such as oat and soy milk are not a threat – New Zealand only exports a small amount of liquid milk. Alternatives are aiming to disrupt the business to business ingredients industry, the very same market that NZ dairy currently thrives in.

Ingredients with the functional properties of animal ingredients are being reverse engineered from plants. Individual proteins (whey and casein) are the initial targets for precision fermentation technology. Perfect Day is producing whey commercially, and others are set to launch in the next two years. Protein exports account for 10% of New Zealand's dairy export revenue - $2 billion in 2020. These are likely to be the first group of products which experience major disruption from alternatives. Cellular agriculture companies are developing technology to produce human breast milk for babies, could this replace infant formula made from cows?

There will be a tipping point. It's a long, intensive process to produce a tonne of milk powder. You need to grow a cow, complete with head, bones, hooves, tail etc. You can't milk her for the first two years until she's had a calf. Once she's in the milking herd, she needs enough food and water to stay alive, walk to the milking shed twice a day and produce milk. If there's enough grass in the paddock this will form the majority of her diet, it'll normally be topped up with supplementary feed such as hay or palm kernel expeller (PKE). The milk will be collected, driven to another location where the water (87% of milk) will be removed via spray drying, leaving just the 13% solids available to sell.

In contrast, precision fermentation technology bypasses the wasteful process above, using a tank of microbes consuming sugar to produce exactly the same molecules as milk – if they were assessed under a microscope, it would be impossible to tell whether they were from a cow or a fermentation tank. This technology has existed commercially for well over 40 years, producing components which used to be harvested from animals (insulin, rennet). It is now being leveraged at a far greater scale to produce components of milk, starting with protein.

Precision fermentation produced protein is predicted to reach price parity with traditional dairy within the next eight to ten years. The industry is not there yet though: the cost to produce insulin by precision fermentation is around $110,000/kg compared with a milk price of $9.90/kg, and precision fermentation start-up companies are signalling a bottleneck when it comes to manufacturing facilities to produce product at scale. Large multinational companies are becoming involved to assist with scaling up – fermentation experts ADM and AB InBev are working on large scale fermentation capacity for food grade precision fermentation rather than pharmaceutical which will start to bring the cost down.

The cost and waste involved in milking cows is far greater than simply fermenting a sugar feedstock. Once price parity is reached, food manufacturers who currently value NZ dairy ingredients for their high quality, consistent, cost effective attributes will have another option. In applications where dairy is anonymously used as a functional ingredient, it's highly likely these will move to the cheaper option which will have the additional benefit of helping meet sustainability goals and appealing to a wider variety of consumers (vegetarians and vegans). This will be the tipping point, where alternatives can displace traditional dairy.

New Zealand dairy needs to act now. This report identifies three key recommendations for the industry:

1. Acknowledge the risk and react - Alternative dairy, especially precision fermentation, represents a significant risk to the New Zealand dairy industry due to the reliance on commodity ingredient products which will be easiest to replicate. The sooner this can be accepted and acted upon the better. Advanced economies that NZ tends to compare itself with are moving rapidly – investing in research via partnerships between government, research institutions and industry. New Zealand risks being left behind.
2. Get involved - There's an opportunity to play a part in this emerging industry – New Zealand has significant expertise in key areas required for alternatives to scale up. Leveraging this will ensure NZ dairy will continue to be profitable in the long term and provide capital to invest in the infrastructure required to make milk into money in different ways.
3. Make milk into money differently – commodity ingredient products made without cows will become available at the same or better quality for the same or lower price within the next ten years. The NZ dairy industry is heavily reliant on spray drying of milk into powder; this will be one of the first products to experience disruption from alternatives. It's imperative that dairy companies identify the elements of their product portfolio which are at risk of disruption and pivot milk towards future-proofed products.

INTRODUCTION

THE MOST CONSEQUENTIAL DISRUPTION OF AGRICULTURE IN HISTORY

"If I had asked people what they wanted, they would have said faster horses" – Henry Ford. The way things have always been is tolerated because we did not have the new product to compare the old ones to. Rewinding cassette tapes and videos was tolerated until CDs and DVDs were on the market. Nobody had a huge problem with the cord on a landline phone until cordless models were introduced. Ice used to be the second largest export from the US until refrigeration technology reached a point where water could be frozen on demand anywhere in the world. Disruption can come from anywhere, accelerate quickly, and obliterate industries in its wake.

RethinkX, a US think-tank focused on technology-driven disruption, released their Rethinking Food and Agriculture report in September 2019 (Tubb & Seba, 2019). The first sentence reads:

> 'We are on the cusp of the fastest, deepest, most consequential disruption of agriculture in history'.

The report explores how the food industry could be revolutionised by advances in biotechnology, fundamentally changing the status quo of food production. Predictions include:

> By 2030, we expect almost 90% of US dairy protein to come from precision fermentation alternatives.

> Protein will be five times cheaper by 2030, ten times cheaper by 2035 than existing animal options.

Despite some sweeping assumptions and a US-focus, the report raises some interesting points. Precision fermentation technology has been used since the 1920s to produce insulin and rennet. Both are proteins which used to be extracted from animals. Applying the same method to produce food products does not seem a huge stretch of the technology.

Convergence of multiple, enabling inventions can accelerate the speed at which technology develops, in turn reducing the cost of production. Mobile phones exemplify this – the iconic Nokia 3310 was released in the year 2000, giving owners the ability to make phone calls, send text messages and of course, play Snake. The original iPhone was released just seven years later in 2007 and took advantage of a convergence of developments in touchscreen technology, 3G internet, digital photography, lithium-ion batteries and processing capability to launch a product far superior to the Nokia 3310.

Figure 1: Mobile phone technology progress in just seven years. (Wikipedia, 2021)

In a similar fashion, advances in precision biotechnology, robotics, genome sequencing and computing power are now converging to enable new ways of producing food. To feed a population of 9.7 billion humans in 2050, while balancing the health of our planet is going to take a radical rethink of the way food is produced.

IT WILL SOUND RIDICULOUS UNTIL IT HAPPENS

The phrase 'it will sound ridiculous until it happens' is from Richard Fowler's 2016 Nuffield Study, "Will it Have Legs?", in reference to McDonalds offering a veggie burger range. Just 5 years later, McDonalds have partnered with Beyond Meat to launch the McPlant burger. Burger King has an entire plant-based section of the menu.

At the time of his study, Richard met with Dr Mark Post at Maastricht University and saw what $10,000 of cell cultured meat looked like (see photo below left). In 2021, just 5 years after Richard's visit, Eat Just's cell

Figure 2: Advancement in cellular meat between Richard Fowler's Nuffield (Fowler, 2017) and cellular meat available for home delivery (Good Food Institute, 2021)

cultured chicken (photo below right) became available for home delivery via an app in Singapore (Good Food Institute, 2021).

Alternative protein is a phenomenon attracting huge sums of money from investors, a growing following of supporters and mixed views from commentators. The pace of change is ramping up, and even over the course of this research project the number of players entering the market has exploded.

To some, switching from animal-derived products is one of the best ways to save the planet; ridding ourselves of greenhouse gas emitting ruminants without having to compromise on burgers and lattes. Others believe the industry to be simply another competitor in the marketplace, one that will never come close to replicating the quality, scale and eating experience of the existing meat and dairy industries.

I'm not the first Kellogger to focus on alternative protein - there have been a wide range of projects that set the scene for this report (Briggs, 2017, Fowler, 2016, Young, 2018). Key drivers for a move to alternative protein identified include:

- A need to produce more food to support a growing population - there is a 56% food gap between what we make today and what we will need by 2050 (World Resources Institute, 2018)
- Environmental concerns, climate change and sustainability
- Increasing consumer awareness around animal health and welfare

Recommended actions from previous Kellogg/Nuffield reports broadly identify four recommended future focus areas for the New Zealand agriculture industry:

- Acknowledge, understand and address factors behind consumers shifting to alternative diets.
- Build on New Zealand's reputation for quality, natural, nutritious products targeted at consumers willing to pay higher prices and look to add value where possible.

- Investigate where New Zealand can be involved in this growing industry through partnerships with existing players, favourable policy and building technical expertise.
- Grow awareness of the subject within New Zealand agriculture.

My ambition for this project is to build on these findings and tailor recommendations specifically for the New Zealand dairy industry using the most up to date information available on this fast-moving topic.

AIMS, OBJECTIVES AND METHODS

1. WHAT PRODUCTS ARE MADE FROM NEW ZEALAND DAIRY, AND WHO BUYS THEM?

I work as a Technical Manager in the dairy industry, optimising processes and equipment at large spray-drying plants such as those at Fonterra. It's part of my job to understand the equipment and the products made in dairy plants. Spray dried commodity milk powders make up the vast majority of production, with much less focus on the 'value add' rhetoric we regularly hear about as farmers.

New Zealand exports 96% of the dairy products it produces (Appleton, 2019). A significant proportion is sold as commodity products such as whole milk powder, used as an ingredient in the manufacture of consumer goods. According to RethinkX (Tubb & Seba, 2019), commodity ingredients are most at risk of displacement from dairy alternatives.

This study will utilise publicly available production and export information combined with industry expertise to investigate the mix of products NZ produces and exports to the world.

2. HOW LIKELY ARE VIABLE ALTERNATIVES TO THE MILK PRODUCTS PRODUCED IN NEW ZEALAND?

I have a degree in Food Science and Nutrition and am currently completing the Massey University Diploma in Dairy Technology. I have been following the progress of novel methods for creating protein for a while now and have a basic understanding of how they work.

There are millions of dollars being invested into research and development to bring these products to market, and some influential food companies becoming involved and helping to advance the technology. Limitations are often cited as ability to scale up to commercial viability, availability of raw materials (energy and feedstocks), consumer acceptance and regulatory approval.

This report will investigate emerging dairy alternatives to investigate:

- What are the alternatives and how are they produced?
- What is currently available for consumers to purchase?
- Factors affecting likelihood of success.

This will be achieved using information in publicly available reports, podcasts and online sources combined with conversations with industry experts (please see Appendix 2 for list of contributors).

3. WHAT'S THE RISK TO NZ DAIRY? WHAT SHOULD THE INDUSTRY BE DOING NOW TO STAY RELEVANT IN THE LONG TERM?

I live on a dairy farm in South Otago and am acutely aware of how much work goes into producing high quality milk, whilst maximising animal health and minimising effects on the environment.

Large investments are often calculated with a long payback period and it concerns me that the industry could look very different in ten years. My husband and I welcomed our first child this year – if he wanted to continue the family farm, how can we make sure the business is future proofed for him?

My hope for this project is to create a balanced view of the risks to the NZ dairy industry from alternative products and identify focus areas to help us maintain relevance into the future.

PART 1: WHAT PRODUCTS ARE MADE FROM NEW ZEALAND DAIRY, AND WHO BUYS THEM?

THE WORLD'S MILKMAN

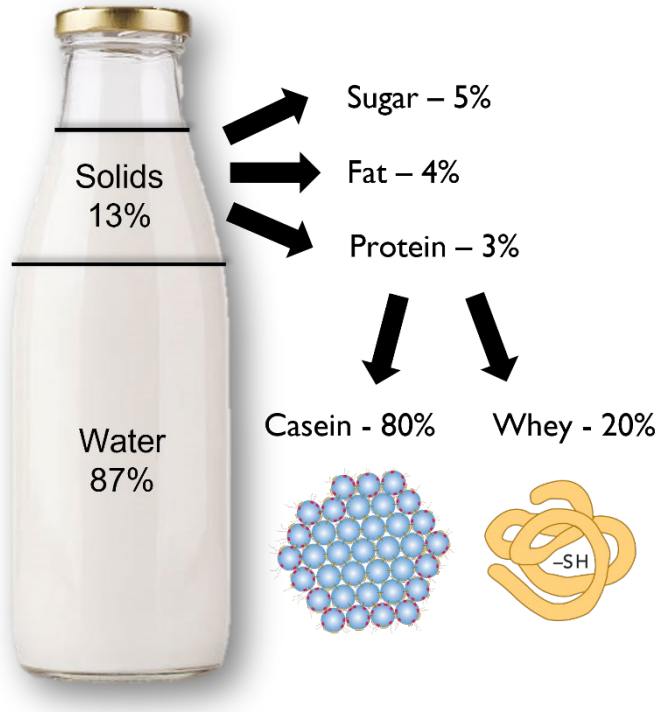
Milk is normally consumed in the country of production. In 2014, only nine percent of global milk production was traded across country borders (Shadbolt & Apparao, 2016).

