Final Report

Project code: V.RMH.0114
Prepared by: Food Innovation Partners Pty Ltd
Date: October 2020

PUBLISHED BY

Meat and Livestock Australia Limited

Locked Bag 1961

NORTH SYDNEY NSW 2059

Beyond meat to quality ingredient component review.

Meat & Livestock Australia acknowledges the matching funds provided by the Australian Government to support the research and development detailed in this publication.

V.RMH.0114 Beyond meat to quality ingredient component review.

Project Leader: Russel Rankin
Food Innovation Partners Pty Ltd
0411 178 227
Russel@food-innovation.com.au

Purpose: This project investigated opportunities to utilise low value meat as an ingredient in the wider food industry. The project undertook a literature review and a series of interviews with leading ingredient manufacturers/suppliers and food technology experts to provide commercial "voice of customer" for 'meat as an ingredient' strategy.

Acknowledgment of funding sources: Food Innovation Partners acknowledge the financial support for this project from Meat & Livestock Australia (MLA).

1 Executive summary

Meat is composed of water, protein and amino acids, minerals, fats and fatty acids, vitamins and other bioactive components, and small quantities of carbohydrates. Proteins are fundamental components within every cell of the body and are involved in a wide range of metabolic processes. Proteins are essential for growth and repair of the body. Protein consumed provides the body with approximately 10 to 15% of its dietary energy and it is the second most abundant compound in the body, following water[i].

This project investigated the opportunity to utilise low value red meat as an ingredient in the wider food industry. A literature review and a series of interviews with leading ingredient manufacturers and food technology experts to provide commercial "voice of customer" for a 'meat as an ingredient' strategy, was also undertaken during the project. Included is a comparison to other "proteins" and a basic list of baseline criteria for ingredient functionalities and applications.

The project identified 6 high value opportunity spaces for harvesting red meat components as quality ingredient components. These opportunities are 1. Australian functional collagen peptides range, 2. Bone broth, 3. Enzyme processing of rendering feedstock into high value ingredients, 4. Protein powders & drinks for sports and lifestyle, 5. Beef and collagen chips and 6 Extract Australian ovine collagen for the nutraceutical markets.

Compliance to the Australia Food Standards codes (FSANZ and labelling laws was investigated and there were no issues to be considered).

This study has reviewed the literature including past Industry funded projects and has drawn parallel conclusions and recommended opportunities. This study has also identified that the failure to develop these and other opportunities to become market successes that increase demand and utilisation of Australian red meat is due in part to the existing players in the red meat industry lacking the skills and capability to develop opportunities that are outside of their core business. Existing meat processing companies are largely focused on processing animals into meat cuts and readily saleable by-products. The opportunities identified require knowledge of different manufacturing processes, understanding of different markets/consumers and different capabilities. To progress these and future opportunities MLA may need to consider new strategies and approaches to driving commercialisation. MLA may like to consider new commercialisation models.

1. MLA develops a process to match new opportunities with businesses and entrepreneurs in the wider food and nutraceutical sector that have an interest and the capability to commercialise potential new products or services.
2. Company creation. CSIRO agriculture & Food has developed a company creation model that builds new businesses around innovation or IP and brings capability and funding to create a new enterprise[ii].

Table of Contents

2 Background

Protein ingredients range from gelatin and red meat to plant-derived proteins, such as those from wheat, soy, rice and pea — and even more recently to protein from cultivated algae. Cutting-edge processes for separation and purification of specific protein components from their original native sources have been the driver behind many of these ingredients.

Foods vary in their protein content (Table 1), and even more so in the properties of those proteins. In addition to their contribution to the nutritional attributes of foods through the provision of amino acids that are essential to human growth and maintenance, proteins impart the structural basis for various functional properties of foods.

Product	Water	Protein
Beef (lean)	75.0	22.3
Beef carcass	54.7	16.5
Pork (lean)	75.1	22.8
Pork carcass	41.1	11.2
Veal (lean)	76.4	21.3
Chicken	75.0	22.8
Venison (deer)	75.7	21.4
Beef fat (subcutaneous)	4.0	1.5
Pork fat (back fat)	7.7	2.9
Milk (pasteurized)	87.6	3.2
Egg (boiled)	74.6	12.1
Bread (rye)	38.5	6.4
Potatoes (cooked)	78.0	1.9

Table 1. Nutritional composition of meats and other food sources per 100g[iii]

Regardless of their source, all proteins are composed of a sequence of amino acids. The specific order of amino acids in the sequence and their ratio determines a protein's physical properties such as molecular size (i.e., shape) and charge, solubility and isoelectric point (IEP). A protein's isoelectric point is the pH at which the molecule's charge is neutral and is generally no longer soluble in water- based solutions. While these physical properties are useful in separating out and concentrating specific proteins, the properties also determine a protein's functionality as a food ingredient. By controlling the various parameters used to manufacturer a protein, the protein's final functionality as an ingredient can be influenced. Gelatin, for example, can be manufactured through an acidic (Type A), alkaline (Type B) or enzymatic process. Acidic processing results in gelatines with a pH range of about 7 to 9. Alkaline processing produces proteins of 4.7 to 5.4 pH.

A characteristic such as a protein's pH is important when formulating a product. The pH of flavoured waters or soymilk are about 7.0 (neutral), yogurt tends to be in the 4-5 range and tofu is slightly alkaline at 7.2. Juice drinks can have pHs down to 2.5. In the simplest example, if the pH of

a protein-based solution such as milk is lowered through its proteins' pH, they will no longer be soluble and will precipitate out of solution.

Rarely if ever does a food consist of only a protein. Formulated foods consist of a complex matrix of other components such as flavours, additives and other proteins to name just a few. Protein interactions with other molecules range from those that are well known and which processors use to their advantage to others that research is just beginning to determine.

Interactions between proteins and flavouring compounds are complicated and result in created, reduced and altered flavourings. For instance, proteins are known to bind to flavourings. This is undesirable when binding decreases the perception of a wanted aromatic (flavour) molecule or alters the ratio of various aromatics to change the overall flavour profile. Examples include the general tendency for dairy proteins to reduce the intensity of vanillin such as occurs with vanilla in dairy products, or when a "fish flavour" is used to enhance the tuna aroma in a textured vegetable protein-based food. However, the ability to bind unwanted flavours can be an advantage if the flavour is reduced (e.g., as in flavour masking).

The Maillard reactions occur between a reducing sugar (e.g., glucose, fructose, maltose and lactose) and amino acids. It results in flavour compounds and browning. Different amino acids produce different amounts of browning. Maillard reactions can produce hundreds of different flavour compounds depending on the chemical constituents in the food, the temperature, the cooking time, and the presence of air. These compounds, in turn, often break down to form yet more new flavour compounds. All other things being equal, a protein with high levels of proline and particularly lysine, which pea protein has, will tend to create a browner product upon heating than one with lower levels. This can be potentially useful in products where achieving a desirable brown shade is a challenge, such as gluten free baked goods.

MLA believes Australian red meat can receive higher premium price as product ingredients in addition to traditional centre of plate protein component. Currently, 20% of the carcase delivers 80% of its value, with some parts of the carcase considered as waste, receiving/attracting little or no value. Viewing the carcase from the lens of how its components could be utilised as ingredients, in both food and products in other industries such as health food, may unlock significant value for the red meat industry and minimise waste.

Consumers are increasingly aware of the health benefits that protein consumption can offer, such as weight management and muscle loss prevention. However, protein additives also have long been valued by food developers for properties such as their ability to gel, foam, emulsify and form films and dough structures. Research is providing a better understanding of protein functionality and how to best utilise these ingredients even as technical advances are also providing product developers new ingredients with unique capabilities.

Consumer trends around convenience, snacking and wellness offer new usages and occasions for red meat. MLA has previously undertaken a number of projects investigating technology platforms that can harvest/transform red meat and by-product-based ingredients but acknowledge often the business model to adopt these product streams has been limited. Clarity of competitor activity and key points of specification and functionality from the lens of an ingredients supplier or food technologist is required to be able and willing to change to an Australian red meat derived ingredients. Knowledge of market, consumer trends and future food systems has been identified as a knowledge gap.

This project helps bring to life red meat as a high value ingredient and demonstrate to Australian red meat sector new pathways for adding value to the carcass.

3 Project objectives

The objectives of this project were.

1. Summarise megatrends & consumer insights associated with meat as an ingredient.
2. Develop application/use framework for attributes and end-use to create an Applications Tool.
3. Recommend (at least) 5 opportunities to unlock higher value for low value red meat as an ingredient and more broadly the Australian red meat industry beyond current commodity offer

4 Methodology

The following methodology was used in undertaking this project,

Stage 1: Literature and information review

A desktop study was conducted to gather information and knowledge of current and past products, processes and applications incorporating meat and meat components as an ingredient in other food products.

The Literature review undertaken was desktop based. Reports were gathered, compiled and reviewed for relevant information as well as opportunities. A report on Protein was purchased from New Nutrition Business. A summary of megatrends & consumer insights associated with meat as an ingredient using insights from New Nutrition Business (Julian Mellentin), Mintel and others.

The review also scoped out current technology platforms (or capabilities) that are being used to extract and create these products. Consideration was given to sustainability of processing platforms, yields and costs.

The literature review also looked at technology for extraction and processing of proteins from red meat to identify any technology gaps and any new products/processes.

Stage 2: Industry expert/user interview

This stage involved interviewing food scientist/technologist familiar with meat as an ingredient as well as ingredient supply companies. This stage also involved capturing any ‘Lessons learnt’ for red meat proteins used as food ingredients to create food products. Interviews/questionnaire will be held with Bob Hamilton & Trish Lindeman of Earlee Products, Bradley Wardrop-Brown of Blu Oak Innovations, Wendy Pasco & Ai-Tsing Tan of Ingredion and Andrew Klapka from Trans Chem. All information collected and insights/themes from these interviews were sanitised and approval sought from participants to adhere to relevant Australian privacy laws.

Stage 3: Attributes, functionality, and compliance

Stage 3 of the project considered the technical feasibility in terms of manufacturing and food science, commercial viability, and desirability in terms of ingredient attributes and functionality as a food ingredient.

This included a comparison to other "proteins" and baseline criteria for ingredient functionalities and applications. For example, if the binding capability and anticaking properties of soy protein are X, beef variant is rated as Y; If viscosity of inclusion of a Beef variant collagen is X in a brine, a pork collagen variant is Y; a beef based enzyme performs at XC, compared to a fruit extract at Y.

This stage also involved consideration of protein selection based on attributes and end-use to create an Applications Framework Table. Meat ingredients identified/sourced were also reviewed against FSANZ regulations to ensure compliance.

Stage 4 Recommendations and Report

This project identified 6 high value opportunity spaces that the Australian red meat industry could pursue as a new high value business opportunity. The project considered consumer trends, sustainable processing to produce such ingredients and what if any, benefits or imposts a red meat variant presents. Compliance to Australia Food Standards codes and labelling laws was also considered.

The report also recommends next steps to progress the 'best' opportunity/s and they can be discussed with MLA/industry.

5 Results and Discussion

This project investigated the opportunity to utilise low value meat as an ingredient in the wider food industry. A literature review and a series of interviews with leading ingredient manufacturers and food technology experts to provide commercial "voice of customer" for a 'meat as an ingredient' strategy, was also undertaken during the project. Included is a comparison to other "proteins" and a basic list of baseline criteria for ingredient functionalities and applications.

The project identified 6 high value opportunity spaces for harvesting red meat components as quality ingredient and considered trends such as sustainable processing to produce such ingredients and what if any, benefits this will return to the Australian red meat industry. Compliance to Australia Food Standards codes and labelling laws was also considered.

