April 2021

Emerging Proteins in Aotearoa New Zealand:

What will it take for the sector to thrive?

Emerging Proteins NZ

food HQ
Where food ideas meet science

AGMARDT
FUTURE SHAPERS

AT A GLANCE

This report summarises key observations and opportunities arising from discussions with 185 people from throughout the emerging proteins sector. It concludes with some recommendations for what is required for this sector to thrive, and some principles upon which we believe activity in this sector should be based.

If we are to succeed in this increasingly competitive space, we need to do more and do it faster. We need to remove barriers, increase national and international collaboration, and be prepared to invest in world-class talent and infrastructure.

This report is not intended to be the final answer. We hope it will spark further constructive discussions on how we can more rapidly develop a thriving emerging proteins sector as part of our future food production systems.

Observations

1. There is significant and diverse activity in emerging proteins throughout NZ, with the current focus being on plant-based foods.
2. 'Plant-based foods' can be divided into two categories – analogues and whole-plant foods - with different implications.
3. "Plant-based" is often associated with healthy, natural and sustainable by consumers.
4. Developing emerging proteins is about portfolio diversification, not replacing all traditional agricultural systems and products.
5. Business models include adding value to imported raw materials or producing one's own raw materials. We can also develop new ones.
6. We must understand our target consumers and what products they want, and ensure these products are visible and accessible.
7. The emerging proteins sector is seen as a potential solution for farmers and growers and as an opportunity to food producers. It is vital they explore the possibilities together.
8. We cannot rely on NZ provenance alone.
9. Currently, NZ law is restricting the development of some emerging proteins sectors.

Opportunities

1. NZ could develop a plant-protein ingredients sector, but this is complex and requires careful consideration and significant capital investment.
2. The emerging proteins sector could also be used to accelerate our move to a more circular food production system.
3. Developing approaches that reduce duplication and support collaboration will deliver better outcomes for NZ from this sector and others.
4. Diversity of the sector could be a real strength, but there is currently limited Māori participation at the food end of the value-chain.
5. Investment in talent and infrastructure will fast-track emerging proteins sector development.

Emerging Proteins NZ

Recommendations

1. Take a NZ-Inc, whole-of-value-chain approach to a suite of initiatives:
    a. Identify commercial or near-to commercial sectors and form collaborative syndicates to progress pre-competitive projects in areas such as R&D, consumer and market insights, regulatory framework development, infrastructure improvements etc.
    b. Determine where investment should be made in scale-up infrastructure to reduce commercialisation barriers.
    c. Explore how we can market NZ emerging proteins foods, leveraging the brand value of NZ traditional proteins and utilising consumer and market insights from export markets.
    d. Establish a talent attraction programme for R&D and innovation experts in key areas, complemented with a multi-disciplinary talent development programme that builds local capability and capacity.
    e. Foster an entrepreneurial ecosystem around emerging proteins.
    f. Review regulations around emerging proteins and compliance pathways for new products.
2. Formalise and fund a collaborative independent national network to coordinate delivery of initiatives and bring cohesion to the discussion. This would involve industry, research providers, venture capital, government and other interested parties in the wider emerging proteins ecosystem. This network will not lead all the initiatives described in recommendation #1 but will provide crucial facilitation and coordination to the collective effort.
3. Enable a single point of contact and integrated response from government for emerging proteins topics by establishing a cross-government working group involving departments such as MPI, MBIE, NZTE, Callaghan Innovation, MFAT, MOE and others interested in this sector.
4. Develop and implement a New Zealand strategy for emerging proteins aligned with potential areas of competitive advantage, leveraging the networks and information arising from 1-3 above.

Principles

Our Recommendations are underpinned by the following Principles to deliver long-term sustainability and benefit to the country:

1. Circular economy – the sector should be developed in alignment with the principles of circular food production systems
2. Integrated value chain – a whole-of-value-chain approach integrating on-farm diversification opportunities with knowledge and expertise on food processing and consumer insights.
3. Māori economy – enable Māori businesses to capitalise on the opportunities presented by the sector, particularly value-capturing and higher returning opportunities.
4. Technology – the sector strategy must explore relevant technologies and lead the discussion on their applicability in the NZ context. This includes a national discussion on genetic modification and the facilitation of understanding that 'GM' is a suite of technologies.

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INTRODUCTION

In September 2019, FoodHQ Business Development Manager, Amos Palfreyman, was seconded to Foodvalley NL (FV), a FoodHQ Strategic Partner in Wageningen, the Netherlands. While there, he collaborated with FV to compile an Innovation Scan summarising some of the more visible activity in emerging proteins in New Zealand and the Netherlands. This was released in March 2020[1].

The Innovation Scan determined that while there was some activity happening in NZ, the Dutch emerging proteins sector was significantly more organised, better resourced, and more firms were operating at a larger scale. In recognition of the need for more collaboration within this developing sector in NZ, FoodHQ subsequently launched a virtual network: Emerging Proteins NZ (EPNZ, www.emergingproteins.co.nz). The primary focus of this network was to accelerate the development of a NZ emerging proteins sector through the sharing of knowledge and establishment of connections in order to capture a share of the rapidly growing international market.

Initial engagement with EPNZ members and the wider agrifood ecosystem indicated a need to gain a better understanding of what is currently going on in NZ, as much of the activity in this space is happening under the general radar. It also identified that the challenges and barriers to the development of the sector and the opportunities for the individual NZ firms that seek to operate within it, need to be further explored.

This led to the launch of the current project, "Understanding NZ's emerging protein sector," jointly funded by FoodHQ and AGMARDT.

It is important to note that this has developed into more than a conversation about protein, although emerging proteins remains a convenient short-cut for the broader category. It is really a conversation about a wide range of foods and ingredients that add diversity to our production systems and diets, and which are responding to significant global drivers.

[1] Reference to joint Alt Proteins scan, March 2020.

Project process and scope

This project captures a snapshot of the NZ emerging proteins sector. It is based on a large number of conversations that occurred between late 2019-early 2021 as part of various FoodHQ and EPNZ activities, along with a series of facilitated individual and group discussions held throughout NZ in Oct-Dec 2020.

Those who participated in these conversations came from across the value chain, from those involved in crop genetics through to engineering design, food manufacture and food service. They covered all sizes of business and stages of involvement in the sector, and also included representatives from the research community and various government organisations.

Participation in the formal discussions was restricted to those already actively involved in emerging proteins or those actively considering becoming involved. Individuals and organisations were identified through a range of approaches, including the EPNZ Membership database, FoodHQ networks, and referrals from collaborating organisations and individuals including the New Zealand Food Innovation Network, B.linc and Callaghan Innovation. These discussions had a very general framework which included questions around current and future activities, challenges and barriers, gaps and opportunities within the wider emerging proteins sector. This enabled free-flowing and wide-ranging discussions which led to observations and comments on topics that may not have been forthcoming in a more tightly structured session.

There were 13 facilitated discussions (each 2.5-3hrs in duration), held across the following locations: Whangarei, Auckland (3 sessions), Hamilton, Gisborne, Napier, Greytown, Palmerston North, Nelson, Christchurch, Timaru and Dunedin. These were complemented by additional individual interviews with those who were unable to attend group sessions. Facilitated discussions planned for New Plymouth and Wellington became a series of individual interviews due to the numbers and availability of participants. All such discussions were held under Chatham House rules.

Overall, 185 people provided useful insights and perspectives that informed this report, either through their participation in structured discussions or via more casual conversations and exchanges of ideas.

Project outputs

The primary output for this project is this report, which aims to summarise the key observations and consistent themes arising from the various conversations.

There were many more interesting and valuable ideas which people generously shared during this project which are not specifically detailed in this report, but which enriched our wider understanding of the sector and the individual experiences and challenges within it.

Another less public outcome has been our increased collective awareness of the numerous individuals and businesses who are active in this sector. Many participants have expressed how valuable it was to meet with others in their local region who share similar interests and are having similar challenges. Hopefully there will be more opportunities to further build and strengthen these local networks.

A list of people who contributed ideas and insights that we drew upon during this project is given in Appendix 1. We would like to once again acknowledge their input. Thank you.

We hope this report will stimulate further discussions around how we can individually and collectively seek to advance the emerging proteins sector.

OBSERVATIONS

1. There is significant and diverse activity in emerging proteins throughout New Zealand, with the current focus being on plant-based foods.

There are a number of individuals and organisations throughout NZ actively working in the emerging proteins space. There are growers who are experimenting with new (and some old) crops, manufacturers who have expanded their traditional ranges to include vegan products, new businesses being built from the principles of sole or primary focus on emerging protein sources, and researchers working along the entire value chain seeking to open new opportunities. Those involved are almost universally passionate about the potential of the sector, while also almost universally identifying significant challenges in achieving that potential. These are discussed in more detail in the coming sections.

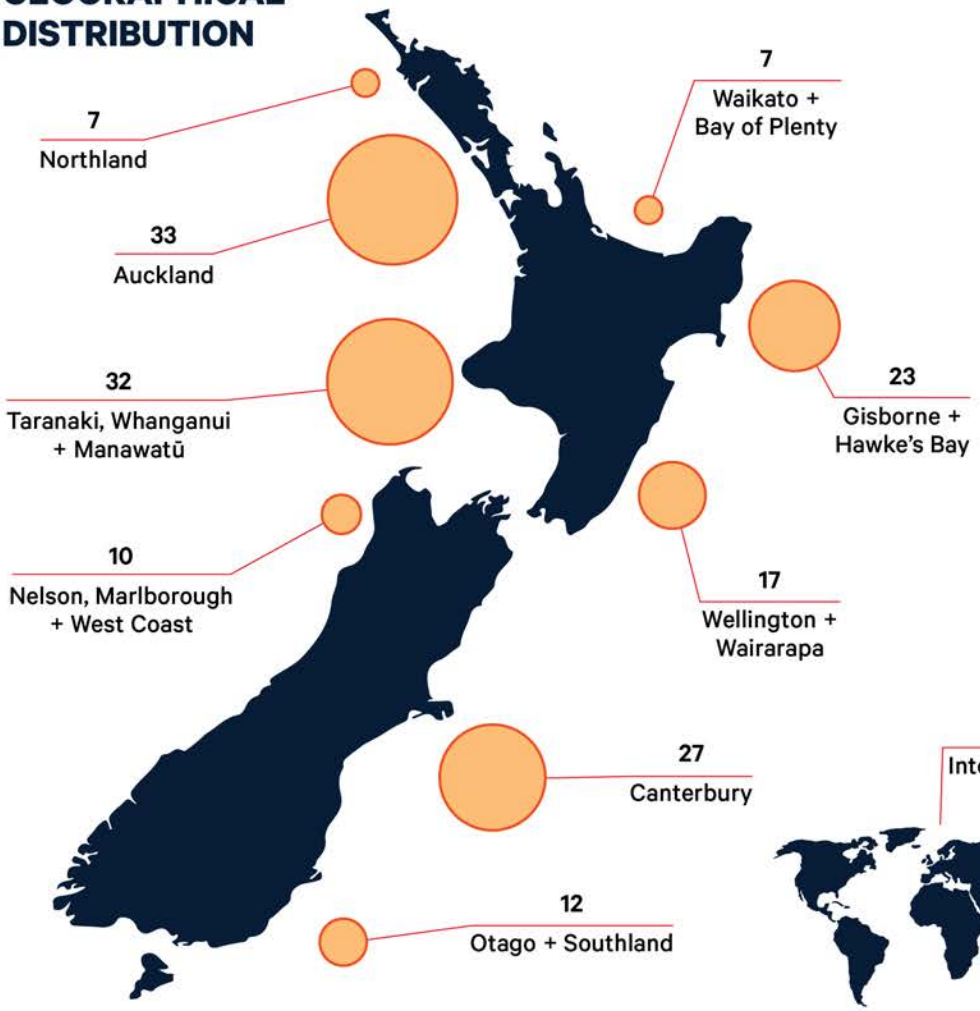
For simplification within this document and in the broader discussion, we have divided the emerging proteins category into subcategories of plant, non-traditional animal proteins and biotechnology.

- Plant is the most well developed category. Although not strictly correct from a taxonomy perspective, we have included fungi (mushrooms) and algae/seaweeds. The development of the algae/seaweeds sector is much less advanced than much of the other more common plants, but is similar to the development of the more novel plant approaches, such as grass protein ingredients.
- Non-traditional animal proteins are insects and other developing opportunities from animal derived products such as wool. There is a lot of diversity within insects, including a wide variety of different species, from black soldier fly to crickets, locusts to mealworms; as well as the various developmental stages of these (i.e. larva, pupa, adult).
- Biotechnology includes fermentation of microbes who have been genetically modified to produce molecules similar or identical to those from animals, cell-culture techniques where stem cells are used to produce meat or milk, and other genetic modification-based techniques such as the genetic modification to enable plants to express animal proteins. These all involved genetic modification and as such any research in these areas is tightly restricted under current NZ regulations.

There are currently no cell culture or fermented protein food products made in NZ, and there are only a handful of small-scale companies who have insect-based foods for human consumption. There is no commercial plant-protein ingredients sector in NZ at present. Thus, the main area of current activity is plant-based foods, and it seems likely that this will remain the key area of focus for NZ producers for at least the short to medium term.

Although there is much interest and activity in emerging proteins within NZ, it is important to put this into an international context. 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 that 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.

GEOGRAPHICAL DISTRIBUTION



TYPE OF ORGANISATION

122 INDUSTRY

34 RESEARCH/ EDUCATION

19 LOCAL/CENTRAL GOVERNMENT

10 PROFESSIONAL SERVICES

185
TOTAL CONTRIBUTORS

FOR INDUSTRY CONTRIBUTORS (122 PEOPLE)

PART OF VALUE CHAIN

15
Farmer/grower/harvester

20
Primary processor
(converts primary produce to ingredients or foods)

35
Secondary processor
(makes more complex food products from multiple components)

31
Integrated producer
(grow/harvest and process into ingredients or food products)

9
Provider of foods to consumers
(retail, hospitality)

12
Other (consultants, technology suppliers etc.)

BUSINESS SIZE

32
Large/Multinational

44
Small to medium enterprise

46
Start-up/Entrepreneur

Vegetarian-friendly animal proteins – no longer an oxymoron.

Although the focus in emerging proteins is often on plant based or biotechnology approaches, there are also interesting animal-sourced proteins with significant market potential. NZ company Keraplast Technologies is leading the way in the commercialisation of keratin extracted from wool shorn from a sheep.

Keratin is one of nature's most important cellular building blocks, giving the human body structure and order, and is fundamental in the development of healthy tissues, including skin, hair and nails. It has some similarities to collagen, which has seen a huge surge in market interest, with a number of successful collagen products positioned as supporting general health and beauty.

The amino acids in keratins are linked in particular sequences that together like small bundles of rope, building strong protein networks. The same sequences are present in human skin and hair and so functional keratin proteins can be considered skin and hair identical proteins. The particular amino acids in the coil link, like teeth in a zipper, to lock the structure in place. This structure is essential for the protein to perform its role, either in helping skin cells make proteins or in keeping hair strong and flexible.

Many keratin extraction or production technologies break up the proteins and damage the amino acids, and in doing so they lose the important "teeth in the zipper" needed for the functional benefits.

Keraplast Technologies has developed and patented proprietary manufacturing and processing technologies which gently extract fully bioactive keratin proteins from natural, renewable sources (including wool). These proteins are then developed into a range of product solutions to support healthier hair and skin, increased lean body mass, as well as advanced wound care.

