Final report

Ovine Collagen Opportunities
Milestone 4 – Final Report

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Abstract

Freeze Dry Industries (FDI) have been partnering with MLA Donor company on Bovine Hide – Extracting Food Grade Collagen from Beef Hides (P.PSH.1274). This project (P.PSH.1347) was launched to explore the possibility of validating the collagen extraction processes developed by FDI for bovine hides on ovine skins and conduct research into the results.

The commercial opportunity of Australian ovine collagen was investigated and was found to be significant. By utilising low quality sheep skins, the production will greatly benefit the Australian red meat industry. These are normally disposed of, so by utilising them the cost normally associated with dumping them is removed and less waste will be created. This alone contributes to achieving carbon neutral status.

The organic extraction process previously developed by FDI for bovine hides was found to be suitable for ovine skins as well. Compared to the first sample of ovine collagen produced by FDI, the ash content was reduced by over 93% and the protein content increased by over 62%. Microbial testing also came back proving the product is suitable for human consumption based on FSANZ standards.

Executive summary

Background

Freeze Dry Industries (FDI) have recently completed a Research Proposal for MDC on Bovine Hide – Extracting Food Grade Collagen from Beef Hides (P.PSH.1274). FDI have confirmed that they can create a human-grade collagen protein powder from waste hides. This process is clean and green, utilising Australian technology, and has resulted in an ACO certification for the organic collagen.

The purpose of this research project was to determine the suitability of the organic extraction process on sheep skin in order to create ovine collagen.

Objectives

The objectives of the project were:

- Mapping of current practise for sheep hides in the Australian sheep meat sector and the opportunity presented by ovine collagen to the red meat industry
- Develop proof of concept ovine collagen and trial batches to validate technical feasibility
- Evaluate the value proposition for freeze dried ovine collagen based on industry, economic and market trends

All three objectives have been achieved.

Methodology

3 key factors were considered for the duration of this project:

- Evaluating the sheep skin market by researching publicly available information and discussions with industry.
- Ensuring the quality of the product and by extension the process by nutritional testing conducted through NATA accredited laboratories.
- Evaluating the commercial opportunity of the product by researching the collagen market and using various financial models and tools.

Results/key findings

The potential opportunity for an ovine collagen is significant due to current market trends. In particular within skin care and pharmaceuticals. FDI's organic extraction process is suitable for sheep skin and produces a high quality hydrolysed ovine collagen.

Benefits to industry

The financial benefit to the red meat industry is clear, as FDI can use lower quality dorper and other sheep skins which currently often have no other use and are disposed of. Utilising these hides removes the costs associated with dumping them and decreases the amount of waste produced.

Future research and recommendations

It is critical now to develop this research into a full commercial model. Ovine collagen appears to be dominated by a few players and as such provides an excellent opportunity to commercialise.

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1. Background

1.1 Project

Freeze Dry Industries (FDI) have recently finished a Research Project with MDC on Bovine Hide – Extracting Food Grade Collagen from Beef Hides (P.PSH.1274). FDI have confirmed that they can create a human-grade collagen protein powder from waste hides. This process is clean and green, utilising Australian technology, and has resulted in an ACO certification for the organic collagen. FDI are currently seeking to scale and commercialise the bovine collagen. This method may be utilised for the use of ovine collagen as well.

Ovine is seen as highly bioavailable as Australian sheep are scrapie free and prion free so may be marketed as such. There is also a global demand for Halal/Kosher certified products for consumers of Muslim and Jewish faith, as such, ovine collagen falls into these categories.

Several layers of value can be generated from the successful creation of another collagen extraction process. This might range from a pet food supplement, health food supplement, cosmetic grade and then medical grade collagen. When fully refined as medical-grade collagen, 10kg has a retail value of $5.4 million USD (Green & Bryan).

While there is currently no transparent process or clear data on the journey that Australian sheep hides take postprocessing, it has been identified that treatment and disposal of wastes, both liquid and solid, from all red meat processing plants in Australia and feedlots exceeds AU$100-200million/year (O'Hara & Van der Berg, 2019).