5.1 Desktop Literature Review

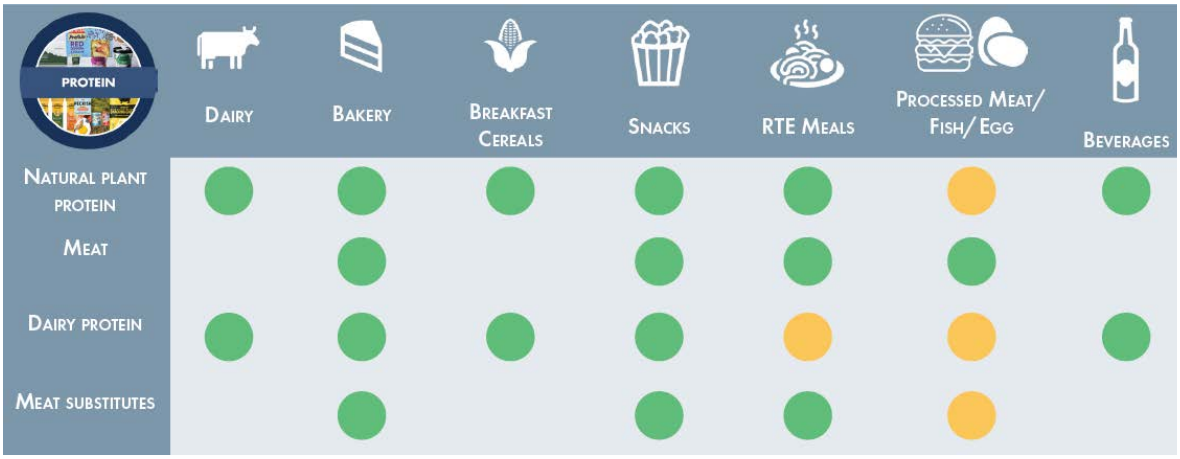
5.1.1 Megatrends & consumer insights associated with meat as an ingredient.

The desktop literature review looked at market megatrends and consumer insights associated with meat as an ingredient. UK based firm New Nutrition Business (NNB) was founded in 1995 by Julian Mellentin, an international specialist in the business of food, nutrition, and health. NNB is the leading global insight firm producing case studies, reports, data and consultancy on the business of foods, beverages, nutrition and health. Each year NNB interviews more than 450 senior executives,

worldwide, in foods, beverages and ingredients which gives a unique insight into the industry. They provide strategic and market insights into the business of food and health, and assist global companies to commercialise nutrition science and provide advise on the communication of functional messages to industry and consumers. Each year New Nutrition Business release their insights, 10 Key Trends in Food, Nutrition & Health 2020.

In 2020 New Nutrition Business has proposed four strategies for capitalising on market trends and consumer interest in protein as a key ingredient in foods and beverages, one focusing on meat as an ingredient. “Contrary to media reports, most people still consume meat even if they are consuming less frequently. People may be choosing more plant proteins, but they are consuming them alongside meat.” (Mellentin).

NNB Protein report also identified protein market growth opportunities which are detailed in Table 2 below.



Green: High-growth opportunities, market is not saturated, there are opportunities to innovate and differentiate.

Amber: Medium-growth opportunities because the market is mature or overcrowded by both emerging and established players.

Table 2. Protein growth opportunities.

The 4 mega trends identified by NNB are, Snackification, Naturally Functional, Fragmentation and Sustainability. These then extend to 10 Key Trends as shown in Figure 1.

Figure 1. Key Trends in Food, Nutrition & Health 2020

New Nutrition Business produced a report *Key Trend 5: Protein*[iv] which showed that protein as an ingredient continues to be considered an important and health promoting micronutrient. New Nutrition Business have identified opportunities for protein as an ingredient in products from different sources. These mega trends represent real opportunities for red meat as an ingredient.

Mega Trend 1: Snackification at the heart of Strategy. NNB has highlighted snacking as a huge driver that is transforming all categories. To drive growth, make it a snack. Demand for protein and plant-based products is growing because companies are delivering protein and plants in good-tasting snack forms. Consumers are very willing to buy all types of innovative snacks, thanks to

fragmentation of consumer behaviours and of markets (Mega-Trend 3). Snacking is no longer about consuming between meals, it is becoming a meal – meals for one, meals consumed on-the-go.

Mega Trend 2: Naturally Functional. Naturally Functional overlaps with and influences every other trend. Naturally functional ingredients are being used to create new brands and new categories. Consumers want more than added science-based ingredients for their foods and beverages, they want a benefit that is perceived as natural and intrinsic to the food.

No health claim is needed. Consumers can draw their own conclusions (thanks to constant positive media attention) about perceived benefits and effects. If products also taste great, are convenient and connected to the key trends, then that is the strongest path to success.

Mega Trend 4: Sustainability. A well-thought-out sustainability strategy is a basic 'must-do' for every company in every corner of the food and beverage industry. Sustainability is becoming a key concern for Western consumers.

The 2019 Food and Health Survey found that 27% of Americans see environmental sustainability as a key driver for purchasing decisions. The survey also found that nearly 50% of Americans consider a product to be healthier if it has been produced in an environmentally sustainable way. This puts pressure on companies to be clearer and proactive in their messaging. But what does 'sustainability' really mean? It includes anything from recyclable packaging to reducing food waste to using renewable energy in production.

Sustainability can also refer to social, economic, or personal/health sustainability. Swedish coffee company Löfbergs and US snack brand Barnana are examples of companies that successfully employ strategies that encompass environmental, social, economic, and personal/health sustainability. Compostable coffee capsules are the cornerstone of the marketing strategy of Löfbergs, the number-two Swedish coffee company. The brand runs and collaborates with several projects to promote social, economic and environmental sustainability and claim to offer" the coffee that is the trendiest today, but also the best for tomorrow". The company aims to use only recycled or recyclable material in all product packaging by 2030.

More and more brands are paying attention to sustainability – and it will soon cease to be a point of difference. New brands and small brands can for possibly the next few years use it as a way to differentiate themselves. If you are creating a new product or brand it will be important to have a sustainability message as part of your brand's positioning, particularly for any brand targeting the premium end of the market.

5.1.2 Review past MLA Project Reports

The Consultant reviewed the previous research and project reports commissioned by MLA. These included,

1. P.PSH.1165 Design and deliver novel meat extract concepts[v].

Project P.PSH.1165 investigated what is desirable and feasible for extracts from red meat and organs and then designed a minimum viable product (MVP) concept. Meat-derived flavours that stimulate the gustatory senses and evoke memories of home-cooked meals have previously been identified as strongly desirable.

To determine desirability, the project explored the factors influencing the nutritional intake of older age consumers. Focus group interviews designed to discover flavour preferences were held at

retirement villages with residents and staff. A strong desirability for meaty savoury flavours was identified as they evoked feelings of nostalgia for the savoury, meat-centric dishes of their youth, most notably the Sunday roast.

To gain an understanding of the product feasibility, flavour generation through protein-related reactions, composition of peptides influencing flavour perception, Maillard browning reactions and the contribution of volatile compounds were considered. Flavour extraction approaches that are proven and scalable (e.g. hydrothermal pressure processing, enzymatic hydrolysis, solubilisation) were investigated for their yield, production cost, waste treatment, and regulatory and safety requirements.

The Authors utilised their existing database of flavour compounds incorporating flavour peptides. The 'tastant' database was used as a cost-effective bioinformatic appraisal and screening tool for candidate flavourings during extraction procedures before proceeding further with sensory evaluation of promising candidates.

The project undertook cost analysis with the price of analogous products and the prices of raw materials and initial estimates on conversion efficiency (yield). The project had a target of raw material cost to product sales price ratio of at least 3.

Initial results suggest that an MVP could be a savoury-flavoured table-top condiments with popular umami flavours, to encourage bioavailable protein consumption. The MVP would not include excess saturated fat, cholesterol, or sodium. Such a product could also be fortified with important micronutrients or designed to be added to a range of nutrient-dense foods targeting a wider population demography.

2. P.PSH.0673 Prototype commercial development of High Moisture Extrusion Cooked meat[vi].

The independent pre-commencement cost benefit analysis that was undertaken by Phil Green of Greenleaf Enterprises considered the viability of the PHMC business case to determine if initial capital investment was justified and how that investment will benefit Australian processors and producers. Based on commencement of sales, reviews of product quality, customer correspondence the opportunities elucidated in the project initiating cost benefit analysis have continued to be solid indicators and manifestation of opportunities.

The project sought to develop the commercial opportunity for the red-meat industry of value adding using the ProForm Foods' Cooking technology (PHMC). The predominant impact of the project is that it provides an innovation injection into the red meat industry to challenge existing value adding paradigms to provide substantial dollar returns.

The outcomes emanating from the project are listed below:

- Provision of an additional value-adding channel for red meat locally and globally by enhanced utilisation of total carcase.
- Generation of yield efficiencies and value effectiveness by harvesting premium value from usable protein.
- Demonstration of an innovation pathway project that commercialises innovative technology to grow demand.

- Opportunity for further stakeholder investment

The demonstration PHMC plant (designed and built as part of the project) has capability for developing a range of products and optimising process yields. The plant run by ProForm Gourmet using the ProForm Foods' technology is producing commercial volumes of PHMC red meat products to secure market feedback on fully cooked meat products in Australia and other markets.

Market intelligence from target overseas markets is, has, and will continue to be key to the identification of new products and for developing the adoption of the technology by the Australian Processing Sector. ProForm Foods will license the technology for full-scale installations, which are to be supported by a technical support package to implement the technology. Full-scale production plants to process over 100 tonnes per week would be financed by commercial investment to meet initial market potential.

Overall, the work enabled the building of an understanding for the requirements for scaled up production via the implementation of the demonstration plant. Further collaborative activities with MLA have been put forward and accepted to bridge the gap between market understanding and requirements and the capability to deliver to those specific target market opportunities.

3. P.PSH.0812 Red Meat Protein Snack[vii].

Beef protein isolates as a food ingredient is largely missing in food market, especially in the snack market. The common processing method of preparing beef protein isolates is enzymatic hydrolysis, which considers with high solubility and easy extractability. However, this extraction method compromises beef proteins' nutritional value by destroying their functional structure. Additionally, enzymatic hydrolysed proteins give bitter flavour which leads to a negative effect on the usage in food industry. Therefore, the technical challenges with the extraction of beef proteins in their native forms have been persistently challenging. A novel simplified and native extraction method for beef protein is a definite need in food market.

Protein isolates, concentrates and hydrolysates are available to consumers and the food industry as functional ingredients. The key difference between these substrates is that isolates are 90%+ pure protein, whereas concentrates contain other dissolved solids (e.g. carbohydrate, fats and therefore 10-15+% less protein content). Hydrolysates are produced by acid/heat/enzymatic processing that partially breaks the protein molecule, resulting in a more readily digested, but bitter tasting end-product. Consequently, consumers are turning to natural whole protein sources. As added-protein products proliferate and start to look faddish, consumers are opting for "naturally-functional" protein sources such as meat.

Whey, casein, egg, soy proteins are included in the eight major food allergens group which pose a risk to induce adverse immune response. Additionally, other issues might be associated with them, such as high sugar content in whey isolate, slow absorbability in casein protein, low cost-effectiveness in egg protein and genetic modification risks in soy protein. Plant derived proteins (e.g. those derived from rice, hemp and peas) are deficient in several amino acids and are not recommended as a primary source of dietary protein. Specific plant proteins need to be consumed together in order to obtain all essential amino acids. Furthermore, plant foods usually contain protein-limiting agents (e.g. phytates) which bind to protein decreasing their bio-accessibility (release from the food matrix) reducing absorption by the body. Hence, they have limited market share. Conversely, whole protein obtained from animal-based foods contain all essential amino acids and are readily bioavailable.

