Final report

Validation Market Desirability Useability of Ovine Collagen – Phase 1

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Abstract

The global collagen market size is expected to reach US $16.7 billion by 2028. Consumer interest in collagen-based products is growing with the nutraceutical collagen market forecasted to account for 40% of collagen product sales in 2025 [J. Green, K. Bryan 2019].

Currently the bulk of the global collagen market is largely serviced by bovine, porcine and marine skin collagen. However, cost, safety and religious/cultural concerns around their use has created a significant opportunity for ovine collagen to enter this growing space, especially given its broad acceptance across several religions and culture. Moreover, with Australia producing 32 million sheep hides each year and being the only disease/prion-free sheep producer in the world, Australian sheep producers and processors stand to benefit significantly by processing their skins into collagen hydrolysates. This is even more critical given the steady decline in global leather demand that's subsequently caused a similar downward trend on the prices of skins, leading to at times, skins being dumped as landfill.

Challenges however exist for sheep producers to achieve full valorisation of their skins. Current commercial collagen manufacturing processes stretch over days, often taking as long as 4-6 weeks or more to process raw skins into a finished collagen hydrolysate product. Apart from the high infrastructure set up and holding costs, the extended processing times means the industry is unable to process the high throughputs required to meet the collagen market demanded.

To overcome this challenge and to enable Australian ovine processors in capturing a significant chunk of the global collagen market, OTH, an innovative Australian industrial technology developer and MLA decided to invest in developing an industrial scalable high throughput ovine hide processing technology that could be adopted by Australian ovine processors

The outcome of this project has been the development of three new proof of concept technologies that enable quick processing of ovine skins, extract not just collagen hydrolysate but also clean intact wool that can be further converted into a high value keratin protein concentrate for application in food, nutraceutical and cosmetic industries

More importantly, these novel technologies enable end to end processing of raw ovine skins into collagen hydrolysates and wool keratin concentrate in just eight hours, thus permitting high throughput processing of ovine skins as required to meet the growing collagen demand. Additionally, by achieving a full valorisation of ovine skins, these technologies can potentially deliver significantly more returns to Australian sheep producers than what they currently receive from selling fresh skins.

The project also generated proof of concept 200g samples of the two end products; collagen hydrolysate and wool keratin concentrate for initial market analysis and feedback with Krumbled Foods, an innovative Australian functional food manufacturer.

Based on the promising results from these mid-scale trials, OTH recommends that mid to pilot scale trials, Phase 2 be undertaken and that OTH and MLA commence this work as soon as possible. OTH has a unique pilot plant set up at its Brisbane facility for conducting the scale-up trials. This facility can process up to 500kg sheep skin batches and generate the larger quantities of collagen hydrolysate and wool protein concentrate samples as required for nutritional studies and application-based trials.

Executive Summary

The global collagen market size is expected to reach US $16.7 billion by 2028, expanding at a revenue based CAGR of 9.0% [Grand View Research, February 2020].

Consumer interest in collagen-based products is growing in various applications, including food and beverage, nutraceutical supplements, cosmetics, and medical products. While collagen's most prevalent use is in skincare products due to its 'revitalising' and 'renewing' properties, consumers are increasingly focusing on its health and performance nutrition, with the nutraceutical collagen market forecasted to account for 40% of collagen product sales in 2025 [J. Green, K. Bryan 2019].

Sources of Collagen

On average collagen makes up as much as 30% of any hide or skin's weight. Currently, the bulk of collagen manufactured globally is from bovine, porcine and marine sources. However marine collagen suffers from inherently low production yields and high cost while the acceptance and growth in bovine and porcine collagen is constrained by religious and cultural sensitivities such as amongst Muslims, Buddhists, and Hindus communities. Additionally, consumer concerns about bovine collagen being manufactured from animals carrying diseases such as Transmissible Spongiform Encephalopathies and BSE naturally restrict its full market growth.

Market Opportunity for Australian Sheep Processors

Typically, the only way ovine producers and processors can generate more revenue and profitability is either to cut costs or growing and processing more sheep or taking advantage of the occasional positive market conditions.

While Australian ovine skins have traditionally commanded high market value and a significant source of revenue for processors, the steady decline in global leather demand has led to a concomitant decline in the value of skins with prices being so low that abattoirs have had to resort to selling hides at throwaway prices or dumping them as landfill.

With lower demand for sheep skins, a large portion of skins are being fellmongered, and the wool is sold separately. The best quality lamb skins are trading at 700¢/skin, while small, short, or damaged lamb skins have no value in the current market, with most being discarded.

The MLA Co-Producer market report, August 2019 (10) reported that the hide market (beef and sheep) remains in the worst position in living memory. The market in China and Italy, remains reticent to purchase until they confirm sales for finished leather which is in soft demand due to worldwide COVID-19 lockdowns.

Against the above backdrop and growth constraints in the collagen market from product acceptance, a huge growth opportunity awaits Australian ovine processors to capture a significant chunk of the collagen hydrolysate market. As opposed to bovine and porcine derived collagen, Australian Ovine (sheep) collagen has a unique market advantage as

1) Ovine derived products are acceptable worldwide across a wide range of cultures and religion

2) Australia ovine herds are the only prion-free ovine in the world

3) Being disease free, Australian ovine derived products are naturally safe and fully traceable from the "farm to the consumer"

Australian ovine processors are usually one of the largest suppliers of salted sheep skins to the world market generating over 32 million woolskins annually. Based on a shorn Merino sheep pelt weight of 1.2kg, the opportunity potential for Australian ovine collagen hydrolysate by 2023 equates to 3,600MT or almost 10% of the predicted global collagen shortfall.

At a market price of $30,000/MT (MLA collagen report V.RMH.0079), this can translate to a significant annual revenue of $1Billion for the Australian sheep industry without having to grow or slaughter any extra animals.

Challenges

There are however serious technical challenges that prevent full realisation of this market potential.

Current commercial collagen manufacturing processes stretch for days or weeks, often taking as long as 4-6 weeks or even more to process raw skins into a finished collagen hydrolysate product. The high infrastructure set up and holding costs and the extended processing times are naturally unable to process the high throughputs required to manufacture the large volumes demanded by the collagen market. In addition, the extended incubation times often end up causing factory odour issues while the aggressive chemicals used in the treatment to dissolve the wool and other skin proteins results in an environmentally unfriendly sludge, creating additional handling and regulatory issues during its disposal.

In absence of an effective technology that can overcome these issues at an industrial scale, much of the valorisation potential of Australian ovine skins remains unrealised, despite a rapidly growing collagen nutraceutical market.