Currently, research surrounding the benefits of ovine based collagen products is very limited, as there is little to no data available regarding the topic. While Holista Colltech remains the sole producer of ovine collagen products, techniques and information surrounding the production of such products and the expansion of research into that area is controlled by them until processes separate from the patent are developed.

2. Objectives

1. a) Mapping of current practise for sheep hides in the Australian sheepmeat sector- including the current pathways, lambskin availability, current value attached to sheep skin market, and validation of potential additional pathways for further value adding of waste skins. What is the current value of the total collagen market (all species) and what do we believe is a reasonable assessment of lamb collagens opportunity with that market?
   b) Initial completion of the Results Chain Analysis (RCA) model by Switch Business on behalf of Freeze Dry Industries to demonstrate the pathway to adoption.
2. Investigate and validate via stakeholder and customer development discoveries and analysis of foresight trends and industry/economic/market forces the value proposition for freeze dried ovine collagen. Map the current value chain and design potential model for ovine collagen.
3. Develop proof of concept ovine collagen and trial batches to validate technical feasibility and customer potential markets.
4. Design and test business model – identify and test key partners and activities for each value chain participant to develop the new service model and associated tipping points.

5. Present key findings, recommendations, completed RCA including industry benefit, cost benefit analysis and lessons learned in a final report.

The above business modelling and RCA will be aligned with MLA's Evaluation Framework, specifically focussing on providing the following:

- Separation of value adding costs between processor and value-adder (FDI or equivalent), noting multiple options may apply here.
- Based on the above, likely transfer price and hence net margins per kg of collagen at the processor and value adder.
- Assumptions of current and likely business as usual market prices for sheep skins (to 2030+)
- Estimated adoption profile (based on collagen quantities converted to skins)
- Any assumptions of demand creation (separate from net margin impacts) that are derived from collagen sales i.e. a shortage of suitable skins driving up overall market prices.
- Conversion of all per skin benefits to a per animal basis.
- Extrapolation of the above on an annual basis to at least 2030, so as to derive a NPV of industry benefit

3. Methodology

3.1 Organic Ovine Collagen Opportunities

The opportunities for ovine collagen was evaluated based on 3 different factors.

3.1.1 Sheep skin market

The current Australian sheep skin market was evaluated in order to determine the potential financial opportunity for organic collagen. Only sheep skins from Australia or New Zealand can be used as a raw material due to diseases found in the skins in other countries. As such this is a unique opportunity. The Australian market is not transparent in terms of how the sheep skins are currently being used and valued, and mapping it out was a priority for FDI to ensure the availability of sheep skins at a competitive price. FDI sourcing of sheep skins confirmed that there is little to no market value for skins that are not used for their wool.

3.1.2 Collagen market

The collagen market is growing quickly and new products are entering the market at an increasing rate. Ovine collagen has unique benefits compared to other types of collagen and currently very limited amounts of ovine collagen are commercially available. Because of this, FDI mapped the current market and its trends to extrapolate the potential of ovine collagen as a raw material and different collagen based products.

3.1.3 Ovine collagen product

Based on the organic collagen extraction process developed by FDI for bovine hides, a new process for collagen extraction from ovine skins was developed. This process was then evaluated based on test results from NATA accredited laboratories. Specifically, the nutritional profile, ash content and microbials were tested. Based on these results the quality of the ovine collagen produced was determined.

4. Results

4.1 Organic Collagen Value Proposition

4.1.1 Why Ovine Collagen?

Ovine collagen is widely culturally tolerable unlike bovine and porcine collagen. Marine collagen cannot be certified organic, may have issues with heavy metal contamination and fish are a major allergen, and people allergic to fish may still have reactions to fish derived collagen. Ovine skins are easier to work with than other mammalian hides and have a higher yield than marine sources of collagen. Further discussion about different collagen sources can be found in section 4.3.1.

Only Australian and New Zealand sheep skins can be used for collagen extraction due to their disease free status. There is also a large surplus of low quality dorper skins which currently have no use and are disposed of. This means that the production of ovine collagen is a significant opportunity for producers as well, as they now get paid for material they previously had to pay to have disposed of. It also means that the environmental footprint is smaller.