When developing protein supplements or high protein food and drink products, the protein content is often boosted by incorporating a protein isolate, concentrate or hydrolysate. These are all highly-refined and processed forms of their original protein sources that provide a concentrated source of protein with the absence or reduction of other nutrients, such as fats and fibre. Whole protein rich products are available in the form of 'whole' foods such as Greek yoghurt, cottage cheese dips, boiled eggs, tinned tuna. Other foods being utilised for their high protein content includes beans, seeds and nuts. Some of the newer sources of protein being used include combinations of ancient grains such as quinoa, chia and teff, while pulses, grains and seeds such as peas, maize, rice, hemp, lupin and linseed are also being used more for their protein content.

Protein products have now proliferated across many categories. Innovation around new high protein products has been driven by the snack and dairy segments, with snack bars and yogurts accounting for the bulk of new high protein products. However, work to spread protein consumption more evenly across a whole day's occasions and usages presents opportunity for breakfast products and snacks to include protein in their formulations to help achieve a more balanced intake of protein. Easy to consume protein rich products could also find popularity among the growing aging population and segments of the flexitarian movement, due to protein's health properties in building and maintaining muscular strength.

Animal-based proteins are known for their difficulties of protein extraction and isolation. Technically beef protein has not found its way into the mainstream protein ingredient markets because of: 1) significant quality issues faced when using traditional processing methods, 2) strong fat-based flavour volatiles which may have increased susceptibility to oxidation (e.g. rancidity); and 3) the inherent high value of meat cuts and their use in main meal options.

The project conducted a Red Meat Snack Workshop that consisted of industry stakeholders and representative innovators and MLA. The purpose of the workshop was to develop red meat snack concepts. Concepts products presented and tasted are shown in the table below.

Innovator	Taste the Snack	Dream the Snack
Earlee Foods	Collagen Chips	Meat based cracker
	Shelf stable snack sausage	Hi-protein low carb muesli/trail mix
	Breakfast Bar	Chocolate with beef fat
		Hi protein lactose free ice cream
		Protein enriched beverage
BluOak Innovation	Beef chips with inulin fibre	Dual textured coextruded beef or lamb bar
	Fortified beef bars	
	Pre/probiotic collagen recovery drink	
	Beauty bars	
Maxime Bilet	Reimagined Jerky	Jerky and force meats
	Beef offal Fish sauce	Crisps with side of beef
	Thin meat crisps	Crispy crunchy foam
	Meat based starch chips	Coextruded meat pockets
	Plant chips impregnated with protein isolate	Fried rice clusters with meat bits
	Tender Puff V1	

	Tender Puff V2	

4. P.PSH.0999 Developing High Value Freeze Dried Australian Red Meat Products and Services.[viii]

Freeze Dry Industry and MLA's project objective was to identify 3 to 5-fold value adding opportunities for the red meat industry through the application of freeze-drying technology. Red meat products researched and reported on in previous milestones included blood, cubed beef, hides, oesophagi, bile acids and paunch. The design led approach has highlighted waste hides and the extraction of collagen as the lead opportunity. This extraction of collagen from hide is the key focus of more detailed investigation, research and development.

Australian meat producers are one of the largest suppliers of salted and wet-blue hides and salted skins to the world market. Australia annually produce 8 million cattle hides, 1 million calf skins and 32 million woolskins1. Australia is one of only a few countries that has open trade in hides and skins, however farmers still regard these skins and hides as by-products and 'waste' so often sell them for whatever the counterparty is willing to buy them for and is then often transformed into leather. With the assistance of the MLA and the Australian red meat industry, the technology developed by FDI is able to offer a significant value uplift for the waste hides currently being discarded. FDI is capable of being positioned at red meat processing facilities and/or regionally in close proximity to processors due to its energy efficiencies.

5. V.RMH.0003 Exploring High Valued Opportunities for Natural Flavour and Wellness extracts derived from red meat (2Morrows Foods)[ix]

The secondary parts of the animal are largely considered to be of low value. Many possess either strong taste (i.e. tallow) or health (i.e. bones) properties, though generally not both. However, they are often considered by consumers to be undesirable, as we have long since moved away from a 'nose to tail' diet, to only consuming the best bits. Whilst it is a tough ask to get consumers to embrace products like offal, in their basic form, there is the opportunity through new processing technologies to bring their more desirable properties to the fore, in new tailored solution offerings. This work was done to explore three opportunity spaces for secondary components of the whole animal to assess if it is worthwhile undertaking further development to realise these opportunities.

This study involved a design led methodology to test the opportunity spaces. Initially the dynamics of each opportunity space was assessed, looking at emerging themes and assessing existing offerings within the relevant categories. Through assessing the fundamental properties of these secondary animal components (i.e. Bovine Collagen) and the role new processing technologies can play, hypothesized Value Propositions were developed against a target customer who it was felt would value the offering. These hypotheses were validated through ethnographic consumer research, where concept statements, representing the Value Proposition were shared and reactions assessed. Finally, for each concept Minimum Viable Products were developed and tested with target consumers to assess if the offering was able to live up the Value Proposition promise.

Two of the three opportunity spaces have produced results that are well worth further consideration.

The Renaissance of Tallow Fries – the superior chip: Whilst lost in time, due to long-since debunked concerns about saturated fats, exposing a generation that has never experienced them before, resulted in a hugely positive reaction to their taste and overall eating experience. Testing in a real-

world situation, one that we felt suited this offering – at a premium burger joint, they were seen as being delicious in their own right, as well as a better accompaniment to a burger, than existing / regular vegetable oil cooked fries.

Bovine Collage for Tendon and Joint regeneration: Males in their 40's and 50's who seek to maintain their sporty ways, are let down by their ageing bodies. But whilst many dimensions of their physical performance have only declined marginally – i.e. endurance and strength, other aspects have a far greater impact. Most of this target customer experience tendon and joint pains that severely limit their capabilities. Whilst this target customer is hesitant to try traditional medical solutions that could address the issue, a daily, natural bovine collagen tonic is seen as offering the best hope for maintaining the body's ability to perform at levels of yesteryear.

Chips (crisps) with real meat flavour: This concept had mixed reviews, so a question mark remains over if and how this opportunity could be realised. At a concept level, the idea of real meat flavour was highly appealing, though some concern existed about actually putting real meat on a chip. It was seen as being the ideal platform for further premiumisation of chips, potentially taking them into usage occasions which existing offerings are just not sophisticated enough to deliver on. However, the MVP was a long way from delivering on the Value Proposition, with the fundamental properties of what makes a chip, a chip, not delivered on – saltiness and flavour intensity.

Two of the three opportunity spaces; Tallow Fries and Bovine Collagen, represent significant value-adding growth opportunities for the red meat industry. The identification of suitable Commercial partners and associated investment are required to further develop these opportunities through the 'Develop' and 'Deliver' stages to realise sustained commercial success.

6. V.RMH.0044 Review and meta-analysis of emerging technologies for tenderising red meat[x]

This project looked at the application of new technologies, high pressure processing, shockwaves, ultrasound, pulsed electric field, sous vide cooking, exogenous enzyme addition and muscle stretching to pre- and post-rigor meat for tenderisation. These non-thermal, and thermal, technologies can be used with varying success to cause physical disruption to muscle structure, enhanced proteolysis and ageing and muscle protein denaturation, solubilisation and gelation resulting in enhanced texture and juiciness. A range of new technologies have potential for application in the meat industry to accelerate or improve the texture of meat. A meta-analysis was conducted on the effect of selected technologies on post-mortem tenderisation.

7. V.RMH.0047 Meat Powder and Hydrolysis.[xi]

This project looked at the production of meat powder and hydrolysis. Secondary by-products (bone, fat trimmings) are a significant proportion of the carcass and mostly deliver a minor return while impacting muscle meat yield. Two technologies were investigated in this project, powdering and hydrolysis which not only significantly improve yield recovery, but importantly the quality and value of meat that then remains fit for human consumption. The project assessed the opportunity through to product concepts and an ex-ante business case analysis.

The assessment of these opportunities involved engaging equipment manufacturers, modifying and building processes and producing product concepts for inclusion in existing commercial products for assessment. This was followed up by engaging the equipment manufacturers to provide budget quotations for these processes to process at 1 tonne/hr.

Powdering: The modifications to the powdering process have made it capable of processing a wide range of secondary products where it was previously limited due to fat content. The product concept developed with this process is the milling of a mixture of 30% bones and 70% fat trimmings called DM70. Two product types can be manufactured; 1. Meat extender and edible fat or 2. Undenatured meat extender. DM70 type 2 (rehydrated) has been shown to substitute 30% of 90 CL trim one for one in 100% beef sausages with good acceptance and no grittiness.

Hydrolysis: A small manufacturing process, including an imported reactor from Europe, was setup to produce sufficient bone hydrolysate to enable production trials substituting it for finely textured beef (FTB) in ProForm Foods HMEC beef product. It was shown that 70 to 80% of the FTB could be replaced and excellent texture maintained while providing cost savings to the manufacturer.

Pay-back for both technologies/processes were found to be within the 2-year time frame while maintaining an IRR of 20%. The stand-out option was definitely the DM70 type 2 product, which could be used in a wide range of meat products that currently use 90 CL trim, such as sausages and burgers.

8. P.PIP.0187[xii] + P.PSH.0415[xiii].

Projects P.PIP.0187 and P.PSH.0415 investigated utilisation of blood collected from meat processing and the various bioactive components.

Project P.PIP.0187 This project investigated adding value to blood, a by-product stream produced in abattoirs and rendering facilities, which at present is mainly used as a low value animal feed. Value addition to blood presents opportunities to produce ingredients which are physically functional, provide 'meaty/brothy' flavour attributes or physiological functionality. The project investigated blood as a flavour ingredient by hydrolysing haem to produce blood hydrolysates that provide a 'meaty/brothy' flavour. Blood contains approximately 18% crude protein and consists of plasma and a red cell/corpuscles fraction. The cell fraction has ~35% solid content with ~33% protein corresponding to ~70% of protein in blood. The red cell fraction contains haemoglobin, a coloured iron containing protein used in oxygen transport. The iron in haemoglobin is held in the form of haem. The initial sensory screening of the eight samples resulted in the detection of a very strong liver flavour note in all samples. This flavour note was very strong and masked all other flavour attributes. Diluting the hydrolysates and mixing with other commercially available stocks were not able to overcome this strong liver flavour attribute.

Meat flavour and bullion ingredients are generally formulated with combinations of various additives and hydrolysates from different protein sources. The project recommended that the blood hydrolysate samples be evaluated as protein hydrolysates to produce meat flavour and bullion ingredients. It was recommended that product development be conducted with companies specialising in developing formulated flavour ingredients.

Project P.PSH.0415 worked in collaboration with a food manufacturer to identify and develop potential uses for bovine blood and blood derived products. The project identified the production of concentrated liquid plasma (CLP) that may be lower in cost than currently available spray dried plasma (SDP) as an opportunity for exploration. To stabilise blood for separation, multiple anti-coagulants were analysed, and one was determined to be the safest, most cost-effective anticoagulant for use in material to be used for food manufacture. The concentration of anti-coagulant was optimised for the collection process designed in conjunction with the abattoir and a third-party manufacturer. Pilot scale plasma concentration trials using membrane technologies

successfully produced concentrated plasma with a high protein recovery. As expected, the addition of preservatives in conjunction with reduced storage temperature resulted in stabilisation of the material for a significant period. The functionality of the CLP samples stored over this period did not indicate any change because of storage temperature or the addition of preservatives. The CLP produced and stored under these conditions was successfully trialled in a variety of products.

5.2 Industry Expert Interviews

Stage 2 involved interviewing food scientist/technologist familiar with meat as an ingredient as well as ingredient supply companies. This stage also involved capturing any 'Lessons learnt' for red meat proteins used as food ingredients to create food products. Interviews/questionnaire were held with Bob Hamilton & Trish Lindeman of Earlee Products, Bradley Wardrop-Brown of Blu Oak Innovations, Wendy Pasco & Ai-Tsing Tan of Ingredion and Andrew Klapka from Trans Chem. The information and insights/themes from these interviews have been sanitised to maintain commercial confidentialities.