2. ‘Plant-based foods’ can be divided into two different categories - analogues and whole-plant foods - with different implications.

There are two distinct categories of foods that are generally grouped together when referring to ‘plant-based’ products. However, these have important differences that need to be considered when looking at options for NZ within the sector.

The first category is the one that often gets the most publicity and investment: meat and dairy analogues. These seek to mimic their animal-derived counterparts in terms of appearance, sensory characteristics, and how they are prepared or used. In fact, the closer they are to ‘real’ meat and dairy, the more successful they are considered to be. Meat analogues tend to use highly refined ingredients and processing technologies such as extrusion, although some of the less structured products (such as mince or sausages) can include less refined ingredients. Dairy analogues are usually prepared from a plant material using a combination of physical and sometimes enzymatic processing steps along with the addition of various oils and micronutrients. These products are heavily reliant on technology and there are a large number of different patents filed on various aspects ranging from ingredients to processing approaches. Once the formulation and processing parameters have been finalised, it is usually possible to produce consistent product because of the limited variation in raw materials.

The second category is whole-plant foods that are principally based on whole vegetables, grains, and other non-animal components (including mushrooms, which are technically fungi and not plants). These are usually formed into products that ‘celebrate’ their plant origins and do not attempt to look or taste like meat. These are often lower in protein, although some have had more concentrated forms of protein (such as plant protein powders) added to boost protein levels, but come with other nutritional value courtesy of the specific plant components used (especially fibre, complex carbohydrates, and various micronutrients). In general, these products are considered less ‘high tech’ than meat analogues and it would be difficult to formally protect through patents, but there is significant expertise and skill in the development of the formulation and selection of processing parameters to obtain a really great product. There can be a lot of natural variability in whole minimally-processed ingredients, which can require significant batch-to-batch adjustments in order to achieve the desired final product.

Overall, it seems that whole-plant foods have advantages in terms of their environmental footprint, as they primarily use minimally-processed ingredients which are able to be grown locally and generally require less capital and expertise-intensive processing equipment. But they do not usually provide protectable intellectual property. Meat analogues have much larger environmental footprints, requiring highly

refined (and currently imported – see section 9) ingredients and expensive specialist equipment. But there is more opportunity for protectable and licensable intellectual property. Different consumers seem to prefer the different categories, with whole-plant food consumers often talking disparagingly about why people who choose not to eat animal product apparently want foods that are copies of animal product, and analogue consumers believing that a good mimic can make it so much easier to not miss the real thing.

NZ companies have successfully commercialised products in both these categories, and there are more companies with both types of products under development. However, if NZ is to develop scale within the meat analogue space, it will either need to develop a domestic plant protein ingredients industry or be dependent on a 'trader' model similar to that of the Netherlands.

There is no data that we are aware of that compares the relative local and export market sizes and values for these two categories, instead grouping them together as plant-based foods.

This fails to recognise the important differences in the products and their consumers, and the subsequent implications for the development of large-scale production in NZ for either product category.

It is worth noting a difference between meat and dairy analogues in this case - NZ currently does not have commercial scale manufacturing infrastructure for plant-based milks, with all commercial scale plant-based milks being imported. There is milk from NZ oats available, but the oats have been shipped from NZ to Europe for processing into milk which is then shipped back. However, this is due to change with construction of a new oat milk extraction plant planned in Southland. It appears that this plant will be solely focused on oat milk, and so all other plant-based milks will continue to be imported. There is no exporting of NZ-produced or NZ-grown plant-based milks at this stage, but it is anticipated that there will be exports of NZ oat milk once the new plant is up and running.

"Oats are very cool right now." *Henry Hawkins, Harraway & Sons CEO*

The increasing market demand for milk alternatives has led to an explosion of plant-based milks. Among the more common almond and soy-based beverages, there have been multiple oat-based milk products enter the market.

Participants in the various discussions expressed a level of skepticism around whether NZ could feasibly compete in the international alternative milks sector, either with the growing of the raw materials or the production of the milks themselves. However, unlike soy or almonds, oats have been grown at scale in New Zealand for over 150 years. This means there is already existing expertise, infrastructure and logistics for their growth, harvest, storage and initial processing steps, concentrated in Southland.

In addition, an eight-year breeding programme by the Oat Improvement Group, a collaboration between research provider Plant Research New Zealand Ltd, Southland Oat Growers and Harraways has led to the development of a proprietary oat cultivar, Southern Gold L5. L5 is a plump oat with a large groat [kernel] that has slightly higher yields than existing varieties, but its main attraction is the overall oat quality, with milk from L5 appearing to have advantages over oat milks from other cultivars.

Harroways and other key players in the oat industry want to capitalise on the potential of L5 oat milk. NZ's reputation for quality food and beverage, the established local oat industry and a proprietary cultivar which produces a more desirable product are all important components required for NZ to succeed internationally. However, the key missing piece of the puzzle is the commercial scale processing infrastructure to produce the milk from the oats.

The oat milk currently sold in NZ is produced overseas, with the milk from NZ oats also having been produced in Europe from NZ oats that have been shipped over to the processing facility.

NZ Functional Foods has been established by Southland's economic development agency, Great South, to investigate the high value, health and wellness, export opportunities provided by oats. They have now secured cornerstone investment for a high-tech oat processing factory from Sir Stephen Tindall's start-up backer, K1W1, and are working on securing further capital. They aim to start construction of the plant near Invercargill within the next 18 months, and hope to kick off production a year from then. L5 oat milk will be the first product launched, targeting both local and export markets. The plant will be available to contract manufacture oat milks on behalf of interested food companies, and the intention is to expand the processing capability to other oat product types as well.

So will NZ be able to play in the international oat milk market? Well, it has the willingness, the sustainable growing conditions, the established oat industry, a proprietary cultivar with advantages over other oats, experience in food product development, and very soon the commercial scale processing infrastructure. Watch this space!

3. “Plant-based” is often associated with healthy, natural and sustainable by consumers.

The international consumer trends for ‘natural’, ‘healthy’ and ‘sustainable’ food products have led to increasing demands for more minimally-processed whole foods, while still maintaining expectations around convenience, shelf-life and taste. Interestingly enough, many of these consumers are also purchasing more plant-based foods, including meat analogues. This is despite current plant-based meat analogue products tending to be highly processed, made from ultra-refined ingredients with a range of additives and processing aids, and in some cases (Impossible Burger) relying on genetic modification.

It is commonly noted that plant-based alternatives to meat and dairy are not nutritionally equal, both in terms of macronutrient content (especially protein levels) and micronutrients (especially iron and zinc). However, participants in the discussions observed that they don’t think that most flexitarian or vegan consumers are concerned about nutritional equivalency, and that messaging related to this does not seem to be having any impact. Flexitarians appear to generally feel comfortable that their overall diet will be nutritionally adequate, with valuable but different nutritional contributions coming from their animal, and their plant-based foods. Vegans are seemingly similarly comfortable with their ability to achieve a nutritionally adequate diet purely from plant sources, even for those nutrients found at lower levels or with lower bioavailability in plants.

Similarly, it has been noted by Wageningen University and Research that while minimally processed plant-based foods generally score pretty well in environmental impact assessments, the more processing involved the worse the score, with ultra-processed products utilising highly refined plant-based ingredients being very carbon intensive. Yet, there seems to be little difference in consumer perception of the product sustainability at this stage.

It is possible that consumers may become more sophisticated in their understanding of these aspects and that this may translate to changes in their expectations for the next generation of plant-based products. However, this is likely to require significant improvements in how information on aspects such as life cycle analysis and nutritional implications are communicated to consumers. Right now, there appears limited interest from most consumers in delving into these areas, and they feel comfortable with their simplistic assumptions that anything plant-based is healthy and sustainable by default.

Consumer perception becoming their reality.

In Ponsonby Countdown dairy-free ice creams have been located under a sign that reads “healthier ice cream”. When questioned about this the Manager replied that he is responsible for sign-posting the products so that consumers can find them, and that this was the language that consumers used when describing the dairy-free ice cream options. This is despite many dairy-free ice creams (especially those based on coconut) being comparable with dairy ice creams in terms of nutritional composition.

There is an interesting chicken-and-egg situation developing here: Are consumers who see the “healthier ice cream” signage above dairy-free going to assume that this is based on a credible nutritional assessment rather than simply a reflection of the language of other consumers?

Food Standards Australia New Zealand (FSANZ) has restrictions around when the word ‘healthy’ can be used on foods, and the Commerce Commission regulates comparative claims (i.e. healthier than what and by how much?). However, it is unclear whether there are any specific requirements around signage in a retail environment.

Protein (and nutrition more generally) not front of mind for all consumers.

Protein has been widely touted as a key focus for local and international consumers, with references made to the increasing popularity of terms such as keto and low-carb on social media and in product launches. However, this does not seem to be carrying over into all areas.

Many plant-based foods and beverages are significantly lower in protein than their meat or dairy counterparts, and the meat and dairy sectors have been advocating the superior nutrition of their products for some time. Yet increasing numbers of consumers are choosing to include plant-based products in their diets.

It has been observed that nutritional content claims do not appear to resonate with many consumers, and that communication about the health and wellness benefits (that may arise from the nutritional content) may be more engaging. These benefit claims are more complex and expensive to validate, and there are different regulatory requirements for them in different markets.

A recent FoodHQ scan of Instagram posts by international plant-based brands found that only 16 out of 100 contained any mention of protein within the posts or visible on packaging shown within their Instagram images. This suggests that these companies do not feel that protein content is of particular interest to their consumers. Health related claims were also made on relatively few products (28% of US brands, 2% of brands from Europe; possibly reflecting either the greater interest in health of US consumers or perhaps the more relaxed regulatory environment in the US for these sorts of claims). Instead, the most consistent theme in the Instagram posts was an emphasis on how great the product tasted (72% of US brands, 54% of brands from Europe or the UK). This is in line with the oft repeated phrase in the food industry that 'Taste is King'. It seems that this is the same for both traditional and emerging protein products.

4. Developing emerging proteins is about portfolio diversification, not replacing all traditional agricultural systems and products

There were quite a few heated discussions around the country regarding the future for NZ in both traditional and emerging protein products.

There are those who are adamant that a successful future NZ must move completely away from traditional animal agriculture; but there are also those who are equally adamant that NZ does not have a clear pathway to international success in emerging proteins. In both cases, there were fairly strong lines of reasoning for why the particular perspective was considered likely to be true, usually built upon broad generalisations and high-level observations.

However, the majority of participants felt strongly that this was unlikely to be an 'either/or' situation, at least for the foreseeable future. Instead, there is an opportunity for NZ to have a more diverse food production system that produces both sustainable high-quality animal and emerging protein products. Holding this perspective requires a somewhat more nuanced view of both sides.

The following table summarises some of the common statements in discussions and provides some alternative perspectives that are not necessarily mutually exclusive.

There is work (much underway) to be done on both traditional and emerging protein production systems and value chains to ensure they are aligned with consumer demands and are environmentally and financially sustainable.

Wageningen University and Research (WUR), an international thought-leader in circular food production, supports the presence of animals within sustainable food production systems. They have proposed redefining the role of animals as 'protein converters' rather than 'protein sources' to better reflect their consumption of protein (from crops, pasture or other sources) in order to produce the protein in their meat, milk or eggs.

Traditional meat and dairy remain strong export sectors for NZ and demand for these products is still growing rather than slowing. However, there is an increasingly broad range of possibilities for future food production being developed by some of the world's smartest thinkers.

It doesn't benefit our existing industry to deny the potential for serious disruption, nor is it necessary to abandon traditional proteins in order to take advantage of emerging ones. The sooner this becomes an 'and/both' discussion rather than an 'either/or,' then the sooner we can work together to identify how NZ can best move forward.

Common statements that may be true	Alternative perspectives that may also be true
People will always want to eat animal protein.	In addition to consuming some animal protein, many people will also choose to eat more plant, fungi, algae and eventually insect-containing foods.
The most efficient and environmentally sustainable food production system is purely plant-based.	Animals can convert protein from feed not suitable for human consumption (pasture, biomass remaining after crop harvesting, by-products and waste from food processing, etc.) into protein that humans can consume. This role of protein conversion is a valuable part of a circular food production system with minimal waste.
Most people won't trust genetically modified or synthetic proteins.	With time, many more people will be comfortable eating proteins from fermentation and cell culture technologies – especially those who are not connected to traditional production systems, such as urban Asian consumers.
NZ will never grow plant-based proteins economically	NZ science and innovation, combined with deep consumer understanding and a genuinely sustainable NZ provenance story, has the potential to enable the economically viable modest-scale production of plants that can be converted into products that discerning consumers will pay a premium for.
Regardless of what happens to our pastural agriculture, we always have seafood and aquaculture.	Although our seafood industry is not currently under as much pressure as pastoral agriculture, there are still many of the same challenges. Climate change will affect our fisheries, both wild-catch and farmed. Consumer concerns about the environmental impact of fishing and microplastics in seafood will increase. Seafood substitutes will become increasingly sophisticated and available.
NZ will always have an advantage because of its plentiful natural resources and provenance.	New technology and innovation (including the use of GM) will allow other nations to produce foods without such plentiful natural resources. They will get better at telling their stories, which may be based on natural resources and provenance or on technology and innovation. Climate change will affect the feasibility and outputs of our current food production systems and locations.
It is not cost-effective for NZ to adopt capital-intensive food production systems because land and water is relatively cheap and plentiful.	Land and water will become more highly valued, driving a focus on better utilisation. High-tech production systems will reduce in cost as the technology matures, and the increased certainty around quality and yield from these systems will become more attractive, especially as climate change increases the frequency of extreme weather events.
NZ always has and always will be a food exporting nation.	NZ could develop a significant 'weightless' export industry leveraging our food-related intellectual property and innovative capital. This industry is starting from a relatively low base but has the potential to grow exponentially as we attract more top talent and investment.

5. There are various business models for emerging proteins, including adding value to imported raw materials or producing one's own raw materials. We can also develop new ones.

The very successful Dutch food industry (the second largest food exporter in the world) is based upon a 'trading model' of importing ingredients, adding value through combining ingredients and processing, then exporting the resulting food products. They have a natural advantage due to their proximity both to the sources of the ingredients and large consumer markets but they also invest in talent and infrastructure related to food, and take full advantage of this model's flexibility to rapidly respond to changing consumer demands.

It is common in the NZ food industry to import some of the ingredients used in foods for both our local and export markets, but it is less common for our exported foods to be predominately based on imported ingredients. There is a certain appeal in adopting successful approaches from the Dutch, but our distance from ingredient sources and our export markets does put us in a different position.

This approach would appear to be most likely to suit NZ foods where there is a significant proportion of NZ sourced ingredients, where at least one of those ingredients is something particularly unique to NZ, or where there is sufficient consumer value in the product being 'made in NZ'. In other circumstances, it may be worth considering whether a more efficient (environmentally and financially) business model is presented for the products to be made closer to the targeted market through a local contract manufacturer or via some sort of partnership with a local firm.

For products dependent on the importation of large volumes of ingredients, there is a risk in the adoption of this import/process/export model around the increasing consumer awareness of the contribution of food production and distribution to climate change. At the moment, consumers do not appear to be aware of and/or concerned about this for plant-based foods as there does seem to be a bit of a sustainability halo around them regardless of the specific nature of their production.

Another business model that is starting to be more widely discussed in the NZ food sector is that of the export of 'weightless' intellectual property rather than our traditional physical food products. We have the opportunity to use our Kiwi ingenuity to develop new knowledge and products within the emerging proteins space that can then be used to produce foods closer to either the primary raw materials or the target market. This requires careful partnerships and/or licensing arrangements, but does open up the opportunity for NZ to be earning income from our food science expertise and innovation capability, without us necessarily having to use NZ resources to produce the products.