Despite its small geographical area and population, New Zealand accounts for around a quarter of this globally traded milk. To put this in context, less than four percent of the milk that Kiwi dairy farmers proudly produce is consumed within New Zealand (Appleton, 2019). The remainder is traded overseas with global customers.

New Zealand is unique in the OECD for the sheer scale of our agricultural product export industry. We rely heavily on primary producers to contribute to the wealth of the country. Dairy products contribute around one in every four dollars earned by New Zealand exports. The export value of NZ dairy has grown from around $2 billion per year to almost $20 billion in 30 years. The industry employs around 50,000 people and generated $3.4 billion in wages in 2019. (Dairy NZ, 2020).

DAIRY CHEMISTRY

Milk is an incredible liquid, designed to be the single source of nourishment for vulnerable infant mammals. Cow's milk is made up of 87% water, 4% fat, 3% protein and 5% sugar with the remainder being vitamins, minerals and ash (Tetra Pak, 2015). Milk is not simply a mixture of these components floating around in a liquid together – there are complex chemical bonds and interactions between them. The fat, protein and sugars are often collectively referred to as the 'solids' and in New Zealand farmers are paid for the solids content rather than the volumetric amount of their milk. Even the value of a cow (her 'production worth' or PW) is influenced by the number of solids she produces, and this is a selection factor when it comes to breeding – the New Zealand herd is optimised to produce milk solids.



There are two different types of protein in milk: casein and whey. Each has a very different structure and therefore a different function in food. Most of the protein in milk (80%) is in the form of casein.

Casein is a unique protein which has a specific folded structure and can link with other casein molecules to form complex structures called micelles. These structures are key to the functionality of certain foods, most notably cheese. The casein allows cheese to ooze, melt and stretch in a way that no other product does. Casein micelles are responsible for the white colour of milk, as they are large enough structures to scatter light so that the liquid is not see-through.

The remaining 20% of the protein in milk is whey. Whey is highly nutritious and is widely used in the food industry due to its' vast functional properties.

The sugar in milk is called lactose. For some people, it can cause gastrointestinal symptoms – this is due to a lack of the enzyme lactase within the body, so the lactose cannot be broken down. A meta-analysis completed by The Lancet estimated that approximately two thirds of the world's population had some level of lactose malabsorption. Just 10% of Kiwis were found to be lactose intolerant, compared with 85% of Chinese (Storhaug, Fosse, & Fadnes, 2017).

DAIRY PROCESSING

Almost all the milk produced in New Zealand is sold overseas, yet New Zealand's remote geographical location means our export goods travel a long way to reach the end consumer. One way the industry copes with this challenge is to reduce the physical volume and extend the shelf life of the dairy products that are exported.

Milk from New Zealand is usually spray dried into a powder. This reduces the volume by removing nearly all the water, which lengthens the shelf life significantly. Depending on the fat content, the milk powder is either categorised as skim or whole milk powder.

Figure 3: A Fonterra dairy processing plant (Fonterra, 2021)

To spray dry milk, the solids are concentrated by evaporating off as much water as possible. With 87.3% of milk being water, this significantly reduces the volume of liquid. This thick concentrate is then fed into large spray driers which atomise the particles and turn the liquid into powder. The process is tightly controlled, and powder specifications can be customised depending on their intended final use. The tall buildings you can see at dairy factories house these spray dryers which are impressively large pieces of machinery – the photo below is from Fonterra Darfield which has two spray dryers, the largest of which was the biggest dryer in the world when it was built in 2013, able to process 30 tonnes of milk powder per hour (GEA, 2021).

Cream is typically made into butter, cheese or anhydrous milk fat (AMF). Butter and cheese are produced by separating the solid fat from the water component, which condenses the cream into a product with a smaller volume and longer shelf life than raw cream. AMF is an oil-like substance, sold in drums and can be up to 99.9% pure dairy fat. It is used by food manufacturers to make chocolate, confectionery, ice cream, baked goods and processed cheese (New Zealand Milk Products, 2021).

DAIRY PROCESSORS

Milk production in New Zealand is seasonal. Milk volume peaks around late spring each year when cows have recently calved and have plenty of grass to eat, then drops off in the winter as grass stops growing and cows are preparing to calve in spring. This milk all needs to be processed within days of leaving the udder. Most overseas dairy farming systems don't experience such seasonality as they do not synchronise their calving dates to be at the same time the way the New Zealand system does. Cows calve all year round, and supplementary food such as grain is utilised rather than relying on grass growth.

As most Kiwi milk is exported, primarily as whole milk powder, sufficient capacity at dairy processors is required to deal with this peak amount of milk. This has required large investment into processing facilities and resulted in a lot of equipment available for milk processing - some of which is only used for a few months of the year when milk volumes are at their highest. Unlike countries where milk is primarily sold as liquid and there can be multiple small processors, New Zealand dairy processing is mostly concentrated to a few companies who have both the capital and milk supply to run the cost-intensive spray-drying plants.

This requirement for capital intensive processing plants has resulted in many dairy processors operating via a co-operative structure, where the farmer suppliers own the processing facilities via a shareholder structure. Fonterra is NZ's largest co-op and the world's largest supplier of whole milk powder. It is the sixth largest dairy company in the world with a turnover of NZ$20.5 billion in 2020 (Rabobank, 2021)

Open Country Dairy is the second largest supplier of Whole Milk Powder to the world but is run as a private company rather than a co-op (New Zealand Productivity Commission, 2020). While Open Country Dairy focus on mass producing commodities like whole milk powder and cheese which are sold to other food companies,

Fonterra produces both bulk commodities and specialised consumer products. Fonterra's major customers include Nestlé and Kraft Heinz - both large, processed food manufacturers.

There are also smaller producers such as Tatua who focus on more complex products such as hydrolysates, bionutrients, caseinates and whey compounds, and Mataura Valley Milk (now owned by The A2 Milk Company) who specialise in Infant Formula production.

DAIRY PRODUCTS

TRADED COMMODITIES.

Commodity: A product that is the same as other products of the same type from other producers or manufacturers. (Cambridge Dictionary)

Commodities such as whole milk powder, butter, AMF and cream contributed to well over 50% of the dairy export revenue in the 2020 season. When you add in skim milk powder and cheese, commodity traded products accounted for almost 75% of the dairy export revenue for NZ in 2020. The table below from State and Outlook for Primary Industries (Ministry for Primary Industries, 2021) shows the revenue each product type contributes to the New Zealand Economy.

Table 3: Dairy export revenue 2017-25 (NZ$ million)

	Actual				Forecast				
Year to 30 June	2017	2018	2019	2020	2021	2022	2023	2024	2025
Whole milk powder	5,271	5,818	6,675	7,565	7,390	8,250	8,080	8,170	8,290
Butter, AMF, and cream	2,794	3,812	3,612	3,365	2,840	3,030	2,930	2,930	2,960
Skim milk & butter milk powder	1,385	1,228	1,323	1,792	1,580	1,800	1,820	1,850	1,900
Casein & protein products	1,735	1,601	1,574	1,997	1,930	1,850	1,890	1,920	1,960
Cheese	1,830	1,905	1,965	2,074	2,060	1,910	1,970	2,040	2,100
Infant formula	778	1,240	1,641	1,851	1,600	1,870	2,300	2,560	2,780
Other dairy products*	845	1,050	1,318	1,492	1,640	1,700	1,750	1,930	2,030
Total	14,638	16,655	18,107	20,135	19,050	20,420	20,730	21,400	22,020
% Change	+10.1%	+13.8%	+8.7%	+11.2%	-5.4%	+7.2%	+1.5%	+3.2%	+2.9%

Source: Stats NZ and MPI.
* Other dairy products include: liquid milk and cream, ultra-high temperature milk, yoghurt, and ice cream.

Figure 4: Dairy export revenue table (State of the Primary Industries, 2021)

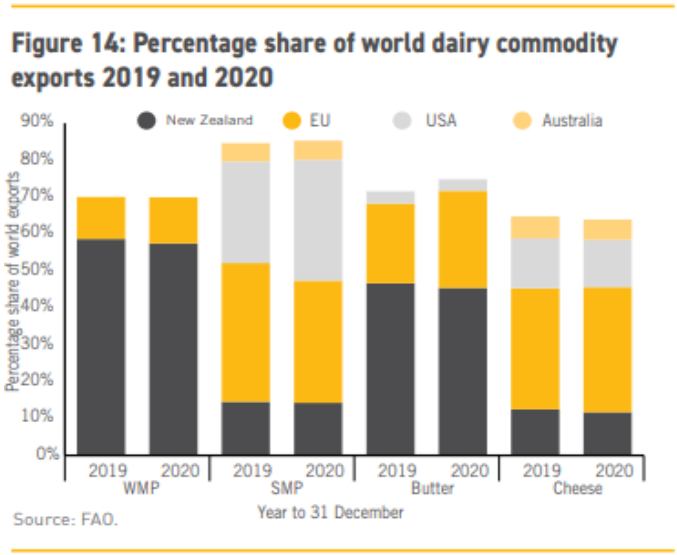


Figure 5: Percentage Share of World Dairy Exports 2019 and 2020 (MPI, 2021)

New Zealand is by far the largest exporter of whole milk powder in the world. The graph on the left from State and Outlook for Primary Industries (Ministry for Primary Industries, 2021) shows that we are nearly 60% of the world's whole milk powder exports, with the EU being second in line with just 10% of global exports. New Zealand butter also has a significant portion of the market.

New Zealand Milk Products (NZMP) is Fonterra's dairy ingredients business (Fonterra Co-Operative, 2021). It's a great place to get an overview of the types of products that can be produced from milk, and I'd highly recommend any dairy farmer to access the site at https://www.nzmp.com and view the ways their milk is packaged and marketed. The product catalogue outlines suggested uses for each product (New Zealand Milk Products, 2021). A full table of products and uses can be viewed in Appendix 1. Milk powders are commonly used as ingredients in bakery and confectionary products, ice cream and beverages. The cheese marketed by NZMP is recommended for processed cheese and pizza production. Anhydrous milk fat is sold in 200L drums and used in the manufacture of bakery products, sauces and processed cheese.

Despite aspirations to grow the 'value add' side of the business, Fonterra's proportion of sales revenue from consumer goods and food service compared to ingredients has remained fairly static. Fonterra's Path to 2030 report (Fonterra, 2021), contains the table on the right showing an aspiration to reduce the amount of milk solids used for 'Core Ingredients', and use the milk instead for Consumer, Food Service and 'Active Living' products with $1bn investment targeted at achieving this goal, with a particular focus on growth in Food Service via new product development. In 2030, they still expect around two thirds of the milk solids to be made into 'Core Ingredients'.