4.1.2 Potential customers

Due to its high tolerability and exclusivity, ovine collagen is seen as a higher quality collagen product. As such, it is suitable for cosmetic and pharmaceutical purposes.

Because of this, cosmetic grade collagen is suitable as a first product. This is also how most of Holista Colltech's products are being used, showing that there is market demand. Their main buyer is Behn Meyer in Thailand which uses the collagen to manufacture cosmetics. They also state that Guangzhou Sinbio Cosmetic in China are currently in the process of testing the ovine collagen. More about Holista Colltech can be found in section 4.7.2.

FDI is currently producing bovine collagen based cosmetic products under Organic Collagen Australia (OCA) and is building experience in this market.

4.1.3 OCA's Unique Selling Points

OCA uses only Australian sheep skins which are guaranteed disease free. All the sheep used are certified organic, which means that they have been raised humanely on open pastures free of synthetic hormones, antibiotics, herbicides, pesticides and heavy metals.

The production process is greener than traditional collagen production. No harsh chemicals are being used and the technology used has been developed by FDI and is 'clean and green'.

4.2 Sheep Hide Market

In the previous milestone the sheep skin market was outlined. It was found that most of the sheep skin was exported overseas without any value add on which presented a clear opportunity to create high value by products. The current data on the sheep skin industry and the amount of wastage it produces is not readily available, so some of the data used in this document is extrapolated from a 1994 report by J.J. Skillehorn Consulting conducted for the MLA.

The financial benefit in selling off sheep skins varies every year depending on a wide array of factors such as the price of leather, wool and competing synthetic products. This will affect the financial benefit in selling them versus disposing of them.

All skins are graded on entry to the processing plant. The merino skins are deemed more valuable – with a circa $35/skin price for export markets, mainly used for sheepskin (Ugg boots, car seat covers etc). The dorpers only attract a circa $4 per skin price and mainly used for leather – upholstery and shoes.

On further investigation, the representative clarified that the only waste produced from their process was the salt used for brining. Even the small sections/portions of skins are sold and exported.

FDI are also speaking to a leading organic producer re their organic sheep skins and will continue to evolve this industry mapping throughout the course of this project.

From this analysis we can presume that the Australian red meat sector is exporting the raw materials with no other value adding process taking place.

This becomes a clear opportunity and focus of the project.

4.3 Collagen Market

The global collagen market was estimated to be worth USD 8.36 billion in 2020 and is expected to continue to grow rapidly (Grand View Research, 2021).