Irrespective of the business model, it will (at some point) need to have scale in order to have impact. Start-ups and SME food businesses have been very successful in sparking increasing consumer interest in emerging proteins with the development of new products either based on what is available overseas or in some cases on novel intellectual property. Small food businesses can innovate fast, develop deep understanding of their niche consumers and engender trust through clear communication of and commitment to their values. It is possible that some of these businesses will be able to successfully scale and become large players in the local and export markets. However, international experience has been that most brands with large market share have grown via start-ups or SMEs who have then partnered with, or been acquired by, large companies. These big food companies can unlock the efficiencies of scale to enable rapid and cost-effective expansion that can make the products more widely available and accessible.

It seems likely that a successful NZ emerging proteins industry will require a combination of innovation and responsiveness from small companies with the resources and involvement of large existing businesses. Many of NZ's larger food companies participated in the discussions for this project and have indicated varying levels of interest in the sector ranging from current active participation through to keeping a watching brief. The challenge will be in finding business models that successfully respect, protect and leverage the respective strengths of the different companies. It also seems likely that other market consolidation models such as syndicates and cooperatives may have roles to play, particularly to enable groups of growers to achieve the scale and reliability of supply required by larger food manufacturers.

6. We must understand our target consumers and what products they want, and ensure these products are visible and accessible.

The international consumers of NZ's food products in the future will be knowledgeable, conscious, tech savvy and data hungry, and in many cases they will be different from those consumers the NZ food sector has previously served. This is exacerbated when we think about the future consumers of NZ's emerging protein products. These consumers are likely to also have expectations not just around the food product but also its packaging, and, increasingly, the wider set of values of the food producer.

Different discussion participants were targeting different consumers in different markets with their products. In many instances, the target consumer group was fairly loosely defined, with participants seemingly relying on a very broad set of potential consumers for their products.

If we are to step outside our reliance on NZ provenance alone, it is very important that our products meet the needs of their target consumers. While the broader the target consumer the larger the potential market, it is rare to find products that large numbers of general consumers really connect with. More often, it is the more niche products that resonate strongly with their consumers and inspire engagement and loyalty. Given the very small scale of NZ's food production on the international market (even our dairy industry only produces 2% of the world's milk supply) and higher production costs, serving premium niches appears an attractive strategy.

Achieving this requires us to segment markets and deeply understand sustainable consumer niches (i.e. not just passing fads) so we can develop products tailored for them, making sure we recognise the different drivers for different consumers and align our products and marketing accordingly. This requires high quality, accessible,

Vegan vs. plant-based.

The language used to describe foods with no animal products seems to be shifting. Not long ago these products would be simply classified as 'vegan'. However, the term 'plant-based' has become increasingly visible in the past few years, especially with younger (more 'hip') consumers and flexitarians.

While technically meaning pretty much the same thing, it seems that 'plant-based' is generally perceived as being more inclusive and accessible than 'vegan', with the latter having become symbolic to many people of an extreme position (both in terms of food and wider social stances) that does not resonate as well with many new consumers.

An example of this is provided by unsuccessful Dunedin plant-based burger joint "Straight Up Vegan". Despite confidence around consumer trends, sales were slow, and it seemed it was viewed as a niche offering for animal free advocates combined with a perception that vegan food was lacking in flavour and required consumers to 'give something up'. They rebranded "Burger Plant", and while the food did not change, business has boomed as a wider array of consumers are coming in expecting (and receiving) tasty food that just happens to be based on plants.

tailored and recent market and consumer insights. This was identified by a number of participants as being either unavailable for the categories/ markets they were focused on, or too expensive for them to access as SMEs or start-ups. Investment is also required to develop business consumer and sensory science capability and understanding to enable them to utilise such data.

Despite the reports of increasing numbers of people choosing to consume a vegan diet, the vast majority of consumers still choose to eat both plant and animal products. Many consumers throughout the world (especially in more developed markets) do report that they are interested in new food choices and are currently or potentially considering reducing or changing their consumption of traditional protein sources. Other consumers (primarily in emerging markets) still appear to consider it desirable to increase the amount of animal protein foods in their diets, although in some cases there may be a shift in what type of animal proteins they may prefer.

At almost every session, there was an acknowledgement that the majority of current potential consumers for NZ emerging proteins food products are not in fact vegans, but are people who are interested in a more varied diet that includes new (at this stage primarily plant-based) foods and ingredients whilst still consuming some traditional meat and/or dairy. These are sometimes referred to as 'flexitarians'.

It seems most flexitarians who wish to increase the proportion of plants in their diet are achieving this by purchasing more plant-based foods (those that in theory would be suitable for vegans). But they do not necessarily require them to be vegan and in principle 'hybrid' products that contain both plant and animal components would also help them achieve their dietary shifts. This observation has led to the launch of a number of hybrid products (usually whole-food blends i.e. beef and beetroot burger patties) that purport to offer the taste, texture and micronutrients of meat combined with the lower environmental footprint, reduced fat and higher fibre of plants - the best of both worlds in a single food item. However, it has been claimed by some consumers that the products are simply not as tasty as real meat and not as healthy or sustainable as plant products. It will be interesting to see whether adoption of these products increases as consumers become more accustomed to them, or whether the products become more sophisticated in terms of ingredients, processing technologies, or other means of improvement. Data shows that sensory experience is key in driving repeat purchasing.

The size of the flexitarian market also potentially influences product branding. It has been assumed that vegans would prefer not to purchase vegan products from companies who also produce animal-protein products. However, this would seem to be less of a concern for flexitarians, and in fact there may be advantages in leveraging a brand these consumers already know and trust.

Where can consumers find emerging proteins at the supermarket?

Several participants commented on the challenges for food producers and consumers in ensuring that the full range of options is easily accessible and comparable.

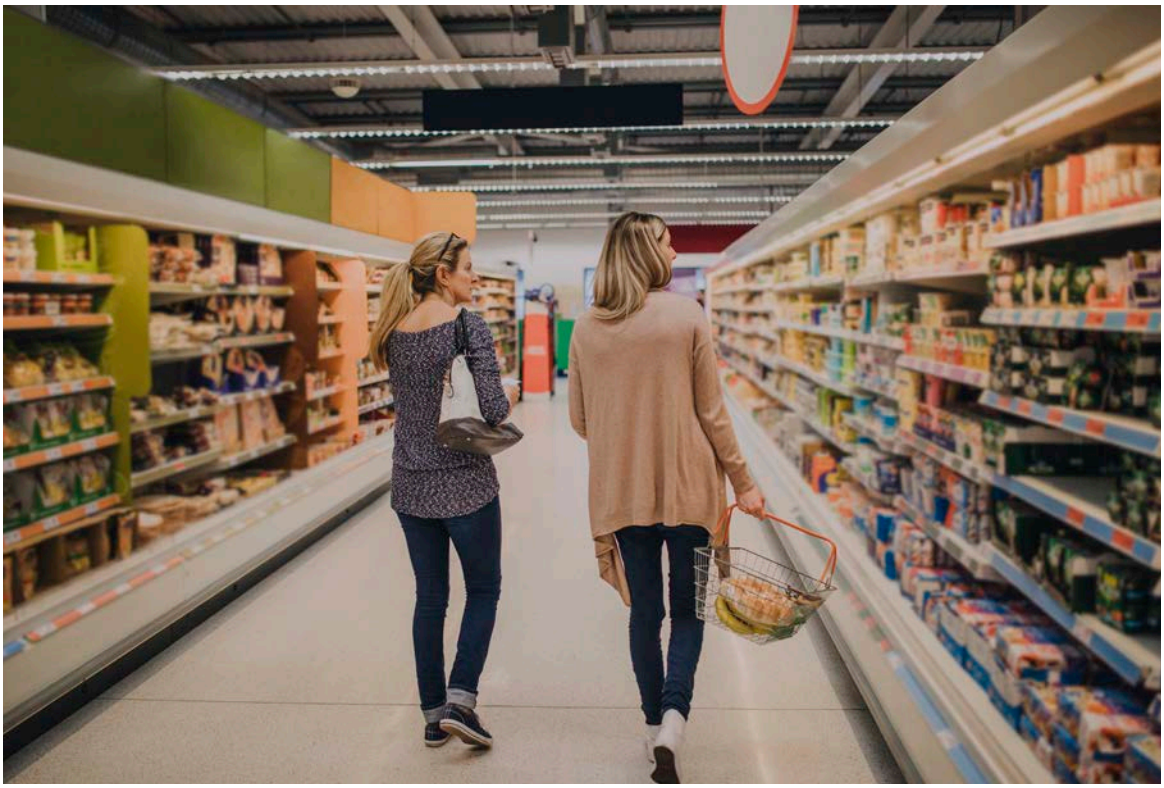
Different retailers (even different branches of the same retailer) are taking different approaches to where they display the 'centre of plate' emerging protein products. 'Centre of plate' products are those which a meal is commonly built around – traditionally the meat, now possibly the plant-based pattie or mince.

Traditional vegan products such as tofu have usually been located in the chilled section along from dairy products, deli meats, soups and hummus. It is now common to find a larger range of soy-based foods as well as a selection of plant-based burgers or sausages from certain brands on these shelves.

However, other similar plant-based food products may be located among their chilled or frozen meat-based or hybrid equivalents either in a dedicated section ("lamb", "beef", "chicken", "plant-based") or else distributed alongside products of similar types (i.e. sausages, minces, crumbed nuggets).

Similarly, most plant-based milks are currently ambient stable and thus displayed in the middle aisles in tetrapacks, while the chilled dairy milks are in a separate area usually around the edge of the store.

Consumers can only buy something if they can find it, and if they don't even know something exists then they won't even think about where it may be located.



Why do some non-meat eaters want products that mimic meat?

A common question in discussions on emerging proteins refers to the increasing numbers of meat analogues or mimics on the market or in development.

Why, if someone does not want to eat meat, might they want to eat something that looks, smells and tastes like meat?

One answer is simply that for many (but not all), just because although they choose not to eat meat they still enjoy the meat eating experience. Another answer is convenience – they know how to structure a meal around meat products, and it is easier to substitute out real meat for a meat mimic. For some, it may be their first brave step towards plant based foods which look and taste familiar to 'meat-like' foods.

Meat analogues continue to be an area of significant sales growth and investment in the consumer foods market. There are increasingly sophisticated options becoming available all the time, and it seems likely that in future there will be more meat mimics that are much closer to the real thing.

Some Dutch colleagues have referred to meat analogue products as a transition stage that is necessary to help individual consumers and indeed wider society move away from more traditional eating patterns into new ones. They believe that with time there will be less interest in meat mimics and instead consumers will embrace more diverse plant-based foods formats and taste profiles. Only time will tell!

7. The emerging proteins sector is seen as a potential solution for farmers and growers and as an opportunity to food producers. It is vital they explore the possibilities together.

The interest in the NZ emerging proteins sector has a range of drivers. These generally fall into two broad categories:

a. Offering a solution to farmers and growers seeking to future-proof their businesses through enabling better financial and/or environmental performance; and

b. Providing an opportunity for new and existing food producers to profitably capitalise on the growing national and international consumer demand for new foods.

For NZ arable farmers, the interest in emerging proteins has sparked as they look for opportunities to shift to higher value crops that would be used for (higher value) human foods rather than animal feed. For many animal farmers, interest has been stimulated as part of an evaluation of potential responses to tightening environmental limitations (either now or expected in the future).

In parallel, increasing awareness of the strong growth (albeit off a relatively low base) in sales of foods incorporating emerging protein sources has led existing food producers to expand their product ranges and encouraged entrepreneurs to establish new businesses focusing on this space. They feel that there are opportunities for products that better align with consumer expectations, particularly around flavour and texture. Some of the participants were seeking to develop or take advantage of technological innovations that would enable them to provide new products or potentially unlock new sectors; others were content to be using existing approaches but possibly adapting these by using new ingredients or tailored for new niche consumer groups.

These two categories are potentially, but not necessarily, complementary. There is the potential for the diversification of land use to align well with new consumer demands, but this does not happen by default. Ultimately, just because we can grow something doesn't mean that we have the right infrastructure to transform it into the right products, in the right format, for enough consumers in a particular market to pay enough for it to be a viable business. This is why it is absolutely vital a whole value chain approach is taken to developing this sector in NZ.

At present, there is significant public and private sector investment into the evaluation of what various tracts of land could successfully grow. However, there is much less investment to support the broader feasibility assessment that considers the consumer and market insights as well as the infrastructure availability. All these components must be looked at together in an integrated fashion to efficiently identify opportunities that are likely to succeed.

Matching supply and demand in any new sector is challenging, especially when crops take months to grow and potential sales of new products can be difficult to predict. In one case, a farmer grew a 'small amount' of a new crop (180 tonnes) of which 1 tonne went into a new food product, with the other 179 tonnes going to animal feed. Fortunately, there was a good relationship

between the parties and they are continuing to work to build this opportunity. There were also several reports of neighbours looking over the fence at trial fields of new crops and proceeding to plant the same crops themselves, then at harvest time the neighbours coming by to ask who would be buying the crop. Most of those neighbouring crops ended up as animal feed. Selling into channels producing food for human consumption offered a significant potential premium over the lower priced commodity animal feed channels, and while it is very useful to have the animal feed market as a fall-back option to take surplus crops, there is insufficient financial incentive to develop new crops purely based on returns from animal feed.

It is inevitable that there will need to be calculated risks taken when developing a new sector. However, the excitement over the potential for emerging proteins to offer profitable solutions to farmers combined with the ease (in many cases) of 'just putting some seeds in the ground' does mean there is a significant risk of supply outpacing demand, especially in these early years. Other sectors have shown that this can lead to the collapse of prices and the loss of appetite for further investment in the sector. It is important that attention is paid to aligning demand with supply as much as is possible, and that there is an awareness that the development of a new sector is a long game.

8. We cannot rely on NZ provenance alone.

The participants generally agreed that, at least in the short to medium term, it seems likely that there will be continued demand for products consumers perceive as safe, sustainable, high quality, 'natural' and as having a great provenance story. However, it was noted that while NZ provenance can be valuable, it is not enough in itself to guarantee consumer purchase, and there are many other countries who are investing significantly in building their reputations as quality food providers, such as Ireland with its Origin Green initiative. Credibly leveraging provenance can also become more complex in processed foods, or where there are multiple ingredients.

There are producers who are successfully achieving a premium both locally and internationally for their NZ-grown or NZ-produced products. Pic's Peanut butter is a remarkable 'brand NZ' success story both here and in key Asian markets, despite the key ingredient, peanuts, being imported to NZ prior to local processing. Peanut growing trials in Northland may lead to a supply of NZ peanuts in future, but local production is likely to remain relatively small scale and more expensive than is possible overseas. As the 'hero' ingredient in peanut butter, it would be expected that use of NZ peanuts would be clearly highlighted on the label, and Pic is anticipating some consumers will pay a premium for this.

On the other side, there are producers who report that they are struggling to get domestic food service and food manufacturers to pay extra for a NZ-grown ingredient. This is especially common where there is limited opportunity (or consumer expectations) to communicate with the consumer regarding the origin of that particular ingredient. Current regulations which enable a general "made in NZ from local and imported ingredients" label do not require transparency at the individual ingredient level, and while these are pragmatic in many ways, they do not support the uptake of locally-produced ingredients.

