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V.RMH.0074 Review of meat bone by-product processing platform and high value opportunities and trends

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V.RMH.0074 Review of meat bone by-product processing platform and high value opportunities and trends

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Purpose: By-products constitute a major percentage of the live weight of an animal. However, in their unprocessed state they are worth 10-20 percent only of the total value of the animal. Technological developments have made it possible to process and convert the many different animal by-products into a host of value-added end-products.

An evaluation of current bone by-product streams such as broths and sauces, gelatin, fat, pet food, including packaging and process design and intended use and market pricing. A description of key technology criteria for commercialisation of bone by-products streams such as broths and sauces, gelatin, fat, pet food – including enabling technology platforms.

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Abstract

By-products constitute a major percentage of the live weight of an animal. However, in their unprocessed state they are worth 10-20 percent only of the total value of the animal. Technological developments have made it possible to process and convert the many different animal by-products into a host of value-added end-products.

This report explored product and business opportunities using red meat *bone by-products* for human and pet consumption. Value chain mapping was completed to assist with conceptualizing where an opportunity might be able to make an impact. Relevant lessons from other protein sources that could be transferrable to red meat have been identified. Many of the technologies and processes used in the treatment of bone material to make other useable raw ingredients is well established. Many of the more interesting current opportunities leverage these known technologies and value add to make a new product or are based on interesting business models. A high-level assessment of consumer trends/insights, as well as interviews with consumer groups and various people in the value chain was conducted to gain understanding of consumers' likely acceptance of products made from bone by-products. Several opportunities that warrant further investigation (inclusive of human food/pet/business models) beyond the current commodity were identified.

Executive summary

By-products constitute a major percentage of the live weight of an animal. However, in their unprocessed state they are worth 10-20 percent only of the total value of the animal. Technological developments have made it possible to process and convert the many different animal by-products into a host of value-added end-products.

This project explored product and business opportunities using red meat *bone by-products* for human and pet consumption. Value chain mapping was completed to assist with conceptualizing where an opportunity might be able to make an impact. Relevant lessons from other protein sources that could be transferrable to red meat have been identified. Many of the technologies and processes used in the treatment of bone material to make other useable raw ingredients is well established. Many of the more interesting current opportunities leverage these known technologies and value add to make a new product or are based on interesting business models.

The report includes a dedicated high-level assessment of consumer trends/insights, as well as interviews with consumer groups and various people in the value chain. Finally, several opportunities that warrant further investigation (inclusive of human food/pet/business models) beyond the current commodity offer were identified and next steps suggested;

1. *Modular bone by-product processing – Coctio*

Next steps include:

- Business opportunity assessment for a high value product manufacturer located at the site of Australian meat processors or nearby. The work should employ a design-led thinking methodology to investigate viability (e.g. local and global market trends and forces, economics of currently available solutions such as those offered by Coctio), feasibility (e.g. key technology capabilities & limitations) and desirability (e.g. customer/stakeholder needs) components.
- Map the industry / sector to identify key partners, competitors, stakeholders, and customers.
- Test business assessment and customer needs hypotheses with key stakeholders and potential investors.

2. *Meat Industry – AIS Partnership*

Next Steps include:

- Understanding of the opportunity with the AIS and further development of a relationship. The authors of this report can be used to initiate a discussion.
- Develop a list of similar organizations, associations, & companies in Australia and globally that might provide benefit to the objectives of MLA. Specific objectives and understanding of how the potential partner may be able to assist should be understood and investigated.
- This approach represents a specific opportunity in the sense that careful diligence with the AIS and other commercial partners will identify the types of businesses (such as those identified in the previous sections) that could be partnered with to exploit opportunities in the Australian red meat context.

3. Product concept: 'Osteofizz' or 'Protein Punch'

Next steps include:

- Design-led thinking methodology to rapidly survey the potential of the above product concept or others by addressing viability (e.g. local and global market trends and forces, economics of currently available products), feasibility (e.g. key technology capabilities & limitations) and desirability (e.g. customer/stakeholder persona identification and engagement to determine needs).
- Depending on the outcomes, further work might involve product manufacturing and scale-up, detailed cost analysis, partner identification, development plans and budgets etc, for high priority product concepts.
- A complete business case for each product concept would need to be tested against customer needs hypotheses and potential investors.

4. Collagen from Bones

Partnering options should be explored with Gelita, who are a world leader in manufacturing and marketing collagen proteins. Gelita appear to be in possession of world best collagen extraction and processing technology.

5. Alternative phosphate source

Undertake a more comprehensive economic analysis of the opportunity, including cost benefit of the manufacturing process and capital requirements.

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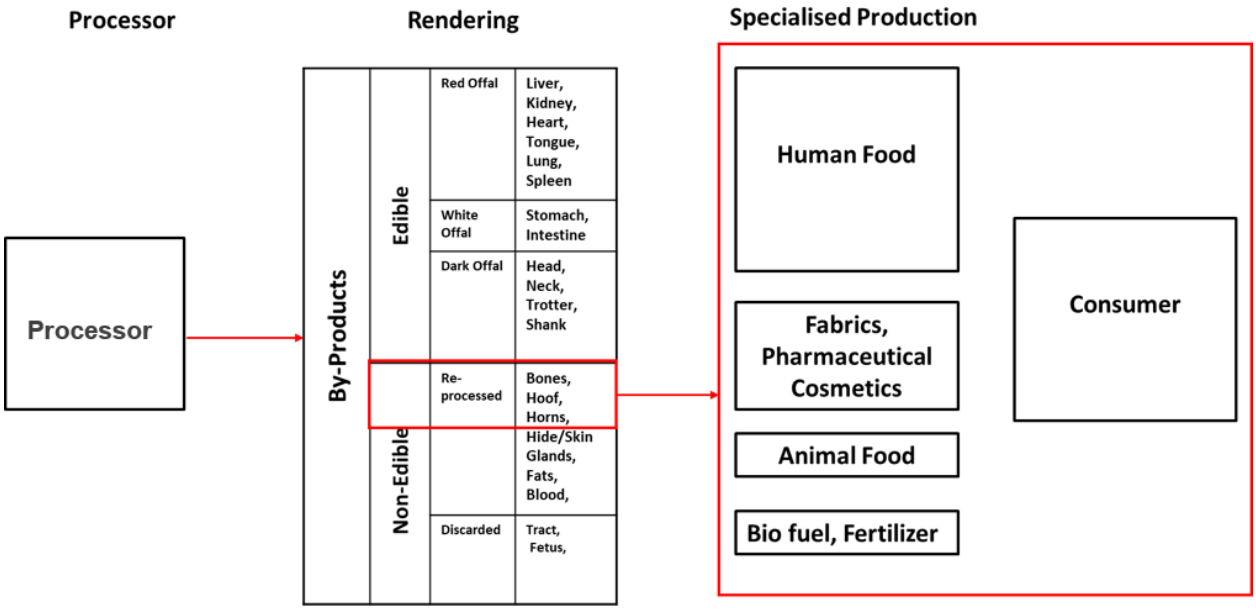
Background

By-products constitute up to 45% of the live weight of beef cattle. However, in the unprocessed state, by-products are worth only 10-20% of the total value of the animal. Compare this to chicken, where by-products constitute only around 30% of the animal. In Australia, the raw animal bone, ligament and fat waste are often given away by meat processors to contract renderers. For renderers and other value adders, scientific advancements have built a greater understanding of the food science. This combined with improved processing equipment over many decades, have made it possible to process and convert different animal by-products into a host of valuable end-products. Australia has well established value chains and traditionally meat processors have focused on providing the best quality meat as efficiently as possible, meaning that the utilization and management of the by-products has not attracted much attention. Integrated rendering facilities within Australian meat processing companies is uncommon, and most by-product is sent unsorted and in bulk, to service contract organizations for further processing.