OTH and MLA

Organic Technology Holdings (OTH) is a unique and innovative Australian industrial technology company that adds significant value to both primary processors and global food, nutraceutical, pharmaceutical and cosmetic manufacturers by developing industrially scalable technologies that upcycle the various ‘waste’ by-products of abattoirs, seafood and plant processors into high value ingredients of superior quality and in the large volumes required by these end users

The success of OTH in understanding the exact market needs is underpinned by its unique business model. Unlike the conventional ‘build and they’ll come’ approach of technology companies, OTH is 100% industry-led, developing industrially feasible solutions to problems or requirements that the industry has clearly identified, and which are not currently being met.

Given the immense opportunity for Australian ovine collagen and the processing challenges, OTH in collaboration with MLA therefore decided to invest in the development of an industrially feasible process that could achieve high throughput collagen extraction from fresh ovine skins without dissolving wool into toxic sludge and with minimal to zero odour generation during processing.

Project Outcomes

In just six months, OTH, with its comprehensive R&D capability, was able to successfully develop three proof of concept technologies that achieved end to end processing of ovine skin from fresh skin to ovine collagen powder in just 8hrs (single shift) whilst generating two additional high value revenue streams - clean and intact wool and a high value wool keratin concentrate product for application in the food flavouring and cosmetic industries.

Proof of concept 200g samples of the three end products; collagen hydrolysate, clean wool and wool keratin concentrate were generated for initial market analysis and feedback with Krumbled Foods an innovative growing Australian functional food manufacturer.

With zero waste generation, these processes can together help achieve 100% valorisation of Australian ovine skins potentially delivering a significantly more return than what abattoirs currently receive for fresh skins.

Next Steps

Based on the promising results from these mid-scale trials, OTH recommends mid to pilot scale trials, Phase 2 be undertaken and that OTH and MLA commence this work as soon as possible. OTH has a unique pilot plant set up at its Brisbane facility for conducting the scale-up trials. This facility can process up to 500kg sheep skin batches and generate the larger quantity samples of collagen hydrolysate, clean wool and wool protein concentrate samples as required for nutritional studies and application-based market trials.

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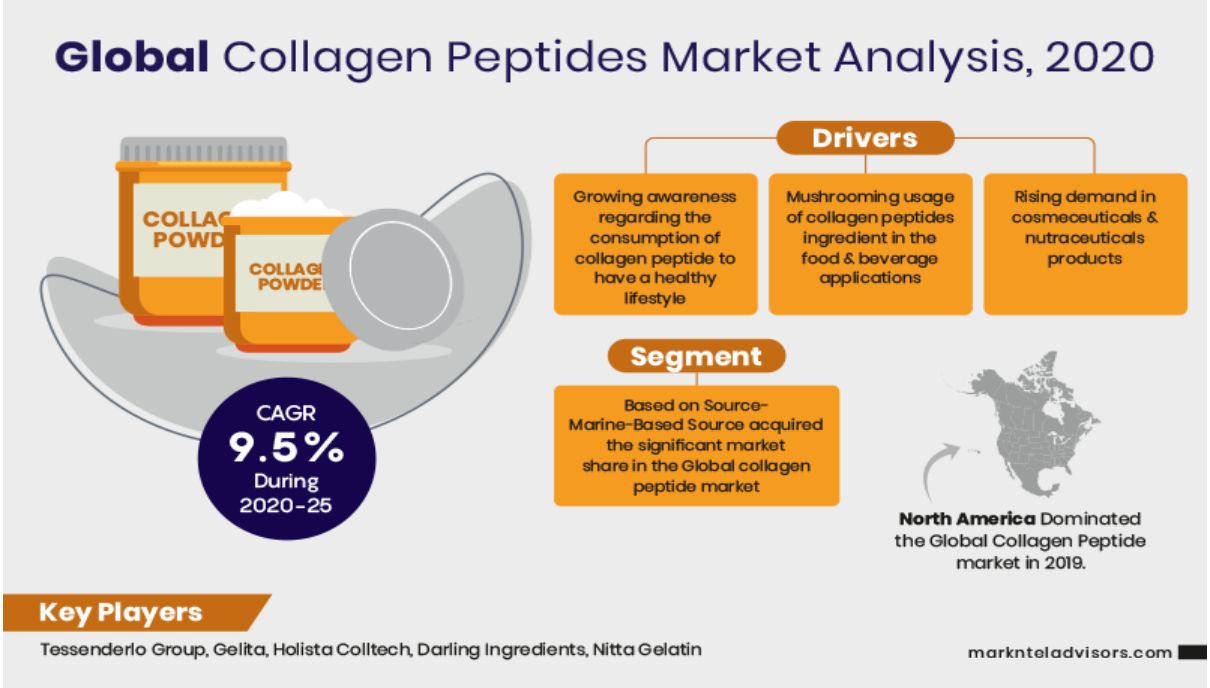
1. Background

1.1.1 Global Collagen market

The MLA Collagen Business Case reported that the global collagen market size is predicted to experience compounded annual growth (CAGR) of 5.09% from US$3.1 billion in 2018 to an estimated market size of US$4.1 billion in 2025 (QY Research 2018) and further on to US$5.6 billion by 2028 (MLA collagen report V.RMH.0079).



Demand for the collagen is expected to surge due to growing end-use applications, changing consumer preferences and lifestyles, increasing disposable income, and rising awareness regarding health and personal care. Developing economies of Asia Pacific, including China, India, and Malaysia, are anticipated to experience robust market growth of volume based CAGR of 6.6% over the next few years. The region exhibits the presence of a well-established meat processing industry, coupled with high expenditure on industrial development by governing agencies to propel economic development. In addition, high investments in research and development activities to produce collagen-based products are expected to favour market growth.

1.1.2 Collagen

Collagen is the most abundant protein in mammals constituting about 25-30% of the total proteins in vertebrates and mammals. It is dominant in animal connective tissues such as skin, tendon cartilage and bones conferring rigidity and integrity to bones and skin.

Biochemically, collagen is composed of three polypeptide chains wound together in a triple helical formation (Figure 1 below). It differs from other proteins by the presence of repeating triplets of Glycine-Hydroxyproline and Proline (Gly-X-Pro). Hydroxyproline is a unique amino acid that provides thermal stability to collagen molecules because of the hydrogen bond formation and the presence of a hydroxyl group (OH), limiting the rotation of the peptide chain. A typical collagen molecule consists of about 1000 glycine, 360 prolines and 300 hydroxyprolines. The triple helical structure is flanked by

two short N- and C- peptides, called telopeptides, which determine the intermolecular interactions and cross-linkages.