	Actuals			Financial Profile Assumption	
Utilisation of New Zealand Solids	FY19	FY20	FY21	FY24	FY30
Consumer	7%	7%	7%	8%	9%
Foodservice	8%	8%	9%	12%	14%
Active Living	10%	10%	10%	11%	12%
Core Ingredients	76%	75%	74%	70%	64%
Total	100%	100%	100%	100%	100%

Figure 6: Utilization of New Zealand Milk Solids by Fonterra (Fonterra, 2021)

Dairy Tomorrow, a report focused on the future of New Zealand dairying (Dairy NZ, Federated Farmers, DCANZ, Dairy Womens Network, 2017) acknowledges the importance of commodities to the industry and recognises that these products are used most often as ingredients in other products.

> "Commodities will always be an essential part of the New Zealand dairy value chain. Commodities are products that are largely standardised, have a fairly uniform 'world' price and are largely used as an **ingredient in other products**."

Interestingly, the same report also outlines New Zealand's competitive advantages in the market due to our pasture-raised products, cost efficiency, animal health credentials and naturalness. While consumers increasingly value animal health and welfare and 'naturalness' traits, do the same values apply when selecting manufactured food products? The slide on the right is from the Fonterra site induction. It shows the wide variety of consumer products their milk goes into such as 2 Minute Noodles, KitKats and M&Ms. These products may not be the best showcase for milk from high welfare, grass-fed New Zealand cows.

Figure 7: Slide from Fonterra's site induction (Fonterra 2021)

Food processing companies want to make their products appealing to the maximum number of potential customers. With allergy considerations and more people choosing to avoid animal protein altogether, this creates an incentive for food products to be formulated without animal-sourced products as ingredients, especially where there is an appropriate non-animal alternative. An example of this is in the alcoholic beverage industry, where a protein called isinglass is traditionally used to clarify liquids. Isinglass is obtained from the bladders of fish, so drinks prepared with isinglass are unsuitable for vegans, vegetarians and people with fish allergies. On the Guinness website's frequently asked questions page, the first topic of concern is

Figure 8: Guinness website Frequently Asked Questions (Guinness, 2021)

whether Guinness is suitable for vegans (Guinness, 2021).

It makes sense for food producers to formulate/reformulate their products to remove ingredients which customers find unappealing or are unable to consume due to health reasons. This has further accelerated research and development into non-animal derived ingredients, particularly where animal-derived ingredients would not technically be expected to be present.

ADDED VALUE

Technological innovation has enabled individual proteins to be isolated from milk. One example is whey protein, a waste product from the cheese-making industry (Rabobank, 2020), which makes up just 0.6% of cow's milk (Tetra Pak, 2015). The protein is extracted from milk and processed using filtration equipment to differing levels of purity, with whey protein isolate being the purest form at around 90% protein. This is made into consumer products such as sports recovery drinks/shakes or added protein snacks. Snack products with additional protein have seen a rise in consumer popularity in the last few years - the number of new whey protein product launches worldwide in 2017 was up 6.6% from 2016 and more than double the number of introductions in 2012 (Rabobank, 2020). Casein and protein products contributed nearly $2 billion dollars to the NZ economy in 2020, more than skimm milk powder or infant formula.

Infant formula is a growing market, with export volumes increasing around 28% over the past 5 seasons (NZX Limited, 2019). China's move away from a one child policy should further increase demand for such products. Cow's milk is formulated very differently to breast milk, so to produce infant formula manufacturers need to adjust the protein type and content, fortify with additional ingredients which are naturally present in breast milk and replace the dairy fat with vegetable sourced fats (Tetra Pak, 2015). Infant formula recipes are an

industry secret, but anecdotally can use as little as 20% milk, with the remainder of the ingredients made up of vegetable oils and sugars – image below of ingredients in a pack of Karicare 1 Baby Infant Formula.

INGREDIENTS:
Milk solids, vegetable oils (contains **soy**, antioxidant (ascorbyl palmitate, citric acid)), maltodextrin, galacto-oligosaccharides (contains **milk**), dried omega LCPUFAs (contain **fish, milk, soy**, antioxidant (mixed tocopherols, dl-alpha tocopherol, ascorbyl palmitate, sodium ascorbate, citric acid)), long chain polyfructose, emulsifier (**soy**, lecithin), taurine, choline chloride, L-carnitine, inositol.

MINERAL:
Potassium, calcium, chloride, phosphorous, sodium, magnesium, iron, zinc, copper, iodine, manganese, selenium.

VITAMIN:
Vitamins (A, B_1, B_2, B_3, B_5, B_6, B_{12}, C, D_3, E, K_1), folic acid, biotin.

Figure 8: Ingredients in a pack of Karicare Infant Stage 1 formula (Karicare, 2021)

Fluid milk and other dairy products contributed $1.5 billion to the NZ economy in 2020. Some manufacturers such as Oceania Dairy produce shelf-ready UHT milk, packaged into 250ml cartons and send these directly to China where it is a highly sought-after product. Sales of liquid milk in China have been particularly strong since the Chinese government promoted milk to boost immunity in the wake of the COVID19 pandemic. Other specialised ingredients include pre and probiotics and lactoferrin (a bioactive whey protein), used as nutraceuticals to boost nutrition credentials of food products.

WHO BUYS NEW ZEALAND DAIRY PRODUCTS?

The below infographic is from State and Outlook for Primary Industries 2021 and is a fascinating breakdown of the types of products exported to different countries – it demonstrates the huge variation in product mix between major markets. China is a key market for New Zealand exports, and in the year to March 2021 39% of dairy export revenue was from China. The next largest market for NZ dairy exports is Australia, worth just 6%

Figure 9: New Zealand Dairy Top 10 Export Destinations (MPI 2021)

of the dairy export revenue, which really highlights the significance of China as a key market for NZ dairy (Ministry for Primary Industries, 2021).

CHINA – 39% OF NZ DAIRY EXPORT REVENUE

China is the second largest consumer of dairy products in the world, and the third largest dairy producer. (DuBois, 2019). This is no surprise considering China is the world's most populated country.

Around half of China's purchases from New Zealand are milk powders (whole and skim), with a further quarter being infant formula and other dairy products (likely UHT milk). Fat products (butter, cream and cheese) only make up a small proportion of the dairy that China imports.

In NZX's report, New Zealand Dairy Outlook 2019 - A Sustainable Dairying Future (NZX Limited, 2019), the importance of commodity dairy into China is discussed – China needs imports to meet domestic demand. However, the report also reminds us that NZ is not the only producer of milk powders, and China's primary decision driver is purchase price, although consistency of supply is also important:

> "Don't think your powder is special though. The storerooms look like the United Nations of milk powder with **SMP or WMP from all around the world being anonymously added to their product** brands.

Dairy consumption in China is very different to New Zealand and it does not play a traditional role in the Chinese diet. The promotion of milk as a health product has greatly increased its appeal, particularly during the COVID pandemic where it's been promoted for immune benefits.

The graph below is from a 2018 MPI report intended to assist New Zealand dairy companies seeking to grow market share in China (MPI, 2018). The largest retail volume is sold as drinking yoghurt – small bottles, similar to the brand Yakult in NZ. This category is predicted to reach $39 billion by 2023.

In contrast, milk powder is expected to be worth just $4.9 billion in the same timeframe, with growth coming from value-added nutritional products rather than volume growth. Examples of value-added milk products are those targeted at expectant mothers and the elderly. Infant formula continues to be a high value product in

China, despite the unremarkable product volumes.

Figure 2: 2018 Retail volume of various product categories in China (in million litres or kilograms).

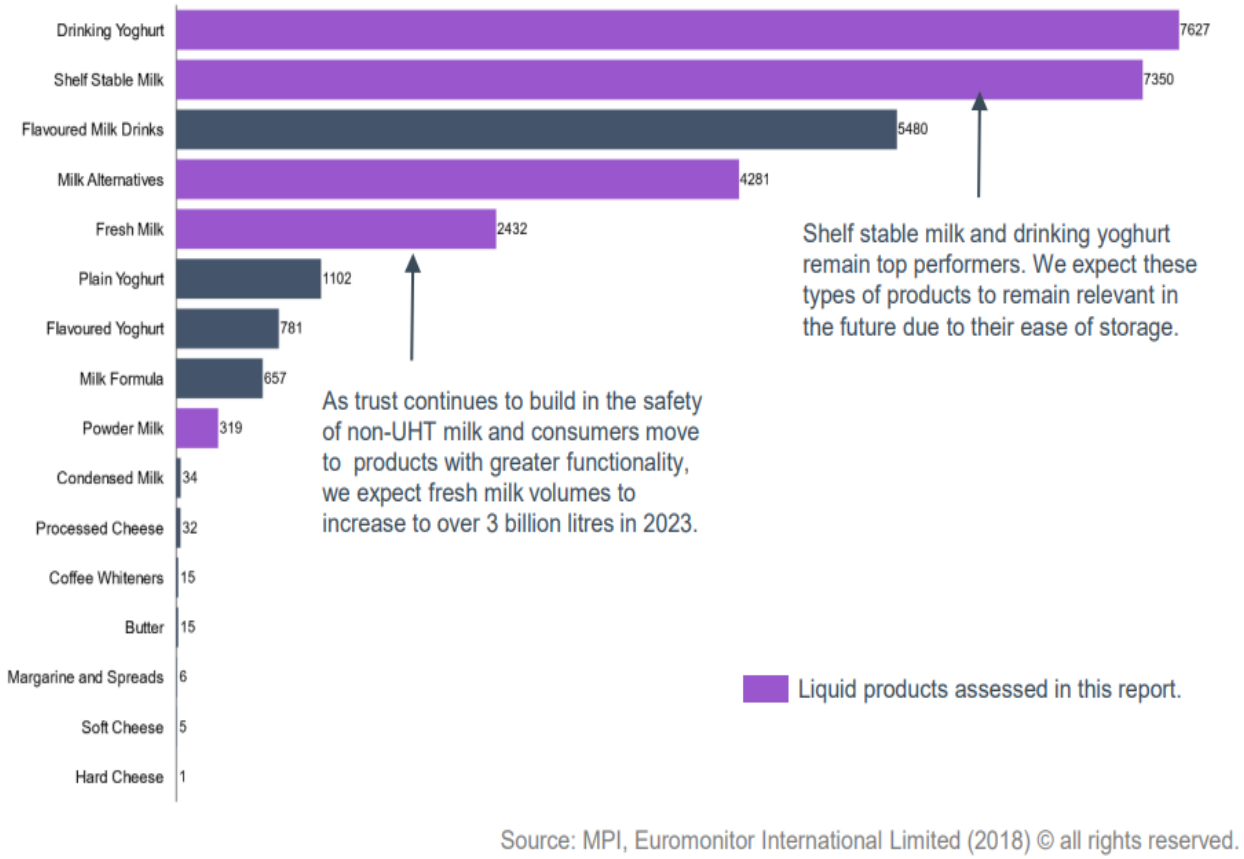


Figure 10: Retail Volume of Product Categories in China (MPI, 2018)

Market-led innovation is going to play a key role in ensuring the Chinese dairy market continues to be a strong export destination for New Zealand Dairy. Yili are a large player in Chinese dairy production and also operate two plants in New Zealand. A recent article on their product development initiatives (Food Navigator Asia, 2021) showcased award-winning carrot flavour ice cream, cheese bubble yoghurt, anti-diabetes milk powder, sparkling water with added milk minerals and high protein plant based milk. Many of these innovations would not succeed in the NZ market, but for dairy companies to continue to achieve success in China it's important to appreciate the types of products that do well in the Chinese market. Fonterra has application centres throughout China for this purpose. On their NZMP website, innovations include probiotic ingredients, immune boosting products and milk phospholipids to support mental wellness.

There are low price yoghurt drink options on the market which are reconstituted from New Zealand milk powder in China such as the Jelley Brown yoghurt shown below – this sits at the lower end of the price spectrum for drinking yoghurts in China. On the one hand, this is a good market for selling high volumes of New Zealand milk powder, especially when you consider the size of the drinking yoghurt market in China. However, if manufacturing of products bearing a New Zealand origin message is taking place offshore, it also represents a loss of control of product quality and safety.