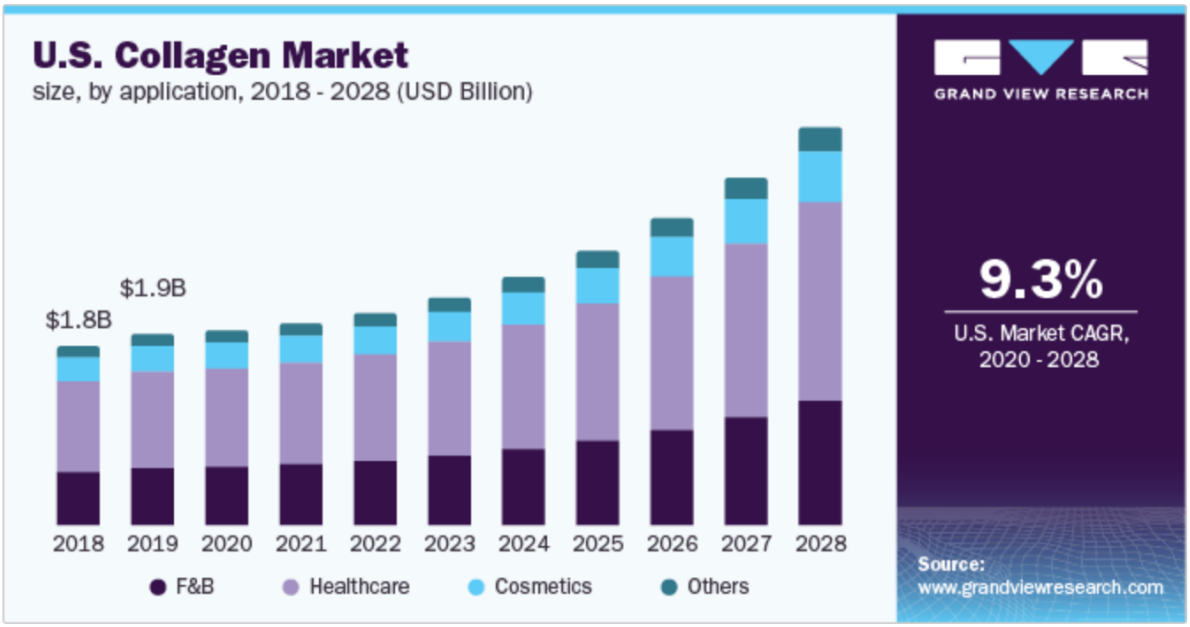

Figure 1 U.S. Collagen market between 2018 to 2028

There is an increasing adoption of collagen based product among consumers, in particular driven by the "beauty" based benefits, i.e. to hair, nails and skin. This is seen both in the food and beverage sector but also in the cosmetics industry and is expected to drive a lot of the growth in the market (Grand View Research, 2021).

The type of collagen based consumer products are becoming more versatile; previously it was mostly sold as a supplement in pill or powder form. Now there are drinks, bars, candies and other

snack foods. Since this will allow consumers to find products that suits their lifestyle and needs, it will allow the market to keep growing.

Collagen is used extensively in the pharmaceutical sector as well, which makes up almost half of the collagen market. Due to its similarity to, and compatibility with, human tissue, it can be used in a wide array of applications (Grand View Research, 2021). It is of particular interest in tissue engineering as a cell matrix as well as wound care. The pharmaceutical industry uses collagen in all its forms, from native collagen to gelatine to hydrolysed collagen, depending on end use.

4.3.1 Collagen Sources

Currently bovine, porcine, poultry and marine are the four main sources of collagen. Bovine collagen makes up nearly 38.1% of the collagen market currently due to the ease with which the raw material can be sourced and the amounts available (Grand View Research, 2021).

Marine based collagen is expected to experience the fastest growth, due to it being considered safer since it does not suffer from the potential diseases associated with farmed livestock, in particular bovine spongiform encephalopathy (BSE) in cattle. However, marine collagen does have the potential for heavy metal contamination as all seafood does (SFA, 2021).

Marine collagen is also generally being marketed as a higher quality product to consumers, to be used for cosmetics and nutraceuticals and not in regular food products the way bovine and porcine collagen are. Marine collagen being perceived to be of a higher quality then porcine or bovine collagen does not have any scientific backing. Native collagen found in fish seem to be slightly smaller than that found in mammals (130 kDa for mammalian α1 type collagen chains and 110 kDa for marine) (Carvalho, Marques, Silva, & Reis, 2018). However, once the collagen is broken down into smaller chains the size of the native collagen chains are unlikely to matter as the size of the collagen molecule is determined by the processing. A bovine collagen peptide can end up being smaller than a marine collagen peptide, by simply processing further. Most importantly, studies so far do not show a correlation between molecular weight and bioavailability.

Marine collagen tends to contain lower amounts of proline and hydroxyproline, though this depends on the source (Holwerda & van Loon, 2021). Collagen derived from mammalian sources tends to have a more similar amino acid breakdown to human sources. This may be important both when the collagen is used for medicinal purposes and when it is consumed.

It is theorised that the health benefits gained from consuming collagen are connected to the high glycine, proline and hydroxyproline content (Holwerda & van Loon, 2021). As such, marine collagen generally having a lower hydroxyproline and proline content is therefore not desirable.

The reduced amount of proline and hydroxyproline leads to weaker bonds within the collagen molecule. This means that a lot of marine collagen types have denaturing temperatures lower than the human body temperature. This limits their use as scaffolding or other biomaterial applications, as they will denature and lose their structure inside the human body, unless they are chemically altered (Davison-Kotler, Marshall, & García-Gareta, 2019).

Furthermore, fish is one of the 8 major allergens. Initial studies have found that people allergic to fish might also be allergic to fish derived collagen (Kobayashia, Kuriyama, Nakagawara, Aihara, & Hamada-Satoab, 2016).