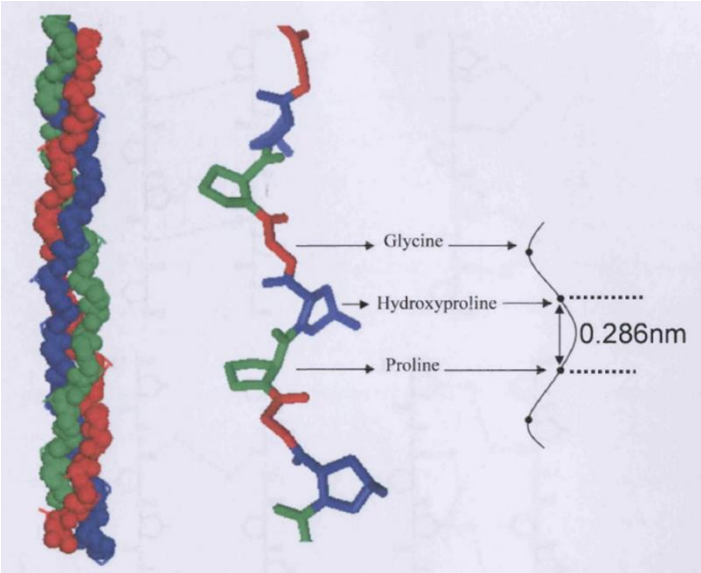


Figure 1. Collagen molecular structure.

1.1.3 Suitability and Desirability

As humans age, collagen levels in the skin and body naturally decline adversely affecting general health, skin suppleness, appearance and wellbeing. The decreasing collagen levels can also give rise to joint cartilage problems which can go on to develop into painful osteoporosis. By the age of 60 years, a considerable decline in collagen production is considered normal.

Collagen however is resorbable. This means it can be broken down, converted, and absorbed back into the body. Since the major helical portion Gly, X, Pro of collagen varies little between mammals, collagen extracted from animal by-products can be easily applied in human food and medical applications with several clinical studies validating reversal of wrinkles and significant alleviation of osteoporosis pain as well as other cartilage degenerative conditions [Koyama, M. N. 2006].

1.1.4 Types of Collagen and derivatives

Although there are over 20 different types of collagen, Type I and Type II are typically used for collagen food and cosmetic applications. Type I collagen is a major constituent of skins, tendons and bone. It consists of 3 polypeptide chains of which two are identical and called α1 (I) and third is called α2(I) chains. Type II is predominantly found in cartilage and composed of three α1 polypeptide chains. Type III is also composed of three α1 polypeptide chains and found in blood vessels, wounds and certain tumours. In mammals, the skin contains Type I and III collagen whereas the cartilage contains mainly Type II and III collagen.

For collagen to be used in food and nutraceutical applications, it needs to be hydrolyzed into smaller sized peptides that can be broken down easily by the human digestive system and absorbed easily into the bloodstream.

To put this in perspective, intact or native collagen consists of high molecular peptides (>100kDa). Partial hydrolysis of this native collagen leads to the formation of gelatine (>25kDa peptides) while further hydrolysis forms smaller sized peptides (<25kDa) termed as collagen hydrolysate.

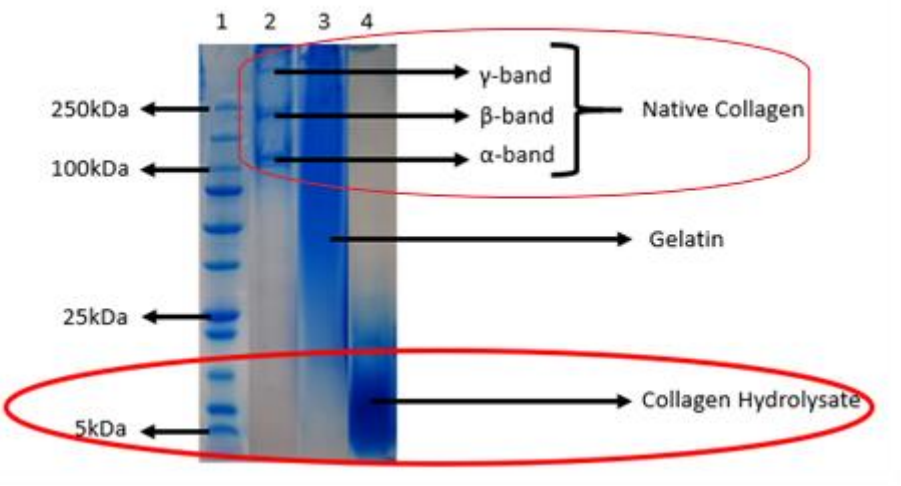


Figure 2: Electrophoretic Profile of Skin Collagen

1.1.5 Applications of Collagen

Whilst native collagen extracted from animal skin and hides is most sought after in medical, pharmaceutical and cosmetic applications due to its low antigenicity and resistance to enzymatic breakdown, gelatine, with its gelling ability, is preferred for food applications such as confectionaries and jellies as well as in photographic industries as a film coating. Collagen hydrolysates on the other hand are preferred by the nutraceutical industries due to their easy in-vivo absorbability and anti-oxidative abilities. Research has indicated that the smaller the peptide size, the better is its bioactivity and absorbability into the bloodstream [Li et al., 2005]

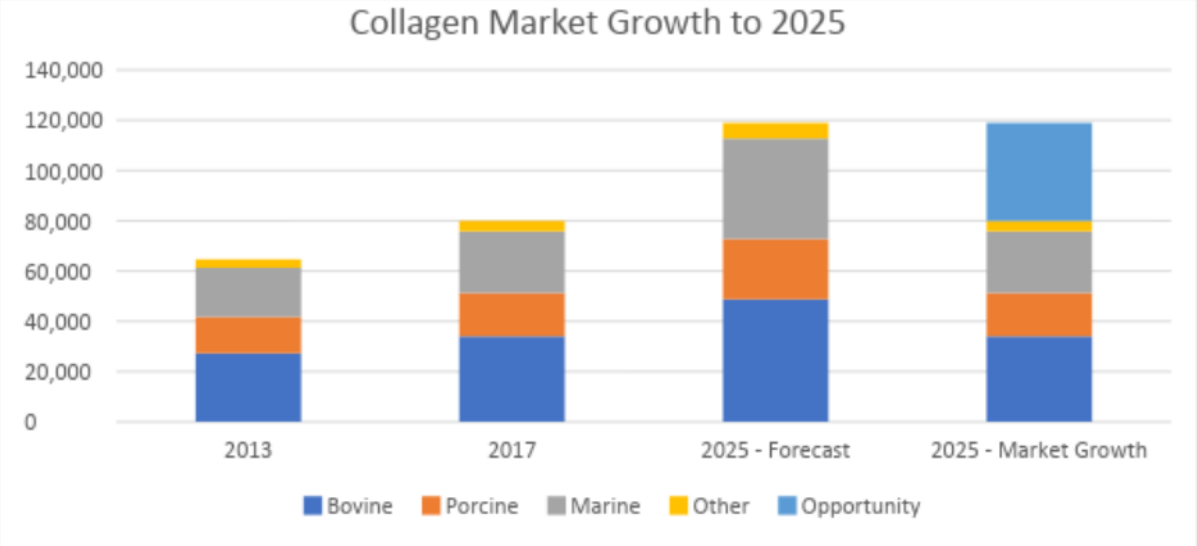
Additionally, collagen hydrolysates have enhanced antioxidation capacity, anti-aging effects, prevents osteoporosis, enhances wound healing and reduces the risk of cardiovascular diseases [Song et al., 2017, Gómez-Guillén et al., 2011, Najafian and Babji, 2012]. Apart from nutraceutical benefits, collagen hydrolysates also find application in cosmetic industries for improving skin properties such as elasticity, skin moisture and preventing skin aging [Aguirre-Cruz, 2020].