Outcomes

BONE BY-PRODUCT VALUE CHAIN

This section provides a high-level overview of the Australian cattle by-product value chain and the process deployed to extract value. As indicated, the focus is on the bone by-product part of the value chain.



Bone by-product value chain

In general animal by-products are classified as edible and non-edible products depending on whether the by-products are being used as human food or re-processed into other products.

Edible by-products are considered safe for human consumption after inspection in the processor, whereas non-edible by-products cannot be directly consumed by humans and are either re-processed for use as secondary by-products or used as animal food or fertiliser. Non-edible by-products, such as bones, hides and skin, hooves and horns, can be transformed from low to high margin products. This is, to a large degree, driven by emerging new social trends and discovery of the value that different types of protein can add to human health.

Processor

The prime product from Australian cattle processors is beef. According to a rendering industry expert, the meat processors in Australia are: "*100% focused on meat production and nothing else and very little beef is sold with the bone-on".* Therefore, Australian abattoirs produce very large quantities of bone by-products (which includes fat, cartilage and ligaments) that are sold to independent renderers.

Rendering

The rendering industry have two types of plant and processes. One is an integrated plant that operates within an existing meat processing and manufacturing plant. The other is a standalone rendering plant that takes by-products from processors and creates products to be used as value-add in downstream production. Non-integrated rendering plants get their products from processors in one big load with bones, fat, cartilage, ligaments, etc all mixed together. According to one executive in the rendering industry: *"When it gets to renderers, bone/fat/tissue have lost its integrity. It's all one big mess and it's treated together".*

The non-edible rendering processes in Australia are mainly performed by non-integrated plants using the "dry" method. The material is first ground, then heated to release the fat and drive off the moisture. It is then percolated to drain off and/or press out the tallow fat. The solids are then grounded to make meat and bone meal. Most edible rendering is done by processing companies. The edible rendering processes are carried out in a continuous process of finely chopping the edible fat materials (generally fat trimmings from meat cuts), heating them and then carrying out two or more stages of centrifugal separation. The separated fat is used in food products or, if in surplus, it is diverted to soap-making operations.

Currently, Australia has two integrated rendering companies (JBS and Nippon Ham) where meat processing and rendering is combined in the same factory. There are 10-12 independent service renderers who take by-products from butchers, small to medium meat processing works, food retailers such as Coles and Woolworths, and process into mainly non-edible by-products. The price for by-products depends on the demand and supply, and is also linked to the number of renders in the region. Most capital cities only have one service rendering operator, although Melbourne has a few.

It is often the case that the supplier (Coles, etc) will pay service renders to collect their by-products, due to the "shelf life" of the product. The cost of rendering (particularly capital equipment, legal compliance and energy) can make the processing of meat by-products expensive. It is also noteworthy that the meat processing suppliers to service renders provide "waste" from chicken, lamb, cattle, and pork. Separation is potential issue in using specific parts of an animal as suppliers will not separate products unless there is a commercial incentive to do so.

According the Australian renders association unless there are significant commercial incentives from the market, producers will not invest in new processes and equipment*. "if you can't show a return of investment within 18month you have no hope".* Both AMPC and the renders association confirm that a lot of past effort (Investigation and research) has embarked on exploring opportunities in and around bone

by-products. In fact, the AMPC currently have a research project with CSIRO investigating how to extract collagen from bone.

Specialized Production

The output from renderers are mainly various grades of tallow and bone meal. It is supplied into various other production and value chains and is used in animal feed, pharmaceutical and cosmetic products, soap and detergents, bakery shortenings, frying oils, margarine manufacture, biodiesel and feedstock.

PROCESSING AND UTILISATION OF BONE BY-PRODUCTS

The processing of green bones and the bone crushing industry produces or enables the manufacture of raw ingredients such as ossein, which can be later converted into gelatin. Other products include dicalcium phosphate, bone glue, bone ash, bone char, neatsfoot oil, and some niche materials for biomedical applications such as bio-actives extracted from marrow and cartilage for use in human reconstructive surgery. Figure 1 below shows the basic types of raw products that can be made from by-products obtained from meat processing. Table 1 details a wider list of end products, uses, industries, and market opportunities for bones from various animals. Globally, these raw products are well known and are currently exploited by industry. In Australia, only a small number of these raw products are being manufactured.

BONE PRODUCTS

Figure 1 – Basic raw products from green (unprocessed) bones. Green bones constitute up to 30% of the live weight of an animal. The following table summarizes major end-products, uses, industries involved and market sizes of bone by-product for various animal types.

Table 1 – List of end products, uses, industries & market opportunities for bones from various animal sources

Animal	End-product	Uses	Industries	Market Size
Cattle	Tallow	Soap making Edible, biodiesel	Cosmetic Food	USD 2.5B in 2016, more than USD 500 M for soaps and detergents[1]
	Bone meal/bone grist	Manure Feed supplement	Fertilizer Animal Feed	In US, 2.3 million metric tons MBM in 2015 from ruminant, porcine, and mixed species[2] Animal based organic fertilizers estimated to account for a market share of more than 50% and be valued at more than USD 3,300 M by the end of 2017, expanding at a CAGR of 7.1% 2017- 2025[3] Animal feed additives market size is likely to generate over USD 25 B by 2024[4]
	Gelatin (technical, edible, pharmaceutical and photographic gelatin)	Printing roller composition Gelatin capsules Jellies in Food Products	Printing, photo Pharmaceutical Food	Global collagen peptide and gelatin market was valued at USD 3,614.1 M in 2016 and is expected to reach USD 9,860.2 M by 2025, expanding at a CAGR of 10.90% from 2017 to 2025[5] Global gelatin market is expected to reach 604.5 thousand metric tons by 2021[6]
	Glue	Adhesive	Abrasive, match and plywood	Growing due to surgical procedures and a reluctance to use synthetic materials[7] Challenges, specifically with animal rights[8] Nth America accounts for >50% of total market ($568m in 2015). Leading companies include Cryolite, J&J, Baxter International.
	Bone ash	Bone china for porcelain wares	Ceramic	Global ceramics market was USD 157.70 B in 2014, housing and construction sector accounting for 40%[9]
	Bone char	Decolorizing Agent	Chemical	
Goat/sheep	Bone meal	Manure, feed Supplement	Fertilizer, feed	
Pig	Bone meal/bone grist	Manure, feed supplement	Fertilizer, animal feed	

[1] https://www.gminsights.com/industry-analysis/tallow-fatty-acids-market
[2] http://pubs.rendermagazine.com/2016-04/pubData/source/Render_Apr16.pdf
[3] https://www.persistencemarketresearch.com/market-research/organic-fertilizer-market.asp
[4] https://www.gminsights.com/pressrelease/animal-feed-additives-market-size
[5] http://www.snjtoday.com/story/37072342/collagen-peptide-and-gelatin-market-size-trends-market-strategies-and-potential-2017-2025-credence-research
[6] https://www.businesswire.com/news/home/20170504005817/en/Gelatin-Market---Global-Forecast-Opportunity-Assessment
[7] https://www.transparencymarketresearch.com/bone-glue-market.html
[8] https://www.grandviewresearch.com/industry-analysis/animal-glue-market
[9] https://www.grandviewresearch.com/industry-analysis/ceramics-market