In terms of export markets, NZ does not have the same long history of growing and producing emerging protein products as we do with our traditional meat and dairy products. International consumers have only recently begun to associate NZ with top quality wine and kiwifruit – and that has taken many years and considerable marketing. It is possible that with time and resources, international consumers will associate NZ with high quality, sustainable plant-based food products as well, but this is not something that will happen overnight.

Businesses looking to export NZ grown products have reported that they are having to compete with cheaper imported emerging proteins products being re-packaged then re-exported with the NZ name prominently displayed (and 'packed in' shown in smaller font). This is permitted under current regulations but is undermining our local producers with higher costs of production and there is significant risk of consumers feeling misled if they realise the true situation.

It is very important that we understand where consumers feel the use of the NZ provenance is authentic, and where it is potentially too much of a stretch. If there is misuse of the provenance it erodes trust and dilutes its value, affecting all producers.

There must also be awareness of the risk associated with relying solely on the provenance angle. There is always the chance of a significant enough event or series of incidents and media reports that undermine the consumer perception of NZ as clean, green and safe. We must do everything we can to collectively protect and live up to the 'brand NZ' our consumers engage with; but at the same time, it seems sensible to ensure that our products resonate with our consumers for other reasons as well.

Regulations and compliance – a challenging tight rope for NZ

Multiple conversations during this project indicated NZ's current regulatory framework and the requirements for food safety compliance are impeding the development of emerging proteins in NZ. This was not restricted to just those who were keen to explore the potential of the technologies involving genetic modification, but also those looking at non-GMO opportunities.

Many participants commented that there is insufficient resourcing of this area within the NZ government, leading to long delays in accessing tailored information on individual situations or in the government being able to undertake reviews or updates that reflect the requirements of the emerging proteins sector. Some concern was also raised regarding the reluctance of government officials in providing advice or recommendations, which is particularly challenging when there are no local precedents for how emerging protein start-ups are able to comply with regulations that were not designed with their products in mind.

Singapore has recently become the first country to approve 'lab-grown' chicken for commercial sale, providing international recognition of their leadership in the intersection between food and biotechnology. It is expected that this will lead to more start-ups and high growth companies working in this area relocating to Singapore to take advantage of this accommodating regulatory environment. Our discussions with food technology start-up Turtletree Labs (based in Singapore) revealed a close relationship with local regulators, including having access to key people within the Singapore Food Agency via WhatsApp and other channels that permitted quick and easy engagement. This means that Turtletree Labs see the regulators as part of their extended team, also keen to see their success and prepared to work together to proactively identify and overcome regulatory issues.

If NZ is to accelerate its emerging proteins activity, the regulatory and compliance area needs to be closely evaluated. It is likely that more resourcing of this will be required, and a more open co-development approach taken, similar to that of Singapore. If no changes are made, there is significant risk that the current regulatory environment will impede innovation and successful timely commercialisation in this area.

9. Currently, NZ law is restricting the development of some emerging proteins sectors.

Regulations and compliance were common topics of conversation for those working in emerging proteins. In many cases it was noted that the current regulations were making it difficult to develop viable businesses.

General constraints

For sectors such as fungi, insects and seaweeds, participants reported finding the regulation, licensing, and compliance aspects of the nascent sectors complex, onerous and expensive.

Sometimes this is because the regulations were written without an awareness of the types of emerging proteins opportunities that are now being pursued, and thus they were simply not a good fit for the products or circumstances they are now being applied to.

Other times it was because the first mover in an area is faced with covering all the costs associated with gaining approvals, and in many cases subsequent movers piggyback on this work and enter the market with a much lower up-front investment. Examples of this include the development of Risk Management Protocols (RMP) for approval by MPI - the lack of data related to a new area meant that the first mover needs to fund large amounts of work to establish this knowledge base, whereas those in more established sectors can leverage information in the public arena generated by many organisations over many years. Similarly, all the costs associated with gaining approval for the importation of new varieties must be met by the company who first applies for this; however, anyone can then import and use that variety immediately upon it being approved. In both cases these up-front costs are preventing new innovative products and restricting the expansion of new sectors. There needs to be an exploration of cost-sharing models in areas considered priorities for growth, or the potential for periods of exclusivity to provide some incentive for companies to invest in the approval process.

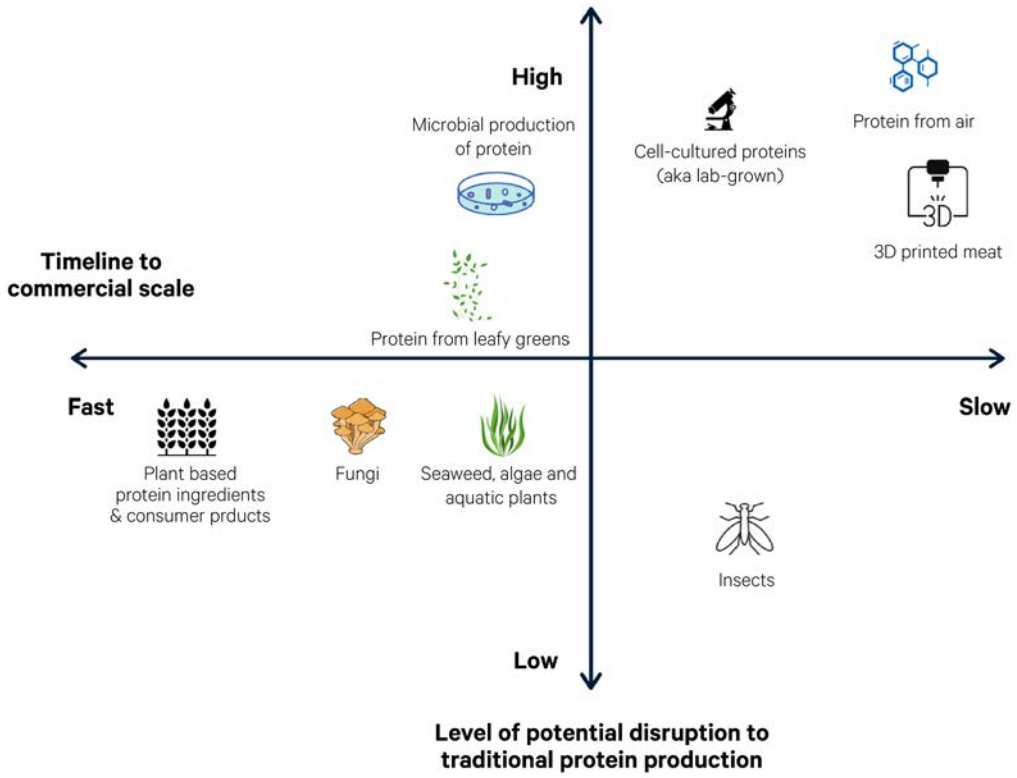
There are also a range of issues associated with how current country of origin labelling regulations are applied, which make it more difficult for NZ ingredients to compete with cheaper imported products due to lack of transparency in on-pack labelling.

GMO related constraints

For those seeking to utilise genetic engineering technologies, our current regulatory system does not permit the commercial production of genetically modified organisms, and makes research and development using these complex and expensive.

The development of unique cultivars may provide a competitive advantage to NZ in plant proteins. Those working in this area seem to generally accept the current situation, but also believe that they could more quickly and cost-effectively develop such cultivars if they were able to utilise modern high-precision genetic engineering techniques.

For those watching some of the international activity around the use of biotechnology for food production, there is an element of frustration and feeling that NZ is currently turning a blind eye to the largest potential disrupter of our economy ever seen. On the other hand, many people feel that the biotechnology approaches are least relevant to NZ, now or in the future. There are still many uncertainties around the true sustainability of these technologies at large scale, and there are questions for some around the safety and consumer acceptance of the products. It seems likely that cost and scale constraints will mean that production will focus on high value proteins (such as lactoferrin) or be constrained to relatively minor quantities for the next ~15-20 years.



It is fair to say that the economic feasibility of some of the emerging protein options (especially those involving biotechnology) do not currently stack up for NZ, based on our current knowledge and approaches. Much can and will change in the next 10 or 20 years, especially given the level of investment currently going into the cost engineering of large-scale emerging protein production systems of all kinds. Future generations of consumers are likely to be less concerned regarding genetic modification or the 'artificial' nature of these technologies, especially those in large urban centres that have grown up surrounded by technology and with no connection to traditional food production systems. It has been postulated that NZ's renewable energy supply could provide a potential comparative advantage in this space given a key challenge for these technologies will be the environmental impact of the large amounts of energy required to power the bioreactors at commercial scale.

Even a purely pragmatic risk-management perspective would suggest that NZ should at the least keep a close watch on the area. There is also a case for NZ to be investing in developing our own understanding and IP related to these technologies as a potential avenue for us to participate within the markets as they mature, but we must be cognizant of where we can realistically play given the large scale of investment internationally. We will need to primarily take an 'adapt and adopt' approach that identifies relevant new technology that can be tailored to the NZ context then deployed. This may be complemented with focused efforts in specific niches where NZ may be able to develop deep knowledge that will be of value to the larger technology players.

If we are thinking about how we diversify and build resilience into our economy, then some people think we should be focusing away from agrifood entirely. However, some of these higher tech approaches to food may enable us to leverage some of our existing skills and networks into new spaces while we also continue evolving our more traditional food production systems.

This area is highly dynamic, with rapid technological advancements and changing consumer attitudes. It is important that we consider not only what our consumers want right now, but also what they are going to be wanting in 10-20 years' time, what technology will make possible at that time, and what role NZ will chose to play in the future international food production system.

Biotechnology Approaches to Food Production

New Culture Foods is a NZ-founded, US-based emerging proteins biotechnology company built around a microbial platform which is being developed to produce recombinant casein dairy proteins. It was founded in 2018 by Matt Gibson, who was inspired by Mark Post's cell cultured meat venture (Mosa Meat), funded by Google's Sergey Brin.

Although there was interest in the technology and willingness to engage within NZ, there was limited local experience and expertise, and the regulatory requirements around genetic engineering in NZ made suitable laboratory space expensive and difficult to access. So, Matt applied for and was accepted into IndieBio, the world's highest profile biotech accelerator which is based in the US, which led to a USD $3.5m seed funding round led by Evolv Ventures (Kraft Heinz's venture arm). New Culture is currently focusing on further developing its casein-focused technology, with mozzarella being used as its exemplar product.

The New Culture experience demonstrates the raft of challenges facing bioengineered foods, including the economic feasibility of scaling to commercial levels, the intensive energy requirements (which can lead to high carbon footprints if powered by fossil fuels), regulatory hurdles and consumer acceptance issues. However, this has not dampened investor enthusiasm for the segment, with billions of dollars flowing into bioengineered protein companies over the past 18 months.

An improved understanding of these approaches can often spark creative solutions through the intersection of new and established industry. If our products will be competing against them on international supermarket shelves, it is vital that we can talk knowledgably about the technologies whether we are utilising them ourselves or not.

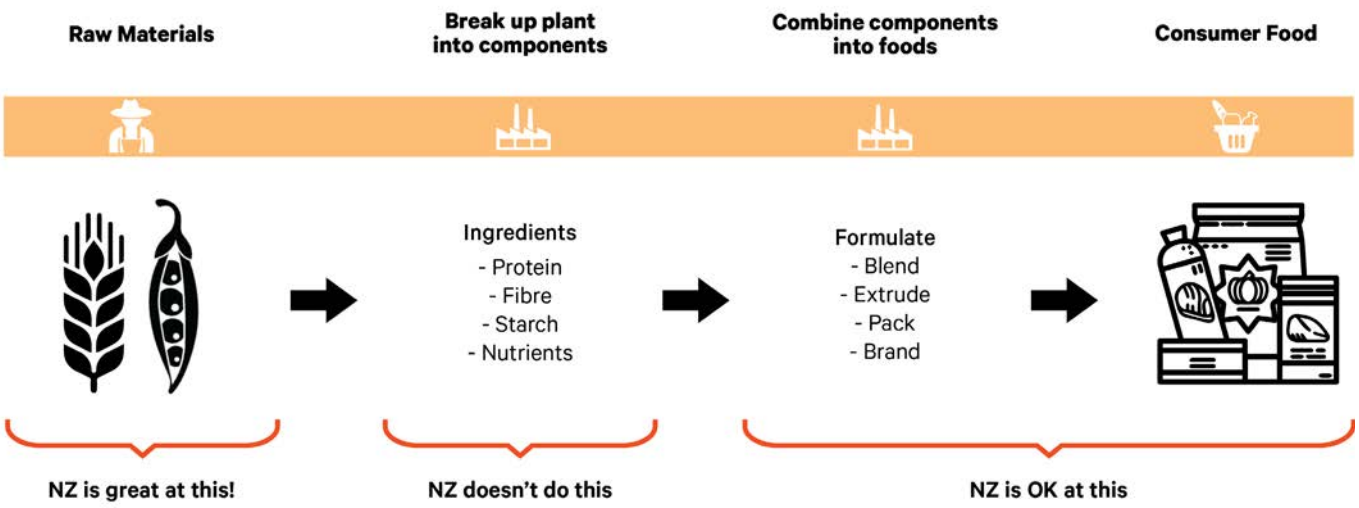
NZ cannot compete in an all-out technological arms race in the biotech space, but we do have smart kiwis coming up with innovative ideas that could enable NZ to have a (small) piece of the biotech pie. However, at present they are primarily either choosing not to progress these ideas or they are being forced offshore to progress them. Since the development of precision genetic engineering techniques, such as CRISPR, there have been calls for a review of NZ's relevant regulations, but there does not appear to be government appetite for this at this stage.

There are a few research initiatives underway in cell cultured meat through the University of Auckland, the Riddet Institute and Plant & Food Research; however, without a corresponding level of start-up activity and an easier research and development pathway, it is unlikely that we will attract top international talent or that investors will see NZ as a credible player in the space.

OPPORTUNITIES

Below we have summarised five key opportunities raised in our discussions.

1. NZ could develop a plant-protein ingredients sector, but this is complex and requires careful consideration and significant capital investment.



Plant protein ingredients are fractionated from plants and used as components within food products ranging from baked goods through to meat analogues. Virtually all refined plant protein ingredients currently used in NZ have been imported. This is because NZ is limited in its ability to produce many of the more purified plant-derived protein ingredients at commercial scale. This is due to a lack of the infrastructure required to fractionate and purify the protein from plant crops.

If NZ was to invest in the required manufacturing infrastructure to support a plant-based ingredients sector, it would need to be with the full awareness that our locally produced ingredients would not be able to compete on cost with the bulk imports. Countries like Canada can grow, harvest, process and distribute at such large scale that their ingredients will always be cheaper, even with the added costs associated with freight to NZ. We would need to have some advantage to NZ-produced ingredients that justified a higher price.

So, will consumers pay extra for products containing NZ plant protein? The short answer is that we don't really know. Discussion participants who use plant proteins in their products were split on their beliefs around the likelihood of consumers (in either our domestic or export markets) being prepared to pay more for the same product with imported protein swapped for NZ protein. To the best of our knowledge, no market insights examining this question have been collected.

It is worth noting that plant protein ingredients are generally not as easy to use in food products as their animal protein counterparts. The plant proteins (especially those at the cheaper end of the spectrum) tend to have stronger flavours (often 'grassy' or 'beany' or 'earthy'), be less soluble (not so much of a problem in baked goods but an issue in beverages) and often have less functionality (i.e. don't stabilise air or oil droplets as well). There are specialist plant proteins which offer improved flavour and performance, usually derived from research-intensive programmes developing proprietary crop varieties and/or refining approaches. These tend to be 5-10 times the price of the standard protein products and so are considered niche products for high-value applications.