Earlee Products

Earlee Products is a food ingredients supplier that has been identifying and responding to food and consumer trends for almost 30 years. Innovation, research capability and technical expertise are core attributes of Earlee Products. Using science and creativity Earlee solves challenges and develops opportunities which has led them to become an industry-leading ingredients supplier to Australian and global food manufacturers. Bob Hamilton is the founder and Chairman of Earlee Products. General Manager is Brett McMullen, supported by Trish Lindeman, R&D Manager and Michael D'Allura, Commercial Manager.

Interview transcript points.

- When consider meat-based source of protein companies need to consider Does the consumer want an animal-based or vegetable protein? This will be the first consideration.
- Need to consider what processing parameters will the protein be exposed to such as temperature, pH and then what is the required functionality, film forming, gelling or does nothing to the structure.
- Does it need to be a clear based beverage? then you cannot use meat proteins except collagen.
- Collagen is the most abundant component in red meat. Lots of work already done with collagen.
- Muscle proteins are difficult to recover as they denature easily. Lots of work has been done before. There are costs impediments. They are small proteins but best used for flavour addition effects.
- Discussed the previous Xinova project funded by MLA, P.PSH.0812 Red Meat Protein Snack.
- Pig fat is special and is used in beef and lamb products. Usually pig back fat. Characteristic of beef fat is that when it solidifies it solidifies as alpha crystals which are very grainy. Pork fat on the other hand crystalises as beta prime crystals which are creamy smooth.

- The margarine industry splits out the stearic acids from the beef fat and tricks the remaining fat to crystalline in beta prime via seeding. This results in a creamy beef fat.
- No one has promoted the use of beef tallow in food products. Cholesterol is the main issue that was of concern to consumers, but this can be removed now. Gives a low melting point which works better with mouth feel. The technology already exists to split out the unwanted components of beef tallow.
- Rendering industry is struggling to survive so we need new processes and uses for the edible fats from meat processing. This allows the food industry to move away from palm oil. The market wants halal ingredients.

BluOak Innovations

Bradley Wardrop-Brown is the founder and Director of Blu Oak Pty Ltd and is the Principal of BOI Food Tech & Packaging. He has extensive experience in food and beverage manufacturing. Bradley is a qualified Food Scientist and former Chef with over two decades of practical experience in product, process and packaging design. Bradley worked for Simplot Australia for nearly ten years holding a number of key roles in both Research and Development and Operations. Simplot Australia Pty Ltd is the owner of well-known food brands, Leggo's, Plumrose, Birdseye, Edgell, I&J, Chiko, John West, Seakist and Ally. Bradley is also a Food Safety and Quality systems Auditor and has spent time in Export/Import Quality Management as well as two and a half years as Production Manager at the Company's Echuca Production facility.

Bradley has extensive experience in developing products using protein ingredients. Bradley was interviewed over Zoom video call during August 2020. He was asked about lessons learnt in developing protein-based products, in particular those incorporating red meat proteins. The discussion also covered factors to consider during processing, benefits and barriers to use. Finally, regulatory issues were explored to better understand issues or requirements in relation to Australian Food Standards.

Interview transcript points.

- As a food sector red meat will struggle to grow and remain relevant to consumers. On the other hand, the biotechnology side of the meat industry will boom.
- Sustainability of the meat sector is important in the minds of consumers and the sector needs to address this issue. Cattle farming has been highlighted in the mind of consumers as contributing significantly to greenhouse gas production and so global warming.
- Red meat protein has an opportunity to make greater impact in the market in snacking. Possible opportunities are Jerky bar, Desktop eating and Ready-to-eat meals.
- Animal fat is an excellent source of flavour. Need to remove cholesterol and saturated fats to allow the use of remaining components.
- Bioengineered collagen should be explored.
- Pet food is still a growing market sector for red meat protein. Pets, dogs and cats, need fat and protein in their diet and consumers are willing to pay for quality.
- Another opportunity is savoury muesli bars, snacks or beef corn chips.

- There are no regulation issues. Even for hydrolysed beef as it can be classed powdered beef.
- Other product opportunities to consider are seasoning and bone broth. A beef powder that is 100% Australian beef for stock.
- Asia is a growing market that is a big user of concentrated beef stock. Bovine broth for soups. Bone off-cuts fat.
- Significant product opportunity is beef flavoured corn chips.

5.3 Technology gaps - new products/processes.

Protein interactions with other food constituents

The hydrodynamic/rheological, surface, hydration, and biological properties of food proteins contribute to their function in food systems. These functional properties are determined by the proteins' intrinsic properties, including the basic chemical and physical properties of their constituent amino acids. These in turn are influenced by interactions with other food components (e.g., salt, water, flavour compounds), by food processes and external conditions (e.g., heating, freezing, pH, redox status) and by other processes (e.g., chemical derivatization or enzymatic modification). Figure 2 below summaries the effect of these parameters on functional properties of proteins.

The chemical properties and functions of proteins are shaped by their interactions both with major food constituents such as water, other proteins, lipids, and carbohydrates, as well as with any number of minor constituents such as salts, metal ions, acidulants, flavour/aroma components, and phenolic compounds. The published literature describes many studies of the interactions of proteins with other food constituents, and only a few examples are included here to illustrate how these interactions may affect the properties of proteins in food systems.

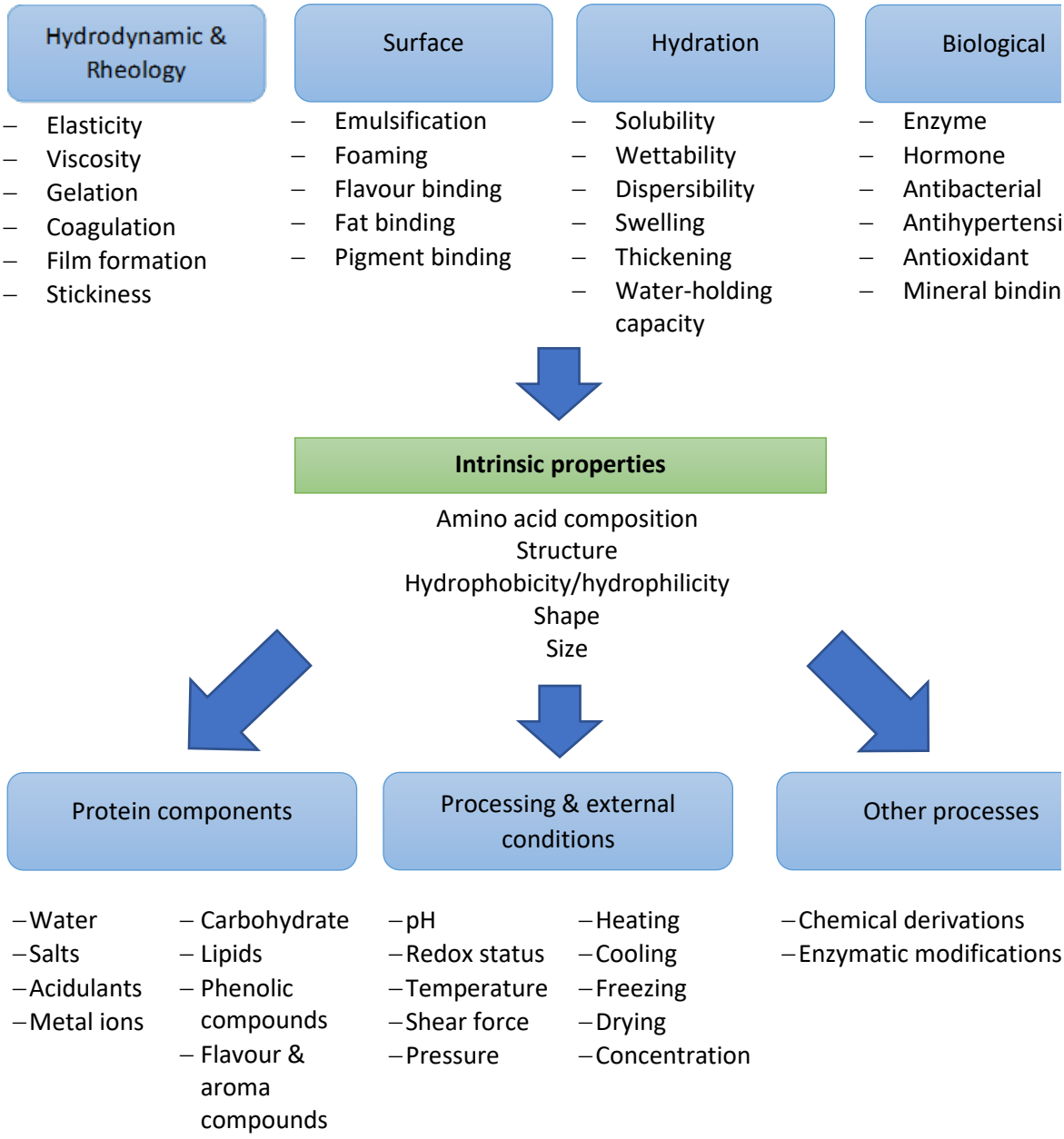


Figure 2. Functional properties of proteins and factors affecting them[xiv].

5.4 Processing technology

5.4.1 Methods used for protein extraction from meat/muscle

Muscle proteins are extracted from animal sources using chemical and enzymatic methods. Chemical extraction methods include: 1. buffer extraction which only uses chemicals in neutral pH to solubilize protein; 2. pH shift extraction which adjust pH to acid or alkali to extract and precipitate them down later using an isoelectric point. Protein hydrolysates-peptides obtained from enzymatic extraction process are also used in the food industry.

Buffer extraction in neutral pH

The sarcoplasmic proteins are readily soluble in water or dilute salt-containing solutions. Extraction of muscle with strong salt solutions dissolves the major portion of the sarcoplasmic plus myofibril proteins. Most of the strong salt soluble proteins can be brought out of solution by diluting the ionic strength to ~0.05. The residue after these sequential extractions was referred to as the connective tissue or stromal fraction. Preparations of myofibrils using this method have very low quantities of proteins. A common scheme for the separation of the various solubility classes of muscle proteins is shown in Figure 3 below.

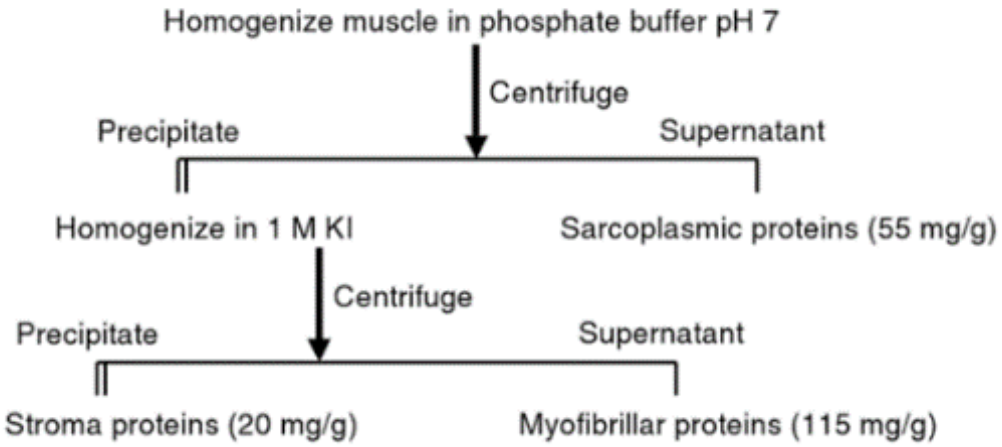


Figure 3 Fractionation of muscle proteins

Enzymatic Hydrolysis

The enzymatic hydrolysis of various biopolymers in foodstuffs, such as polysaccharides, proteins and pectins, is an important process which is used to improve the physical, chemical and organoleptic properties of the original food in relation to the nutritive value and the intestinal absorption characteristics. The enzymatic hydrolysis of protein is carried out under acid or alkaline controlled conditions without degrading their nutritional qualities for the acceptance in the food industry and broad spectrum of products can be produced for a wide range of applications.