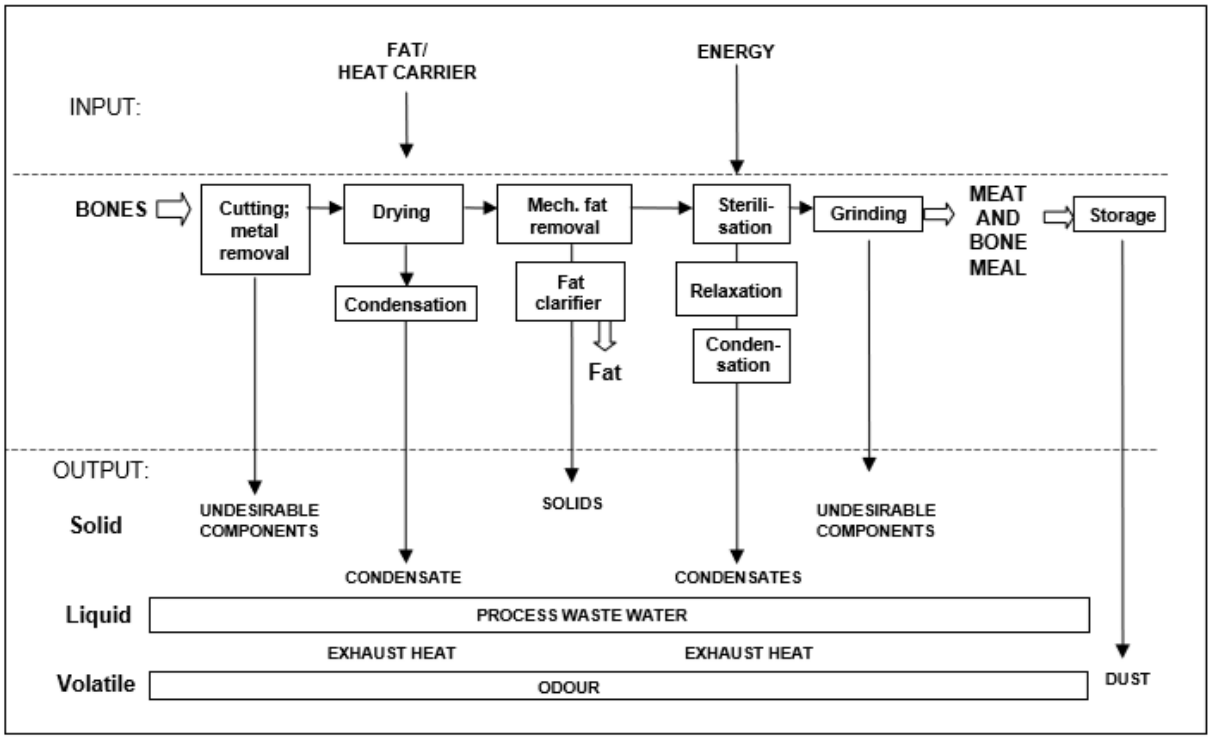
PROCESSING OF GREEN BONES FOR BASIC INGREDIENTS

Meat and bone meal (MBM) are major products of the rendering industry and are typically comprised of 45-52% protein, 33-35% ash, 8-12% fat and 4-7% moisture. Quality tallow can also be recovered from green bones (using solvent extraction technique or simple cooking in water) at an average yield of ~5%.

BONE CRUSHING

Green bones after the recovery of tallow, as well as dry bones, can be crushed in specially designed bone crushers for different end-uses. Figure 2 shows the processing of green bones to produce MBM for use mostly as animal feed, fertilizer, and outside Australia, as a fuel source. Sterilized bone meal together with bone grist is used as a poultry and stock feed supplement. Non-sterilized bone meal can be used as manure for calcium and phosphorus enrichment of grazing lands. Dry bone crushed to standard sizes can also be used in the manufacture of ossein and gelatin.

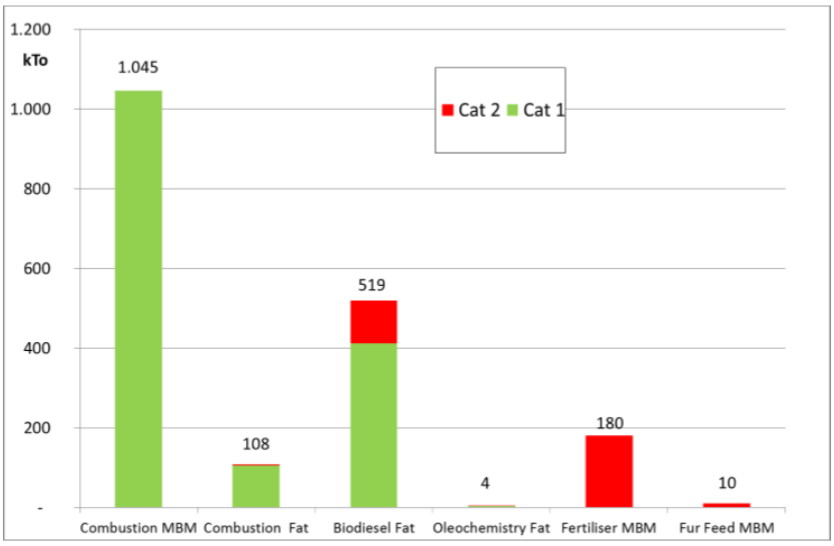
Bone sinews (fibrous tissues), a by-product of bone crushing (yield ~7% of dry bones by weight), are a good raw material for the manufacture of glue either alone or with the fleshing.



Source: http://eippcb.jrc.ec.europa.eu/reference/sa.html (Bone processing (2.2.4))

Figure 2 – Bone crushing to produce MBM

Meat and bone meal (MBM) and Processed Animal Protein (PAP) are primarily used in the formulation of animal feed to improve the amino acid profile of the feed, and as a low-cost meat in pet food sold in the US. This is also the case in Europe, however there has been various shifts towards its use as a fossil-fuel replacement for renewable energy generation in processors such as cement kilns, and then shifts back within a few years [10]. To demonstrate how end uses can rapidly change, the distribution of animal meals and processed animal protein in EU17 in 2005 was: 52% incineration, 23% pet food, and 20% fertilizers. By 2008, the distribution was: 39% incineration, pet food 33% and 24% fertilizers. This shift could partially be because in 2008 the comparison was made within EU20 instead of EU17.[11] However, more likely the growth of the pet food industry and its willingness to pay more for the raw ingredient contributed to the shift. It should also be noted that opportunities in renewable energy have often been made economically viable with the assistance of government subsidies.



Source: http://efprahamburg2017.com/wp-content/uploads/2017/05/Dobbelaere_Overview-on-the-EU-Animal-By-products-Processing-Industry-in-2016.pdf

Figure 3 – Use of category 1 and 2 (Not for human consumption) fat and MBM

According to the European fat processors and renderer association (EFPRA), setting aside niche biomedical opportunities, the highest value mass product that can be made from animal by-products is human food, followed by pet food, animal feed and fertilizer. Biomass and energy substitutes generally have the least intrinsic value from category 1 and 2 by-products.