4.4 Market & Economic Forces for Ovine Collagen

4.4.1 Australian disease free status

Australia and New Zealand are the only countries in the World whose sheep are classified as disease and prion free. They are certified disease free by the US Department of Agriculture (USDA, 2019). This means that only these two countries can produce ovine collagen safely. This puts ovine collagen on par with marine collagen as far as safety is concerned for the consumers, since the concern of diseases associated with farmed animals, such as scrabies, is not there.

4.4.2 Organic and Free From

Due to sheep being raised in captivity, more control can be had on where and how they are raised. This takes away the concern around heavy metal contamination that marine products have. It also means that unlike marine collagen, ovine collagen can be certified organic.

4.4.3 Cultural tolerance

Ovine collagen is widely culturally accepted. Porcine collagen is not suitable for Jewish or Muslim people and cannot be certified halal or kosher. Bovine collagen is not suitable for people practicing hinduism or buddhism. This means that ovine collagen opens up large sectors of the market in the Middle East and South East Asia which otherwise may not have been accessible.

While marine collagen has the same cultural tolerance, the yield is much lower hence the production cost of marine collagen is significantly higher.

4.4.4 Mammalian collagen

Humans and sheep are both mammals. Given this ovine collagen is more similar to human collagen, than marine collagen is, with similar levels of glycine, proline and hydroxyproline. These are the key amino acids found in collagen. Ovine skins are also richer in collagen than marine sources are, hence higher yields are achieved meaning a lower production cost. The yield from marine sources is generally around 1 – 2% and around 8 -20% for mammalian sources (Green & Bryan). FDI's organic collagen extraction process has achieved up to a 30% yield from bovine hides.

4.4.5 Biocompatibility

All types of collagen are considered to be highly biocompatible and safe to use for medicinal purposes. Biocompatible materials do not produce a toxic or immunological response when the human body is exposed to them. It is also biodegradable and can be broken down in the body (Gaetana Aruta, Croce, Quaglino, Guerra, & Tiozzo, 2009).

This means that collagen is suitable for a wide array of medical uses. Both more traditional uses, such as treatment of burns and wound sutures, but also new advanced technology such a scaffolding material for tissue engineering (Meyer, 2019).

4.5 Ovine Collagen Results

4.5.1 Nutritional Profile

The nutritional profile of the ovine collagen produced by FDI was tested by a NATA accredited laboratory.

The protein content for the ovine collagen is 82.1% compared to 90.1% for the bovine collagen. The relatively lower protein content in the ovine collagen is most likely caused by an increase of fat. This can be solved through adjusting the pre-processing.

The first ovine collagen produced by FDI had a 50.6% protein content and the ash content was 41.1%. The main objective of changing the processing was to reduce the ash. FDI has achieved an ash reduction of over 93% which is a great result.

The full laboratory report can be found in Appendix 1.

4.5.2 Microbial Testing

Microbial testing was performed on the ovine collagen produced by FDI by a NATA accredited laboratory. A summary of the results is outlined in the table below.

Table 1 Microbial Testing Results for Organic Ovine Collagen

Test	Result
Escherichia coli	<3 MPN/g
Campylobacter species	Not Detected in 25g
Listeria species	Not Detected in 25g
Salmonella	Not Detected in 25g
Water activity @ 25 ^{o}C	<0.05

The ovine collagen was categorised as satisfactory for human consumption based on FANZ Compendium of Microbial Criteria for Food.

The full laboratory report can be found in Appendix 2.

4.6 Further Value Add On

While extracting collagen from the sheep skin, there are opportunities to create further products.

4.6.1 Glycosaminoglycans

Glycosaminoglycans (GAGs) are mucopolysaccharides, and are present in every mammalian tissue. Types of GAGs include hyaluronic acid, dermatan sulfate, chondroitin sulfate, heparin sulfate and keratin sulfate. There are many potential uses for GAGs including skin care, anticoagulants and tissue modelling (Casale & Crane, 2022).