There is a thus an increasing trend to use collagen hydrolysate peptides in various wellness and beauty products including food and beverage, As 90% of the total collagen present in skin is type I, the convergence of food, nutraceutical and cosmetic applications provides significant opportunities for the animal processing industry to maximize their revenue from their skins.

1.1.6 Market Potential of Collagen

1.1.7 Size and Potential of Collagen Market

According to MLA's collagen business case report, global collagen requirement by 2025 is expected to be 120,000MT/yr. The light blue section in 2025- Market Growth - approximately 40,000 tonnes of collagen represent the opportunity to increase the volume of supply to the collagen market.



By 2025, the nutraceutical collagen segment is forecasted to account for 40% of collagen product sales as also being the second highest value per tonne market segment.

Food applications are the second largest, with a forecasted 27% market share. In comparison, the medical and cosmetic applications for collagen are smaller, with forecasted 2025 market shares of 14.1% and 10.4% respectively.

Presently, commercial collagen manufacturing is dominated by global manufacturers such as Rousselot International, PB Gelatin, GELITA AG, Nitta Gelatin and Weishardt International Group. Rousselot International was the market leader in the collagen peptide market in 2013, followed by GELITA AG and Roxlor LLC.

In Australia, collagen manufacturing is currently limited to only a few manufacturers such as Gelita who manufacture mainly edible gelatin, Devro who make collagen based edible casings and non-edible packaging films and Holista-Colltech who manufacture <100MT of food and cosmetic grade ovine collagen combined.

MLA's Collagen Business Case Report V.RMH.0079 stated that the primary increase in market value for collagen is from the increase in volume. This increase is largely due to an increase in demand for food and nutraceutical collagen sales. Nutraceutical collagen yields a substantially higher sale price per tonne than food collagen and as the market segment with the highest demand and the second highest $/MT, the report recommends this should be an area of focus for collagen producers.

1.1.8 Collagen Opportunity for Australian animal processors

According to MLA's Co-producer Market report Aug 2020, the hide market remains in the worst position in living memory due to consistently declining global demand for leather. Australian meat producers have typically been one of the largest suppliers of salted sheep skins and wet-blue hides to the world market being one of the few countries that has open trade in hides and skins. According to MLA Report P.PSH.0999 - Developing High Value Freeze Dried Australian Red Meat Products and Services (2019), Australia annually produces 32 million woolskins, 8 million cattle hides, and 1 million calf skins. However, with increased substitution for leather with synthetics in footwear and accessories and increased environmental regulation leading to decreased leather production, the Australian hide and skin industry is coming under increasing downward pressure on market prices.

The negligible market prices for hides and the practical challenges of routing hides through conventional rendering systems has led to the abattoirs having to dump hides into landfill which expectedly have begun to cause serious environmental issues.

Ironically, hides and skins are rich in collagen. Up to 30% of the hide/skin weight is from collagen with the rest being contributed by water (65%), hair and fat. Against the growing demand for collagen, this presents a huge opportunity for hides and skins to be used for collagen production instead of diverting them to landfill or low value applications.

MLA has identified that an immense opportunity exists for Australian animal processors to invest in collagen production facilities and capture a significant share of this growing global food and nutraceutical collagen market.

1.1.9 Ovine Collagen opportunity

Commercially, the bulk of collagen manufactured globally is from bovine and porcine sources. However cultural/religious sensitivities and perceived safety risks can limit their applicability and market potential such as low acceptability of bovine collagen amongst Hindus, Sikhs and Buddhists and porcine collagen being forbidden for those of Muslim and Jewish faith. Additionally, 3% of the global population is allergic to bovine collagen along with a prevailing negative perception amongst consumers of BSE risk.

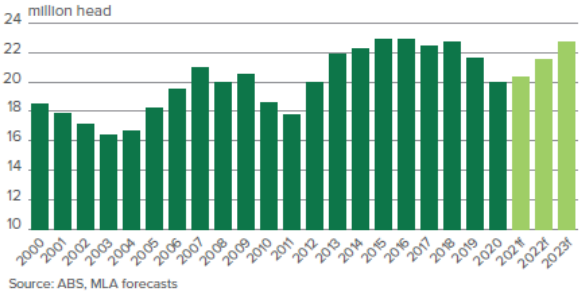
While marine collagen is free of these cultural factors and safety risks, the significantly less volumes (by weight) of fish skins (as compared to bovine and porcine hides) and lower yields of collagen (1.2% compared to 10-20% from bovine and porcine skins) make it extremely expensive limiting its wider adoption into the growing collagen application market.

This presents an immense opportunity for ovine collagen, particularly Australian ovine processors to capture a significant share of this rapidly growing nutraceutical collagen space. Ovine collagen is not only free of cultural sensitivities but also isn't limited by supply of raw materials or low collagen yields as marine collagen. Additionally, Australian ovine is the only disease and prion-free ovine in the world. Australian sheep grade is certified by the US Department of Agriculture to be free from disease. The no-risk-of-BSE classification can enable Australian ovine manufacturers to assure consumers that their products are 100% disease free, providing an opportunity for Australian sheep producers to capture a significant chunk of this market segment.