[10] http://icrepq.com/icrepq%2711/609-ariyaratne.pdf ; http://www.mreuk.com/glanfordfuel
[11] https://helda.helsinki.fi/bitstream/handle/10138/17108/MSc%20thesis,%20Priit%20Tammeorg.pdf;sequence=1

OSSEIN AND DICALCIUM PHOSPHATE

Ossein is the starting material for making the superior grades of gelatin and is derived from good quality animal bones washed, dried, and crushed to standard sizes (approximately 0.5cm) via a demineralization process known as maceration. In the maceration process, the ossein bone chips are treated with dilute hydrochloric acid in a countercurrent operation for about 7 days. During this time, calcium phosphate and calcium carbonate are converted into their soluble forms and are later separated by precipitation. On completion of the maceration, all that is left is the proteinaceous structure framework of the bone. Dicalcium phosphate can also be obtained from ossein and has a yield of ~60%.

Figure 4 – Raw material Ossein

Phosphorus is an important nutrient for both plant and animal growth and is contained within human and animal bones in large quantities. Humans and animals obtain phosphorus through their diet. It is common practice for animal feeds to be fortified with phosphorous compounds. Soils naturally contain phosphorus compounds; the level and composition varies with geological conditions. Soils that are low in phosphorous are fortified with manure and fertilizers derived from rock phosphate to improve productivity. Rock phosphate tends to contain high quantities of heavy metals and requires significant refinement before use. Recovering phosphorus via bone processing rather than refining from rock phosphate has several important advantages including a high level of human and animal digestibility (95%), a safe and traceable product, low levels of contaminants, and is a strong contributor to sustainable livestock production.

GELATIN

The ossein produced from bones could be further processed to make various grades of gelatin with a yield of ~50% of the ossein (15% yield of dry bone). The processing technique will vary according to the type of gelatin being made. Low-grade gelatin is used in the manufacture of printing roller composition, as sizing agent in the textile and paper industries, in the clarification of wines, and in ore flotation composition. Edible gelatin is used in the production of ice creams, soft chocolates, jellies, marshmallows and similar food products. Pharmaceutical gelatin is used as a binder for soft and hard capsule coatings and in syrups. Photographic gelatin, which is a much superior grade, is required as an adhesive, a thin film and a protective colloid for halide ions in photographic films.

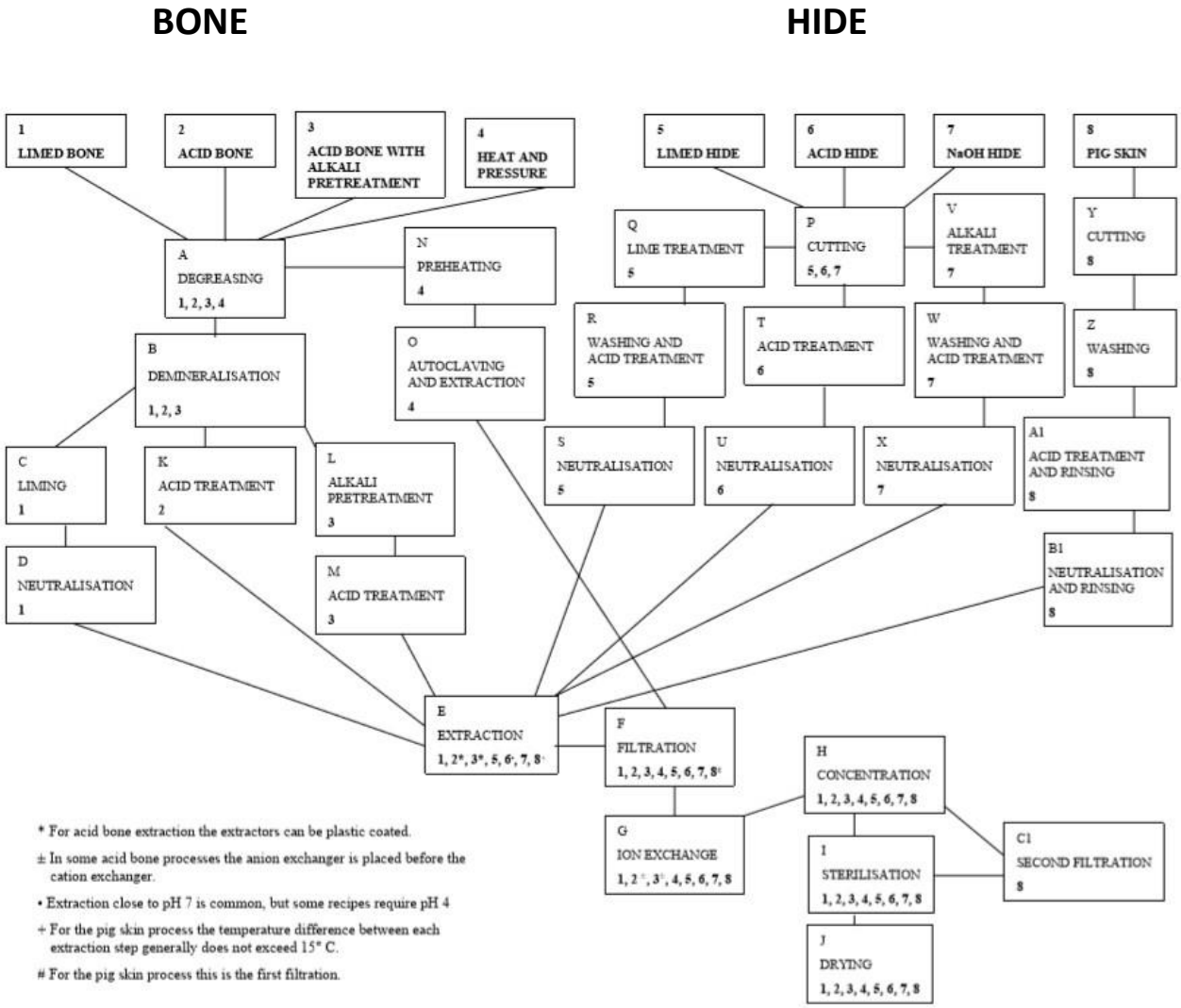


Figure 5 – Bone and Hide Product flow processing stages

Source: http://eippcb.jrc.ec.europa.eu/reference/sa.html (Gelatin manufacture (Section 2.2.6), 1-4 are from bones)

BONE GLUE

Green or dry bones can also be used for making bone glue for use in human and veterinary surgery, through a process of direct extraction under pressure. In the case of green bones, the tallow could also be recovered. The bones are crushed, and the tallow extracted either by means of organic solvents or by boiling with water, after which the glue is extracted under pressure. The yield of glue is ~16-20% on the dry bone weight. As an opportunity, bone glue is relatively small and niche. In 2015, the global bone glue market was valued at US$ 568.9 Mn but represents a profit opportunity of US$ 30-40 Mn. The US accounts for over 50% of the world market, with the applications shown below in Figure 6.

Figure 6 **–** World bone glue market applications.

BONE ASH

The deproteinized bone residue left after the extraction of glue is an ideal raw material for calcinating and conversion into bone ash for bone china. The yield of bone ash from deproteinized bone is ~75-80%, or ~60% from dry bone weight. Bone ash is a white material produced by the calcination of bones. Heating bones in an oxygen-rich atmosphere gives bone ash, which is chemically quite different from bone char.