Isoelectric solubilisation/precipitation (ISP)

The isoelectric point (pI) of a protein is the pH where the net charge on the protein is zero. Proteins tend to aggregate and precipitate at their pI because there is no electrostatic repulsion keeping them apart. Proteins have different isoelectric points because of their different amino acid sequence, and therefore, they can be separated by adjusting the pH of a solution. When the pH is adjusted to the isoelectric point of a particular protein it precipitates leaving the other protein in the solution. ISP processing may be a useful technology to recover nutritious and functional protein isolates for development of nutraceutical food products destined for direct human consumption from underutilized fish resources such as krill and invasive nuisance species like Asian carp, fish and meat processing by-products (i.e., frames, heads, etc.), and other low-value animal protein sources that otherwise may be discarded. The effect that pH has on water solubility of muscle proteins has long been known; however, the process of separating proteins and lipids using pH-shifts was proposed by Hultin and Kelleher.

The ISP process efficiently recovers high quality protein isolates in terms of nutritional quality and functional properties from sources difficult to process such as krill, fish, chicken, and beef processing by-products. While proteins are dissolved, they are separated from lipids and other insoluble materials such as skin, bones, scales, etc. Following separation, a subsequent pH-shift induces protein precipitation. During the first pH-shift meat proteins are dissolved at either acidic or alkaline pH. Centrifugation is typically used to separate lipids by floatation (light fraction) and other insoluble materials (bones, skin, and stromal proteins) by sedimentation (heavy fraction) from dissolved meat proteins (middle fraction). The protein solution (middle fraction) is then adjusted to pH 5.5, the isoelectric point (pI) of meat proteins. At the pI proteins lose their water solubility; and therefore, precipitate out of the solution. Finally, the precipitated proteins are separated from the process water (i.e., de-watering) typically by centrifugation or ultrafiltration. Since proteins dissolve at very high (pH 10.5–13.0) or very low pH values (pH 1.5–3.0), ISP processing results in mild microbial reduction. ISP is a useful technology to extract protein isolates from muscle food processing by-products and low-value meat that could be used as a main, bulk ingredient in nutraceutical/functional food products; and therefore, be destined for direct human consumption.

Protein extraction methods can vary widely in reproducibility and in representation of the total proteome, yet there is limited data comparing protein isolation methods. Different extraction procedures have been established and the commonly used methods include chemical and enzymatic hydrolysis extraction. These three protein extraction procedures have their advantages and limitations, depending on factors such as the type of muscle tissue, protein yield and downstream analysis of the extracted proteins.

The pH-shift method is used in the food processing industry for separating proteins. The principle is to solubilize proteins at high or low pH, removing debris and precipitating the proteins near their isoelectric point. Because of its outstanding functional properties, protein isolates can be used as a protein additive. It has been found that functional proteins can be extracted from muscle using acid-or alkali-aided solubilisation and recovered with ISP. A higher level of proteins can be extracted with high compared with low pH because of higher protein solubility at high pH. From the perspective of developing functional protein ingredients, the pH-shift method can efficiently recover the muscle protein, including myofibrillar protein and the water-soluble proteins. The recovered proteins have a good colour and excellent functional properties and are safe for consumption. As a result, the use of pH-shift as a method for recovering muscle protein is worth further evaluation.

Enzymatic hydrolysis of the by-products is another method of protein recovery from animal processing industries. The isolate is mostly used for production of dried nutritional, flavouring and emulsifying ingredients. In the hydrolysis process, only a minimum amount of water is added, and temperature is raised to activate (55-60°C) the enzymes. By using different enzymes and by controlling temperature, time and pH, different end-products can be produced.

Advantages of enzymatic hydrolysis:

- Very high yield of Nutritional Protein
- High Protein and High Nitrogen
- Contains all Essential Amino acids
- Soluble

Disadvantages of enzymatic hydrolysis

- Low emulsification activity index and emulsion stability due to extensive hydrolysis.
- Poor product quality
- Lack of functionality
- A rancid odour/taste

Protein isolates recovered using ISP processing is of high quality, meaning they contain all nine essential amino acids (EAAs) in adequate amounts. Although ISP processing efficiently recovers high quality protein isolates, attempts at commercializing food products developed from the ISP-recovered protein isolates have been limited. Results from laboratory-scale product development demonstrate the potential for the use of ISP-recovered protein isolates from seafood processing by-products and low-value meat as a main, bulk ingredient in the development of nutraceutical food products.

Challenges

ISP is a technology that efficiently recovers functional and nutritious protein isolates from sources difficult to process through conventional means. Although high quality protein isolates can be efficiently recovered with ISP, the key challenge is to develop marketable food products for direct human consumption. Nutraceutical food prototypes whose main, bulk constituent are the ISP protein isolates enriched have been developed and tested at a laboratory scale. It is suggested that storage stability as well as nutritional assessment studies should be conducted. In addition, marketing and financial feasibility studies are recommended.

5.5 Application tool for attributes and end-use.

When consider the use of protein as an ingredient within a particular food system there are always advantages and challenges associated with the protein source. Table 1 below lists out some of the pros and cons of various novel protein sources.

PROS AND CONS OF NOVEL TYPES OF PROTEIN				
	Plant Protein	Mycoprotein	Cultured Meat	Insects
Advantages	Consumer familiarity and perception as "naturally high in protein" Some have neutral taste or a good flavour profile Low environmental impact Available and developed supply chains Low price	Versatility and neutral flavour for product innovation High digestibility and amino acid balance score Affordable pricing Sustainable	Mimic meat texture, taste and protein profile Once technology and production costs come down, it can be a "clean label" cost-effective alternative Sustainable	High quality protein available in large scale Efficient in conversion of feel into edible weight Can be raised on low-value agricultural by-products Sustainable
Challenges	GMO concerns Side-effects concerns (over estrogenic effect by soy) Allergenic concerns Not all have high score on amino acid balance and digestibility High volume of by-products from processing	Taste & texture profile Artificial additives and a long ingredient list Might involve energy- intensive techniques Consumers are unfamiliar with it Term "mold" might affect consumer perception Not perceived as very "natural" nor "clean label"	Technical challenges and high cost of production means it will only be available for a high-end market during initial stage Complexity of process can be challenge for consumers as well as "artificial" perception	Texture, appearance, and flavour creates significant challenges for product formulation Negative consumer perceptions towards eating "bugs" in many markets Costly production

Table 1: Pros and cons of novel types of proteins.

5.5.1 Ingredients versus functionality

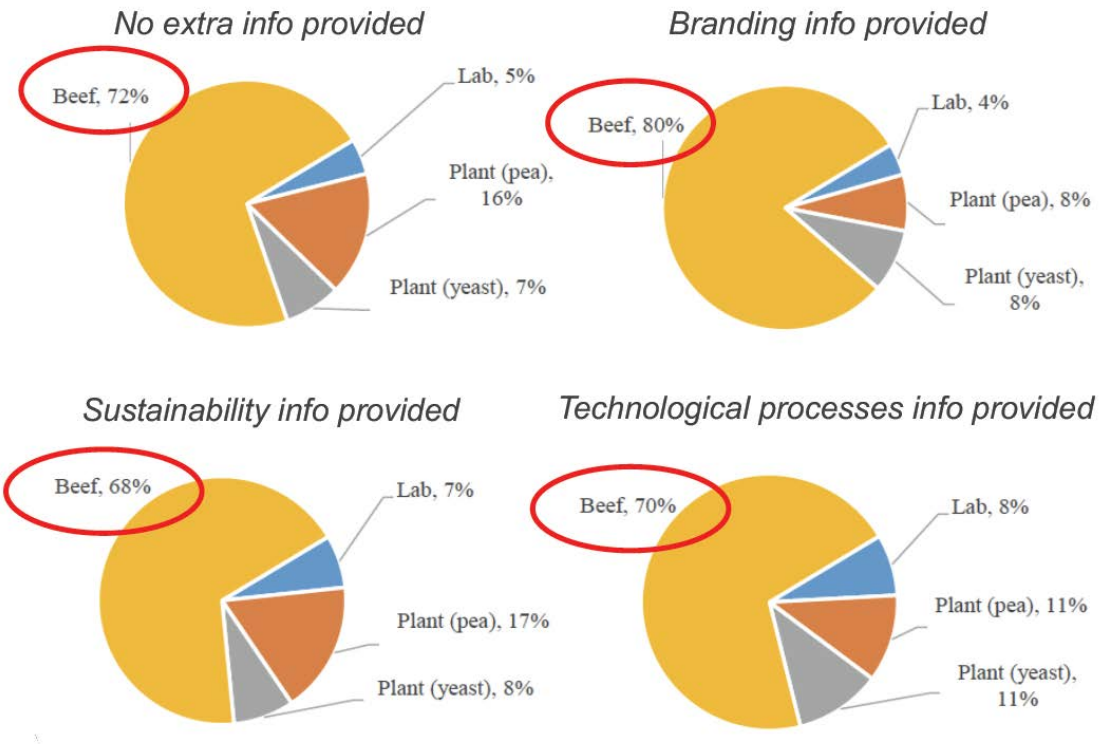
Ingredient source										
Baseline Functionality criteria		Red meat Protein	Red meat Collagen	Marine Collagen	Porcine collagen	Soy	Pea	Lupin	Egg	Whey
	Protein level (digestible)	High	Nil	Nil	High	High	Medium	Low	High	High
	Heat stability	Poor	Poor	Poor	Poor	Poor	Poor	Poor	Poor	Poor
	Flavour contribution	Meaty	Nil	Nil	Nil	Bitter	Nil	Bitter	Eggy	faint milk or cheese taste
	Solubility	Poor	Good	Good	Good	Good	Good	Good	Poor	Good
	Water holding ability	High	High	High	High	High	High	High	Medium	High
	Texture addition	Good	Poor	Poor	Poor	Medium	Medium	Medium	Medium	Medium
	Functionality	Medium	High (peptides)	High (peptides)	High (peptides)	Low	Low	Low	Medium	Medium
	Allergen free	Yes	Yes	No	Yes	No	Yes	No	No	No
	Labelling requirements	None	None	Yes	Yes	Yes	None	Yes	Yes	None
	Cost	Low	Medium	High	Medium	Low	Medium	Low	Low	Low
	Religious consideration	Halal	Halal	None	Non-Halal	None	None	None	None	None
	Dietary consideration	Non-vegan	Non-vegan	Non-vegan	Non-vegan	Vegan	Vegan	Vegan	Non-vegan	Non-vegan

5.5.2 Application/Use versus performance criteria

Application/Use requirements									
Performance requirements		Beverage (liquid)	Beverage (powder)	Protein powder	Protein bar	RTE Meals	Weight loss meals	Fitness meals	Snacks
	% Protein	✓	✓	✓	✓	✓	✓	✓	✓
	Heat stability	✓	✓	✓	✓	✓	✓	✓	✓
	pH effect	×	×	×	✓	✓	✓	✓	✓
	Flavour contribution	×	×	×	✓	✓	✓	✓	✓
	Solubility	✓	×	×	×	×	×	×	×
	Water holding ability	×	×	×	✓	✓	✓	✓	✓
	Texture	×	×	×	✓	✓	✓	✓	✓
	Functionality	✓	✓	✓	✓	×	×	×	×
	Allergen free	✓	✓	✓	✓	✓	✓	✓	✓
	Labelling requirements	✓	✓	✓	✓	✓	✓	✓	✓
	Cost	✓	✓	✓	✓	✓	✓	✓	✓
	Religious consideration	✓	✓	✓	✓	✓	✓	✓	✓
	Dietary consideration	✓	✓	✓	✓	✓	✓	✓	✓

5.6 Opportunities for red meat as an ingredient.

The New Nutrition Business 10 Key Trends 2020 study found that contrary to media reports, most people still consume meat, even if they are consuming meat less frequently. However overall meat consumption remains little changed and, in some countries, has even increased. People may be choosing more plant proteins, but they are consuming them alongside meat, and few are willing to reduce consumption. A recent study by Wageningen and Michigan University showed that regardless of the type of information about meat alternatives retained by consumers (sustainability, branding, technological info), plant- and lab-based meat alternatives did not replace farmed raised beef for the majority of consumers[xv].