Hyaluronic acid is widely used commercially, including for dermal fillers, skin care, as a treatment for osteoarthritis and dry eye. The global market for hyaluronic acid was estimated to be worth US$ 9.4Bn in 2022 and is expected to grow to US$ 16.8Bn in 2030 (Grand View Research, 2022). The breakdown of the different regions can be seen below in Figure 3.

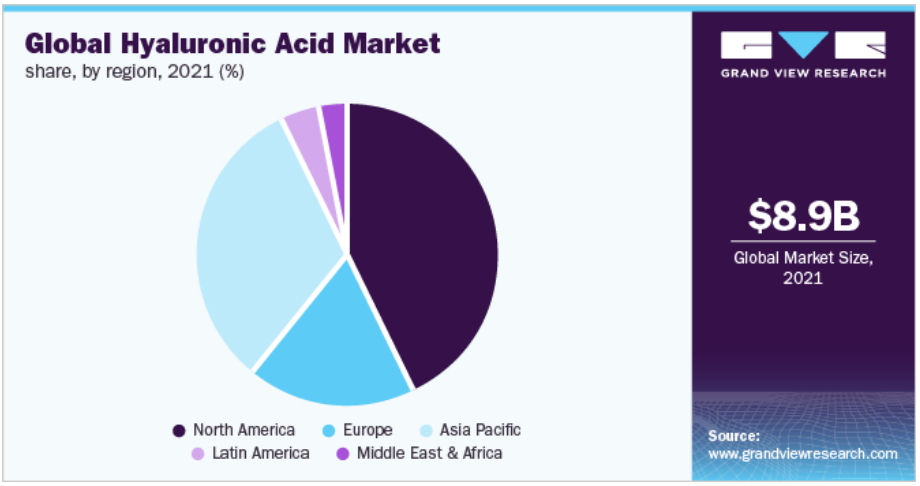

Figure 2 Global Hyaluronic Acid Market by Region (Grand View Research, 2022)

Sheep skins were found to have a significantly higher amount of GAGs than bovine hides, around 0.9% and 0.4% respectively (Naffa, Holmes, & Norris, 2019). This provides the opportunity to extract the GAGs separately and create another product.

4.7 Competitor Analysis

The main companies currently selling ovine collagen are OviGenex and Holista Colltech. The ovine collagen market makes up a small section of the overall collagen market globally. As such, it is hard to find public data on it.

4.7.1 OviGenex

OviGenex is a privately owned company that was founded in Australia in 2018. On their website they list their headquarters in California, US but says that their ovine collagen is produced in Australia from Australian sheep. They sell liquid or powdered ovine collagen. They sell atelocollagen, which is a type of collagen where end sections of polypeptides are removed but the triple helix is preserved.

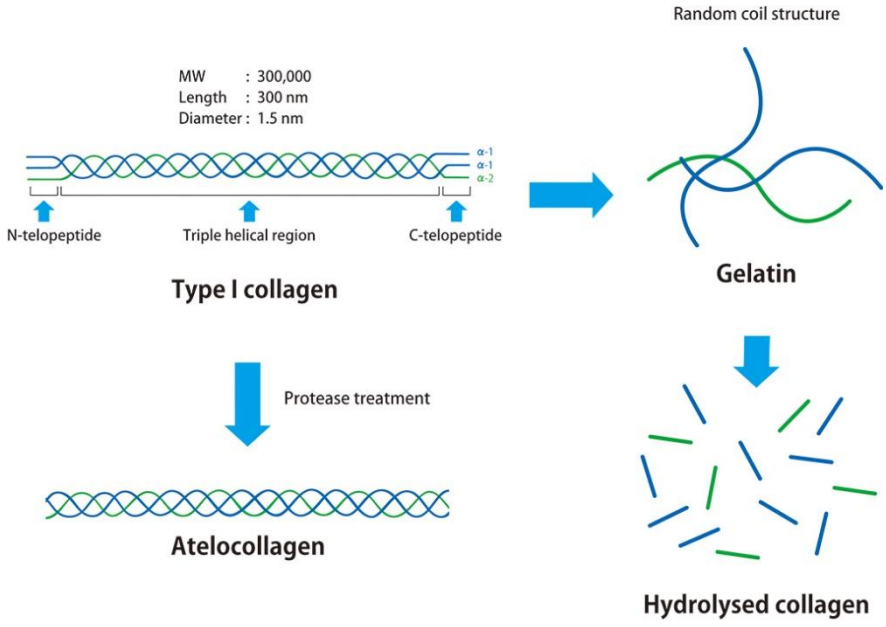

Figure 3 Different Types of Collagen Products (Koken, 2017)