Uses of bone ash include:

- Bone china
- Fertilizers
- Machining – as polishing compounds, protective powder coatings for metal tools, and as sealant for seams and cracks
- Metallurgy – often used in cupellation (a high temperature refining process to extract noble metals such as silver and gold)

BONE CHAR

Waste bones that are unsuitable for ossein production (such as the head and scapula bone), cooked bones and any other bones of granular nature are suitable to produce bone char. The process involves carbonizing the bones at high temperature in the absence of air. The yield of bone char as a decolorizing agent is in demand for the sugar industry. Bone oil, bone tar and ammonia are the main by-products obtained during the processing of bone for bone char. The bone oil is used as a drying oil by many industries, particularly the paint industry.

The bones are heated in a sealed vessel at up to 700 °C; a low concentration of oxygen must be maintained while doing this, as it affects the quality of the product, particularly its adsorption capacity. Most of the organic material in the bones is driven off by heat, and was historically collected as Dippel's oil; that which is not driven off remains as activated carbon in the final product. Used bone char can be regenerated by washing with hot water to remove impurities, followed by heating to 500 °C in a controlled atmosphere.

Uses of bone char include:

- Water treatment – the tricalcium phosphate in bone char can be used to remove fluoride and metal ions from water
- Sugar refining – as a decolorizing and deashing agent
- Black pigment
- Niches uses – to refine crude oil in the production of petroleum jelly

NEATSFOOT OIL

Neatsfoot oil is a yellow oil rendered and purified from the shin bones and feet (but not the hooves) of cattle. It is in demand for dressing leather and as a lubricant for delicate machinery in the textile industry. The neatsfoot stock is obtained by boiling the cattle feet in indirectly heated steam kettles. About 300 to 500 ml of oil can be obtained from good quality shine bones of one animal.

Work in this area has been conducted at CSIRO - CSIRO "Recovery of Neatsfoot Oil" project including detailed process and cost analysis. This report indicates that a >30% ROI is possible with a retail price of 1000 AUD/tonne. Current retail price is 2000-4000 AUD/tonne[12].
http://www.meatupdate.csiro.au/data/Waste_Management_15-76.pdf.

OTHER BIOMEDICAL APPLICATIONS

The bio-actives in bone marrow have also been used in the treatment of human blood disorders. Bone cartilage and bone fragments are used as substitutes for diseases or damaged human tissue parts (xenotransplantation). For example, specially processed cartilage from the breast-bone of young cattle is used by plastic surgeons to replace facial bones in humans. There is a wide range of work occurring in biomedical application across the globe in a research setting and will be discussed in later sections. Some of these efforts may provide interesting value add opportunities, however they are unlikely to make a significant impact on the volume of animal waste in Australia.

[12] https://www.shopbot.com.au/neatsfoot-oil/price/australia/827981

ECONOMICS

The following table sets out returns on end products from 1,000 kg of green bones from cattle/buffalo. Simply by recovering the tallow, and then processing the bones for gelatin, the returns from these two end-products represents approximately ten times the value of the raw bone.

Product/end-product	Yield (%)	Total quantity (kg)	Price (US$/kg) (as of 1989)	Total value realizable (US$)	Current price	Adjusted total value realizable (US$)
Green bones	-	1,000	0.02	20.0		
Tallow from 1,000 kg of green bones	5	50	1.00	50.0	797.43 – 848.75 AUD/tonne (less than 4%FFA – less than 1% FFA)[13] (~650 USD/ton)	~32.5
Dry bones from 1,000 kg of green bones	35	350	0.10	35.0		
Crushed bone, bone meal and bone grist from 350 kg of dry bones	93	325	0.15	49.0	616.02 AUD/tonne (50% protein MBM)[14] (~500 USD/ton)	~162.5
Bone sinews from 350 kg of dry bones	7	25	0.10	2.5		
Glue from 25 kg of bone sinews	30	7.5	1.50	11.0	1-5 USD/kg[15] (= 1000-5000 USD/ton)	7.5-37.5
Glue from 325 kg of crushed bone (by direct extraction)	16	52	1.50	78.0		52-260
Ossein from 325 kg of crushed bones	30	97.5	0.80	78.0	250-1200 USD/metric ton[16]	24.375-117

[13] 2017 MLA data
[14] 2017 MLA data
[15] https://www.alibaba.com/product-detail/Industrial-Bone-Glue-for-Making-Hard_60041815360.html?spm=a2700.7724838.2017115.32.1199e4b60TH0y5&s=p
[16] https://www.alibaba.com/product-detail/Cattle-Ossein_133372645.html?spm=a2700.7724838.2017115.15.1199e4b60TH0y5

Dicalcium phosphate (DCP) from 325 kg of crushed bone	60	195	0.15	29.0	298-340 USD/ton (feed grade)[17]	~58.5
Gelatin from 97.5 kg of ossein	50	49	2.5	122.5	3000-6000 USD/metric ton (food grade)[18]	147-294
Bone ash for bone china from 273 kg of deproteinized bone	80	218	0.40	87.0	700-900 USD/metric ton[19]	152.6-196.2
Bone char from 325 kg of dry crushed bones	50	162.5	0.40	65.0	900-950 USD/metric ton[20]	~150

[17] https://www.alibaba.com/product-detail/Cattle-Bone-Dicalcium-phosphate-for animals_60548580979.html?spm=a2700.77248580979.html?spm=a2700.7724838.2017115.17.1199e4b60TH0y5

[18] https://www.alibaba.com/product-detail/250-Bloom-Halal-Animal-Gelatin-Glue_60674079647.html?spm=a2700.7724838.2017115.1.1199e4b60TH0y5&s=p

[19] https://www.alibaba.com/product-detail/The-Best-Bovine-Bone-Ash-or_60449557686.html?spm=a2700.7724838.2017115.27.1199e4b60TH0y5

[20] https://www.alibaba.com/product-detail/Feilong-manufacturer-supply-Natural-Bovine-Bone_60462203250.html?spm=a2700.7724857.main07.9.231d3b63TqCHMm

EMERGING RESEARCH OPPORTUNITIES

This section takes a future-looking perspective by detailing some interesting areas of early research that could produce exciting business opportunities for the utilization of red meat bones. Some of the areas detailed include; Bioplastics from MBM, Biodiesel from tallow, hydroxyapatite (HAP) for biomedical applications, and conversion to edible products such as collagen.

MBM for bioplastics

Researchers at Clemson University, USA have developed a process for mixing MBM with ultra-high molecular weight polyethylene (UHMWPE) and showed that the MBM/UHMWPE plastic is almost as durable as UHMWPE with the bonus of being partially biodegradable. Any BSE infectious agents were deactivated.[21]

Biodiesel from tallow

Animal fats and tallow (mostly inedible tallow, choice white grease and some poultry fat) have been consistently used as a biodiesel feedstock since 2008 in the USA. Reasons supporting this use include availability, eligibility as biomass-based diesel fuel and generate RINs under the Renewable Fuel Standard, and their price advantage over vegetable oils. The shift in use towards biodiesel production has had a beneficial impact and generated additional revenues stream for the livestock industry. However, as previously discussed, the biodiesel opportunity has generally been heavily subsidized by Government and more sustainable uses for traditional waste are more aligned to human and pet food applications.