If there were tangible additional benefits to the food products containing the NZ protein (improved nutritional attributes, improved flavour or texture, improved product performance) then it seems more likely that consumers may pay more for a product that offers a combination of one or more of these benefits in addition to NZ provenance.

Having a NZ plant protein ingredients industry could potentially shift the balance in the meat analogues category, as we may no longer need to import the primary ingredients in these. However, the higher cost of NZ plant proteins would mean that these meat analogues would need to be targeting higher price points with better margins and not a low-cost commodity play.

One thing to note with the production of more refined plant-derived protein ingredients is that there is a lot more of the plant material than just the protein, so to have a financially and environmentally sustainable process, it is usually necessary to consider how to utilise the other parts of the plant as well. These other components include starches, fibres, oils, polyphenols and micronutrients. In some instances, the plant material remaining after protein extraction may be able to be further processed into specialist ingredient(s), which is the most desirable option. In other cases, it may be able to be used as animal feed (less desirable option) or else must be disposed of as a waste stream (undesirable option). To capture the most value from the plant material, the protein extraction needs to be designed as part of a wider process that considers how each step will affect the potential uses and value of the remaining components as co-product streams, even if the commercialisation of these is not an initial focus.

NZ-grown plant proteins will need to be unique.

A number of participants were very thorough at identifying a wide range of different reasons why NZ cannot easily compete with large-scale producers of plant proteins such as Canada and the Ukraine. They are quite right. And we shouldn't try to set ourselves up in direct competition to these large-scale commodity producers. However, many of our current exports are produced on a smaller scale and at a higher price point than similar products from other countries. They rely on a combination of product characteristics (taste, functionality, reliability, safety, etc.) and often to some degree the NZ provenance angle. Why would we not be able to find a similar approach for plant-based proteins?

That's not to say it will be quick and simple, and we are setting ourselves up for disappointment and failure if we go into this without being aware of the challenges and complexities.

It is likely to have a better chance of success if we have one or more comparative advantages associated with the plants we chose to grow. Our ability to grow fantastic pasture all year round underpins the comparative advantage of the NZ dairy industry, and companies such as Leaft are looking to leverage that same advantage around pasture to support a new high value grass protein ingredients business. What other comparative advantages can we use to underpin our plant protein industry?

Can we develop some unique varieties and/or identify advantageous attributes that arise from being grown in NZ? It's been done before – think NZ sauvignon blanc, or (at a much earlier stage of development) new blackcurrant varieties with higher levels of bioactive polyphenols due to a combination of cultivar and our high UV light levels. The Southern Gold L5 cultivar (see section 4) is one example relevant to emerging proteins which is already at commercialisation stage.

NZ also has a distinctive position arising from Te Ao Maori values and knowledge of indigenous sources of emerging proteins from taonga species, including insects, plants, seaweeds, fungi and bacteria. It is essential that any activities involving these are undertaken in partnership with tangata.

It is possible that our lack of existing plant-ingredient infrastructure may be an advantage in our development of differentiated products. Much of the global oil-seed protein supply is currently a by-product of traditional hexane-based oil extraction processes which have been developed and optimised with a focus on maximum oil yield. The refining, bleaching and deodourising steps within this process have significant impacts on protein quality and functionality. NZ has the opportunity to design processes to deconstruct plants into high-value ingredients based on different priorities (such as specific proteins with desirable functionalities) and the latest green technologies. This could help set our plant protein ingredients apart on the global commodity market.

It will require whole-of-value-chain thinking, commitment to the development of a new sector over many years, and significant investment – not just in infrastructure but also in gathering consumer and market insights, research and optimisation across the value chain, regulatory frameworks, and marketing and branding.

NZ has a long tradition of taking on the world despite the odds. Here's another opportunity to take some calculated risks and back ourselves to do it again.

2. The emerging proteins sector could be used to accelerate our move to a more circular food production system.

There is increasing awareness of the need for NZ (and the rest of the world) to take a more circular approach to our food production systems. This is challenging in established sectors where existing infrastructure, knowledge bases and standard operating procedures have usually been developed with a focus on economic efficiencies. However, the emerging proteins sector is in a nascent state in NZ, and there is much more opportunity for a conscious design approach to be taken to set it up aligned with the principles of circularity, minimising waste streams and seeking to capture more value for our local producers and processors.

It is important to note that this does not necessarily mean that our emerging proteins production systems need to operate separately to the traditional protein systems. In many instances, a more circular food production system is more achievable when it includes a diverse portfolio of different food types, especially at large scale. This means that incorporating both emerging and traditional proteins aspects within a food production system may enable a better outcome than either is able to achieve in isolation.

As an example of this, a significant portion of the biomass of any plant crop is not suitable for human consumption or for feeding bioreactors in microbial or cell-culture technologies, and a significant amount of food in general is wasted at various points along the supply chain. Both the plant biomass and food waste may be able to be utilised (wholly or partly) as feed for ruminants or insects. These ruminants are then able to convert the biomass into milk or meat (or wool). Insects can efficiently convert the feed into protein too, either for direct consumption by humans or else as feed for chicken or fish. It is of course possible to compost the biomass and food waste

or anaerobically digest it to generate energy, and both these strategies are likely to be part of a circular system. However, most hierarchies of food recovery (there are many variations of these) have feed for animals preferred over energy generation or composting.

The development of a circular food production system was the primary driver for some entrepreneurs and businesses who are looking at emerging proteins, while others saw it as a valuable secondary benefit. But almost all felt that there was an opportunity too good to let go here – leveraging the development of this new sector to achieve broader positive changes within our agrifood systems, leading to beneficial outcomes for our businesses, communities and environment.

Market constraints limit unlocking the potential of insect farming.

Insect farming provides a means of efficiently converting waste from the food sector that would otherwise go into landfill (releasing methane and carbon dioxide) into high quality protein with minimal land and water requirements.

There are a number of insect farming start-ups and small businesses in NZ. Rebel Bakehouse (crickets) and Otago Locusts both have produced insects for human consumption, while Prescient Nutrition (black soldier flies), iNZect Direct (crickets and black soldier flies) and Biosuppliers (various flies, worms, crickets and locusts) are focused on production for feeding live to captive birds and reptiles. All of these are operating at relatively small scales, and a number have expressed a need to increase production in order to reach long-term financial viability.

Although many consumers are prepared to try insect-containing food products (an AgResearch survey reported that 67% of NZ consumers would be likely or very likely to consume insects if ground up and included in products), this does not mean that they are prepared to preferentially purchase insect-containing products over other options on an ongoing basis. Rebel Bakehouse recently withdrew their cricket wraps from NZ supermarkets, presumably reflecting insufficient consumer demand.

Aquaculture or chicken feed seem logical alternative pathways to scale. The US and EU have approved the substitution of insect meal for fishmeal or soybean meal in feed for poultry and aquaculture. Multinational fast-food chain Nandos announced last year that it would be trialing feeding its chickens on insects and algae as part of efforts to reduce reliance on soy and overall carbon emissions.

However, this is not as straight-forward as it may intially appear for NZ insect farmers.

Large scale NZ chicken and aquaculture operations are generally focused on cost per unit, and there seems little appetite for insect protein unless it is a similar or lower cost to the imported feed components, such as soya meal, fish meal, cereals and grains. There is also insect meal available on the international market for $4/kg, which would undercut NZ insect meal.

The nutrient composition of insects varies depending on what they eat. This means it would be necessary to either standardise the insect feed or adjust the other components going into the blended chicken or fish feed in order to ensure optimal nutrition – something that adds cost and complexity. There have been no large trials demonstrating the nutritional adequacy of NZ-produced insect meal substitutions in intensive chicken farming or aquaculture.

Further complexity arises given the reliance on large global feed providers such as Skretting to ‘take care’ of all aspects of the feed, from R&D to supply. These companies primarily source ingredients from large scale overseas producers with lower labour costs than NZ.

A common situation in NZ and overseas is that much of the investment in research and scale-up is being funded by individual businesses. This is treated as confidential intellectual property. As a result, there is limited information to inform regulators, provide guidance to industry, and give confidence to potential customers and investors.

All this means that despite the potential of insects to contribute to our food production system, the current insect farms are struggling to line up demand and capital to scale their production capacity to achieve economic sustainability.

To develop a viable insect sector, we need to consider the improved sustainability and circularity of our food production system – such as the positive environmental factors that would come from using locally produced proteins rather than cheaper imported feed in our aquaculture and chicken industries - chosen on a simple cost basis. This may require consumers to pay more for the resulting chicken and fish products, but this is arguably a more accurate reflection of the true cost of our food.

3. Developing approaches that reduce duplication and support collaboration will deliver better outcomes for NZ from this sector and others.

During this project, it became clear that almost every region in NZ is looking at the emerging proteins sector. Regional economic development agencies (EDAs) are generally responding to this by engaging in discussions and commissioning work exploring what emerging proteins could be grown in their specific region, with some (but not all) also looking at the broader processing infrastructure for those proteins and what might be involved in establishing that in their region as well. Often there was mention of developing a regional brand identity, seeking to communicate to consumers that the particular products were from a certain region in NZ.

This approach is understandable given the specific mandates of regional EDAs, but there is significant risk of duplication, missed opportunities (especially for the development of scale) and sub-optimal decision-making through this region-by-region approach, as well as doubtful value in the marketing investment required to talk to international consumers about specific regions of NZ. After all, many overseas consumers still think that NZ is part of Australia.

The participants in this project unanimously felt that the NZ emerging proteins sector is fragmented and lacks clear leadership. Many also commented that access to information, expertise and facilities was difficult or in some cases impossible, and that the sector is relying heavily on a few individuals and small groups with limited resources to champion it. The lack of a sector strategy for emerging proteins was often mentioned, especially by smaller start-ups and SMEs who felt frustrated by a lack of clarity, collaboration or leadership in the sector. There have been calls for a NZ food strategy for many years, and The Aotearoa Circle announced in late 2020 that they were establishing a National Food Strategy (NFS) workstream, with KPMG appointed as the workstream secretariat. It is unclear at this stage what sort of consideration will be given to individual food industry sectors within the NFS.

Regardless of the outcome of the NFS, if NZ is going to be able to make a mark in a new sector where we are already falling off the international pace, we need to be working together rather than seeing each other as competition.

It is already the norm for the food scientists and technologists working at NZ universities and CRIs to work closely with companies, as it is almost impossible to get public funding without demonstrating industry links and potential commercialisation pathways. This close relationship between research and application is to be encouraged and strengthened where possible. However, it has also been noted that this can also limit the ability of IP developed with public funds to be well used by the broader NZ food sector. Care must be taken to ensure the input of IP and resources by a company is recognised appropriately (periods of exclusivity or preferential access to facilities or expertise are examples of potential options), but it is also important that this is balanced against the NZ-Inc opportunities when most of a project's funding is coming from government sources.

It is also worth noting that many emerging proteins entrepreneurs and businesses are looking to progress quite similar ideas, yet each is often of the belief that their idea is unique. In most cases, there is limited budget and restricted expertise to develop and launch these ideas into

successful products, and a very evident lack of collaboration in the industry, as many are hesitant to share 'their' idea because they feel that this puts their intellectual property at risk.

As a result, those working in R&D supporting these individuals are being asked to undertake very similar projects multiple times for different people, each time without sufficient funding and resourcing. This means that we are developing a whole lot of okay, but not exceptional NZ products. There is a major opportunity here if we could find a way to foster a genuinely collaborative approach, pulling together those with similar interests and jointly fund these ideas to maximise our chances of being able to create really great products. Each company could then focus on different market niches, countries or applications. Or perhaps there is an opportunity to develop new models of government funding to enable publicly-owned IP in identified high-interest areas that our NZ companies can leverage and take to market?

These challenges are not unique to the emerging proteins sector. New ways of working that reduce unnecessary duplication, support more active collaboration and deliver better value for NZ are likely to be applicable in other sectors as well. Thus there is the opportunity for us to prototype creative (and potentially disruptive) approaches in this small and flexible sector but with the potential for those that are successful to be rolled out more broadly.

4. Diversity of the sector could be a real strength, but there is currently limited Māori participation at the food end of the value-chain.

Much of the conversation around the emerging proteins sector is regarding its potential value for NZ in both an environmental and economic context. However, we uncovered that the diversity of the sector could be a key strength as different perspectives, insights and approaches will help build diversification and resilience in NZ's new emerging proteins industry, for both local and export markets.

From our experience thus far, there appears to be greater diversity of entrepreneurs and advocates interested in emerging proteins than is seen in the traditional agri-food industry. Anecdotally, it seems there are more women, young people, and people with different ethnic backgrounds engaged in the sector.

This could be for many reasons. In surveys in the UK and US, it seems between 67-79% of vegans identify as female, and 44% of US vegans are under the age of 35 years, so perhaps there is increased awareness of the opportunities offered by the related consumer trends? It could also be that those coming to NZ from overseas are bringing with them an awareness of what is happening internationally and therefore are identifying new non-traditional export products and markets. A less rosy possibility is that perhaps it is more challenging for some of the people within these demographics to enter the more well-established parts of the agri-food industry, and the early development stage of the emerging proteins sector means that it is not yet dominated by established players and networks.

However, it is also important to acknowledge that while it appears that there is more diversity here than elsewhere in agrifood, it is still not truly representative of our society, nor is it something that we should assume will continue. It is important that we look at how we can support continued diversity within the sector, as well as removing barriers to encourage more.

It has been noted by various participants, including some from central government and related organisations, that a potential unique aspect to NZ's emerging proteins sector could come from the participation of Māori. Many of the drivers for the development of this sector are ones that align with Māori values such as kaitiakitanga, and there are significant tracts of Māori whenua that may have the potential to contribute financially and socially through the development of new agri-food activities.

There are several government agencies working with Māori throughout NZ to explore opportunities arising from whenua, and the growing of crops or other plants (such as seaweeds or algae) related to the wider emerging proteins sector is something under consideration by many.

Despite this, there are presently only a small number of Māori entrepreneurs and businesses actively involved in the food end of the emerging proteins value chain, mainly associated with plant-based foods such as hemp. The majority are currently concentrating their efforts on the whenua, with just a few individuals and groups successfully moving further up the value chain and developing food products and launching their own brands.

There doesn't appear to be any single reason for this, but a complex mix of challenges that vary between different Māori groups. Some are related to internal capability and capacity to be able to embrace the scope and scale of work required for whole-of-value-chain initiatives. In many instances there is a lack of awareness and understanding of food businesses among leaders and decision-makers, which translates through to their estimation of risk and subsequent appetite for investment.

There have been suggestions for initiatives that may be useful in helping address these challenges more broadly. Partnerships with (and possibly investment in) established food businesses or experienced food entrepreneurs are being explored by some iwi groups as a strategy to de-risk and accelerate their food-related ambitions. Some are engaged with research providers in food-related R&D programmes to help build internal knowledge and awareness to enable more informed decision making. Other ideas mentioned by Māori currently exploring establishing food businesses included such things as focused internships with innovative food businesses or mentorship from successful food entrepreneurs, or facilitated discovery trips to introduce more Māori leaders and decision-makers to the depth and breadth of exciting activities in food happening both nationally and internationally.

If Māori are to take a significant role in NZ's future emerging proteins sector, then it is essential that they also take a significant role in the development of it. If capability, capacity, knowledge and understanding are limiting factors for the establishment and growth of Māori emerging proteins food businesses, then targeted co-designed approaches to addressing these aspects may be required.