Brand:	Jelley Brown
Price:	$2.05
New Variety:	May 2015
Weight:	4 x 100ml
Packaging:	Plastic bottles

The product is made using selected milk from New Zealand, Danish Danisca exclusive bacteria, and Howaru NCFM bacteria. The drink is free from cholesterol, trans fat, preservatives and artificial sweeteners.

Figure 11: Example of drinking yoghurt product sold in China (MPI, 2018)

New Zealand agriculture prides itself on a grass-fed, free range system, however according to MPI's Dairy in China report, product claims such as 'grass fed' are received differently in China with no correlation between claims around grass fed and higher pricing (MPI, 2018). In fact, many low-cost dairy products claim to be grass fed. The report found messaging is inconsistent and there is poor quality control on claims. The report even found some on pack messaging seeming to confuse 'pasture fed' with 'pasteurised'.

At this stage, our analysis indicates there is no evidence that pasture / grass-fed products are a reason for a product to be priced higher than others.

OTHER KEY MARKETS FOR NZ DAIRY

Malaysia, UAE, Saudi Arabia, Thailand and Indonesia are important markets for milk powder. Japan has a different product profile - over half of their NZ dairy imports are fat products. They also purchase a lot of 'protein products', as do the USA – in fact it is the majority of what the US imports.

CONCLUSIONS

New Zealand is disproportionately reliant on exporting agricultural products, especially dairy, compared with other countries in the OECD. The sector supports a large portion of the economy and provides employment for many Kiwis.

When farmers see the tanker driving away after a collection, it's nice to assume their carefully produced milk is off to be enjoyed by a grateful consumer drinking a nice cold glass, adding it to their morning coffee or pouring it on cereal. The reality is that around three quarters of the milk processed by Fonterra will be turned into ingredients for use by a food manufacturer. It could be made into biscuits, chocolate bars or powdered drinks. These types of products are not traditionally purchased based on their sustainability credentials, particularly not for a minority ingredient that a consumer may not expect to be there in the first place. Have you ever wondered about the welfare of the cows who produced the milk powder in your KitKat? Their packaging shows information around their cocoa credentials, yet milk powder is closer to the start of the ingredients list (meaning there is more in the product) and there is no mention of where it comes from.

Ingredients

Sugar, Full Cream Milk Powder, Wheat Flour, Cocoa Butter, Vegetable Fat (Emulsifier (Soy Lecithin)), Cocoa Mass, Cocoa, Glucose Syrup, Emulsifiers (Soy Lecithin, 476), Yeast, Raising Agent (Sodium Bicarbonate), Salt, Flavours

Figure 12: KitKat ingredients (New World, 2021)

China is an important export market, buying over a third of New Zealand's dairy production. China mostly purchases milk powder, but the retail market in China for other dairy products such as yoghurts and liquid milk is far more valuable than milk powder. It's likely that Chinese manufacturers are buying NZ milk powder and using it to produce these products in country.

PART 2: HOW LIKELY ARE VIABLE ALTERNATIVES TO NEW ZEALAND DAIRY PRODUCTS?

To pose a threat to New Zealand dairy products, alternatives will need to be high quality, available at scale and accepted by consumers both in terms of taste/texture and production methods. There are three ways milk alternatives are produced:

- **Plant-based** - utilising ingredients such as soy, nuts or oats combined with water to produce a milk-like substance. Examples: Oatly, Silk, Alpro
- **Precision fermentation** – programming micro-organisms such as yeast to produce molecules such as proteins, fats and vitamins then combining these to produce a milk product or replicate dairy ingredients. Examples: Perfect Day, New Culture
- **Cell culturing** – taking existing milk-producing (mammary) cells, culturing them to increase their number, then using these to produce milk outside of the body of the mammal. Example: BIOMILQ, Turtle Tree Labs

As the first chapter demonstrates, much of New Zealand's dairy (46% of export revenue) is exported as whole or skimmed milk powder to be further processed by manufacturers overseas. NZ milk is also converted into infant formula (9%) and individual protein products such as casein and whey (10%). Cream is made into butter or AMF (15%), and cheese (11%). This chapter aims to further investigate the viability of plant based, precision fermentation and cell culturing methods to disrupt the specific types of dairy products produced in New Zealand. Will it render the NZ dairy industry obsolete? Or is Sir Keith Woodford correct in describing this technology as "science fiction led by shock-jock communicators" (Woodford, 2020)?

This section of the report looks at each of the production methods in turn to understand:

- What are the alternatives and how are they produced?
- What is currently available (as milk or an ingredient) for consumers to purchase?

It will then go on to assess the factors affecting likelihood of success of these alternatives.

PLANT BASED

WHAT IS IT AND HOW IS IT PRODUCED?

Plant based milks are milk-like substances produced from a nut (e.g., almond, cashew), seed (e.g., sesame, pumpkin), grain (e.g., oat, rice) or legume (e.g. soy, pea). Methods of production primarily involve steeping the plant with water, and then adding vegetable oils such as sunflower into the mix to increase the fat content. New Zealand does not export liquid milk in any great quantities, so these liquid, consumer-branded products do not pose a big risk to the dairy industry.

New Zealand does, however, export a huge amount of dairy-based ingredient products (milk powders, butter etc). There are companies working on recreating individual components of milk using plant sources, with the aim to 'reverse engineer' animal dairy characteristics from plant components. This is where New Zealand dairy products could face some significant disruption.

Animal protein has a complex structure which plays a functional role in processed foods. For example, casein (from dairy) allows a mozzarella to stretch and melt or albumin (egg white protein) can incorporate air into a foam to produce a pavlova. These complex structural proteins don't exist in plants – plant proteins are

normally globular in shape rather than, for example, the complex bundles of fibrous tissue surrounded by triple helix structured collagen found in meat (McClements, 2021).

This said, there are numerous businesses aiming to recreate functional animal proteins using plant ingredients. There are two main approaches to this:

- Stockeld Dreamery and NotCo are working to create plant-based casein by reverse engineering it from combinations of plant extracts. NotCo, who have announced a joint venture with food giant Kraft Heinz, use AI to recognise exact matches for animal products in the botanical world. Their goal is to mimic the exact composition of milk and create a realistic replica. Interestingly, their NotMilk product contains extracts from pineapple and cabbage, alongside sunflower oil and pea protein.
- Nobell Foods leverages plant molecular farming (PMF) to produce casein by genetically modifying soy plants to express the protein. Soy has been grown on a large scale for many years and there is a well-established supply chain. This could be a scalable method of producing casein in large quantities. Nobell Foods claim on their website to be ready for launch by the end of 2022 or early 2023, initially focussing on mozzarella and cheddar cheeses which make up 60% of the cheese consumed in the US (Nobell Foods, 2022).

WHAT IS CURRENTLY AVAILABLE?

Plant based dairy has been around for many years, with soy milk consumption in Asia dating back to the 14th century. The main threat to NZ dairy products comes from plant based ingredients displacing dairy ingredients in processed foods rather than consumers moving from cows' milk to oat milk in their coffee.

Figure 13: Nestle Plant Based Condensed Milk (New World, 2022)

There are plenty of established brands of plant-based dairy alternatives available, with many 'big food' companies producing a plant-based range. These have been growing rapidly in recent years as food companies adapt to greater customer demand for such products. Iconic brands such as Hellmann's mayonnaise, Magnum, Ben & Jerry's and Nestle Condensed Milk now all offer a plant-based version (Addy, 2020).

Companies such as Nestle and Unilever are creating targets for how much of their portfolio they aim to make plant-based within a certain timeframe – Unilever's goal is 1 billion euros per year of plant based business by 2028 (Wood, 2021). Nestle is Fonterra's largest customer – their three step climate action plan involves backing regenerative agriculture and reforestation programmes, transitioning to 100% renewable electricity by 2025 and building its carbon neutral and plant-based ranges.

SUMMARY

A new generation of plant-based ingredients is coming. Big food companies comitting to grow their plant based portfolios will increase demand for large volumes of highly consistent, functional ingredients which can be utilised in their large scale manufacturing operations. Innovations such as genetic engineering and AI are enabling this move.

Fonterra's biggest customer (Nestle) is aiming to increase the proportion of its portfolio which is plant-based, reformulating their traditional products (Kit Kat, Milo, Nescafe coffee) to create dairy-free versions. Much of the milk powder that is exported from New Zealand is used in processed foods. If customer acceptance of plant-based versions is high, Nestle and other processed food manufacturers may look to replace some of their dairy-based ingredients with plant equivalents to help them meet their sustainability targets and appeal to the

maximum number of consumers possible. An example of this elsewhere in the food industry is that less than 2% of Americans are Jewish, yet 41% of packaged food in the US is certified kosher (BBC News, 2020). Is vegan the next iteration of this?

PRECISION FERMENTATION

WHAT IS IT AND HOW IS IT PRODUCED?

Humans have used fermentation to produce food for thousands of years. Initially utilised for food preservation and safety purposes, fermentation technology has come a long way since 600BC. While most people are familiar with fermentation to produce wine, cheese and beer, this ancient process is now being harnessed for so much more.

Until 1978, insulin was extracted from the pancreas of cows and pigs, requiring the slaughter of 50,000 animals to produce just 1kg of insulin. In 1978 Genetech used a genetically modified yeast to produce human insulin that did not require animal slaughter, and by 2000 animal insulin made up less than 1% of the insulin market (Tubb & Seba, 2019).

The World Economic Forum has highlighted fermentation as a key global innovation area as part of their Food as a Force for Good workstream (World Economic Forum, 2020):

"Fermentation presents an opportunity to fundamentally change the way the world eats and improve global human and environmental health and the economy"

Precision Fermentation uses microbial host cells as 'factories' for producing specific functional ingredients. Microorganisms can be 'programmed' using genetic engineering to produce complex organic molecules such as enzymes, proteins, fats, vitamins etc. Examples include Impossible Foods' Heme (the component that makes the burger 'bleed'), vitamins, minerals, flavours, citric acid, nature-identical vanilla flavouring.

Essentially, with precision fermentation humans can produce nature-identical molecules anywhere you could brew beer. Required inputs are energy, water, microbes, a feedstock such as sugar and a controlled environment to grow in.

Cows are ruminants, fermenting grass inside their stomach to turn it into energy, which can in turn be used to produce milk. But what if cows are actually not the most efficient technology to ferment plants into milk? What if food producers could use fermentation in a controlled environment instead of an animal to produce the same components that an animal does? Precision fermentation offers the possibility to bypass the macro-organism (cows) and build up the same products (milk and cream) from their individual components. This moves from a system of extraction (i.e., milking then separating) to one of creation, with the potential to produce products of greater purity, consistency and with less waste.

In the current cow-based production system, single component products are the hardest and most expensive to produce. They require many physical, chemical and/or biological processes to extract the purest form possible. Whey protein isolate is the purest form of whey produced in NZ, and an example of a high value, high purity component extracted from milk. Whey protein isolate consists of 90% whey protein with 10% sugar (lactose) and fat remaining. Precision fermentation alternatives such as Perfect Day's product are 100% whey protein and contain no lactose so are suitable for lactose intolerant individuals. Products are produced in strictly controlled environments which means they can be purer, of more consistent quality and there is no

chance for contamination from faecal bacteria (salmonella, E. coli) which are a fact of life when dealing with cows.

Some of NZ's highest earning dairy exports are produced by isolating individual components from milk. Exports of casein and protein products were worth $2 billion in 2020, more than infant formula ($1.9 billion). These individual proteins are the easiest targets for emerging technologies, with multiple companies openly focusing on producing casein, whey and lactoferrin without animals.

WHAT IS CURRENTLY AVAILABLE?