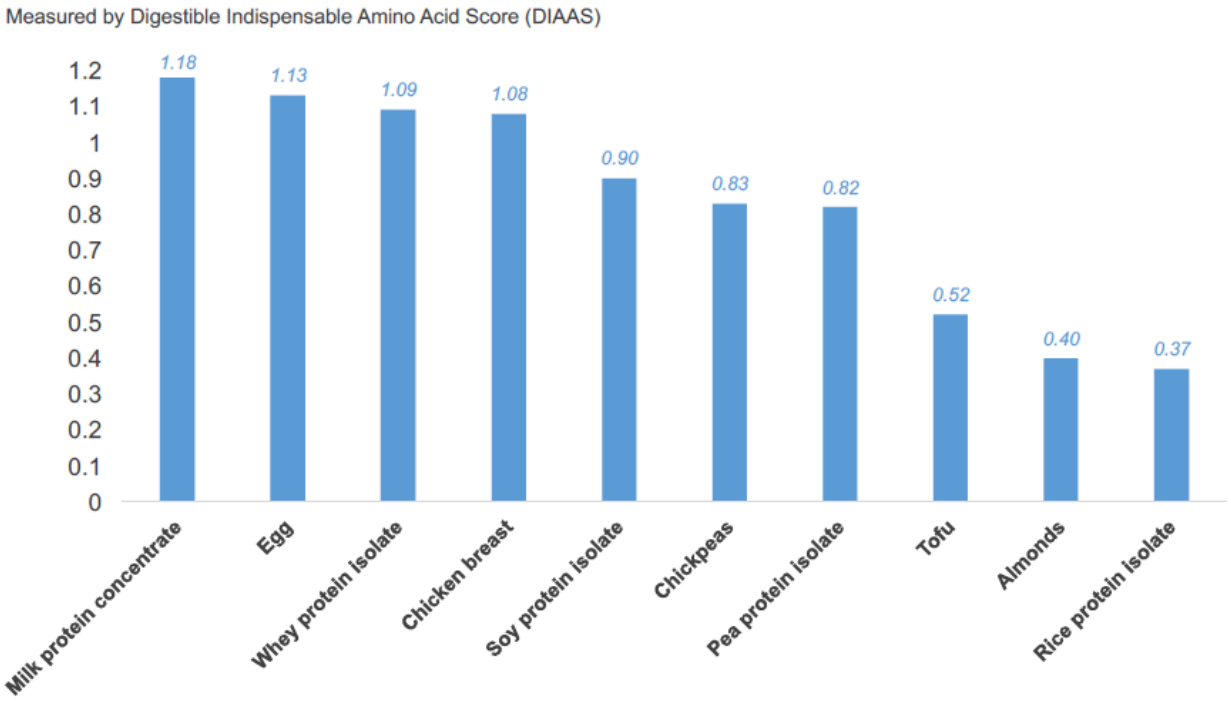


Animal protein will continue to dominate the plate, driven by key advantages such as customer familiarity and taste and texture preferences. Although it's often claimed that more people are cutting back on meat consumption, the facts don't always back this up.

- In the US meat sales are steady and increasing.
- Per capita meat consumption has increased in the EU by 3.2% between 2010 and 2019.
- In the Netherlands, where there have long been strong anti-meat messages targeted at consumers and where some meat substitute brands (such as Unilever-owned The Vegetarian Butcher) have done well, meat consumption grew slightly from an average 76.6kg per person in 2017 to 77.2 kg of meat per person, in 2018, according to Wageningen University.

Many food products made with plant-source proteins describe their proteins in marketing as high-quality, or equivalent to dairy, or use words such as "complete". But in fact, animal proteins are the best source of these digestible amino acids. Currently, most consumers do not know about protein quality, with the exception of keen fitness lovers and, they are interested only in quantity. The majority of consumers believe that plant proteins are equivalent to meat proteins.

There is an opportunity for the meat and dairy industry is to introduce the idea of protein quality, possibly working with sports people as brand ambassadors, using PR and social media. Perhaps multiple companies could collaborate to fund a communications effort about protein quality (Mellentin 2020).



Sources:

1. *FAO. Report of an FAO Expert Consultation. Dietary Protein Quality Evaluation in Human Nutrition. Rome: FAO (2013).*
2. *Rutherfurd SM, Fanning AC, Miller BJ, Moughan PJ. Protein digestibility- corrected amino acid scores and digestible indispensable amino acid scores differentially describe protein quality in growing male rats. J Nutr (2015) 145:372–9.*
3. *Phillips S. Current Concepts and Unresolved Questions in Dietary Protein Requirements and Supplements in Adults. Front. Nutr. 4:13.*

Interest in lower carbohydrate and high-protein diets, and positive messages online about protein and health, means meat is still seen in a positive light. In fact, there is emerging a counter-narrative that is bringing more positive messages about meat and health and meat and the planet, and a small but growing number of consumers are turning to “better” versions of conventional meats, such as grass-fed beef. Meat is about to undergo a renaissance.

5.6.1 Opportunity 1. Australian functional collagen peptides range

The global collagen market size has an estimated valuation of $3.136 billion USD for 2018. The market is expected to experience compounded annual growth (CAGR) of 5.09% from 2017-2025[xvi]. Consumer interest in collagen-based products is growing in various applications, including food and beverage, nutraceutical supplements, cosmetics and medical products. Consumers are particularly focusing on health and performance nutrition, with the nutraceutical collagen market forecasted to account for 40.06% of collagen product sales in 2025. Collagen’s characteristics as a bioavailable bonding material has resulted in growth in both cosmetic and medical applications. Its most prevalent use among cosmetic consumers is in skincare products, with this popularity due to its ‘revitalising’ and ‘renewing’ properties.

Challenges for Australian companies using Australian red meat collagen looking to supply the market are largely competing with marine collagen which is perceived as ‘cleaner’. It does not have same speculation regarding safety of consumption (BSE outbreaks cause uncertainty among many consumers).

Marine collagen is extracted at lower yield, 1.2% yield were as bovine collagen extracted at 8-20% yield, less efficient process - Lower yield = higher price. Marine collagen costs $44539 USD/ metric tonne, whereas bovine costs $33457/MT. Cost leadership allows bovine collagen to have big cost advantage in lower-value products (e.g. food) - Australia has BSE-free status; big selling point for bovine collagen-based products. BSE-free bovine collagen commonly used due to being more genetically compatible with humans than marine collagen.

Australian meat producers are one of the largest suppliers of salted and wet-blue hides and salted skins to the world market. Australia annually produce 8 million cattle hides, 1 million calf skins and 32 million woolskins[xvii]. Australia is one of the few countries that has open trade in hides and skins The Australian hide industry has virtually collapsed with prices at an all-time low. Australia exports animal hides overseas, where the tanning process is carried out. This leather and skins are then imported back to Australia to be made into goods such as shoes, bags, jackets, and car trim. The cost of prepping and shipping untanned hides to be tanned overseas is currently greater than the value of the final products.

Recommendation 1: *MLA scope and fund a project to develop a process to produce Australian functional collagen peptides from Australian beef and sheep hides, for the food and nutraceutical markets, with Gelita Australia and Krumbled Foods. This opportunity delivers on the following 2 Mega Trends and 3 Key Trends.*

Gelita Australian based in Beaudesert, Queensland manufactures bovine gelatine locally for edible/pharmaceutical/technical sectors. They also import porcine/bone gelatine/functional proteins, bioactive collagen peptides for food/complimentary medicines and sports supplements markets. These last products are high value ingredients that are currently produced in 22 manufacturing plants worldwide. With the value of animal skins and pieces collapsing, there is an opportunity to adopt and adapt Gelita's collagen peptide manufacturing and purification process to Australian conditions with Australia's feedstock.

Krumbled Foods are the New South Wales based business that created and owns Beauty Bites, an innovative beauty health bar. Beauty Bites are a healthy snack bar that includes a unique combination of ingredients; collagen, probiotics, prebiotics, Vitamin C and Vitamin E. Collagen protein has been shown in scientific studies to increase the production of Type I and Type IV collagen under the dermis and to reduce cellulite in human subjective assessment. Currently Beauty Bites is ranged nationally in Coles and Priceline Pharmacies and on-line. Krumbled Foods are seeking an Australian source of collagen peptide.

This opportunity is for Gelita and Krumbled Foods to work together to develop an Australian source of collagen peptide suitable in terms of functionality for consumers concerns over health and beauty. Krumbled Foods would validate consumer's willingness to buy and also test their acceptance to pay a higher price for Australian sourced ingredient.

Gelita Australia would,

- develop the peptide manufacturing process using Australian hide inputs,
- construct the pilot to validate process, operating parameters and quality specifications,
- conduct peptide assessment to ensure appropriate quality standard and molecular weight peptide,
- develop waste handling & treatment process to minimise environmental impact and deliver on sustainability objectives,
- undertake financial and process modelling for commercial scale plant design,
- undertake yield and economic analysis of product, produce collagen peptide samples suitable for market validation and
- develop manufacturing process to produce sheep collagen peptide samples for consumer evaluation.

Krumbled Foods would,

- develop products using Australian collagen peptide ingredient,
- produce limited packaging promoting Australian peptide for consumer validation,
- modify online platform to validate consumer demand for products containing Australian Collagen peptide and willingness to pay a premium,
- conduct consumer online demand assessment of products containing Australian collagen peptide,
- undertake sensory comparison of Australian peptide product versus existing products, (taste, mouthfeel, functionality),
- develop product utilising sheep collagen peptide,
- conduct consumer sensory evaluation of sheep collagen peptide product and
- conduct consumer online demand assessment of products containing sheep collagen peptide versus beef.

5.6.2 Opportunity 2. Bone Broth

Bone broth is a savoury liquid made from brewed bones and connective tissue, typically from beef or chicken. The highly nutritious elements of the bone, such as amino acids, gelatin, glucosamine and minerals, are infused into a hearty and tasty liquid that's easy to digest. The broth market size is expected to surpass USD $2.5 Billion, and is estimated to grow over 3.5% CAGR between 2020 and 2026. Growing awareness regarding health among consumers across the globe coupled with the numerous health benefits offered by broth consumption will drive the industry growth. Surge in demand for broth type products comes from athletes and bodybuilders desire to boost performance, general fitness, and overall health which will provide a strong broth market outlook for manufacturers. Key ingredients including gelatin, collagen, glutamine and glycine are expected to propel product utilization. Promoting health benefits including improved digestive health, immunity and soft tissues recovery are the major supporting factors for product penetration.

Global companies with Broth products include,

- Campbell Soup Company,

- Pacific Foods of Oregon,
- College Inn,
- Progresso,
- Knorr,
- Manischewitz,
- Paleo Broth Company,
- Bonafide Provisions,
- Bare Bones Broth,
- Kettle & Fire,
- Bone & Co.,
- The Stock Merchant and
- Belcampo.