Māori designing a food system that works for Māori

There are a number of Māori-led initiatives throughout Aotearoa that are developing new business models and exploring new opportunities for Māori within the agrifood sector.

An example of this is Te Pū Oranga Whenua. An inter-regional collective of diverse Māori agribusinesses led by wāhine (Pou Arataki Lisa Warbrick), it is building the capability of Māori agribusinesses so they can be more resilient and self-sustaining and achieve more than they could alone. Its kaupapa is of whānau feeding whānau first, of healing Papatūānuku, of mahi powered by open-source technology and informed by scientific data and matauranga Māori. Strategies include strengthening whānau leadership and a whānau voice in land use, addressing data sovereignty, and creating decentralised, smaller scale infrastructure.

Other examples of Māori-led initiatives relevant to the broader emerging proteins space include:

- Te Anga Whakamua, a streamlined High-Value Industry Pathway for the commercialisation of bioactive ingredients and functional food products developed from NZ biomatter that promotes the protection of indigenous organisms and mātauranga Māori, convened by AuOra (of Wakatū Incorporation) and supported by MPI, MBIE, MFAT and wider government and strategic science partners;
- The evaluation of water lentils as a sustainable protein source within the NZ context, led by Parininihi ki Waitotara (PKW);
- MIHI (Movers in Hemp Innovation), a collaboration of Māori and non-Māori entities seeking to grow the hemp industry in New Zealand, coordinated by Poutama Trust;
- Kaitahi, a business formed by Ngaa Rauru Kiitahi that is developing an integrated value chain from the sustainable growing and harvesting of ingredients through to export of food products;
- Kanapu Hemp, a vertically-integrated company targeting premium culinary applications;
- AgriSea is a family-owned business making products for farmers and growers from seaweed and exploring new food applications.

5. Investment in talent and infrastructure will fast-track emerging proteins sector development.

Talent

NZ has a long history of smart people developing clever solutions to enable our primary produce to be exported internationally. Our dairy sector has a strong talent base with significant depth and breadth of expertise, as well as the supporting infrastructure from laboratory through pilot to commercial scale. These are the result of decades of public and private sector investment of support our major agrifood export earner.

There has been very limited investment in the development of the talent and infrastructure to support emerging proteins in NZ. There are opportunities for us to leverage knowledge and equipment from the dairy or meat sectors and adapt this to emerging proteins, and this is happening in many of our research providers and companies; but this approach still takes significant time and resources.

One of the fastest ways for us to accelerate the development of the emerging proteins talent pool would be to supplement the current approaches with a targeted programme that attracted international experts in priority areas. These experts could come to NZ on 3-5 year contracts, working across both publicly- and industry-funded R&D projects to inject specialist expertise and insights, develop our local capability and capacity through mentorship and supervision of established and emerging researchers, and contribute to training and education progammes. At the end of their contract they may return overseas, but they would leave us with an enriched local talent pool and stronger connections into international networks. However, this approach would only work if the programme also ensured that the experts had immediate access to the facilities and funding required to be delivering outcomes – not spending most of their contract writing grant applications.

We also need to lift the entrepreneurial capacity of the sector. We want to grow our own local entrepreneurs, but there is also the potential to benefit from experienced international entrepreneurs engaging with the NZ ecosystem. There have been innovative models such as the Global Impact Visa that was established to underpin the Sir Edmund Hillary Fellowship programme which could be used to establish a specific initiative around building NZ's entrepreneurial capability and capacity in emerging proteins. However, it is important to understand that entrepreneurs tend to gravitate to locations with other entrepreneurs, with access to the research and innovation facilities and talent they need, with supportive regulatory and compliance frameworks, and with vibrancy and energy – so we need to ensure we have these in place.

NZ's international profile has benefited from our COVID-19 response, and we are seeing capable Kiwis with international experience and networks returning home. There will also be a window of opportunity to attract smart researchers, business people and entrepreneurs to work here within the emerging proteins sector – but only if we make this a priority and develop strategies that will suit the needs of each different type of recruit.

Infrastructure

The lack of commercial scale infrastructure required for the development of a NZ plant protein ingredients sector has already been mentioned, but this lack of appropriate infrastructure more broadly was a common thread in conversation.

For most start-ups and SMEs, the journey from idea to successful product in market involves the

use of pilot or small commercial scale equipment (such as is available through the New Zealand Food Innovation Network and our food-focused universities and CRIs) for the development phase, then a graduation to a contract manufacturer for full commercial production. It is very unusual for these small innovative businesses to be able to purchase their own equipment or have their own production facility, and so they are restricted to using the processing and packaging equipment available through the public and private sector.

At present, very little of the food processing equipment available at pilot and commercial scale has been specifically designed for producing emerging proteins foods. In most instances the equipment has either been designed for use with dairy or meat products, or is generalist equipment that has broad application. This means that there are likely to be some compromises in the product quality or process efficiencies, and in some cases means that at present it is simply not possible to launch NZ-made products at commercial scale across whole categories.

There are significant technological advances in all sorts of equipment related to different emerging protein types and product categories, ranging from modifications to existing equipment that allow it to produce better products through to new equipment and approaches. Our international competitors are taking advantage of the benefits offered by these advances, while we are continuing to take a 'number 8 wire' approach. While there is much to be said for Kiwi ingenuity, it is highly unlikely we will be able to play a meaningful role in the international emerging proteins sector without investment in the right equipment for the right purposes. This investment in equipment must be complemented with an investment in the essential applied R&D required to develop the understanding needed to deliver optimal outcomes with broad NZ contexts – something that struggles to gain sufficient recognition and government funding at present. There is simply no point having the equipment if we don't know how to use it properly.

It is easy to say that this investment should be the responsibility of the businesses who seek to use the equipment. However, many of the businesses are SMEs and start-ups which are simply unable to find the capital required at their current stage of development. We also have a chicken-and-egg situation where it is especially difficult in new sectors to be certain of the demand for equipment prior to businesses having access to it to undertake product development and market validation. This increases the risk associated with such investment and means that private contract manufacturers are less willing to purchase equipment at the early stages. There is an important role for government in helping bridge this capital investment gap to enable the emerging proteins sector to develop.

The fledgling seaweed industry illustrates many of the challenges facing the more novel parts of emerging proteins sector.

Many countries are investing heavily in seaweeds due to potential functional and environmental benefits. There are established markets for seaweed products as a whole food, extracts for nutritional supplements (e.g. fucoidan), animal feed and biofertilisers. New products are evolving rapidly.

NZ entrepreneurs trying to establish seaweed businesses feel it is not recognised as a serious aquaculture industry in NZ, with little representation in aquaculture, fisheries or seafood industry strategies.

Beach-cast seaweed is collected for use in animal feed and biofertilisers, but the few businesses selling seaweed for human consumption are importing it due to regulatory barriers, even though in many cases there are the same or similar seaweeds growing in NZ waters.

There is limited availability of commercial-scale ocean lease areas in most NZ waters, which is a major barrier to progress. Without space to cultivate seaweeds in the ocean, production will never achieve the necessary scale.

There are no commercial scale hatcheries or seedbanks in NZ. Each new entrant needs to develop its own breeding knowledge, hatchery facility, seedstock and seed ropes. The alternative, government approval for wild collection of seaweed to use for start-up inoculation, can be challenging and prohibitive for new entrants. New commercial entrants have very steep learning curves around scaling-up, optimising production and avoiding the numerous and diverse pitfalls.

There is limited knowledge on native seaweed populations, and concerns have been raised regarding the translocation of seedstock, pests and disease. Upscaling the production of native species will require appropriate engagement with Māori and a significant investment in R&D, but the alternative of importing species used in other countries raises concerns around biosecurity and the potential impact on the local ecosystem.

Technology transfer and adaptation from countries where seaweed farming is well established will accelerate the development of our local sector. Similarly, there are few people in NZ with seaweed-specific skills, knowledge and practical experience, and the engagement of international experts combined with local training and development programs will be required.

A number of NZ research providers have small projects related to seaweeds underway, but there is no national 'expert' organisation that brings together the multidisciplinary knowledge needed by the sector, and no integration or coordination across either the researchers or interested commercial parties.

Overall, the development of the sector is at a very early stage. A strong vision for the sector has yet to emerge, and the outcome of current attempts to build a seaweed industry is as-yet uncertain. However, research momentum is building in this area. For example, Cawthron's soon to be opened National Algal Research Centre will establish key infrastructure to undertake research to enable a path-to-market for both microalgal and macroalgal species. Due to the not-inconsiderable challenges, significant further governmental investment will be required to enable the sector to progress.

RECOMMENDATIONS

1. Take a NZ-Inc, whole-of-value-chain approach to a suite of initiatives that will collectively underpin our success in emerging proteins:
    a. Identify commercial or near-to commercial sectors and form collaborative syndicates to progress pre-competitive projects in areas such as R&D, consumer and market insights, regulatory framework development, infrastructure improvements etc.
    b. Determine where investment should be made in scale-up infrastructure to reduce commercialisation barriers.
    c. Explore how we can market NZ emerging proteins foods, leveraging the brand value of NZ traditional proteins and utilising consumer and market insights from export markets.
    d. Establish a talent attraction programme for R&D and innovation experts in key areas, complemented with a multi-disciplinary talent development programme that builds local capability and capacity.
    e. Foster an entrepreneurial ecosystem around emerging proteins.
    f. Review regulations around emerging proteins and compliance pathways for new products.
2. Formalise and fund a collaborative independent national network to coordinate delivery of initiatives and bring cohesion to the discussion. This would involve industry, research providers, venture capital, government and other interested parties in the wider emerging proteins ecosystem. This network will not lead all the initiatives described in recommendation #1 but will provide crucial facilitation and coordination to the collective effort.
3. Enable a single point of contact and integrated response from government for emerging proteins topics by establishing a cross-government working group involving departments such as MPI, MBIE, NZTE, Callaghan Innovation, MFAT, MOE and others interested in this sector.
4. Develop and implement a New Zealand strategy for emerging proteins aligned with potential areas of competitive advantage, leveraging the networks and information arising from 1-3 above.

PRINCIPLES

Our Recommendations are underpinned by the following Principles to deliver long-term sustainability and benefit to the country:

1. Circular economy – the sector should be developed in alignment with the principles of circular food production systems
2. Integrated value chain – a whole-of-value-chain approach integrating on-farm diversification opportunities with knowledge and expertise on food processing and consumer insights.
3. Māori economy – enable Māori businesses to capitalise on the opportunities presented by the sector, particularly value-capturing and higher returning opportunities.
4. Technology – the sector strategy must explore relevant technologies and lead the discussion on their applicability in the NZ context. This includes a national discussion on genetic modification and the facilitation of understanding that 'GM' is a suite of technologies.

APPENDIX 1

Contributors to the project

The following people have contributed to the observations and ideas outlined in this report through various means, ranging from participation in formal facilitiated discussions through to more casual conversations and exchanges of emails over the course of the past 12 months. The companies noted are those they were working for at the time of such discussions.

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

We would like to once again express our gratitude to all those who gave us their time and insights during this process.

Adam Bergman - Eco-Tech Capital
Adrian Russell – Plant Research
Al Baxter – NZFIN
Aladin Bekhit – University of Otago
Alex Radley – Plant Tech Nation
Alex Worker - HGH Brands
Alice Shopland – Angel Food
Allan Main - Plant & Food Research
Amanda Clarke – Cedenco
Anne Probert - Venture Taranaki
Anant Dave – Riddet Institute
Andrew Darling – Ada Farming
Andrew McKenna – Treetop Foods
Andrew Prest – Powered By Plants
Ariana Estoras – AgResearch
Arohaina Owen – Kaitahi
Ben Stiff – Sustainable Foods
Ben Ward – Inghams / Let's Eat
Benoit Guieysse – Tahi Spirulina
Bianca Le - Cellular Agriculture AU
Brad Lake – The Brothers Gree*n*
Brian Astridge – Tegel
Bruce Miller – Prescient Nutrition
Carl Massarotto - Plant & Food Research
Carla McCulloch – Cedenco
Carli van Zyl – Cellence
Carlienne MacQueen – Fonterra Cooperative
Cathy Gould – Daily Catch
Charlotte Parker – Oliver's Oat milk
Clare Duncan – Fresh Pork
Colin Woods – Angel Food
Craig Armstrong – NZTE
Craig Hoare – FoodWaikato
Dan Cottrell – Kiwi Quinoa
Daniel Ruben - Hooked Foods
David Smith – Fresh Pork
Debbie Stowe – Olive and Ash
Dennis Hucker – Prescient Nutrition
Donato Romanazz – Cawthron Institute
Ed Butler – Fart Free
Elizabeth McGruddy – Federated Farmers
Emma Blott – Powered By Plants
Esther Hutchinson – Synlait Milk
Eve Kawana-Brown - Venture Taranaki
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George Dias – University of Otago
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Gil Meron - Sprout Agritech/Finistere
Graham Eyres – University of Otago
Grant Pearce – University of Canterbury
Gretta Carney – Eatwell HapiOra
Hamish Dunlop – NZ Quinoa
Hamish Gow – Massey University
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Isha Datar - New Harvest
Jack Dustin
Jack Keeys – KPMG
Jacob Johnson – Real Food Direct
Jacob Kohn – End to End
Jacqui Cottrell – Kiwi Quinoa
Jade Gray – Plant Tech Nation
Jarrod Robinson - Wakatū
Jeff Orsbourn – Oppenheimer
Jenny Zo – Good Chowz
Jeremy Hill – Fonterra Cooperative
Jeroen Wouters - Foodvalley NL
Jesse Henderson – Get Better Problems
Jessica Smith – Te Puni Kōkiri
Jo Williamson – Golden Goose
Joanne Hort – FEAST, Massey University
Jocelyn Eason - Plant & Food Research
John Hart – Rebel Bakehouse
John Morgan – NZFIN
John Penno – Leaft
Jono Cox – Westlake
Jonty Hall
Jordon van der Wel – Tatua
Joseph Stuart – Nai
Josie Lambert – Food Nation
Julia Jones – NZX
Julian Heyes – Massey University
Julien Stevens - NZ King Salmon
Julie Cakebread – AgResearch
Justin Hall – Tahi Spirulina
Justin Lemmens – Sustainable Foods
Justine Gilliland - Venture Taranaki
Justine Muollo – Justine's Cookies
Karen Williams – Ahiaruhe Farm
Kate Dunlop – NZ Quinoa
Kati Ohens – Plantcraft
Katrina Bach – The Olive Press
Katy Bluett – Callaghan Innovation
Ken Morison – University of Canterbury
Keri Iti – Ministry for Primary Industries
Kevin Guthrie – Sanford
Kevin Wilcox – AS Wilcox
Kim Ballinger – Powered By Plants
Kimi Knott – Good Vibes Fungi
Ky Rei – Sustainable Foods
Lana Kennett – Kaipara Kai
Laura Domigan – University of Auckland
Leann Smith – AR Group
Lee Huffman – Plant & Food Research
Lily Liu – Kraft Heinz
Linda Samuelsaon – AgResearch
Lisa Warbrick – Smith Warbrick
Maggie Olsen – iNZect Direct
Mandy Armstrong - SpringTide
Mark Lawrence – Farmers Mill
Mark Piper – Fonterra Cooperative
Mary-Anne Webber – Great South
Matt Maney – iNZect Direct
Matt Punter – Kaipara Kai
Maya Benam - Bright Green Partners
Max Rye - TurtleTree Labs
Mei Peng – University of Otago
Meika Foster – Edible Research
Michael Burnett – The Brothers Green