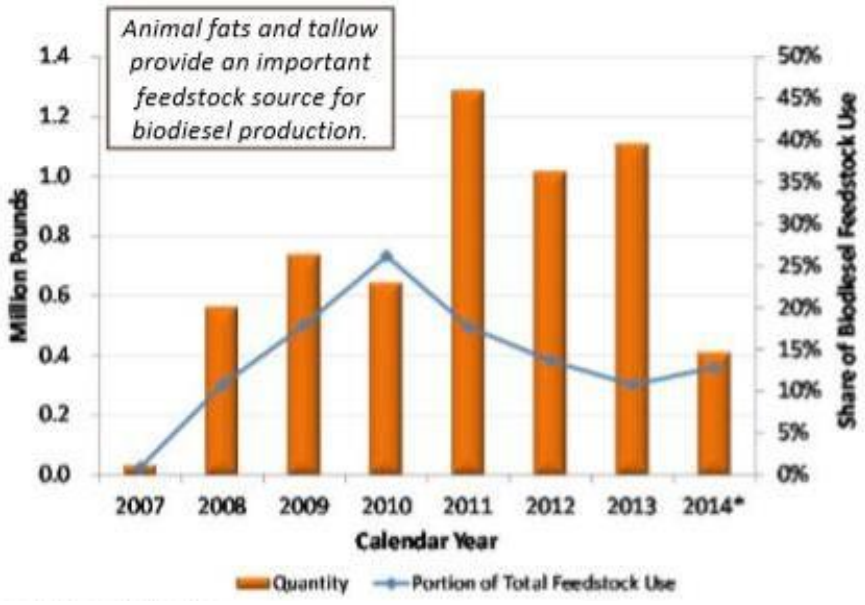


Figure 7 – Share of animal fats as a biodiesel feedstock 2007-2014 in the USA.

Source: http://biodiesel.org/docs/default-source/news---supporting-files/animal-fats-and-tallow-bd-demand-impact-report.pdf?sfvrsn=2

[21] https://eponline.com/articles/2011/03/28/researchers-transform-bone-meal-waste-into-partly-biodegradable-plastic.aspx

Animal-bone derive hydroxyapatite (HAP) for biomedical applications

HAP has wide chemical and biomedical applications, e.g. as an absorbent, a chromatographic packing material, a catalyst, a catalyst support, an enzyme immobilization substrate, and as a bone graft substitute material for applications such as dentistry, orthopedics and aesthetic surgery.

Animal bones from meat processing, from countries such as Australia and New Zealand where the incidence of BSE or other serious animal maladies like Foot and Mouth Disease is non-existent, could provide a niche market as a potentially valuable local source of extractable HAP. It is accepted that animal bone-derived HAP has better bioactivity (e.g. osteo-conductivity) than synthetic HAP. The bone-derived process may also have the advantage of allowing high yield, in contrast to other synthetic processes.

Preparation methods include: bone calcination thermal decomposition; bone treatment at elevated temperatures with sodium hydroxide solution/alkaline hydrolysis; critical water process; acid hydrolysis; and bone treatment with water or sodium hydroxide under hydrothermal conditions.[22] An exemplary process begins with obtaining fresh animal bones and removing any soft tissues still attached. Subsequent thermal treatment is used to remove internal contents, water, and ensure that disease-causing agents are eliminated. Afterwards, remaining materials are crushed to a fine HAP powder.

A xenograft, a tissue graft or organ transplant from a donor of a different species from the recipient was recently developed from New Zealand sourced bovine cancellous bone by a successful defatting and deproteinizing procedure[23]. It has also been reported to use animal bone-derived HAP as a feedstock for forming plasma sprayed coatings on biomedical implant materials[24]. Animal-bone derived hydroxyapatite in biomedical applications, by Michael Mucalo[25], offers a detailed range of other applications.

Conversion of bone to edible products

The Lensfield processes[26] have been developed which enable fresh bone to be fractionated into its constituents (protein, fat, calcium phosphate) in forms which are suitable for use as food ingredients. In fish for example, the Lensfield processes extract useful protein and phosphate from the bones in de-boner waste giving yields of about 24% and 13% of the protein and phosphate preparations respectively. In the Lensfield processes, all material is first size reduced and defatted by a centrifugal washing. There follow two alternative process options as shown in figure 8. In the cooking process, the defatted bone is pressure-cooked and hydrolysed collagen extracted leaving a residue of bone phosphate. In the alternative 'acid' process, the defatted bone is steeped in cold dilute hydrochloric acid which dissolves the bone mineral and leave behind native bone collagen. Di-calcium phosphate is recovered as a by-product of lime treatment of the spent acid.

[22] https://www.researchgate.net/publication/43225772_Preparation_of_hydroxyapatite_from_animal_bones
[23] http://onlinelibrary.wiley.com/doi/10.1002/jbm.b.33644/abstract;jsessionid=57F9D758C5151966432B32825783D6A4.f03t01
[24] https://www.ncbi.nlm.nih.gov/pubmed/20803443
[25] Prof Mucalo, University of Waikato http://sci.waikato.ac.nz/about-us/people/mucalo
[26] The complete book on managing food processing industry waste, Dr. H. Panda, Asia Pacific Business Press Inc., 2011 (Chapter 9)

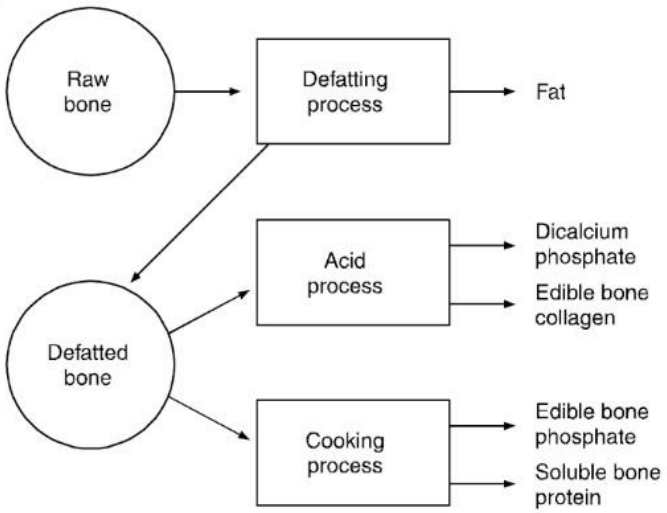


Figure 8 **–** Lensfield process options to extract useful edible products

From Figure 8, the possible products include:

- Edible bone collagen: secondary source of animal protein in comminuted meat product, alone or in combination with blood/plasma proteins.
- Soluble bone protein: a neutral bone collagen hydrolysate, for use as an ingredient in soups, sauces and gravies and for protein supplementation of meat products; also of interest as an ingredient in reaction flavor processes to produce new ranges of improved meat flavours.
- Edible bone phosphate: a natural source of calcium and phosphorus in the correct ratio in health foods, pharmaceutical and veterinary products in the form of tablets; as a free-flow additive in powdered food products such as salt, sugar and powdered fruit drink concentrates. This product also contains some useful trace elements, particularly fluorine and zinc.

RENDERING AND THE MEAT PROCESSING INDUSTRY

The Australian Renderers Association (ARA) is the national body within Australia which presents the interests of producers and traders of rendered products – meat and bone meals and tallows – at the State and Federal government levels and facilitates trade in rendered products domestically and internationally. The European Fat Processors and Renderers Association (EFPRA) represents the European animal by-product processing sector. Its objective is to continually improve the safety, security and sustainability of European food production by efficiently processing animal fats and other by-products.