2. Ovine Collagen Potential

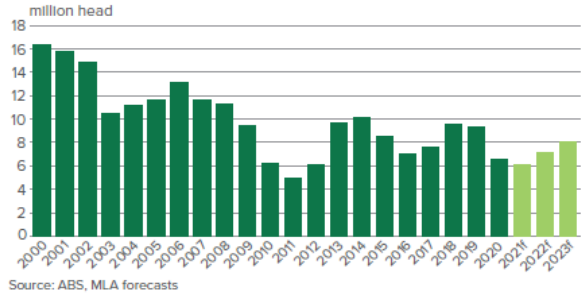
As per the June 2021 edition of MLA's Australian sheep industry update, forecasted sheep and lamb slaughter for 2021 are 6.1 million head and 20.3 million head, respectively and expected to increase to 8 and 23 million head respectively by 2023. Thus cumulatively 30 million ovine heads for slaughter and therefore 30 million skins for collagen extraction by 2023.

Figure 7: National lamb slaughter



Source: ABS, MLA forecasts

Figure 8: National sheep slaughter



Source: ABS, MLA forecasts

Based on a dehaired and de-fleshed Merino sheep pelt weight of 1.2kg and an estimated average powdered collagen hydrolysate yield of 10% (influenced by pelt weight, breed and age of animal), the opportunity potential for Australian ovine collagen hydrolysate by 2023 equates to 3,600MT or almost 10% of the predicted global collagen shortfall.

Additionally, given Australia's natural advantage of being able to produce collagen products from disease and BSE free ovine, the realised value multiplier could be much higher.

At a market price of $30,000/MT (MLA collagen report V.RMH.0079), this can translate to a significant annual revenue of $1Billion for the Australian ovine industry without having to grow or slaughter any extra animal.

2.1 Australian context and opportunity

Australia produces about 32 million woolskins every year, roughly 12 million sheep skins and 20 million prime lamb skins.

Australian sheep skins had traditionally commanded a high market. However, in recent times the price has plummeted.

The price for sheep skins is highly volatile making it difficult for sheep producers to estimate returns more than 6 months ahead. Premium merino skins demand a market price of 2000c/skin and those in second and third grades make about 200c/skin to 1300c/skin while small, short or damaged lamb skins have no value in the current market [MLA, 2019].

2.1.1 Australian Hide & Skin Supply

While Australian ovine skins have traditionally commanded high market value and a significant source of revenue for processors, the steady decline in global leather demand has led to a concomitant decline in the value of skins with prices being so low that abattoirs have had to resort to selling hides at throwaway prices or dumping them as landfill.

Although local prices for hides were steady with better quality product up $20 to $40 per piece above 2020 levels, this was mostly from the improved exchange rate from 2020. Overall, the Australian hide industry is on a steady decline with average 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.

With lower demand for sheep skins, a large portion of skins are being fellmongered, and the wool is sold separately. The best quality lamb skins are trading at 700¢/skin, while small, short or damaged lamb skins have no value in the current market, with most being discarded.

Premium merino skins demand a market price of 2000c/skin and those in second and third grades make about 200c/skin to 1300c/skin while small, short or damaged lamb skins have no value in the current market [MLA, 2019].

Increased popularity of synthetic leathers continues to impact the sheep skin market, with many manufacturers transitioning to the cheaper alternative instead of genuine leather for shoes, clothing and car seat covers. As such therefore the demand for ovine skins is expected to be decline over the coming years. Additionally, the inherently changing nature of the fashion industry adds another degree of uncertainty to the sheep skin and leather industry, causing wide fluctuations in skin revenue for ovine processors.

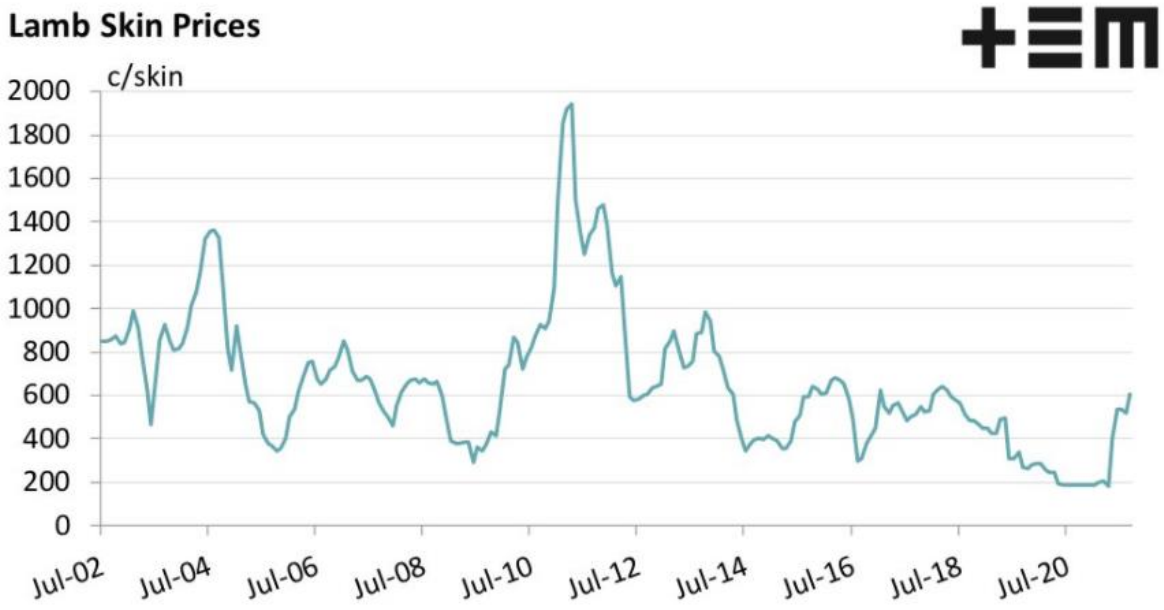


Figure 1. Average lambskin prices in cents a skin for the past 20 years (Thomas Elders Market 2021)

Against the above backdrop and market potential for ovine collagen, the production levels of Australian ovine collagen in volume terms however have been exceedingly small. This is because current commercial collagen manufacturing processes can stretch for days or weeks, often taking as long as 4-6 weeks or even more to process raw skins into a finished collagen hydrolysate product. The high infrastructure set up and holding costs and the extended processing times are naturally unable to process the high throughputs required to manufacture the large volumes demanded by the collagen market. Additionally, the extended incubation times often end up causing factory odour issues while the aggressive chemicals used in the treatment dissolve the wool and other skin proteins into an environmentally unfriendly sludge creating additional regulatory issues during its disposal.

In absence of an effective technology that can overcome these issues at industrial scale, much of the valorisation potential of Australian ovine skins remains unrealised, despite a rapidly growing collagen nutraceutical market.

2.2 Further Valorisation potential of ovine skins

Apart from collagen, ovine skins contain significant quantity of residual wool. Current commercial collagen manufacturing processes often end up either damaging the wool or convert it into an environmentally unfriendly sludge to be disposed as landfill.

If however, a process can be developed to recover this wool intact and undamaged, it could be provide an additional source of substantial revenue to the ovine processor.