Mick Williams – Ahiaruhe Farm

Mike Ashby – Biosuppliers

Mike Gin – Silver Fern Farms

Miranda Burdon – Food Nation

Miranda Mirosa – University of Otago

Natasha Clarke – Ministry for Primary Industries

Nathan Stead

Nick Willis – Provincial Development Unit

Nick Carey – Green Meadows Beef

Nick Pyke – Leftfield Innovation

Nicky Solomon – NZFIN

Nicola Hockley – Leaft

Nigel Davenport – Venture Timaru

Nigel Slaughter – Ligar

Oxana Krutilina – Sea Swell

Pat Silcock – University of Otago

Paul Bamforth

Paul Hamilton – Callaghan Innovation

Paul Sapsford – Keraplast

Paulette Elliott – Westland Milk

Peter Brown – Goodman Fielder

Phil Bremer – University of Otago

Rebecca Hunink – Re-Leased

Rebecca Macfarlane Mills – Kraft Heinz

Ria Chapman – University of Canterbury

Richard Chadderton – Costarters

Rod Lingard – The Olive Press

Roger van Hoesel – Foodvalley NL

Ross Milne – Leaft

Russell Haines – Oliver's Oat milk

Sam Hutchinson – BlueH2O

Sam Johnson – Te Puni Kōkiri

Sam Johnson – Real Food Direct

Sandra Chambers – Green Mount Foods

Sarah Page – Diva Plant Cheese

Scott Hutchings – AgResearch

Scott Knowles – AgResearch

Shannon Williams – Provincial Development Unit

Shine Hu - ChemLinked

Simon Loveday – AgResearch

Simon White – Provincial Development Unit

Sofia Arthurs-Schoppe - Stray Dog Capital

Steve Whitaker – Toha

Susan Goodfellow – Leftfield Innovation

Tane Bradley – Agrisea

Tarek Salam - Sharjia Innovation

TC Chadderton – Plant & Food Research

Thomas White – BurgerPlantnz

Tim Lynch – Otago Polytechnic

Toine van de Pol – Ingetesca

Tony Wise – Gelita

Vanessa Heyes – Torere Macadamias

Vaun Gadodia - KaiTech International

Warren McNabb – Riddet Institute

Warwick Tauwhare-George
– Parininihi ki Waitotara (PKW)

Wayne Young – AgResearch

Wim de Koning – B.linc

Zane Gerrie – Good Vibes Fungi

APPENDIX 2

AgResearch

Project Title:

Cooking and processing of seaweed to improve consumer acceptance, protein digestion and nutrient bioavailability.

Key Contact:

Dr Linda Samuelsson,
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Organisations involved:

AgResearch; Agency for Science, Technology and Research (A*STAR, Singapore); University of Otago; University of Auckland; AgriSea; Ideas 2 Plate; AMiLi

Description:

Seaweed is rich in important nutrients, but many of them are locked inside the seaweed, making them inaccessible to our bodies after we eat this food. Researchers across New Zealand and Singapore have teamed up with a chef and industry partners to modulate the flavour, digestibility and nutrient availability of seaweed to create a promising alternative whole food protein source that will offer benefits to New Zealand and Singaporean consumers.

Project Title:

Smart Protein

Key Contact:

Simon Loveday
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Organisations involved:

AgResearch

Description:

Smart Protein is a 5-year AgResearch project (2019-2024) aligned to the European consortium "Smart Protein for a Changing World", which aims to industrially validate production of innovative, cost-effective and resource-efficient plant, fungal and microbial protein foods. We are building the capability to extract or enrich food protein from a range of sources, using conventional and novel processing approaches. These new materials and processes are being studied through nutritional and sustainability lenses to identify opportunities for NZ Inc to capitalise on global protein transitions.

Cawthron Institute

Project Title:

He tipu moana he oranga tangata: Revealing karengo as a high-value functional food.

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Organisations involved:

Cawthron Institute; Malaghan Institute of Medical Research; AgResearch; Hokkaido University (Japan); Te Rūnunga o Ngai Tahu; Wakatū Incorporation.

Description:

This programme aim to evaluate New Zealand karengo species for their suitability as the basis for a future high-value foods industry. To do this, we are determining the composition of individual karengo species through the growing season at several locations throughout the South Island, verify the effects of the bioactive-enriched extracts of karengo in model systems, and investigate the challenges of establishing commercial-scale aquaculture. Pathways to market will be investigated to facilitate the development of karengo as high-value functional foods.

Project Title:

Realising the value of algae as a source of alternative protein.

Key Contact:

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Organisations involved:

Cawthron Institute,; Riddet Institute; University of Auckland; Plant & Food Research; Agency for Science, Technology and Research (A*STAR, Singapore); Te Rūnunga o Ngai Tahu; Wakatū Incorporation.

Description:

This programme investigates the methods for producing protein-enriched extracts and their food and health-related attributes from two algal sources - karengo, a group of NZ native macroalgae) and chlorella (a microalga). Scalable extraction methodologies are being developed and the rheological and other related properties are being evaluated. The research also includes compositional investigation using proteomics, as well as their health-promoting effects when incorporated into a manufactured food format.

Plant & Food Research

Key Contact:

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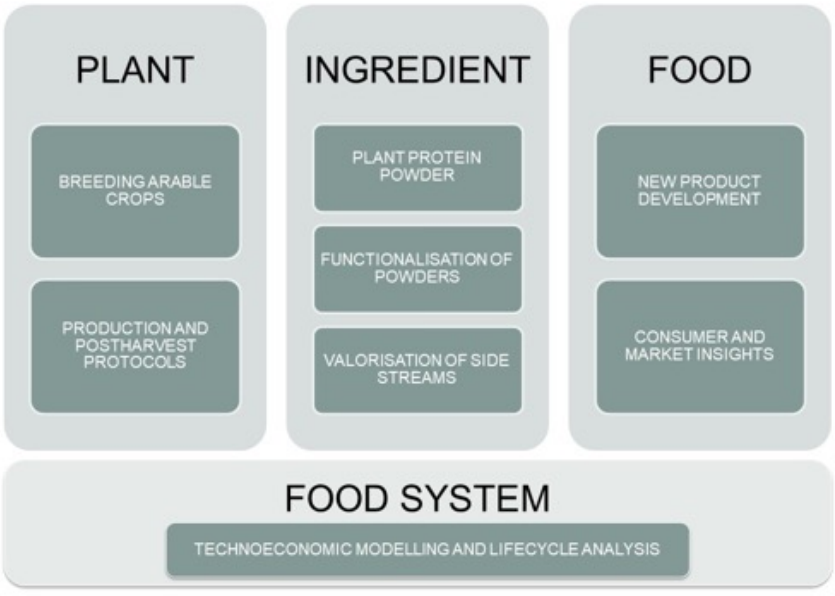

Proteins from Plants - 2021:

PFR has the experience and capability to deliver an integrated approach to emerging protein opportunities for New Zealand. One of the key aspects of our approach to emerging protein opportunities is the economic analysis of technologies as well as a focus on the critical ingredients and foods specifications for the manufacturing companies and for the food companies. Our teams translate science to ensure successful application of R&D outcomes, prototyping, and commercialisation.

Nutritional Products from Potatoes – PFR is working with a large multinational developing nutritional protein ingredient products from potatoes. Our work to date has given the company confidence to implement the project results, and invest in a large semi-continuous pilot plant that will deliver commercial product samples. Entering its 7th year, this project has given PFR substantial experience and knowhow in the isolation of highly functional plant proteins and their use in foods and beverages, and in the application of a whole bioresource utilization mindset to achieve an economic outcome.

Forage Leaf Protein – techno-economic analysis for production of forage leaf protein ingredient under New Zealand's conditions shared with industry partners and bench-scale experiments completed on three forage crops conducted on key processing steps to assess technical and economic feasibility. This underpinning work and knowledge supports the development of PFR's 'Protein from Pasture' proposal with industry for submission to MPI for SFF Futures investment.

Plant-based Beverages – PFR is investing in new product concepts including a ready-to-drink, plant-based milk alternatives, some developed with New Zealand-grown PVR-protected arable plants. The work considers raw material, and harvest through to processing formulation and techno-economic analysis of the total process. PFR has in the past worked with AgResearch and Miraka on hybrid dairy-plant beverage development, and is currently working with Olivers All Good and others on oat-based beverage product development. PFR has recently been invited to support the NZ Functional Foods project sponsored by Great South.

Plant-based Foods – PFR has led the submission of an Endeavour proposal in the 2021 MBIE bidding round "Creating sustainable and delicious plant-based foods by utilising in situ naturally-produced exopolysaccharides". This work focuses on developing technologies that can be applied to plant-based protein foods to deliver to consumer valued traits (e.g. sensory and health properties).

Karengo Algae – Dr Lee Huffman is recognised for her fundamental and applied knowledge of the isolation and processing of proteins and their recovery from raw materials. As a result Dr Huffman has an advisory role on the Cawthron-led ASTAR collaboration "Realising the value of algae as a source of alternative protein project".

Nuts - There has been considerable interest in nut crops for NZ and new activity around nutrition and health benefits of nuts. PFR is working with industry to trial peanut production in Northland. PFR has an HVN funded project with Tohere Macadamia focused on the nutritional profile of NZ grown macadamia.

Alternative Emerging Proteins:

Cellular Foods – Cellular agriculture, the production of agricultural products from lab-grown cells, is at the cutting edge of alternative protein technology worldwide. PFR has considerable expertise in marine fish as well as mammalian cell cultures and is investigating fish cellular foods as part of an MBIE funded Smart Idea.

Insect Foods – Several years ago, PFR brought together expertise in entomology and food science to investigate insect-based concepts.

Mindset - 100% Utilisation

Any new emerging protein industry in NZ requires a 'whole of bioresource utilisation' mindset in order to design bioresource streams and products that can be 100% utilised and not cause waste. **The Bioresource Processing Alliance (BPA)** provides a channel to co-fund commercially feasible research that derives value from under- or unutilised bioresource streams. PFR has a pipeline of work being developed in this area with a series of value-add opportunities for algae bioresources, apple processing waste, avocado side-streams, corn milling side-streams, citrus processing waste, feijoa side-streams, and hop bioresources under investigation. The diversity of opportunities for bioresource processing includes functional/bioactive extracts, packaging, biochar development for contaminant removal from wastewater; antimicrobioal wound dressings, and bioconversion of industry side streams.

Food Transitions 2050

The Food Transitions 2050 Joint Postgraduate School is a new multi-party Joint Postgraduate School involving the University of Canterbury, Lincoln University, AgResearch, Plant & Food Research and Manaaki Whenua Landcare Research. This virtual school comprises a community of PhD students and collaborative supervisory teams linked by the overarching theme of 'Food Transitions 2050'. The theme encapsulates the need to support the transition of New Zealand's food sector to a carbon zero future, whilst ensuring sustainable landscape development. PFR scientists are co-supervising a number of projects relevant to Emerging Proteins.

Massey University

Project Title:

Te Rangahau Taha Wheako mō ngā Kai o Āpōpō: The Consumer Dimension of Future Foods

Key Contact:

Joanne Hort,
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ph: 06 951 6241

Organisations involved:

Massey University; A*STAR; Edible Research; Riddet Institute; Goodman Fielder; Fonterra; Wakatū; NZ Algae Innovation; Nuku ki te Puku; MIHI (Movers in Hemp Innovation)

Description:

This research will understand the key issues impacting consumers' evolving relationship with plant-based protein, to ensure science and industry innovation can focus on efforts developing foods consumers want to adopt routinely in their diet. The research will determine the relative importance consumers ascribe to issues like sustainability, health, animal-ethics and attitudes to food processing, alongside sensory appeal of alternative proteins. We will identify barriers to adopting sustainable and healthy plant-based diets and provide guidance to producers on how to encourage consumers to embrace alternative protein.

https://sites.massey.ac.nz/futurefoodscatalyst/

Project Title:

Spirulina production

Key Contact:

Benoit Guieysse,
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Organisations involved:

New Zealand Algae Innovations Ltd; Massey University.

Description:

The biomass of the cyanobacteria ***Arthrospira platensis*** (commonly known as spirulina) is mainly composed of proteins (> 60% dried weight) and is rich in mineral (especially iron) and antioxidants (especially betacarotene and phycocyanonine). Under support from SFFF, New Zealand Algae Innovations ltd (NZAI) and Massey University are engaged in a range of projects investigating new product development of spirulina-based food (incl. the use of spirulina as a functional ingredient), process optimisation, and sustainability assessment. Future research will also seek to establish the health credentials of spirulina-based foods and supplements.

Project Title:

Farming New Zealand native water lentils in the Taranaki

Key Contact:

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Benoit Guieysse,
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ph: 06 951 6241

Organisations involved:

Parininihi Ki Waitotara Incorporation; Massey University.

Description:

Under support from AGMARDT, this project investigates the feasibility of farming water lentils in the Taranaki as an alternative mean to produce high-protein human food and animal feed. The team thus seeks to provide field data to support locally-relevant economic and environmental impact assessments in order to establish i) if cultivation at scale is technically feasible, economic and environmentally sustainable; ii) what is the most strategic pathway to commercialization; and iii) what are the main roadblocks to this path.

Project Title:

The potential of Leaf proteins as a source of human food

Key Contact:

Lovedeep Kaur,
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Organisations involved:

Massey University; Riddet Institute

Description:

This research programme explores the potential of NZ grasslands to produce alternative protein for use in human food. A chemical-free grass protein extraction process has been developed at the pilot scale. The nutritional and functional characteristics of the isolated grass protein concentrates (GPC) are being characterised. The developed GPC is enriched in important minerals, and fibre components along with protein when benchmarked with commercial protein supplements such as Spirulina. The programme will also understand the influence of leaf proteins on sensorial properties when added in different food formats.

Project Title:

Hybrid Meats

Key Contact:

Jaspreet Singh,
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ph: 06 951 7290

Organisations involved:

Massey University; Riddet Institute

Description:

The objective of this project is to develop new types of restructured meat analogues- 'Hybrid Meats', containing plant only and plant-animal protein combinations (plant-dairy; plant-meat; plant-insect proteins) through innovative technologies (provisional patent filed). Hybrid meats are targeted towards flexitarians and possess physical dimensions like real meat cuts and have excellent textural and nutritional attributes. Varying formats- beef-like and chicken-like textures of these products are being developed. The use of 3D food printing to create soft hybrid meats is also being explored.

Riddet Institute

Riddet Institute
Advancing Frontiers in Food Science

Project Title:

Plant based meat alternatives and snacks from New Zealand grown hemp seeds

Key Contact:

Harjinder Singh,
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ph: 06 951 7319

Organisations involved:

Riddet Institute; Greenfern Industries Limited; Sustainable Foods.

Description:

This industry funded research project aimed at developing plant based meat analogues and protein rich healthy snacks primarily using hemp seed hearts along with other plant proteins. Hemp seeds are rich in good quality proteins and are being produced in New Zealand in an eco-friendly, sustainable manner. This project was successful in developing prototypes which captured further industry attentions for commercialization purpose in a partnership venture model. After initial scale up trials, the hemp-based chicken alternatives have recently been launched in the NZ market as a limited time offer in partnership with a leading Pizza making company.

Project Title:

Novel processing to enhance plant protein functionality and utilisation

Key Contact:

Harjinder Singh,
h.singh@massey.ac.nz
ph: 06 951 7319

Organisations involved:

Riddet Institute; AgResearch, Massey University; Otago University; The University of Auckland; Plant & Food Research.