Figure 4 shows a visualisation of what the different types of collagen look like. This is mostly used for pharmagrade collagen to reduce the likelihood that it will cause an immune response even further and it makes the collagen water soluble (Koken, 2017).

OviGenex products are mostly targeted towards pharmaceutical uses though they do also mention that their products can be used for food products or cosmetics. They charge US$1500/gram of ovine collagen in the form of 10 – 30 mL samples available of their website.

Because they are a privately owned company, there is no verified publicly available financial information. Estimates put them at having less than 25 employees and less than US$5M in revenue (Zoominfo, 2022).

4.7.2 Holista Colltech

Holista Colltech is a public company listed in the ASX. It currently has a market capital of AU$9.36M. It was founded in 2009, by the merger of the Australian company Colltech Australia and the Malaysian company Holista Biotech. It is headquartered in Perth, WA. It has a patent with regards to the production of ovine collagen in New Zealand and Australia.

Holista Colltech offer both cosmetic grade and food grade ovine collagen on their website. They do not specify the type of collagen they offer, but since their patent refers to hydrolysed collagen peptides that is most likely what they are offering. Their website does not state prices, however other sources are stating that the price is around AU$75/kg for their cosmetic grade collagen (Green & Bryan). Their cosmetic grade collagen is sold as a liquid solution but they do not state the form their food grade collagen is sold.

Holista Colltech's annual report for 2021 states that their ovine collagen sales grew by 43% to AU$248,000 in 2021. They state that the growth is due mostly to increased orders from Behn Meyer in Thailand. Behn Meyer uses the collagen to manufacture cosmetics. Holista Colltech also states that Guangzhou Sinbio Cosmetic in China are currently in the process of testing the ovine collagen. If the tests are successful and the collagen receives Chinese regulatory approval, Sinbio will sign a five year agreement to purchase 48 tonnes of collagen in the first year of the contract. They are expecting this to scale up to 144 tonnes in year two, 288 tonnes in year three and 576 tonnes in years four and 5. The report does not mention any food grade collagen sold.

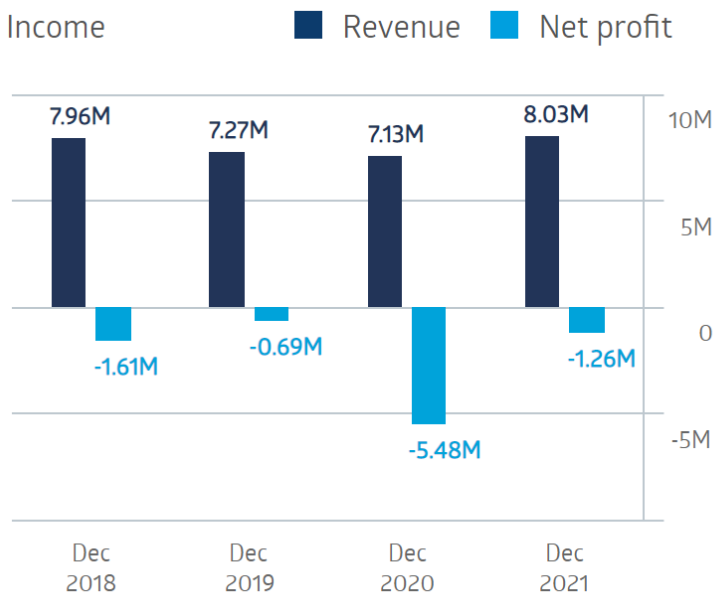

Figure 4 Revenue and Profit for Holista Colltech from the ASX

Ovine collagen only makes up a small part of what Holista Colltech does according to its annual reports. Their annual revenue and net profit recorded for the last 4 years can be seen in Figure 5.

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