A small range of 'animal free dairy' products made via precision fermentation are commercially available in the US. There are a few companies leading the way with precision fermentation dairy alternatives, all at different stages of scale up. The number of companies in the space is rising rapidly, with many new entrants from around the world including one in New Zealand – Daisy Lab.

At the time of writing, only one company has a commercially available precision fermented dairy product. Perfect Day produce nature-identical whey proteins, with no involvement from a cow whatsoever. They are targeting the ingredients industry, selling to ice cream manufacturers who use their whey to make entirely animal-free real dairy ice cream. In late 2021, protein powder and cream cheese (in partnership with food giant General Mills – see photo, right) were added to the portfolio – real dairy proteins, but no cows involved. Starbucks introduced animal free milk into two of their Seattle stores in December 2021 as a trial, made by Betterland Foods using Perfect Day whey – this became a commercially available product in early 2022 (Watson, 2022).

Figure 14: Bold Cultr Cream Cheese made by Kraft Heinz using Perfect Day's animal free whey (Bold Cultr, 2022)

NZX's Dairy Outlook Report in 2019 (NZX Limited, 2019) profiled Perfect Day and featured an interview with the founders. They are looking to encourage rapid adoption of technology by sharing their intellectual property (IP) and will work with other partners to scale up quickly. They have entered a partnership with Archer-Daniels-Midland Company (ADM) - one of the world's largest agricultural processors and food ingredient providers with more than 330 manufacturing facilities in almost 200 countries including NZ. ADM already has significant expertise in fermentation of ingredients so Perfect Day will leverage their existing infrastructure and manufacturing know-how to scale more quickly and cost-effectively. In recent months ADM have been building their fermentation capacity, partnering with existing companies such as Acies Bio in Slovenia (October 2021) and Temasek in Singapore (November 2021).

New Culture are working on animal-free casein to make dairy free mozzarella cheese. In 2019, they received $3.5 million funding from a venture fund partially backed by Kraft-Heinz. Co-founded by a Kiwi (Matt Gibson) but based in San Francisco, they are looking to produce a product that is both an ingredient and a consumer product. The casein protein has a very specific structure which causes milk to 'stick' together to produce cheese – something that cannot yet be replicated by plant-based ingredients, a major limiting factor for consumer acceptance of plant-based cheese. In June 2021, the team announced they will launch a commercial product by the end of 2023 (Watson, Animal-free Dairy: New Culture Plans 2023 launch of Mozzarella - Minus the Cows, 2021), focusing initially on the food service market where the majority of mozzarella is consumed.

Also working on precision fermented dairy are Those Vegan Cowboys (Belgium), Formo (Berlin), Remilk (Israel), Change Foods (Australia) and Better Dairy (UK) but these companies are still at the development scale and have not announced commercial product launches yet. Many companies producing precision fermentation dairy alternatives are still at start-up scale, and the amount of publicly available information is limited to protect intellectual property. Podcast interviews with the founders of these companies have proved to be an

effective way to gauge current scale and ambition for the purposes of this project. The pace of change is extremely fast, with many new companies being formed or announcing product launch dates during the researching of this report.

SUMMARY

While producing real dairy proteins without a cow sounds like science fiction, the reality is that the technology exists and has been in commercial use for over 40 years.

Unlike plant-based ingredients, which will require significant reformulation of the end food product to incorporate them, proteins produced via precision fermentation are identical to the dairy proteins currently in use, so manufacturers can swap them in one for one.

Consumers can currently purchase a small range of foods made using animal-free protein from one company in the US, and a raft of start-up businesses are working on bringing products to market. Large multinational companies such as ADM and General Mills are involved and investing in technology to enable scale up of fermentation capability.

CELLULAR DAIRY

WHAT IS IT AND HOW IS IT PRODUCED?

Often termed as 'lab-grown' milk, cellular dairy isolates the mammary cells involved with milk production in mammals, growing them outside the body and then creating the right conditions for those cells to produce milk.

Unlike precision fermentation, where single components are produced one at a time (e.g., whey, casein), cellular dairy makes the whole product (i.e., milk). Companies working in this space are focusing primarily on human breast milk as a starting point, as they can achieve extremely high revenues for small volumes. This is how Tesla scaled up their electric car business – initially making very expensive, exclusive sports cars then rolling the technology out to increasingly affordable models that more of the population can afford. Tesla is now worth more than industry stalwarts Ford and General Motors combined.

WHAT IS CURRENTLY AVAILABLE?

There are no cellular dairy products on the market yet, however there are several companies working towards this milestone. TurtleTree Labs and BIOMILQ are developing breast milk produced using cultured mammary gland cells, several new entrants have also signalled their intention to produce cellular breast milk.

Turtle Tree have announced their first commercial product launch: a lactoferrin identical to the compound naturally present in human breast milk. Bovine lactoferrin is currently manufactured in New Zealand by Synlait and Tatua dairies as a high value nutritional ingredient (Coriolis Ltd, 2019). In 2018 Synlait produced 16 tonnes of lactoferrin at a gross profit of $4.4 million or $285,757/tonne (Moore, MacIntyre, Barton, Murphy, & Campbell, 2019). At over a quarter of a million dollars *profit* for a tonne of product, it's easy to see why this is a target for cellular agriculture companies to replicate. It will be far easier to reach price parity with dairy lactoferrin than, say, a tonne of whole milk powder (costing $6,700/tonne at the GDT auction on 15th February 2022).

At the Global Dairy Summit 2021, Turtle Tree's chief strategist, Max Rye, suggested they will have a commercial product within the next three years. To produce this, they will only need small bioreactors (2-

5,000 L capacity). To scale up, they will require 5-10,000 L continuous flow bioreactors which they predict will take five to seven years to build. To put 10,000 L in context, a dairy farm milk vat is normally around 15,000 L. They will look to partner with existing dairy brands to scale their ingredient products and leverage existing dairy expertise and supply chains. Similar to Perfect Day's precision fermentation whey protein, Turtle Tree will be a business to business company (B2B) but show their logo on food containing their ingredient.

BIOMILQ are another company targeting cellular milk and have announced they can successfully create human milk outside of the breast (BIOMILQ, 2021). Rather than Turtle Tree's B2B ingredient products, BIOMILQ are targeting a direct to consumer (B2C) model – a service for parents where breast milk can be prepared from a sample of an individual mother's mammary tissue. Sounds like science fiction, but so did IVF babies when the technology was first introduced. We've come a long way from 'test tube baby' narrative now. BIOMILQ are targeting a launch within four years, a timeline which seems slower than some cell-based meat companies but potentially takes into account the additional layer of regulation they will need to navigate to produce food for babies.

Nestle recently advertised for a 'Specialist in Mammary Gland Development and Lactation Biology' to work at Nestle research in Switzerland, potentially signalling a move into the cellular breast milk space.

While breast milk produced via cellular methods will still not match the complexities of true human breast milk (antibodies, changing composition throughout the day to meet baby's needs), it will eventually offer parents a solution which is much closer in composition. While there could be some initial consumer perception pushback, maybe one day consumers will look back at the production of infant formula from cow's milk as shocking, and cell-produced milks will be as mainstream as IVF. Infant formula accounted for 9% of New Zealand's dairy export revenue in 2020 and is currently a growing market.

SUMMARY

Similar to precision fermentation, producing milk via cellular agriculture is possible. The question is whether it's possible to produce it on a commercial scale at a cost that consumers will be willing to pay. Targeting a high-value market to begin with may help the technology get going and cost of production could reduce over time allowing for cellular dairy products to reach the mainstream.

Some of the products being developed may eventually be competition for New Zealand dairy products, particularly some of our high value exports e.g., lactoferrin and infant formula.

FACTORS AFFECTING LIKELIHOOD OF SUCCESS

Plant ingredients are already on the market and in production. Cell based products utilise much of the same technology as precision fermentation but will require much more advanced technology to reach commercial scale. Precision fermentation is the key production method with the potential to displace NZ dairy products in a relatively short timeframe, so is the focus for this section of the report. Many of the same constraints will apply to cell based dairy alternatives.

COMMERCIALISATION AND SCALE

There is a theoretical tipping point. If achieved, dairy products from cows will be more expensive than identical products made from microbes or cellular methods. Analysis by Boston Consulting Group (Blue Horizon and Boston Consulting Group, 2021) predicts:

> "Plant-based alternative proteins will achieve parity by 2023, those based on microorganisms by 2025, and those based on animal cells by 2032."

Precision fermentation technology is currently used to produce food and pharmaceutical products for minority, high value ingredients such as flavours and functional ingredients. The cost to produce medical insulin for diabetic patients is around $110,000/kg which is accepted because it's only used in tiny amounts (Dennis, 2021). This cost of production does not stack up when it comes to producing a kilogram of dairy protein; Fonterra predict a farmgate milk price of up to $9.90/kg of milk solids this season (Fonterra, 2022). To produce insulin requires medical grade fermentation capability, which is more costly than food grade, but even taking this into consideration, the cost of production between dairy and PF components is currently light years apart.

This is set to change with experienced, large-scale businesses entering the precision fermentation for food industry. Incumbents who already produce fermented ingredients for the business to business ingredients industry include Cargill, Kerry, ADM and DuPont. According to The Good Food Institute, many of these companies recognise the growing trend toward precision fermentation for food production and are developing solutions accordingly (The Good Food Institute, 2021)

AB InBev who produce beers like Budweiser and Corona launched BioBrew in 2019. BioBrew is specifically designed to leverage AB's large scale brewing experience and apply this to precision fermentation (BioBrew, 2022).

> "Over hundreds of years, AB-InBev has perfected the ability to ferment at scales unprecedented by any industry standard. BioBrew seeks to apply this knowledge and expertise to lead the development and profitable growth of 'precision fermentation' at large, commercial scale."

Archer-Daniels-Midland (ADM) are one of the largest food companies in the world. They have partnered with several precision fermentation start ups and are contract manufacturing Perfect Day's whey protein and Geltor's collagen protein. ADM are primarily a trader and processor of oilseeds, corn, wheat and agricultural commodities and are therefore uniquely positioned to take advantage of the precision fermentation market due to their combination of fermentation expertise, capacity and access to feedstocks (Business Wire, 2021).

These large-scale, experienced food ingredient manufacturers introducing precision fermentation capacity will change the game. For food manufacturers such as Nestle to consider utilising any ingredients, they need to be available at a very consistent quality, on a large scale and for a suitable price, underpinned by a raft of documented safety and quality practices. Start-ups do not tend to have the capital or experience to produce ingredients to the scale and standard required for large manufacturers.

Despite these established companies entering the market, the industry is signalling a bottleneck when it comes to contract manufacturing capacity. Mark Warner is a consultant in the US focusing on advancing precision fermentation capacity. His recent article 'Microbes all dressed up…with no place to go' (Warner, 2022) explains how there are lots of companies working on building the microbes to enable this technology (the 'software'), but not enough focus on the production facilities (to produce the 'hardware'). Existing fermentation facilities are an average of 35 years old, built for pharmaceuticals and biofuels and not really suitable for scaling up this burgeoning food industry.

The graphic below from BioBrew (BioBrew, 2022) outlines the basic process for precision fermentation. Feedstocks are added to a fermentation tank, sometimes known as a bioreactor, similar to the kit used to

make cheese in NZ. The resulting liquid is then put through a centrifuge – this is the same equipment used to separate milk and cream at dairy plants. The next step is ultrafiltration, a common process in dairy processing, used to separate different proteins based on molecular size. Finally, the product is spray dried – yet another dairy process used at scale in New Zealand.