Description:

This project will provide a fundamental understanding of the functional and nutritional potential of non-animal proteins from sustainable sources for inclusion in future food products. The potential of using emerging food processing technologies to modify protein food structures and interactions to enhance desirable functional properties will be investigated. The focus will be on protein sources that are of interest to future New Zealand agricultural systems (such as quinoa, hemp, tree nuts, algae and pasture legumes). There is a significant opportunity to alter the plant-based protein foods to create more innovative and uncompromising products for the consumer. Understanding how plant protein materials and processing technologies interact to impact on food formulation, nutritional values and taste profiles is essential to product innovation in this space.

Project Title:

Combinatorial proteins – understanding the functionality and nutritional impact of composite proteins

Key Contact:

Harjinder Singh,
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ph: 06 951 7319

Organisations involved:

Riddet Institute; AgResearch; Massey University; Otago University; The University of Auckland; Plant & Food Research; Fonterra; UAMS (University of Arkansas Medical School).

Description:

New ways to extend the use of animal-based proteins by developing a fundamental understanding of their interactions with plant and algal proteins will be investigated. Plant proteins on their own often have a sub-optimal protein pattern (lacking in essential amino acids) and lack some of the micro-elements and vitamins of animal-derived foods. Conversely, plant foods contain compounds (such as vitamin C, vitamin E, fibre and polyphenolics) that are lacking in animal-based foods. An opportunity exists to bring together the best attributes of both plant- and animal-based foods, and to benefit from the synergistic interactions that are present. A new range of environmentally sustainable 'combinatorial' protein ingredients and proteinaceous foods addressing specific physiological endpoints will result. We envision blends of proteins processed in novel ways, to produce completely new protein ingredients and foods with targeted amino acid balances and protein quality scores (DIAAS).

Project Title:

Recombinant technology for food protein production

Key Contact:

Harjinder Singh,
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ph: 06 951 7319

Organisations involved:

Riddet Institute; AgResearch; Massey University; Plant & Food Research; Te Herenga Waka — Victoria University of Wellington

Description:

The use of microorganisms in the production of foods and beverages, such as bread, cheese, wine or beer, has a long tradition dating back to ancient times. However, microorganisms—bacteria, algae and fungi—can now be precisely altered to optimise their roles in food production. By means of genetic engineering, the properties of microorganisms can be changed more precisely. Major goals are the optimisation of the production process, the improvement of product quality, safety and increasing product diversity A staged approach will be used to develop expertise in emerging recombinant technologies, beginning with well-characterised techniques for bacteria and fungi, and proceeding to the more complex microalgae and then macroalgae.

Project Title:

Plant based beverages with modified texture and taste profile

Key Contact:

Harjinder Singh,
h.singh@massey.ac.nz
ph: 06 951 7319

Organisations involved:

Riddet Institute

Description:

This project aims at developing novel plant-based beverages using legume proteins. Using fermentation and other processing techniques, it successfully developed varieties of completely novel base formulations with superior organoleptic qualities and excellent heat stability, thus making them suitable for formulated beverage and drinkable yogurt type applications. A provisional patent application claiming its novelty was filed in Australia in 2021.

Project Title:

New opportunities from hemp seed proteins

Key Contact:

Anant Dave,
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Organisations involved:

Riddet Institute; AgResearch, Massey University; Otago University; The University of Auckland; Plant & Food Research.

Description:

The Riddet Institute has formed a strategic partnership with a North Island-based hemp cluster of Māori and non-Māori businesses (MiHI), joining a collaboration to develop value-added differentiating products made from New Zealand-grown hemp. The Riddet Institute team helped facilitate the development of a market intelligence and regulatory insights report on hemp-derived products in North America. This 6-month project was funded by a High-Value Nutrition (HVN) National Science Challenge 'Development Grant' for Māori food & beverage businesses. The findings from the initial report will help inform the research direction for a high value, complete protein ingredient using hemp, which will leverage the specialist knowledge on protein digestion and utilisation at the Riddet Institute.

University of Auckland

Project Title:

Cell-based production of animal meat protein products

Key Contact:

Laura Domigan,
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Organisations involved:

University of Auckland; University of Canterbury; Riddet Institute

Description:

This project will develop New-Zealand-sourced livestock cell lines, and methods to produce cultured cells and cell-based animal meat products. Our research into the production of cell-based meat products is focused on four main areas; (i) Cell lines – current technology relies on biopsies from animals. There is an opportunity to develop immortalised cell lines from New Zealand animal species that are traditionally used for meat production. (ii) Cell culture media – cell culture media represents a major cost associated with cellular meat production. Additionally, a major issue is its reliance on foetal bovine serum (FBS). There is significant academic and commercial interest if we can replace FBS with recombinantly expressed growth factors and small molecules. (iii) Structure and scaffolding – the technology is currently restricted to producing very small pieces of muscle, which therefore resemble only processed or minced meat products. Edible scaffolds to produce larger sized structured meat products need to be developed. (iv) Bioreactors – cultured cells are adherent, which means that traditional bioreactor designs are not suitable. Further development, such as the incorporation of scaffolding materials into new bioreactor designs is necessary to enable large-scale production.

University of Otago

The Department of Chemical and Process Engineering has equipment for ultrafiltration, reverse osmosis, freeze drying and spray drying. A new food-safe facility will enable protein products to be produced at the kilogram scale. The Biomolecular Interaction Centre has significant experience and equipment for analysis of proteins at a molecular scale. Together with Chemistry we have a wide range of chromatography equipment, mass spectrometers, an analytical ultracentrifuge, a nanoDCS and standard biological equipment.

Project Title:

Ultrafiltration of Pea Protein

Key Contact:

Ken Morison,
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ph: 03 369 3818

Organisations involved:

University of Canterbury

Description:

PhD student Mahnaz Shahverdi is investigating the ultrafiltration of protein extracted from yellow peas. This study covers extraction conditions; membrane selection (material and molecular weight cut-off); feed treatment; ultrafiltration pressure, cross flow velocity, temperature; and membrane cleaning. Excellent protein recovery and purity have been obtained. The hope is that New Zealand can leverage the dairy industry's whey processing skills to develop superior products.

Project Title:

The Effect of Processing Conditions on the Flavour and Functional Properties of Ultrafiltered Pea Protein

Key Contact:

Ken Morison,
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ph: 03 369 3818

Organisations involved:

University of Canterbury

Description:

PhD student Mingyang Xia is testing the pea protein obtained from Sharverdi's project. He is developing tests for functional properties and for detection of flavour compounds, including saponins. To support solubility tests, he is evaluating different methods for protein analysis and might add evidence to challenge the use of the 6.25 nitrogen factor. In the next stage of his work, he will determine the effect of extraction and separation conditions on functional properties and flavour.

Project Title:

Extraction of plant proteins and off-flavour reduction.

Key Contact:

Patrick Silcock,
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ph: 03 479 7564

Organisations involved:

University of Otago; Commercial partners

Description:

Extraction of proteins from a variety of sources have been investigated. Some of these projects have had commercial partners. Our current focus is understanding off-flavour generation and then taking a whole of process approach to minimising off-development. Expertise includes flavour characterisation, mechanisms of flavour generation, protein characterisation, protein extraction and downstream processing, functionality testing.

Project Title:

Product development of plant-based foods.

Key Contact:

Patrick Silcock,
pat.silcock@otago.ac.nz
ph: 03 479 7564

Organisations involved:

University of Otago; Commercial partners

Description:

The Product Development Research Centre has carried out product development on plant-based milks, smoothies and whole foods.

Project Title:

Development of innovative techniques to profile and enhance the functionality and utilisation of New Zealand oats

Key Contact:

Professor Indrawati Oey,
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Organisations involved:

University of Otago; Harraway & Sons Ltd

Description:

This project will develop different processing strategies to enhance the functionality and utilisation of oats grown in New Zealand. We will assess the feasibility of using these cultivars to create new products or ingredients. Robust and comprehensive fingerprinting techniques will be developed to profile the properties of different oats and predict the impact of food processing on the resulting functionality. This project will provide NZ emerging plant-based food sectors to envisage opportunities for new product development and market strategies.

Project Title:

Production of meat and dairy-like flavours from plant materials.

Key Contact:

Professor Phil Bremer,
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ph: 03 279 6469

Organisations involved:

University of Otago

Description:

We will produce high-value, clean-label, natural, plant-derived meat and dairy-like flavour compounds by gaining a mechanistic understanding of the biochemical processes by which micro-organisms (bacteria, yeasts, fungi) utilise principal (sugars, amino acids, fatty acids) and minor (thiamine and ß-carotene) constituents in plants during fermentation to generate recognisable meat- and dairy-like flavour ingredients. Further by utilising plant material derived from what are currently processing waste streams, we will upcycle this material and further add to the sustainability of plant-based diets.

Project Title:

Chinese consumers' perceptions and preferences for plant-based foods.

Key Contact:

Associate Professor Miranda Mirosa,
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ph 03 479 7953

Organisations involved:

University of Otago

Description:

This PhD project will provide the NZ emerging protein sector consumer insights into Chinese consumers' perceptions and preferences for plant-based foods. In-market survey research will elicit the broad range of determinants that influence consumption. Ethnographic work will help us to understand the complex interplay of these determinants in the real world. Cutting edge biometric behavioral technologies will help to understand the neuro-psycho-physiological processes behind individuals' preferences and decision-making for plant-based products, allowing more effective product promotion to consumers in this market.

Food innovation to commercialisation – NZFIN is a catalyst for growth in emerging proteins

Aotearoa is an international food basket and through continued value-add innovation in the food and beverage sector the New Zealand Food Innovation Network (NZFIN) is contributing to this growth industry, which accounts for nearly half of all goods and services exported annually.

As a key player in the food eco-system, NZFIN support businesses to innovate, scale up and commercialise a broad range of new products - ultimately to international export scale.

From research and development through to manufacturing, five sophisticated food and drink production facilities provide a unique level of expertise and access to a diverse range of equipment for industry.

Sitting under the banner of Callaghan Innovation, NZFIN is a government funded, food innovation service which bridges the gap between a new product idea and a multimillion-dollar factory. Start-ups can bring a vision to life, while established companies can trial new products or test specialised manufacturing machinery before purchase. Included is an ability to undertake small scale manufacture offering an accessible pathway to market for new entrants.

Added value comes from the close collaboration with FoodHQ and the crown owned food research organisations, New Zealand Trade and Enterprise and the Ministry of Primary Industries.

Visit our Library on the website to see how a range of New Zealand businesses have improved their outcomes by using NZFIN. foodinnovationnetwork.co.nz

NZFIN are seeing new opportunities emerge for alternative proteins. Like the wider industry, NZFIN does have capability gaps that, unless filled, will hamper this emerging industry. NZFIN endorse FoodHQ's recommendations that an enhanced NZ

The 5 NZFIN facilities

1. The FoodBowl – Auckland

Six independent food and beverage manufacturing suites for hire offering over 300 pieces of equipment delivering manufacturing flexibility.

Equipment specifically relevant to the Emerging Proteins field:

- Extrusion capability with Clextral twin screw extruder for plant-based meat analogues.

- An Ultra Heat Treatment plant (UHT) with an aseptic filling line to fill into 250ml PET bottles for plant-based milk analogues

2. FoodWaikato - Hamilton

Spray drying experts to support innovation in nutritional powders for bovine and non-bovine dairy products.

3. FoodPilot – Palmerston North

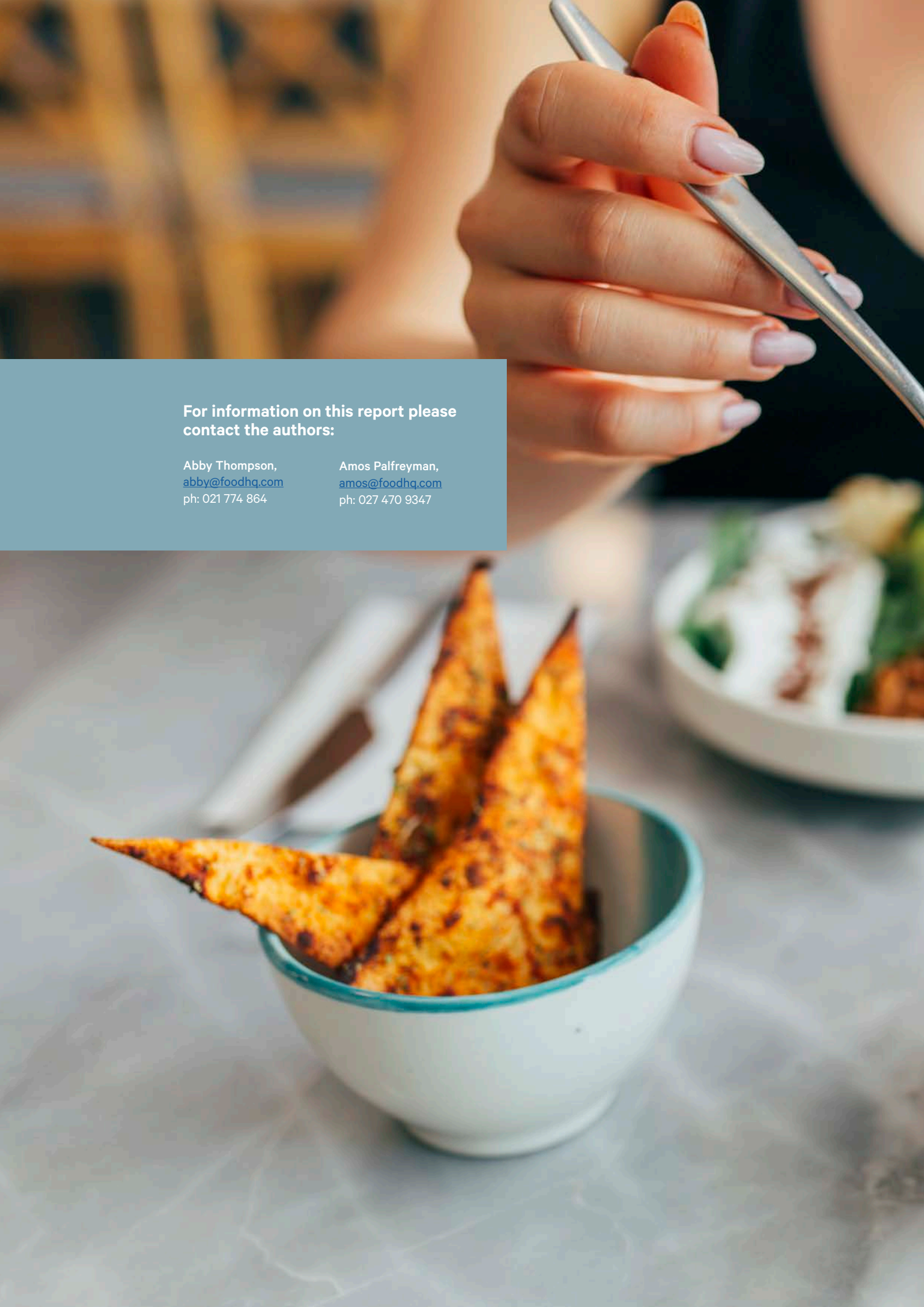
Linking all aspects of food and beverage technology, this specialty research and development facility is part of Massey University and helps turn research and food ideas into reality.

4. FoodSouth – Canterbury

Generalist food and beverage equipment and capability with specialist expertise in plant-based products including separation, filtration, UHT beverage and spray drying.

5. FoodSouth – Otago

This kitchen to pilot scale food grade product development based in the University of Otago.



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