Furthermore, biochemically, wool is mainly composed of keratin, a protein that is used and in demand in cosmetic industries and which can potentially also be upcycled into the food and flavouring industries.

2.3 OTH Industrial Extraction Process

Organic Technology Holdings (OTH) is a unique and innovative Australian industrial technology developing company that adds significant value to both primary processors and global food, nutraceutical, pharmaceutical and cosmetic manufacturers by developing industrially scalable technologies that upcycle the various 'waste' by-products of abattoirs, seafood and plant processors into high value ingredients of superior quality and in the large volumes required by these end users

The success of OTH in understanding the exact market needs is underpinned by its unique business model. Unlike the conventional 'build and they'll come' approach of technology companies, OTH is 100% industry-led, developing industrially feasible solutions to problems or requirements that the industry has clearly identified, and which are not currently being met.

OTH's Advanced Food and Nutrient Research Centre facility is based in Brisbane. This facility is unique in that it encompasses 3 different processing capacities and scalabilities, Laboratory, Pilot and Pre-commercial. The Laboratory Scale, can process up to 10kg batches, and is where the conceptualization and proof-of-concept breakthrough technologies are developed. The Pilot Scale line is where the developed technology is scaled up to 50-100kg batches with the focus on validating process and product quality and producing sufficient samples for in-depth biochemical analysis and preliminary market feedback

Once the product quality and market demand for the end products have been validated, the technology is then scaled up using the Pre-commercial Scale platform. OTH's dedicated multi-product pilot facility can process several 500kg -1MT batch trials under simulated industry conditions and produce 100-500kg samples of finished products. Several repeat trials can be conducted to confirm the consistency of the process and end product quality.

The process data generated from these trials assist the process and chemical engineers to develop a blueprint for a larger commercial manufacturing plant, and the 100-500kg samples can be supplied to end-users - large food, feed, and nutraceutical manufacturers to undertake critical application trials and provide validation of market and price acceptance. Together this helps generate a validated P/L model inclusive of capex, opex and market pricing required to justify the establishment of commercial plants to convert by-products waste streams into high purity, high value, contaminate-free food, nutraceutical and pharmaceutical grade ingredients.

To enable the development of effective solutions, OTH conducts extensive market as well as scientific research, liaising closely with key commercial and technical end-users and raw material

stakeholders to understand their pain points and specific requirements, to enable a customized technology solutions to be developed that industry needs.

Based on its research and market insights into the growing demand for Australian ovine collagen as well as wool and keratin, OTH strongly believes there is immense potential for Australian sheep growers and abattoirs to generate significantly higher returns from their skins if a suitable industrially scalable and cost-effective technology is developed to upcycle them to high value and in demand concentrates for the food, nutraceutical, and cosmetic industries.

OTH in collaboration with MLA therefore decided to invest in the development of an industrially feasible process for producing collagen hydrolysates, clean wool and keratin concentrates from ovine skins and generate samples to validate market acceptability, demand, and price points of these products with the overall objective to deliver increased economic returns to Australian sheep producers.

3. Objectives

The aim of this project was for Organic Technology Holdings (OTH) to undertake the development of a technology that can achieve high throughput processing and maximal valorisation of Australian ovine skins by the extraction of ovine collagen peptides and generation of clean wool and keratin concentrate. As proof of concept, this included trials at benchtop (1-5 kg batches) and mid-scale (50-100 kg batches) levels.

The project involved the following objectives:

1. Development of a unique industrially scalable process that could achieve high throughput processing of raw ovine pelts, shortening processing times from months to a single shift
2. Maximal valorisation and zero waste generation by extraction of skin collagen, recovery of short fibre residual wool and its conversion into keratin concentrate
3. 100-200gm Laboratory scale samples of collagen hydrolysate produced for biochemical profiling by external labs and to validate consumer and market demand.
4. Getting the ovine collagen samples evaluated by Krumbled Foods (health Food manufacturer selling to consumers) for inclusion into their products
5. Krumbled Foods to undertake A / B product testing – produce concept products (such as their bars) and create concept artwork with Australian ovine collagen call out and test on-line. Complete trials on consumer acceptance and demand insights plus triangle sensory testing to pick if different against other collagen sources. Complete factory yields and costings. Validate what if any, potential point of difference for Australian collagen.
6. Produce a Final case Study report of Phase 1 work summarising key findings and approach.

4. Methodology

The following methodology was used to undertake this project.

4.1 Define and confirm desirability and usability. Develop and define supply chains.

Organic Technology Holdings conducted a desktop study to determine supply chains, markets and consumer desirability. This included a review of existing practises for the disposal of ovine hides.

4.2 Develop Laboratory Scale Extraction

OTH developed an extraction process at Lab scale that could complete end to end processing of ovine skins – from fresh skins to collagen hydrolysate powder within 8 hours. The initial lab process (Lab 1) processed batches of up to a few kilograms of ovine skins. Once proof of concept was established, the process was subsequently scaled up (Lab 2) to process batches of between 50 to 100 kg. An effective process to extract collagen from fresh Australian Sheep skins within a single shift (8hrs) was thus successfully developed and validated at the laboratory scale.

4.3 Collagen Peptide Assessment

OTH conducted a preliminary assessment of the collagen peptide produced to ensure appropriate quality standard and peptide molecular weight. 100-200gm Laboratory scale samples of ovine collagen hydrolysates were also produced for biochemical profiling (external labs) and to validate consumer and market demand.

An evaluation of the application of OTH's Australian ovine collagen proteins and peptides as an ingredient in existing products was conducted. OTH utilised design thinking principles to understand useability and desirability requirements for end user food manufacturers as well as consumers. OTH worked with Krumbled Foods (Food manufacturer selling to consumers) to evaluate the functionality and attributes such as taste of the ovine peptides in Krumbled Food products.

4.4 Preliminary Commercial Evaluation

OTH conducted an analysis to identify any logistics and technical challenges involved in volume processing and carry out any process refinement where feasible.

4.5 Preliminary Consumer Acceptance

As part of the Userability element of the Design Thinking process, Krumbled Foods (www.krumbledfoods.com) conducted an online survey of existing 'Beauty Bite' consumer's perception and likely demand of specific collagen sources, beef and ovine. These insights will help inform possible marketing positioning of ovine collagen peptides.

Figure 2. Krumbled Foods product 'Beauty Bites'

5. Results

5.1 Define and confirm desirability and usability. Develop and define supply chains.

Australia's natural advantage over other countries in having disease (BSE and prion) free ovine together with consumer trends consistently showing an increasing preference for clean label and safe products, highlight the Australian ovine processing industry can stand to gain significantly if technologies to enable local production of these high value foods are developed and made available to MLA members for implementation. Collagen is one of these high value foods identified by MLA as having the potential to deliver significant value add to Australian ovine processors.