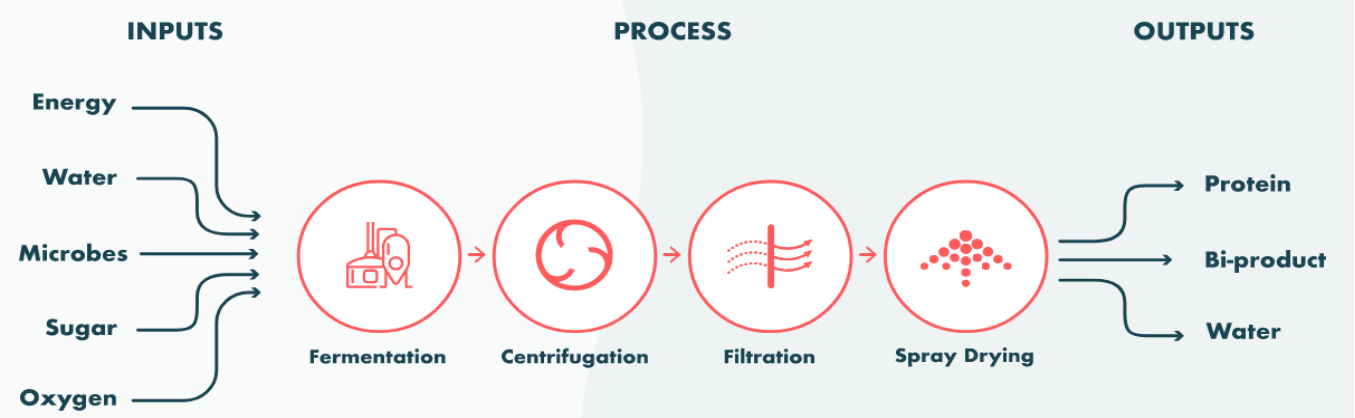


Figure 15: Process flow for precision fermentation (BioBrew, 2021)

Dairy processors could be the answer to the scale up challenge for this industry – a lot of the technology and expertise to operate this equipment exists in New Zealand, and we have it at scale. I sense-checked this with Mark Warner and he responded: "What you outline is certainly possible and there are a handful of companies in the novel protein space that are evaluating such options, especially ones looking to make milk replicates". Eden Brew is one of these companies – a partnership between Australia's oldest dairy co-op (Norco) and science agency CSIRO. Their plan is to make precision fermented milk alongside their traditional dairy milk at existing facilities. They are currently at prototype testing stage and looking to launch February 2023 (Ferrer, 2021).

While it may sound counterproductive for New Zealand assist with scaling potentially disruptive products, there are a number of advantages to the New Zealand dairy industry. These are further discussed in the opportunities section in the report conclusion.

BioBrew report that one of their fermentation tanks can replace 5000 dairy cows, so 1000 fermentation tanks would roughly produce the same milk supply as New Zealand's almost 5 million cows. While 1000 tanks sounds large, if you see the number of silos and tanks already used at dairy facilities, this is not outside the realms of possibility.

SUSTAINABILITY AND INPUTS

Grass uses photosynthesis to harness solar energy and turn it into carbohydrates (sugars). When ruminant animals eat grass, they use energy from carbohydrate and ferment it into protein in their stomach – either creating muscle mass (meat) or milk. Land unsuitable for growing crops can normally grow grass, so it's an ideal way to ensure productivity from the area available.

Animal agriculture is perceived as a villain in the climate crisis due to its high methane emissions. Its sustainability credentials are seen as low, and humans are increasingly being encouraged to forgo animal products to save the planet (for example in the recent UN IPCC report and the UK's National Food Strategy). And while there are debates for both sides of this argument, the overall effect is that many people are looking to consume responsibly, and for some this is leading to a more flexitarian diet, or even vegetarianism or veganism.

Life cycle analyses have found that precision fermentation alternatives are more sustainable than animal products. Perfect Day cite that their animal free whey uses 99% less water, 60% less energy and 97% lower greenhouse gas emissions than dairy whey (Perfect Day, 2021). BioBrew are more conservative and state that their dairy protein uses 30% less water and emits 60% less CO2 per kg of dried product than dairy, with all of their energy requirements being renewable (BioBrew, 2022).

To produce precision fermented or cell based milk requires inputs: energy, water, microbes, feedstock ('food' for the microbes) and oxygen. The feedstock used by most companies at present is simple sugar as this is the easiest to get hold of and standardise, but RethinkX states "once glucose is the highest cost part, that will be optimised" (Tubb & Seba, 2019). There will be opportunities to utilise waste streams from other processes, as the microbes simply require a source of carbon to produce their target molecules. AB InBev are looking to utilise spent grain from the brewing process via their Evergrain business venture, 3F Bio in Scotland are following a similar train of thought. The term valorisation is becoming widespread – the use of one industry's waste to feed another. Feeding palm kernel to cows is an example of this in dairy.

Another important aspect to recognise is milk powder from New Zealand is not without environmental trade-offs, despite our position as world's most carbon efficient producers of dairy. Fonterra is the country's largest emitter based on their processing footprint alone. They are the second largest coal user in the country. (New Zealand Productivity Commission, 2020).

Once the liquid has left the cow or the fermentation tank, the energy and water required to process both dairy and precision fermentation milk into powder will be similar – both require separation and spray drying. The sustainability comparison should really be between growing a suitable feedstock then powering a fermentation tank for PF, versus growing grass and feeding a cow for traditional dairy. When you consider a dairy cow takes two years before she can be milked, there's lots of bits that are surplus to requirements (head, hooves, male calves etc), then things start to stack up in favour of PF. If you then consider that feedstocks for PF could be optimised to use waste streams from other processes, then it's starting to look pretty bleak for traditional dairy on sustainability credentials.

CONSUMER ACCEPTANCE

Consumers are increasingly demanding foods that are more ethical, sustainable and nutritious to improve the health of themselves and the planet. But there is a limit to the level of sacrifice consumers are willing to make, and often taste and price win over sustainability and health credentials when it comes to food choice.

In a Sam Harris interview with Bruce Friedrich, founder of The Good Food Institute, there was a conversation around just how few mindsets need to change to make a shift to alternative food happen. Rather than convincing everyone that animal agriculture is bad for the environment and that they should stop consuming it, it would only take a relatively small number of people within the food industry to shift the dial towards a diet free of animal-sourced foods. If food manufacturers can produce products with equal or better taste at equal or lower prices than traditional products, then the likelihood is that consumers will buy them – Friedrich calls this 'taking the friction out of the system'. Food manufacturers are signalling a shift already with their promises of growing plant based options; the increased choice and availability of alternative ingredients will further accelerate this.

> "We don't need to convince people animal agriculture is good or bad,
> if the solution is better, they will take it"

A common counter-argument to consumer acceptance of alternative proteins is that people will not want to consume products made in a 'lab'. As someone who regularly works inside dairy processing plants and slaughterhouses, I can assure you they are not especially romantic places for food to be produced either.

Dairy factories contain a lot of carefully controlled stainless steel equipment, pipes and tanks, they are noisy and hot. In fact, the equipment required to produce precision fermentation and cellular dairy will be similar to what is used to produce milk powder. The principles of separation and spray drying are common across all three disciplines, with fermentation and cellular requiring bioreactors rather than cows as the initial step. Below left is a photo of a Fonterra R&D centre (Newsroom, 2021), and below right is a photo from the GOODMeat website showing what their bioreactors look like – it's remarkably similar to the inside of a dairy processing plant.

Figure 16: Left, photo of Fonterra factory (Newsroom, 2021). Right, photo of GOODMeat's production facilities (GOODMeat, 2021)

The argument that consumers won't accept new alternatives because of their production methods does not stack up – precision fermentation is already used to produce common food ingredients such as rennet in cheese. The strategy of most companies producing this new breed of products is business to business – selling their products as ingredients for use in items manufactured by other companies. For example, Perfect Day sell their precision fermentation whey protein to ice cream manufacturers who substitute it for milk and make 'animal-free real dairy' products. There's a small logo on the tub saying 'Better with Perfect Day' to signal that their product is used as an ingredient – see photo right (Brave Robot, 2022).

Figure 17: Brave Robot Ice Cream using Perfect Day's whey protein

If new ingredients can fit into existing product formulations as well as traditional ingredients (such as whole milk powder into a KitKat), there may be a tipping point where it's cheaper for food manufacturers to use non-dairy ingredients that perform exactly the same as the existing dairy ones. This will help their sustainability credentials and appeal to a wider consumer base. The likelihood is that future consumers will not differentiate based on whether the milk powder in their food comes from a cow or a fermentation tank – they'll differentiate based on price and performance. Each tub of Perfect Day ice cream (pictured above) costs an eye-watering $20, so they will currently only appeal to a consumer who is looking for that specific animal-free dairy experience. Price parity with dairy proteins is certainly a target alternative protein companies are aiming for, and some predict they will reach this milestone within the next four years (Boston Consulting Group, 2021). This milestone will be achieved much sooner if the price of milk keeps rising, as it's an easier target for alt protein firms to attain.

Of course, the widespread use and acceptance of new ingredients is dependent on the quality and safety that is achievable on a mass scale. There are definitely challenges for the industry to overcome in terms of building capacity to meet demand – see next section. One thing that it's really important for the New Zealand dairy

industry to note though, is that milk powder is the low hanging fruit for displacement. Replicating the complex structures and textures of meat is highly technically challenging. This is not an issue when it comes to replicating a milk powder – in fact a powder is the end point for many of these new ingredients.

INVESTMENT AND ENABLERS

Investment is a key factor in enabling the alternatives to dairy to grow to a point where they could be viable alternatives to the dairy products made in New Zealand. Funding for alternative protein is growing as shown by the table below (The Good Food Institute, 2021). 2021 has seen some record deals in the alternative protein investment space, so the trend is continuing.

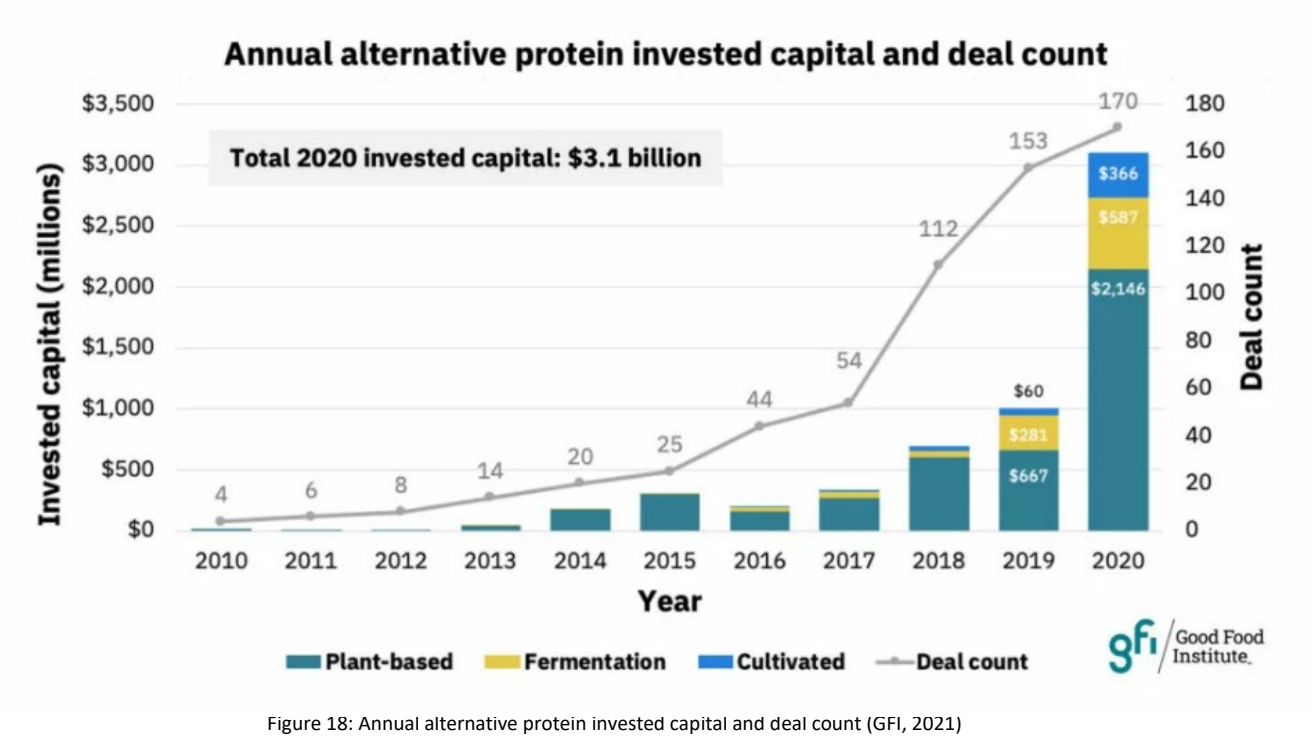


Figure 18: Annual alternative protein invested capital and deal count (GFI, 2021)

The industry has many enablers: high net worth backers such as Bill Gates are investing via their venture capital firms. Accelerators such as IndieBio and New Harvest help bring start-up companies to the market. Spanish dairy company, Pascual Dairy, is running their own alternative dairy incubator called Mylkubator. The Good Food Institute is a non-profit organisation which serves as a hub for all aspects of alternative protein, bringing together the science, marketing and business aspects to advance the technology. Their vision is 'a world where alternative proteins are no longer alternative'.