In Australia companies such as the Australian BoneBroth Co[xviii] offer a range of bone broth products and formats. Melbourne based company Broth & Co believe nutrition is important to wellbeing and that the food we eat affects and contributes to our body and our health. The company claims that effects from consumption can be instant, such as feeling energised. Broth & Co offer both traditional and Asian inspired flavours such as our Beef Pho (a traditional Asian soup), in both liquid and dehydrated forms for added convenience. They also make a vegan Broth is made with the gut healing properties of fermented miso with the added benefits of adaptogenic mushrooms, Reish, Lion's Mane and Shiitakii Mushrooms. Adaptogens are a select group of herbs and mushrooms that support the body's natural ability to deal with stress. They are called adaptogens because of their unique ability to “adapt” their function according to the specific needs of the body.

Recommendation 2*: MLA work with a commercial company such as Blu Oak Innovation or The Merrier to develop and commercialise a meat and/or bone Broth. This opportunity aligns with 2 Mega Trends and 3 Key Trends as below.*

5.6.3 Opportunity 3. Enzymes processing of rendering feedstock into high value ingredients

The Australian red meat sector consists of nearly 100 Rendering plants converting meat processing waste streams into 1,200,000 tonnes of low value protein meal of which 35% is exported. New innovative proprietary manufacturing processes have been developed that efficiently and effectively break down organic material so its component parts can quickly, and at low cost, be separated and refined without being denatured through excessive heat, time or with the addition of chemicals, that normally occurs in traditional rendering plants. This new process produces high quality, high value protein sources suitable for use in the pharmaceutical and food industries.

DSM Food Specialties has discovered an enzyme that can extract protein that might otherwise go to waste from animal by-products. The enzyme, Maxipro HSP[xix], selectively hydrolyse proteins in meat processing waste streams, isolating proteins without affecting their sensory or functional properties. The enzyme allows producers to increase ingredient functionality, and nutritional value and is colourless, odourless and taste neutral. The enzyme works by specifically selecting the amino acid histidine.

New processing methods applied to the red meat processing industry that use the Maxipro enzyme will enable the sector to become more economically viable and sustainable. Converting food production system waste streams globally into high value ingredients represents a significant growth opportunity for the red meat industry.

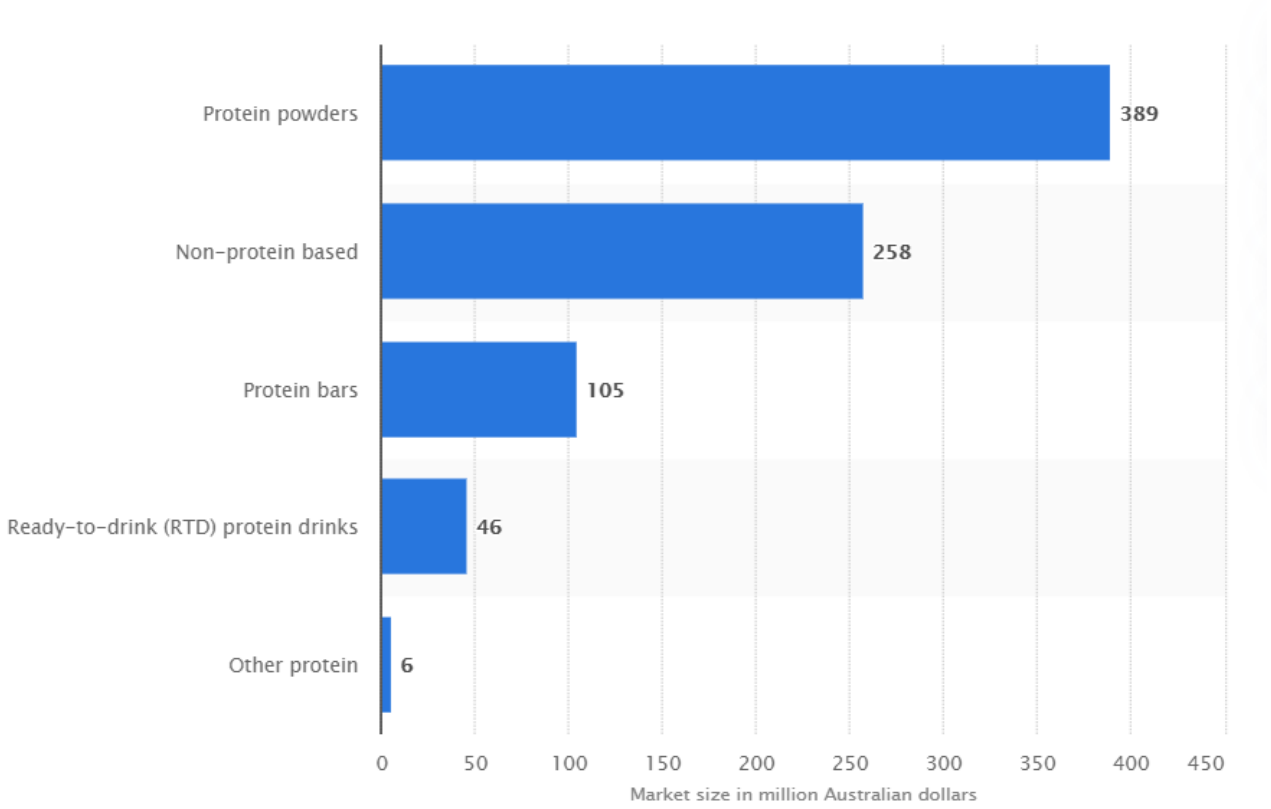
Recommendation 3: *MLA work with Organic Technology Holdings http://www.organicshift.com.au/ to develop an industry funded project type for developing an enzyme processing system to convert feedstock streams for traditional rendering processes into high value components to be sold into food and pharmaceutical industries. This would be a commercial prototype scale to confirm viability and feasibility. This opportunity aligns with 1 Mega Trends and 2 Key Trends as below.*

5.6.4 Opportunity 4. Protein Powders & Drinks for sports and lifestyle

The Australian Protein Supplements market is expected to grow at a CAGR of over 9% in value by 2025, owing to increasing demand for healthy diet supplements and growing consumers awareness for protein-

based products. Growing women's demand for healthy products which are fat free, to maintain their weight are some factors that drives the demand for protein supplements in Australia. Furthermore, increasing disposable incomes, growing focus on leading active and balanced lifestyle in Australia drives the Protein supplements market. Based on product type, protein powder in 2019, dominates the protein supplements market and is expected to maintain its dominance over the next five years as well.

Protein intake that exceeds the recommended daily allowance is widely accepted for both endurance and power athletes. Evaluation of a protein is fundamental in determining its appropriateness in the human diet. The quality and digestibility of proteins are the most important attributes for the development of protein powders. Animal sources (red meat or dairy) provide a complete source of protein, they contain all essential amino acids, whereas plant sources generally lack one or more of the essential amino acids. Animal sources of dietary protein, despite providing a complete protein and numerous vitamins and minerals, have some health professionals concerned about the amount of saturated fat common in these foods compared to vegetable sources. The advent of processing techniques has shifted some of this attention and ignited the sports supplement marketplace with derivative products such as whey, casein and soy.



Sports nutrition market size in Australia in 2014, by category (in million Australian dollars)[xx]

An example of a red meat protein supplement powder is CARNIVOR™. This beef protein isolate contains 23 grams of pure beef protein, and 20 times more creatine per serving than steak. The product is also packed with added branched-chain amino acids (BCAAs) to promote a positive nitrogen balance, increase protein synthesis, decrease catabolic muscle breakdown, improve workout performance and reduce muscular fatigue. The manufacturer also claims that CARNIVOR™ SHRED helps activate brown adipose tissue (BAT) and boost the metabolism. Brown fat (brown adipose tissue, BAT) is a metabolically active, calorie-burning tissue in the human body that converts food energy directly into heat. The capability of

harnessing one's own brown fat for fat burning is revolutionary, the more brown fat you have, the more calories you burn. The product also includes 'Grains of paradise', Aframomum melegueta a species in the ginger family and closely related to cardamom. Its seeds are used as a spice; it imparts a pungent, black-pepper-like flavour with hints of citrus. Researchers at Tenshi College in Japan found that oral ingestion of grains of paradise extract increases whole-body energy expenditure through the activation of BAT in humans[xxi].

One company that provides hydrolysed beef protein isolate to the market is True Nutrition (https://truenutrition.com). They highlight that fact that beef protein isolate has an amino acid profile that is comparable to standard whey protein. It is naturally high in the amino acids alanine, arginine, glutamic acid, glycine, and proline, and serves as a significant source of leucine, isoleucine, and valine, as well. A single standard serving of 30 grams will contain an astounding 29.5 grams of protein, with zero carbs and less than 1 gram of fat. This gives the Beef Protein Isolate one of the highest concentrations of functional protein out of any of the materials that are currently available on the market. As a soy-free, gluten-free, and dairy-free protein powder, it is also a hypoallergenic source of protein for individuals that may suffer from any number of dietary limitations.

Recommendation 4: *The opportunity for Australia' red meat industry is to develop a high red meat protein powder with the inclusion of Grains of paradise for weight control. MLA could identify a food industry stakeholder with a commercial interest in protein powders and work in partnership to develop and commercialise the opportunity. This opportunity aligns with 1 Mega Trend and 3 Key Trends as below.*

5.6.5 Opportunity 5. Beef or Collagen Chips

Chips are a dominant category in any supermarket, with an entire aisle dedicated to a range of salty and savoury snacks. IBIS world states that the Australian Savoury Snack Food market turns over some $2 Billion per year. Though the market is stagnant, in terms of growth (volume in slight decline vs. slight value growth) there are significant dynamics going on within the category. IBIS Word identifies a desire for more premium / gourmet versions and healthier snacks as the key driver of this change. Whilst premium chips give the impression of containing cosmopolitan ingredients, the reality is vastly different, with the flavour largely delivered by MSG type compounds. In other categories, real ingredients have been a strong platform for a further step up from premium – i.e. ice cream

Whilst chips are predominantly bought and consumed for self, the sharing and entertaining occasion is also significant. Consumers are becoming more conscientious about what goes into the products they are consuming – turning the packet over, hoping to see a short list of recognisable ingredients.

Project PSH.0812 Red meat protein snack involved conducting a Red Meat Snack Workshop in early 2018. The workshop consisted of food innovators and food development companies whose was to prepare and present 4 to 6 meat protein snack concept prototypes each, for tasting and assessment providing feedback to inform the development pathway and understand value proposition to consumers for market positioning. The workshop was framed as a design thinking process where concept products were reviewed and assessed in terms of desirability, feasibility, and viability.

The Beef and collagen opportunity was also highlighted in both Project PSH.0812 undertaken by Xinova and project V.RMH.0003 conducted by David Jenkinson in 2019, but nothing has yet to be progressed.

Collagen Chips

EARLEE PRODUCTS
WE MAKE GOOD FOOD...GREAT

Desirability

High protein, clean label, combined with other valuable products – could sprinkle with prebiotics. Could add new flavours to it & play with texture, but don't tamper with above. Adding vegetables + olives, components to add value. Collagen + pulses to provide more complete aa profile, nutritional snack market, carb snack replacement

Where is the retail space? Chips/snack, or health product? Does it go in a supermarket, or direct to consumers? Retailers need to get behind it. Challenge of consume understanding of collagen

Viability

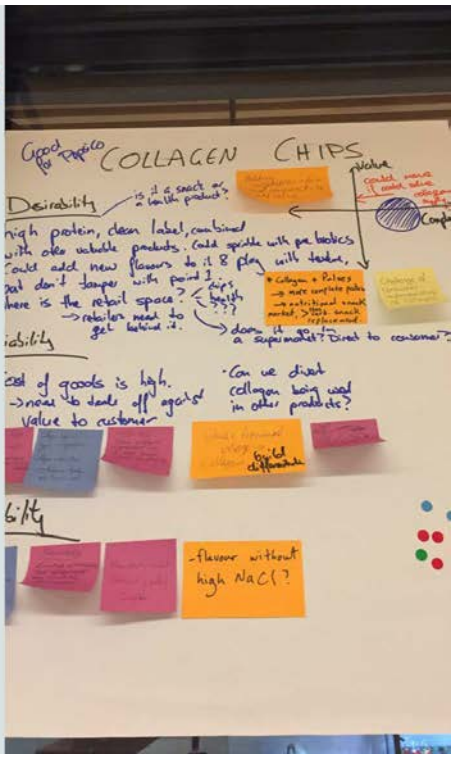
Cost of goods is high – need to trade off against value to customer. Collagen deficient in lysine and tryptophan. Collagen + corn/pea to get balanced protein and lower cost. Position on high value, combine collagen with lentil to reduce cost. Also inexpensive nutrition. Base collagen ingredient as a wet base. Cost is drying. Pepsi candidate.