In Australia, bone by-products within integrated plants are either sold to overseas markets as packaged bone in boxes, cooked into tallow or into bone meal. Market forces will dictate which of the three products processors will focus on. Some large processors offer a wider variety of products than just tallow and MBM, but is not much broader than bone meals and bone chips.

Some boning rooms have an ability to separate by-products into high value low value products, however

that does not appear to be common practice. Service rendering, which is highly prevalent in Australia, produce 50% bone meal, protein and non-editable Tallow of which 50% currently is exported to bio-fuel in Singapore (340 MT). Several processors send their bones to specific processing plants, such as those run by JBS and Nippon. Monbeef rendering products is currently directed towards animal food (mainly chickens).

It is interesting to note that CJ Nutracon, a manufacturer of beef stock and beef leg bone extract, have faced challenges in achieving efficiencies in the local Australian market. The most significant challenge has been gaining access to a secure supply of bones. Local meat processors do not have adequate freezer facilities to store the bones, so prefer to process bones on-site by placing them onto on-site cookers to produce MBM. This highlights a challenge in achieving success in any new business venture in Australia. It will be vital to ensure that the value chain is consulted, and joint benefits can be attained. Capital investment and current infrastructure will be another key consideration.

PREVIOUS MLA INVESTMENTS

This section identifies past MLA projects that are relevant to the current review. These may be useful cross-references and to assist determine future areas of investment.

Coextraction of chondroitin sulphate and collagen

Development of an efficient means of extracting and refining Chondroitin Sulphate pharmaceutical grade (95%) and collagen II from the trachea and scapula blade cartilage of beef and sheep at commercial volumes (4000kg/month)[27]. Results on solvent free extraction of chondroitin sulphate derived from cartilage were reported in another project[28]. The laboratory scale processes had a forecast lower cost than current manufacturing and could aid market entry without sacrificing margin. This project may have relevance to a general "collagen" opportunity reported later.

High value natural flavour compounds from red meat

Forefront Ingredients Ltd undertook a project with MLA to develop a modular meat and bone stock production technology designed to produce high quality products for the domestic and export markets. The process involved the extraction of protein material from both red meat and bones to produce valuable high quality flavourings and use by-products, such as sheep placenta, to produce cosmetic/nutraceutical ingredients[29]. During the project, beef extract and sheep placenta products were manufactured on a pilot scale and then validated in the market with acceptance of the product by end customers. Processes were developed for producing beef extract and bone stock for use as food ingredients that demonstrated at 1,000L scale. A process was developed for the manufacture of dried placental extract. Market feedback on trial samples showed the products to be commercially viable. A

[27] https://www.mla.com.au/research-and-development/search-rd-reports/final-report-details/Develop-New-Products/Coextraction-of- Chondroitin-sulphate-and-Collagen-2/2757 (only two reports are available – a patent search on "extraction and uses of collagen" and a report summarizing the relevant patents and potential issues and opportunities)

[28] http://www.mla.com.au/research-and-development/search-rd-reports/final-report-details/Develop-New-Products/CSEP-Solvent-free- extraction-of-bioactives-CSIRO/2759

[29] https://www.mla.com.au/research-and-development/search-rd-reports/final-report-details/Develop-New-Products/High-value-natural- flavour-compounds-from-red-meat/2762 (no details on how bone stock was produced were found in the final report)

modular plant was designed for beef and placenta extract production. The project was later terminated by mutual agreement due to difficulties sourcing partner funds for the final stage of the project.

Powdered meat proof of concept

Five red meat co-products, being bone, lung, hide, blood and meat trim, were evaluated for stabilizing microbiologically through moisture reduction. This process utilized an innovative adaption of a fluid energy mill that incorporated a mechanical rotor as the supply of fluidizing energy. Lung, hide and blood were found to process effectively and were recommended for further assessment. Larger sized trials on trim and bone also were successful with desirable powdered profile < 10 um[30]. While there are aspects of this process that are not well characterised or optimal, its ability to dry blood at under 60 °C, from 80% to 10% moisture resulting in a water activity of 0.5 (below dried fruit or honey), in less than one second, is unique and worth exploiting.

Another project sought to identify potential milling technologies that would be appropriate to the production of stabilized dry or semi-dry powders, from raw materials which might include blood, bone, skin, trimmings, internal organs, glands and waste streams.

In a further project to develop powdered meat prototypes derived from food grade by-products typically produced in Australian abattoirs (trimmings and bone destined for pet food and/or rendering), a patented (WO2011108920) bone hydrolysis process was used (see exemplary patents for more details). The hydrolyzed/extracted material required no heat addition for milling and drying and was produced as a fine off-white powder, with very encouraging results, indicating the milling/drying system could have the capacity to remove the moisture from the average abattoir bone production (approximately 1,500 kg/hr based on an average abattoir processing 425 cattle per day and bone being around 15% of the average carcass weight of 325 kg. It may be a potential source of phosphate for fertilizer production, which may be recovered by solubilization and ion exchange removal of the calcium. Or if the bone does remain as hydroxyapatite, then its potential use as a coating for metal implants may be an option.

Other relevant projects & reports under a bioactives initiative:

Strategies to identify and develop bioactive peptides in meat and bone meal (A.COP.0047) – initial findings support proof of the principle that MBM contains growth-positive protein-derived bioactive agents[31].

Tallow enhancement (A.COP.0073 & A.COP.0067) – a literature and patent review to investigate value-adding opportunities for beef and sheep tallow by identifying feasible processes for converting tallow to healthier oil and for extracting significant flavor compounds from crude or fractions of tallow. However, it was not felt that a persuasive business case existed to support the proposed research. See also: EU regulatory and market access expert briefing (A.COP.0034) – some related to MBM Coproducts workshop (A.MQA.0018) – see page 279 chart “co-products targets for value adding”.

[30] https://www.mla.com.au/research-and-development/search-rd-reports/final-report-details/Develop-New-Products/Powdered-meat-proof- of-concept/2776

[31] http://www.mla.com.au/research-and-development/search-rd-reports/final-report-details/Develop-New-Products/Non-red-meat- bioactives-and-co-products-publications-and-communication-material/2774; http://www.mla.com.au/research-and-development/search-rd-reports/final-report-details/Develop-New-Products/Support-activities- bioactives-and-co-products/2783

NEW OPPORTUNITIES TO EXPLORE: INTERESTING COMMERCIAL OPERATIONS

Coctio

www.coctio.com

Finland company **Coctio**, founded in 2014, by chef-turned entrepreneur Kailiskola, offers a comprehensive value-added solution that delivers 100% yield of converting animal bone residue into valuable commercial products. Coctio targets food manufacturers, meat and fish processors, food service operators, as well as the rendering and biotech industry. Coctio addresses the growing trend for healthy and natural, non-processed "raw" foods. Products that the Coctio model and processes target include bone broths, sauces, stocks, and marinades, bouillons, and soups. Waste materials from these products can also be separated and dealt with in the Coctio manufacturing line and converted into the following commercial end products; Industrial fat, dry pet food, compost material and fertilizer, heat energy feedstock, and gelatin.