Investment in Perfect Day to date has been over NZ$1 billion. In 2020 alone, NZ$4.6 billion was invested into alternative protein, with NZ$865 million spent on precision fermentation. To put this in context, Fonterra's annual research and development (R&D) budget has recently been doubled to NZ$160 million.

PART 3. WHAT'S THE RISK TO NZ DAIRY? WHAT SHOULD THE INDUSTRY BE DOING NOW TO STAY RELEVANT IN THE LONG TERM?

CONCLUSION: WHAT'S THE RISK TO NZ DAIRY?

'Alternative protein' will become a term consigned to the past – the world has moved on from curdled soy milk in cups of tea and dry, hard veggie burgers made from mashed chickpeas. A deep understanding of foods at a molecular level, and how this influences function and flavour is bringing appealing products to market: a veggie burger that 'bleeds', ice cream made with animal–free real dairy protein. And it's no longer just protein in the spotlight - new technologies can replicate fats and other components of animal products. Animal ingredients are being reverse engineered to be made from non-animal sources. Food manufacturers are utilising these to formulate 'animal-free' options without compromising consumer's enjoyment.

It is possible, and I believe probable, that commercial scale, functional replicas of dairy ingredients made without animals will become commonplace within the next 10 years, whether these are isolated from plants, produced with precision fermentation, or grown via cellular agriculture.

The challenge for New Zealand is to recognise where we are exposed to displacement from alternatives and prime our dairy industry to survive. I've assembled my conclusions into a SWOT (strengths, weaknesses, opportunities, threats) analysis of how the NZ dairy industry is set up to respond.

STRENGTHS

DAIRY EXPERTS

- New Zealand has a mature dairy industry with vast expertise in dairy supply chains, wide market access and a great reputation.
- Kiwis solve food problems. A2 milk was a Kiwi discovery, as was using the waste from cheese production to make whey powder. Fonterra holds 350 milk-related patents for inventions such as spreadable butter, long-shelf-life milk powder and mozzarella that matures in a few hours rather than four months. (Fonterra, 2021).
- NZ has many highly skilled technical people and strong Food Science credentials within academic institutions.

NATURALLY BETTER MILK

- 'Brand New Zealand' is a well-used rhetoric when it comes to our agricultural exports. Our clean, green image overseas combined with a good reputation for product quality and safety is a great accolade, but not one we should take for granted.
- Sustainability is a key focus for today's consumer. Research has identified that New Zealand dairy has the world's lowest carbon footprint – 48% lower than the average of the 18 countries studied (Mazzetto, Falconer, & Ledgard, 2021). Carbon neutral claims are starting to appear on products around the world (see UK egg carton, right).
- Regenerative agriculture is a global buzz word, but a definition/standard is yet to emerge. Nestle (Fonterra's biggest customer) are investing heavily in regenerative agriculture via scientific research, investment support and offering premiums for regeneratively farmed products (Nestlé, 2021). Arla, a large European dairy co-op have created a network of pilot farms across Sweden, Denmark, Germany, Netherlands and the UK to start to measure, track and build understanding of how farming with regenerative principles affects their farms. New Zealand dairy farming follows many of the principles of regenerative agriculture already. How could this be captured and communicated to customers?

Figure 19: Carbon neutral eggs on sale in the UK (Sainsburys, 2021)

- New Zealand does not allow the use of genetic modification (GM) within food production. Many of the alternative technologies discussed in this report utilise GM or genetic editing (GE) technologies in their production methods. There certainly is a conversation to be had about New Zealand's future approach to GM, as this limits our ability to become involved with emerging technologies. In the meantime, if NZ does not allow GM technology, this should be signposted to consumers.

CHINA CHUMS

- New Zealand has a long-standing, strong trade relationship with China, and they consume 39% of Kiwi dairy exports. New Zealand dairy companies have good market access and supply chains to sell goods in China.
- Fonterra has multiple application centres in China, helping them to tailor products specifically for the Chinese market. Chinese-owned company Yili, who operate Westland and Oceania Dairy in NZ, are the fifth biggest dairy company in the world – larger than Fonterra who are sixth (Rabobank, 2021)
- New Zealand's dairy exports to China have grown substantially – from $13.5 million in 1990 to $5.5 billion in 2020 (Hancock, 2021). That growth has helped accelerate the sector in New Zealand.

WEAKNESSES

ANONYMOUS INGREDIENTS

- In FY21, Fonterra made 74% of the milk solids they processed into Core Ingredients.
- Ingredients are used by food processors where the dairy ingredient may not be the consumer's reason to purchase such as chocolate bars.
- The positive attributes of New Zealand dairy (grass fed, high animal welfare etc) are not the reason consumers purchase these products – they likely don't know they are in there. The nutritional benefit of milk is not a prime consideration when choosing a KitKat.
- The ingredients market is the initial disruption target for emerging alternatives, promising manufacturers a tailored product of more consistent quality with no residual lactose, bacteria, antibiotic residues etc.
- While the costs do not stack up for manufacturers to move to alternative ingredients yet, the promise of lower cost and wider consumer appeal for finished goods is on the horizon. Price parity will be reached a lot sooner if the milk price remains high.

EXTRACTION DISTRACTION

- In the year to March 2021, 10% of dairy export revenue came from casein and protein products, worth $2 billion.
- Individual proteins are the easiest milestone for precision fermentation to achieve. These proteins are identical to dairy proteins and will fit the same manufacturing pathways.
- Most of the casein and protein products are exported to the USA (it's most of what they buy from NZ dairy). This is where many of the precision fermentation companies are headquartered.
- Some of the highest value ingredients are also low hanging fruit for alternative dairy companies. Nutritional compounds such as lactoferrin are purified out of milk and sold for extremely high prices for small quantities. TurtleTree in Singapore are launching cell produced lactoferrin as their first commercial product as it's where they will receive the most value for small volumes of product.
- When individual products are extracted, the rest of the milk also needs somewhere to go. When alternative dairy companies are building these components from scratch, they do not have this to consider.

SUNK ASSETS

- New Zealand's dairy processing industry was built on the necessity for ever-increasing volumes of milk to be processed. Dairy plants are capital intensive to build but as the milk volume grew, New Zealand needed more processing capacity. This has resulted in a huge amount of stainless steel equipment, some of which is only used for a few months of the year at the peak of the season.
- Peak cow has now been reached in NZ, so the need to process ever-increasing volumes of milk has ended. The only way the industry can now grow is to obtain more value from the existing volume of milk that is produced. Much of the processing capacity in NZ is targeted at producing milk powders, which could constrain the types of products that can be developed in order to grow value.
- The Productivity Commission report on the shape of the dairy industry in NZ notes that "As a supplier-owned cooperative, Fonterra's access to capital was constrained. Furthermore, arguably the priority for its limited capital tended to be given to building new factories to process the growing milk volumes rather than to market development and creating consumer brands" (New Zealand Productivity Commission, 2020).
- Around the globe, this level of processing capacity for one product is uncommon. Developing nations looking to produce their own food could leapfrog New Zealand in utilising new technologies as they would not be beholden to their existing food production infrastructure (sunk assets).

OPPORTUNITIES

NEW WAYS OF TURNING MILK INTO MONEY

- Kiwis are proud of New Zealand dairy –highly nutrient dense, produced efficiently through an optimised dairying system with the lowest carbon emissions globally. At the moment, this is not adding value as consumers will mostly be eating them as an ingredient other food.
- To truly reap the benefits of NZ milk, it's time to stop pulling it to pieces and selling it as ingredients that can easily be displaced by alternatives. This will be a big shift for dairy processors to make, and not an easy one due to the level of investment already made into milk powder plants. NZ cows are bred to maximise solids for milk powder. Where Kiwi milk powder is used in processed food products, we could look at signalling this on pack to consumers, similar to Perfect Day have done, see picture to the right (Perfect Day, 2021).
- Innovation will be key. Fonterra's Path to 2030 strategy includes $1 billion investment to shift milk to higher value products, including boosting the annual R&D budget by 50% to $160 million annually, with $1 million of this dedicated to moving milk into higher value products (Fonterra, 2021).

Figure 20: Better with Perfect Day on pack logo (Perfect Day, 2021)

- We need to understand what matters to consumers when it comes to dairy products and make sure we are meeting that need. It's important to note that 95% of NZ dairy consumers are not Kiwis! There's a huge opportunity for retail yoghurts into China – the retail value of yoghurts is predicted to be $39 billion by 2023 as opposed to $4.9 billion for milk powder.
- New Zealand products such as Lewis Road Creamery show that we can occupy a luxury dairy niche – less cows, more value for customers and companies.
- From a sustainability perspective, NZ needs to be keeping a close watch on what other countries are doing to ensure it doesn't fall behind. Regenerative agriculture, carbon zero, high animal welfare are areas being investigated by other primary industry businesses around the world, NZ needs to be leading here rather than playing catch up. While there may not be an initial monetary benefit to the farmer, this is how NZ products will be differentiated in future. It could be viewed as a business continuity measure.

GET INVOLVED

- New Zealand has significant dairy expertise and experience, with some of the most advanced equipment for producing dairy powders in the world and access to renewable energy. Alternative dairy start-ups are looking to partner with existing producers to get beyond pilot scale and leverage their experience "Many of the requirements for isolating and manufacturing plant proteins are similar to those for dairy proteins, creating an opportunity for expertise from the dairy industry to be applied to the development of plant-based proteins" (New Zealand Productivity Commission, 2020).
- If New Zealand dairy processors partnered with precision fermentation companies looking to scale, they could utilise periods when spray drying equipment would normally sit idle (winter, non-peak season) to produce a complementary product which would bring profit back to farmers and ensure NZ had a foot in the door of this disruptive technology. This could eventually be a way to fill spray drying plant capacity and start moving dairy milk into high value product streams.
- New Zealand is already investing in plant milk, with a $50 million oat milk factory under construction in Southland. European co-op Arla is making oat milk using oats grown on dairy farms which gives farmers options for diversification of land use. Daisy Lab, NZ's first precision fermentation milk company, was founded in 2021 and is producing casein at lab scale in Auckland. The company is valued at $3.7 million, and are not at pilot scale yet, so it'll be a while before commercial products are ready to launch (Steele, 2021).