5.1.1 OTH Process Development

OTH sourced over 150kgs of ovine skin having about 5-10cm of wool from a local abattoir and carried out different sets of combinations of physico-chemical treatments both at benchtop and mid-scale levels. Parameters specific to sheep skins such as the thickness of collagen layer, presence of residual meat and fat, presence and length of residual wool, industrially suitable process time windows etc were considered in developing an effective ovine collagen and wool extraction technology.

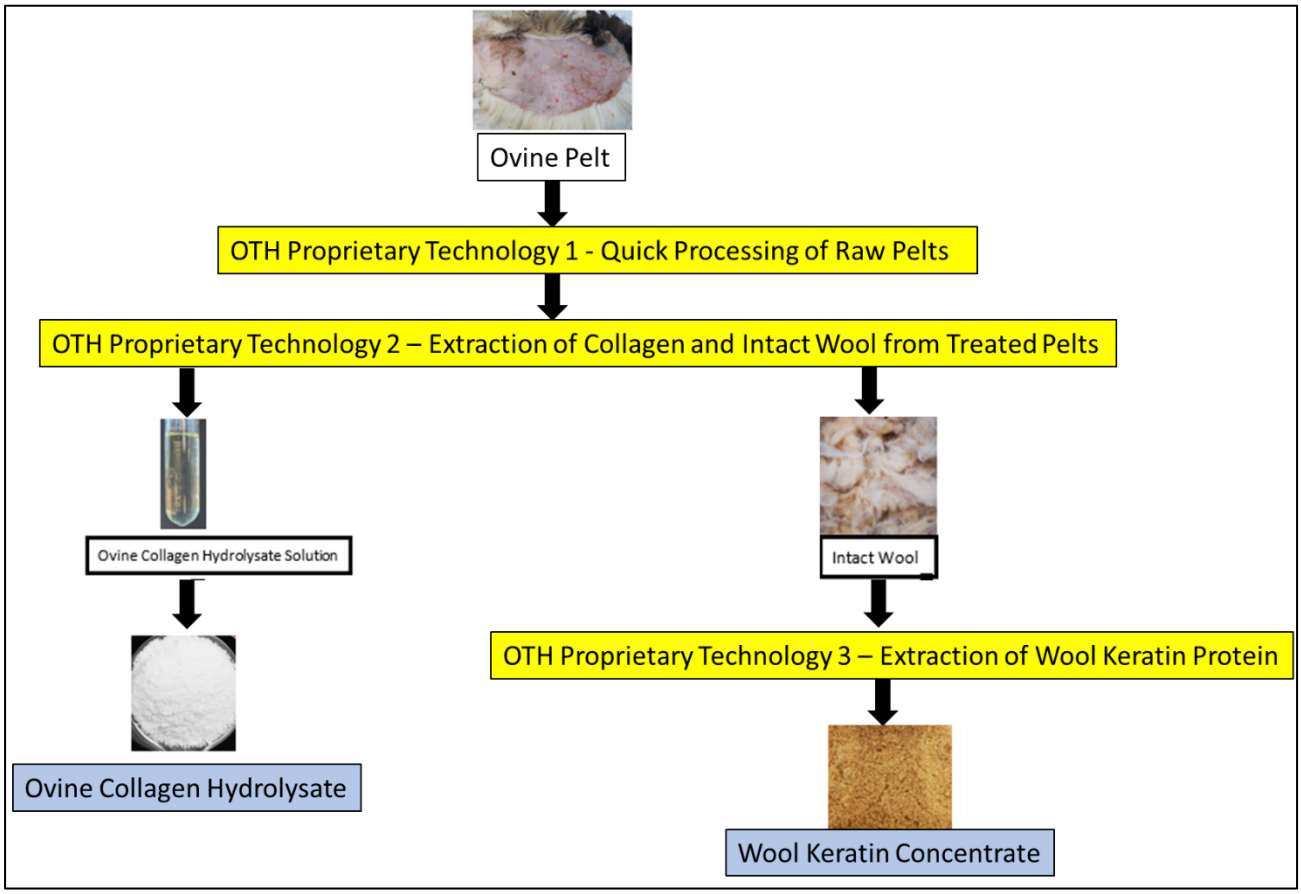


Figure 4: Generation of OTH Ovine Skin products from Sheep Skin

5.2 Collagen Peptide Assessment

5.2.1 Product Quality

(A) Skin Collagen Hydrolysate

OTH conducted extensive research and several trials using different proprietary combinations of treatments to separate out residual skin fat and extract collagen hydrolysate from ovine skin. Initial assessment of the collagen hydrolysate quality was conducted using in-house electrophoretic studies followed by a confirmatory and quantitative analysis conducted by the Australian Proteome Analysis Facility.

The bulk of the collagen hydrolysates produced by the OTH process were found to consistently be <10kda, a feature that is highly valued and demanded by the food, nutraceutical and cosmetic application market.

Interestingly, analysis of commercially available collagen hydrolysate products revealed it contained variable peptides with a substantial percentage >15kDa and some being even greater than the collagen hydrolysate defined limit of 25kDa. Given nutritional and market value of collagen hydrolysates is greatly influenced by the molecular weight of its peptides, the consistent low molecular weight of collagen peptides generated from the OTH technology can offer a strong value differentiator for Australian ovine processors in this growing collagen market