Can we divert collagen being used in other products? Could see competition from other collagen players. Key partners, business model, current industry supply & capability: Devro, Gelita, JBS Dinmore (hide processing). Whole animal usage. Build differentiation

Feasibility

Process method – direct expand sheet, ex twin screw extruder, rather than forming a pellet. Initial thickness determines the hardness in biting – can be manipulated. Existing processes and equipment are suitable, not complex. Moisture content, amount of puff/crunch. Flavour without high NaCl

Xinova



Beef Snacking Corn Chips

BOI
FOOD TECH & PACKAGING

Highlights

A combination of minced beef (55-60%), starch, corn meal, herbs and spices – total protein content 22%

Filling and functional product with additional daily protein

Traditional corn chip manufacturing line suitable

Fat content will need to be reduced but achievable by vacuum drying

Target consumer: men 18-40+, gym users, looking for "better choice" snack

Feedback from Tasting

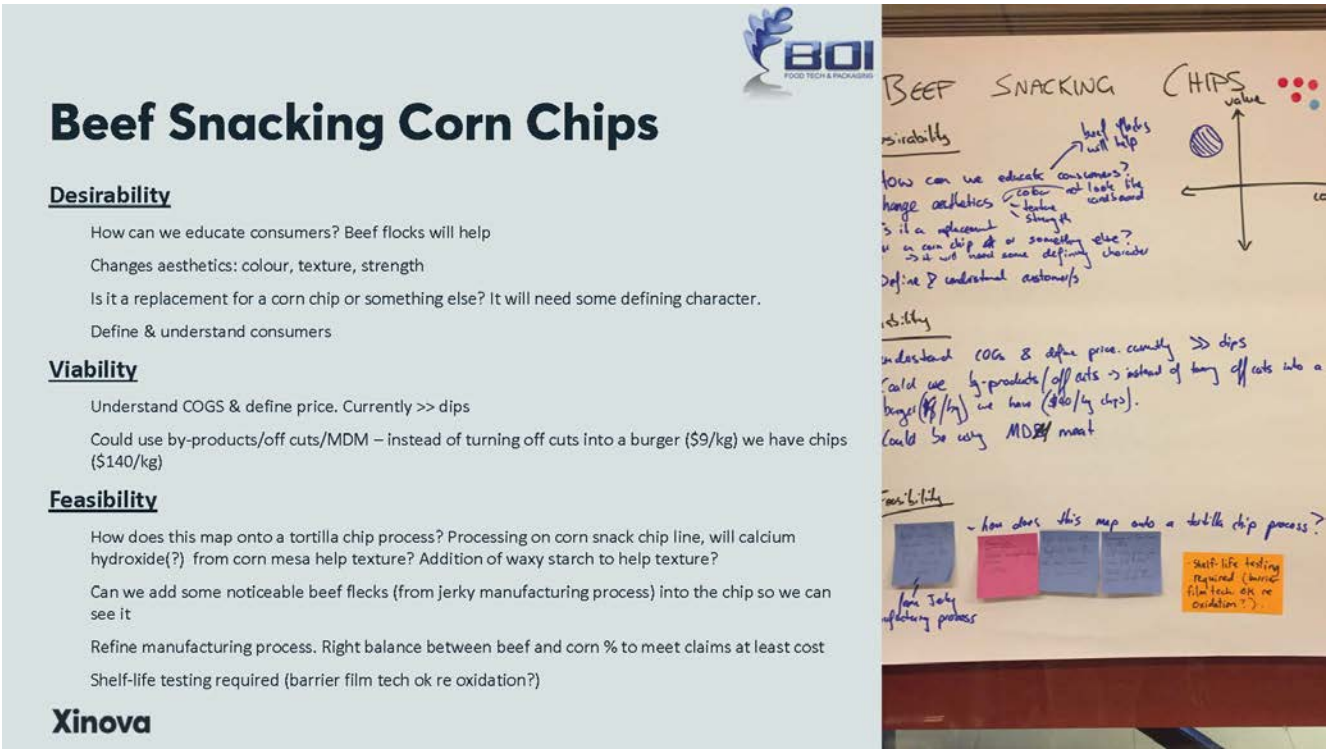
SCORE 10 8.1 (concept) / 7.8 (taste)

Added dimension to corn chip, high satiety, crunchy texture, real beef in it, high protein/beef content, flavour, good nutritional profile, versatile-multiple markets, all existing tech/tortilla process/partner to scale up, relative clean label, "chips & dips/guacamole"

Slightly too brittle – hard to transport hard to dip, frying - %fat, high salt, appearance/texture could be better, COGS

CHALLENGES Price, market acceptance/identification/consumer education, appearance/texture/flavour improvement, fat content (lamb), salt, size control, COGS vs. value created & captured, refine manufacturing process/scale efficiently

Xinova



***Recommendation 5**: MLA work with Blu Oak Innovation and Earlee Products to develop and commercialise a red meat or collagen chip. This opportunity aligns with 2 Mega Trends and 3 Key Trends as below.*

5.6.6 Opportunity 6. Ovine Collagen production

Ovine Collagen is produced in Australia using Holista Colltech patented process - they have exclusivity to produce ovine collagen in Australia & New Zealand unless a new method of collagen extraction can be developed. Australian ovine is the only disease and prion-free ovine in the world. Holista basically have a monopoly on the ovine collagen market and to overcome this barrier the industry needs to explore the possibilities of using a different extraction process or form a partnership with Holista Colltech or focus solely on bovine collagen opportunities.

Organic Technology Holdings have a patented enzyme process that does infringe the Holista Colltech patent and can extract collagen form ovine meat by-products in particular skins.

Recommendation 6: *MLA scope and fund a project to develop an enzyme process to extract Australian ovine collagen from Australian sheep hides, for the nutraceutical markets, with Organic Technology Holdings and an Australian sheep processing sector stakeholder. This opportunity delivers on the following 2 Mega Trends and 3 Key Trends.*

6 References

[i] British Nutrition Foundation. Protein. Accessed June 2020. https://www.nutrition.org.uk/nutritionscience/nutrients-food-and-ingredients/protein.html

[ii] CSIRO Company Creation Model. 2020. Personal communication Duncan Ferguson, Director CSIRO Company Creation.

[iii] Meat processing technology for small- to medium-scale producers (FAO 2007)

[iv] Mellentin. J. 2020. 10 Key Trends for Food, Nutrition & Health 2020, Key Trend 5: Protein. New Nutrition Business.

[v] Deb-Choudhury. S, Haines. S, Scott Knowles, Finlay-Smits. S, Middlewood. P, Loeffen. M. P.PSH.1165 Design and deliver novel meat extract concepts 31st August 2019 AgResearch Limited, New Zealand https://www.mla.com.au/research-and-development/search-rd-reports/final-report-details/Design-and-deliver-novel-meat-extract-concepts/4309

[vi] Dunn, S. P.PSH.0673 Prototype commercial development of High Moisture Extrusion Cooked meat. 2017. Meat and Livestock Australia Limited. https://www.mla.com.au/research-and-development/search-rd-reports/final-report-details/Prototype-commercial-development-of-High-Moisture-Extrusion-Cooking-HMEC/4104

[vii] Needham. S, Chen. Y, Caire, G & Rankin, R. P.PSH.0812 Red Meat Protein Snack. 2018. Xinova Australasia Pty Ltd. https://www.mla.com.au/research-and-development/search-rd-reports/final-report-details/Red-Meat-Protein-Snack-Xinova/3806

[viii] Dobbrick, F and Buckley, M. P.PSH.0999 Developing High Value Freeze Dried Australian Red Meat Products and Services. 2019 Meat & Livestock Australia. https://www.mla.com.au/research-and-development/search-rd-reports/final-report-details/Developing-High-Value-Freeze-Dried-Australian-Red-meat-Products-and-Services/4356

[ix] Jenkinson, D. V.RMH.0003 Exploring High Valued Opportunities for Natural Flavour and Wellness extracts derived from red meat (2Morrows Foods). 2019. https://www.mla.com.au/research-and-development/search-rd-reports/final-report-details/Exploring-High-Valued-Opportunities-for-Natural-Flavour-and-Wellness-extracts-derived-from-red-meat-2Morrows-Foods/4263

[x] Warner, R. Dunshea, F. Bekhit, A. Vaskoska, R. Ha, M. The University of MelbourneV.RMH.0044 Review and meta-analysis of emerging technologies for tenderising red meat. 2016. https://www.mla.com.au/research-and-development/search-rd-reports/final-report-details/Develop-New-Products/Desktop-review-on-emerging-technology-platforms-to-tenderise-raw-and-cooked-meat/3487

[xi] Dahm, C. V.RMH.0047 Meat Powder and Hydrolysis. Thricor 2017. https://www.mla.com.au/research-and-development/search-rd-reports/final-report-details/Meat-Powder-and-Hydrolysis/3836

[xii] LiHui, L and De Silva, K. P.PIP.0187 Development of novel technology to manufacture blood derived functional ingredients Stage II report – enzyme modulated blood protein flavour. CSIRO 2009.

https://www.mla.com.au/contentassets/5bf4010cb36247dda2e1b30d49373af7/p.pip.0187_final_report.pdf

[xiii] P.PSH.0415 Utilisation of blood and blood components– Adding value to blood by using processes to separate and stabilise key components with the added benefit of removing blood from current slaughterhouse waste streams. Industry sponsor and MLA. September 2013. https://www.mla.com.au/Research-and-development/Search-RD-reports/RD-report-details/Develop-New-Products/Co-products-from-blood/2758

[xiv] Rickey Y. Yada. Proteins in Food Processing (Second Edition), Woodhead Publishing, 2018.

[xv] Van Loo, Ellen & Caputo, Vincenzina & Lusk, Jayson. (2020). Consumer preferences for farm-raised meat, lab-grown meat, and plant-based meat alternatives: Does information or brand matter? Food Policy. 95. 101931. 10.1016/j.foodpol.2020.101931.

[xvi] J. Green, K. Bryan V.RMH.0079Collagen Business Case Report. Meat and Livestock Australia Limited. https://www.mla.com.au/Research-and-development/Search-RD-reports/RD-report-details/Develop-New-Products/Co-products-from-blood/2758

[xvii]Co-products Compendium 2009. Meat & Livestock Australia.

[xviii] https://www.australianbonebrothco.com.au/

[xix] https://www.naturalproductsinsider.com/specialty-nutrients/dsm-unveils-new-method-sustainable-functional-protein-isolation

[xx] https://www.statista.com/statistics/583637/sports-nutrition-market-size-australia-by-category/

[xxi] Sugita J, Yoneshiro T et al. Grains of paradise (Aframomum melegueta) extract activates brown adipose tissue and increases whole-body energy expenditure in men. Br J Nutr 2013 Aug;110(4):733-8. doi: 10.1017/S0007114512005715. Epub 2013 Jan 11.