THREATS

FOOD SECURITY

- Food security is becoming a global priority. COVID has impacted supply chains, international tensions are creating uncertainty around trade partnerships. Nations are looking closely at where their food comes from and looking to produce more at home. Precision fermentation and cellular agriculture offer a vision of being able to produce nutritious food with a much lower physical footprint than traditional agriculture, closer to the point of consumption.
- Singapore is one country leading the way on this move, with a policy of trying to bring 30% of their food requirements to be produced within the country by 2030. Government policy in Singapore is very supportive of alternative protein technology, and it's the first country in the world to offer cellular meat for commercial sale. Perfect Day are building a research and development centre in Singapore in partnership with their national science agency.
- China's Ministry of Agriculture and Rural Affairs launched their official five year plan in early 2022, which included cultivated meats and future foods for the first time (Baker, 2022)
- The US army has launched a project called Cornucopia, looking for partners to develop fermentation technology to create nutritious food in the field or on humanitarian missions. The technology could also be accelerated by requirement for nutritious food for commercial space missions.

STAKEHOLDER APATHY

- With high (and still climbing) prices for commodity milk products, farmers making good returns and alternatives not yet at a scale to pose a threat, the appetite for change in NZ is understandably low. The problem is that if alternatives scale quickly and the NZ dairy industry is still the same shape, then it will take a long time to pivot to new products.
- One of the largest decreases in priority score in the 2021 KPMG Agribusiness Agenda (KPMG, 2021) was for tracking global evolution of alternative protein. There have been a few articles recently, especially in the farming press, around plant based meat not measuring up to consumer expectation and growth that has possibly been over-hyped. This is understandable; it's extremely hard to replicate a beautiful piece of steak with all its' textural and flavour complexities. But milk, and especially milk powder, is much less difficult to produce with alternative methods. If alternative protein drops off the radar of Kiwi Primary Industries, then we risk getting left behind.

- "Many of the more advanced economies we tend to compare ourselves with - the Netherlands, Singapore, Israel - are investing significantly more, moving much more rapidly, and doing it at scale. They have deep engagement between industry, government (especially regulators) and research providers, and ambitious targets for the role emerging proteins will play in their future agri-food sectors. At the moment, NZ is being left behind our peers within this increasingly competitive sector." (Emerging Proteins in Aotearoa, 2021)
- Fonterra's response to emerging alternatives has been to invest in a minor stake of Motif Foods, a US company working on biotech ingredients. Fonterra's website refers to 'complementary nutrition' co-existing alongside animal-sourced foods (Fonterra, 2021), but there is no mention or recognition of the direct threat to their ingredients business or any other actions they plan to take. As a farmer-owned co-op, Fonterra has little incentive currently to look at the threat and undertake anything other than a token response.

APPETITE FOR CHANGE

- The alternative dairy industry is being driven from several angles. Some disruption is already coming from within the dairy industry. Eden Brew in Australia are using dairy processing sites to 'brew' casein protein. Danone have long been involved in both dairy and alternative milks. Pascual, a large Spanish dairy firm, has started Mylkcubator, the first global incubation program for cellular agriculture technologies in the dairy industry (Ferrer, 2021). Alternative dairy companies are appearing on traditional dairy platforms – Perfect Day, TurtleTree and Formo were participants at World Dairy Congress alongside Nestle, Arla and Danone.
- The world's largest food companies such as Nestle, Kraft Heinz, ADM and General Mills are investing and partnering with start-up companies to access this new technology, legitimising and accelerating the advancement of alternatives.
- Eating habits are changing, and many people are looking to remove or reduce animal-sourced foods in their diet. Food companies are adapting to this, keen to maintain their consumer base. This in turn makes it easier for consumers to access animal-free products without compromising too much on product choice. Supermarkets such as Tesco in the UK are supporting initiatives like Veganuary, with special offers and dedicated areas of their online shop for vegan food.

RECOMMENDATIONS: WHAT SHOULD THE INDUSTRY BE DOING NOW TO STAY RELEVANT IN THE LONG TERM?

1. **Acknowledge the risk and react**.
   New Zealand is the biggest dairy exporter in the world. The types of dairy product most easily disrupted by emerging technologies are the ones New Zealand excels at: ingredients sold to other businesses to be made into processed food, especially powders and protein ingredients.

   The risk of disruption is not coming from within New Zealand: it's not individuals who don't agree with dairy farming, and it's certainly not from oat milk lattes. It can't be solved by resorting to the 'grass-fed, free range, high quality' standpoint that is so often quoted within New Zealand, which in reality doesn't travel with the majority of our dairy produce to the end consumer. This is a global movement, driven by purpose-orientated start-ups and accelerated by large food corporates looking to meet sustainability goals and maintain their social license to operate.

   There needs to be open minded coverage of the challenges and opportunities New Zealand could face from emerging technologies – not the 'them and us' rhetoric that is quite often in the press (especially the farming press). A high burden of responsibility will sit with dairy processors who take

the responsibility for converting milk into saleable products. They will need the support of farmers to make this transition.

While the current market for NZ dairy is strong, it is incredibly important that this drives investment into future adaptation rather than endorsing the current business model. There is a real risk here, and by burying our heads in the sand, we could well miss the opportunity to react.

2. **Get involved.**
New Zealand dairy has a unique opportunity to become involved in emerging technologies. As the largest exporters of milk powder in the world, the scale of existing equipment and expertise in New Zealand is second to none.

'Downstream processing' of ingredients has been identified as a key bottleneck for the alternatives industry. These are processes (filtration, separation, spray drying) that New Zealand has significant expertise in and equipment capacity which is often under used for dairy processing.

Of course, the production bottleneck could be seen as a win for the existing industry – preventing alternatives reaching commercial stage too quickly and delaying any disruptive activity. The risk here is that if production facilities do scale up (which I truly believe they will), the existing industry will be left out in the cold. Using spare capacity now could assist with shifting milk into more future-proofed product streams which don't require spray drying.

3. **Make milk into money differently.**
The term value-add elicits eye-rolls from many in the industry – it's regularly referred to as the way to 'fix' the primary industry, but few do it well. It's extremely difficult to achieve at scale.

The issue for New Zealand dairy is reliance on commodity ingredient products leaves it very exposed to alternatives. The scale of the industry ensures NZ can supply large volumes of high quality ingredients that function the way food manufacturers need them to in their factories. The economy of scale ensures that NZ milk powder is competitive in the global marketplace.

But imagine product appearing in the market which not only matches all of the quality parameters the buyer is looking for, but also helps them meet their greenhouse gas reduction sustainability targets and also appeal to a wider group of customers. And it's cheaper than traditional dairy. This 'tipping point' has been predicted by some to be as soon as 2025, others by 2030. When this occurs, New Zealand needs to be ready, and there is not long to get there.

The key will be to make products where consumers value the inclusion of dairy ingredients. Luxury, niche dairy products, at scale needs to be the aim. There's a huge market opportunity for yoghurt drinks into China, this is how they consume most of their dairy. Move butter, cream and cheese away from ingredients markets which will likely be displaced by alternatives towards New Zealand branded products for customer's tables.

FINAL THOUGHTS FROM THE AUTHOR

While proofreading this report prior to submission, I realised it could be perceived that I'm 'against' the dairy industry. I want to make it clear this is not my intention – I love the passion of Kiwi farmers, and the pride they have in the industry. Researching this report from our dairy farm in South Otago, watching the cows leave the shed after milking I felt both a sense of unease and urgency about the changes required to future-proof the industry.

I truly believe that the industry has the strength to weather this disruption, but to do so successfully requires a shift in mindset and strategy from multiple angles, the scale of which will be hugely challenging to most. It's a shift that is mostly being overlooked.

I'll finish with this. Theodore Levitt is famed for his theory of product life cycles. In his essay, Marketing Myopia (Levitt, 1960), he outlines four conditions that guarantee "a self-deceiving cycle of bountiful expansion and undetected decay":

1. The belief that growth is assured by an expanding and more affluent population.
2. The belief that there is no competitive substitute for the industry's major product.
3. Too much faith in mass production and in the advantages of rapidly declining unit costs as output rises.
4. Preoccupation with a product that lends itself to carefully controlled scientific experimentation, improvement, and manufacturing cost reduction."

Consider the four conditions in relation to the dairy industry in New Zealand. My very sincere hope is that the industry will not reach the point of 'undetected decay', and grateful consumers around the world will be enjoying New Zealand dairy products for years to come. Hopefully my 8 month old son, Henry, will be a part of this one day if he chooses.

I would love to discuss readers thoughts around this report – please feel free to contact me on annabenny5@outlook.com if there's anything you agree or disagree with or would like to talk about more.

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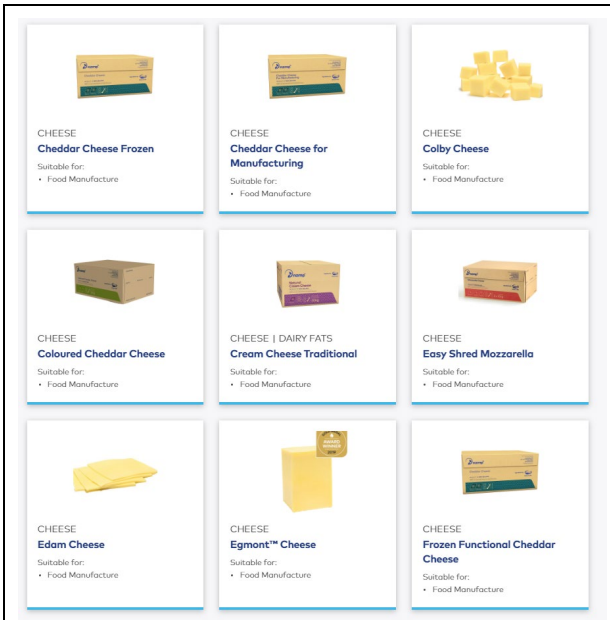
APPENDICES

APPENDIX 1 – NEW ZEALAND MILK PRODUCTS

 MILK POWDER **Regular Whole Milk Powder** Suitable for: • Beverages • Food Manufacture	Whole Milk Powder Suggested uses: • reconstituted milk, ice cream mixes and confectionary products • bakery products and snack foods • milk source for any situation where regular liquid milk supply or refrigeration is not available • beverages
 MILK POWDER **Regular Skim Milk Powder Medium Heat** Suitable for: • Beverages • Food Manufacture • Yoghurts & Cultured	Skim Milk Powder Suggested uses: • recombined products including sweetened condensed milk, pasteurised milk, milk cheese, cottage cheese, ice cream mixes • confectionary products • bakery products • yoghurts • beverages

	Cheese Cheddar, Colby, Mozzarella, Edam, Gouda and Cream Cheese. Available chilled/frozen, shredded Suggested uses: • processed cheese applications • pizza • shredding and slicing
	Butter Available as salted or unsalted. One organic carbonzero™ certified option. Suggested uses: • spreads • baked goods • widely used food ingredient
	AMF (Anhydrous Milk Fat) Suggested uses: • frying, grilling, roasting • sauces • recombined dairy products • ice cream • processed cheese • confectionery • bakery applications

 PROTEIN **SureProtein™ Whey Protein Concentrate 392** Suitable for: • Beverages • Medical & Healthy Ageing Nutrition • Sports & Active Lifestyle	Whey Suggested uses: • UHT beverages • processed cheese • yoghurt • dairy desserts • soups and sauces

APPENDIX 2 – CONTRIBUTORS TO THIS PROJECT.

The following people have contributed to the observations and ideas outlined in this report through various means, ranging from participation in formal discussions through to more casual conversations and exchanges of emails over the course of the past 12 months.

The presence of any name below does not constitute an endorsement of the findings of this report.

I would like to once again express my gratitude to all those who gave their time and insights during this process.

Julia Jones – NZX

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Blake Holgate - Rabobank

Mark Warner – Warner Advisors LLC

Jack Keeys - KPMG

Jenny Cameron – DairyNZ