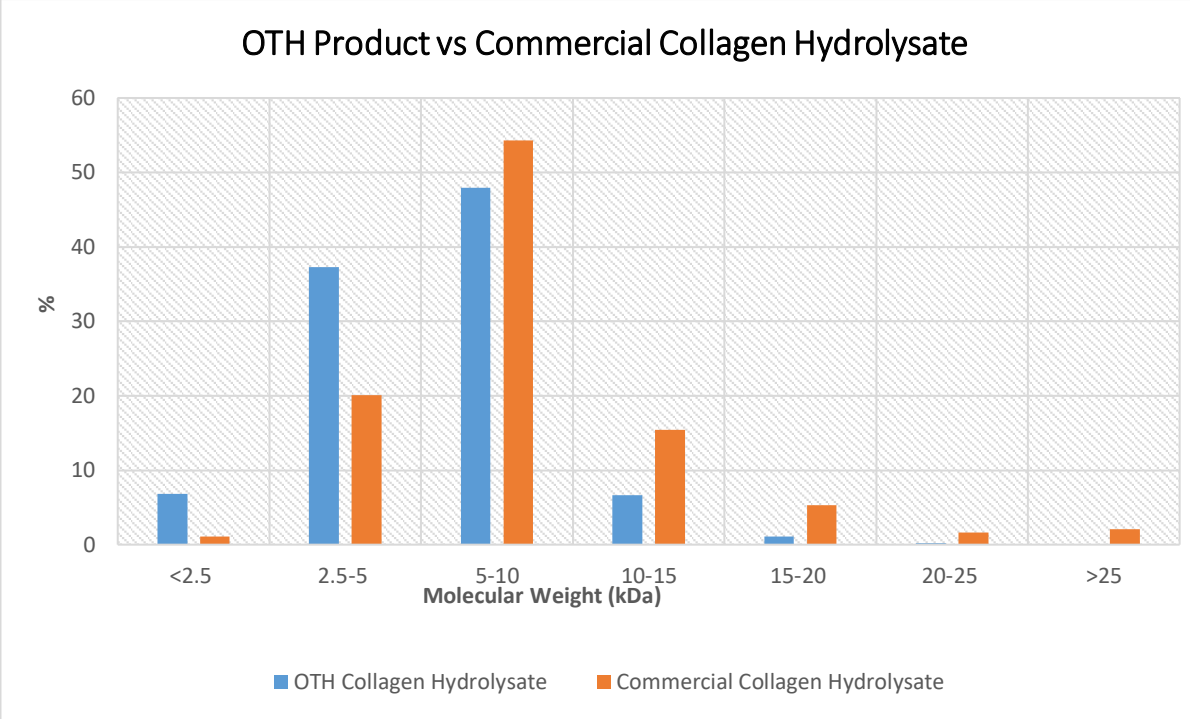


Figure 6: Molecular Weight Comparison of Collagen Hydrolysate

To validate the biochemical quality of the collagen hydrolysates, the amino acid profile of the OTH generated collagen hydrolysate product was analysed for proline and hydroxyproline levels. Research indicates that ovine collagen contains 22% glycine and cumulatively 25% of proline and hydroxyproline.

Analysis by external NATA accredited labs confirmed the amino acid profile of OTH technology derived ovine collagen hydrolysate matched with the expected theoretical biochemical profile, thus validating its high purity and quality

(B) Wool Keratin Concentrate:

In addition to collagen hydrolysate, the OTH process also preserves the residual wool producing an additional value add product in the form of intact clean short fibre wool. Moreover, using another bespoke OTH technology, this wool was able to be converted into a wool keratin protein concentrate.

(C) Maximal valorisation:

With market feedback indicating a high demand for collagen hydrolysates as well as intact wool and keratin rich ingredients across the food, flavouring, textile and cosmetic industries, the OTH processes can thus deliver maximal valorisation of ovine skins potentially delivering significantly more returns to the ovine processor than what they currently receive from selling fresh/salted skins.

5.2.2 Process time

Importantly, the entire OTH process from raw skins to collagen extraction and drying into a collagen hydrolysate powder can be completed within a single 8 hr shift - a significant enabler in processing high volumes of skins as needed to meet the growing demand of ovine collagen.

5.2.3 Preliminary Consumer Acceptance

Krumbled Foods have an established market domestically and in key international markets of the UK and the US for their Beauty Bite product range, containing collagen peptides as a key ingredient. Currently, Krumbled Foods source bovine collagen peptide as an ingredient from Argentina.

It is crucial with consumer centric products that the manufacturer understands the desirability element of products. To ensure a product or any changes to a product, such as the inclusion of sheep collagen peptide, is a success in the market we should as part of the Design Thinking process test for desirability. Focuses on whether sheep collagen is a nice to have, a must have or is not desirable for your customer. Krumbled Foods conducted an online survey of existing 'Beauty Bite' consumer's perception and likely demand for beef versus ovine sourced collagen.

The results of the survey of Krumbled Food's revealed that while consumers were certainly interested in Australian collagen, there were not as aware of the functional similarities between bovine and ovine collagen, highlighting the critical need for market education. Apart from the immense potential for ovine collagen in overseas religious and cultural markets, a better-informed Australian consumer can help to further generate a significant local demand for Australian ovine collagen.

6. Conclusion

Currently the only way ovine producers and processors can generate more revenue and profitability is either to cut costs or growing and processing more sheep or taking advantage of the occasional positive market conditions.
The steady decline in fresh skin prices and inherent market volatility in red meat prices have further increased revenue pressures on ovine processors.

Against this backdrop, the above OTH technologies can enable ovine processors to generate significant additional and sustained revenue without having to grow or process any additional animal. Instead of ovine processors having to dump skins as landfill due to decline in skin prices and incurring losses, OTH technologies can deliver significant profits back to Australia's ovine producers by enabling high throughput processing of ovine skins within a single shift whilst generating high value and in demand collagen and keratin concentrates for the food, nutraceutical and cosmetic industries

6.1 Project Outcomes

The outcomes of this project has been the successful development of three benchtop technologies to realize the full valorisation of ovine skins.

The first technology enables raw/fresh ovine skins to be easily and quickly processed at industrial levels, allowing all Australian ovine skins to be processed into high value ingredients instead of being sold at throw away prices or dumped as landfill.

The second technology generates high and consistent quality food and nutraceutical grade skin collagen hydrolysate from the treated ovine skins whilst preserving the residual wool as intact and generating clean wool as an additional product for the textile industry.

The third technology enables this separated out wool to be converted into a high value wool keratin protein concentrate for application in high margin cosmetics as well as in food flavouring industries

Together, these technologies can potentially deliver significantly more returns to the sheep processor from what current is a low value or a 'waste for landfill' by-product of the Australian ovine processing industry

In addition, the high process quality of the OTH process derived ovine collagen hydrolysate has been validated by results from NATA accredited analytical labs that proved the OTH process consistently generated low molecular weight collagen peptides as demanded and valued by the market. Similarly, the wool keratin concentrates were found to consistently contain high protein levels, with minimal ash as required in food and cosmetic applications

7. Future Research and Recommendations

The establishment of a laboratory scale process to produce samples for market/consumer validation is now complete. OTH recommend that detailed planning and costing for Phase 2 be undertaken and that OTH and MLA commence this work as soon as possible. OTH has a unique pilot plant set up at its Brisbane facility for conducting the scale-up trials. These trials will process upto 500kg of ovine skins to generate larger sample quantities of collagen hydrolysate and wool protein concentrate samples as required for nutritional studies and application-based trials.

Industrial scale up challenges with respect to equipment type, throughput and material transfer will be identified during the Phase 2 research & development. Consequently, the optimal logistics of the raw material flow and its treatment at industrial scale will need to be determined. Chemicals and catalysts will need to be sourced in larger quantities for these mid-scale trials.

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