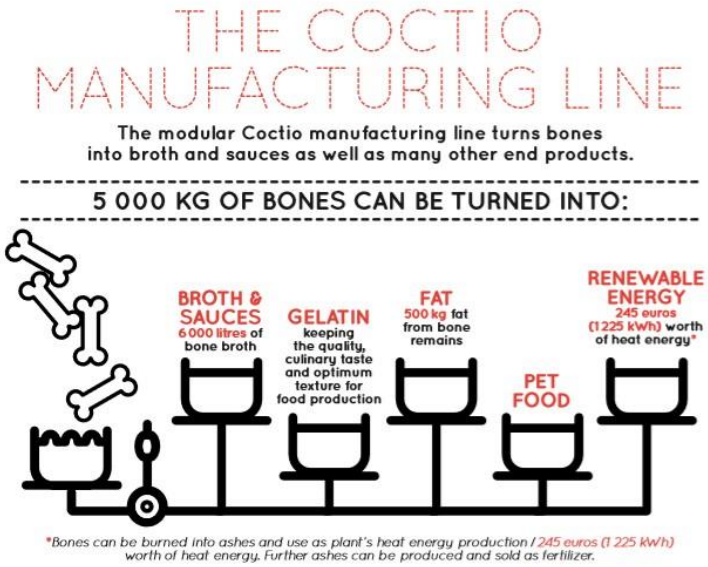


Figure 9 – Coctio product offering

Equipment: http://www.coctio.com/bone-broth-manufacturing-line-equipment
Process: http://www.coctio.com/get-overview-for-coctio-bone-broth-manufacturing-line
Economics: http://www.coctio.com/how-much-income-your-business-gets-by-using-coctio-method

Sonac

www.sonac.biz

Sonac is a Dutch Company affiliated to Darling Ingredients since 2014, and is operating in Maryborough, Victoria. The company has a unique residuals-to-resources concept and develops specialty ingredients from raw materials of animal origin. They engage heavily in R&D which has produced varied applications of animal by-products and places them among the world's most diverse animal products company. Their portfolio of products includes derivates from blood, bone, and proteins for feed, pet food, and functional purposes, and feed minerals. Bone derived products include;

- Food grade
    - Calbon N – a natural ossein hydroxy-apatite for use as a calcium and phosphate supplement. It contains all ingredients necessary for healthy bones: 32% calcium, 14% phosphorus and 10% protein.
    - BP 85 – a multifunctional ingredient derived from porcine origin collagen with a high level of protein and a low content of fat
    - ValoColl – a high functional porcine collagen with excellent emulsifying properties, a strong gel forming capacity and stable product characteristics
    - Hydro P Premium – a food grade hydrolyzed collagen (type I collagen). In the production process the collagen is heated to a liquid phase and extracted. After a filtration and further concentration step the enzymatic hydrolysis takes place. The liquid product is then sterilized, spray dried and packed for delivery to the customer.
- Feed grade
    - Calfos – natural bone hydroxy-apatite phosphate. It is produced from animal bones that have been crushed and degreased. The bone chips are further processed by a heat-and- pressure treatment. The gelatin is removed and the remainder is dried and finely ground to improve the digestibility.
    - Delfos – natural dicalciumphosphate-dihydrate (DCP:2H2O) of bovine or porcine origin. It is produced from animal bones that have been crushed and degreased. This material is left during 5 days in a HCl solution to dissolve the gelatin and bone phosphate.
      Gelatin is separated and the remaining phosphate is carefully precipitated.
- Technical grade
    - Bone ash
    - Bone ash mc – useful value adding tools in non-ferrous metals casting industry, e.g. as a superior protective coating to increase working life of launders, moulds and equipment
    - Technical gelatin (bone glue) – essential aid for electrolysis, e.g. to improve the homogeneous growth of copper crystals to the cathode

Terra Humana

Terra Humana Ltd.

www.3ragrocarbon.com
http://www.3ragrocarbon.com/sites/default/files/downloads/terra_humana_company_info.pdf

Terra Humana Ltd. is a Swedish origin eco-innovative technology development and industrial engineering organization, one of the leading international pyrolysis technology, biochar, bio-phoshate and carbon-refinery knowledge centres. The company has a focus on phosphorus recovery and biochar industrial production.

The Animal Bone bioChar (ABC) BIO-PHOSPHATE product is a recovered organic phosphorus fertilizer, produced from food grade category 3 animal (pig and poultry) bones between 600 °C – 850 °C reductive thermal processing and under advanced zero emission environmental performance ("3R" Recycle- Reuse- Reduce technology – a European Commission priority selected R&D program since 2002). ABC contains ~92% calcium-phosphate (with 30% P_2O_5). Its applications are organic fertilizer, soil improver, growing medium and/or fertilizing product blend.

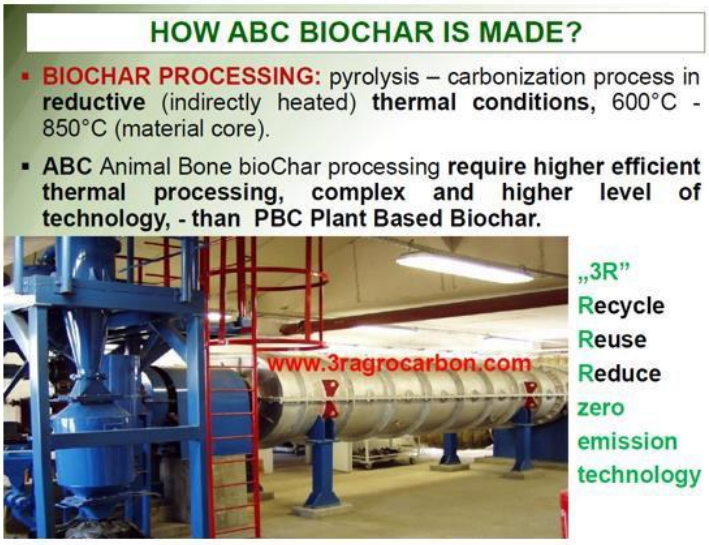


Figure 10 – Tera Humana biochar process

Business opportunity: http://www.3ragrocarbon.com/business-opportunities

NH Foods

http://www.nh-foods.com.au/sales/beef-by-products/

NH Foods Australia is a wholly owned subsidiary of the NH Group, a publicly listed company and Japan's leading company in the fresh meat, ham and sausage industry. All of the NH Foods Australia processing facilities have on-site rendering plants which produce several in-demand by-products including:

Meat & Bone Meal	**30,000mt per annum**
Blood Meal	2,000mt per annum
Tallow	45,000mt per annum
Bone Chips	1,200mt per annum
Concentrated Gall	30mt per annum
Beef Bone Extract	500mt per annum

CJ Nutracon

www.cjnutracon.net

CJ Nutracon, part of CJ Group, a major conglomerate with market leading brands in Korea's food, biopharmaceutical, entertainment, media and home shopping sectors, was established in 2006. CJ Nutracon specializes in the manufacture of enzyme hydrolyzed beef stock, beef leg bone extract and other meat extract products at their Toowoomba based plant, close to cattle processing plants in south east Queensland and northern NSW and to eastern Australia's feedlot industry. A large proportion of their liquid beef extract is exported back to its parent company CJ Foods in Korea, where it is combined with other ingredients to manufacture a popular powdered beef stock called "Dashida", one of the biggest selling beef-flavour enhancers available in the Korean market.

The factory has grown to become a recognized global leader in stock production, exporting real beef stock, beef leg bone extract and other meat extracts to customers in China, Taiwan and the United States, and is also looking to expand its range of customers within Australia.

EXEMPLARY PATENTS

In general, the opportunity for registering intellectual property in making high value products from bones would be strategic and specific. The knowhow of extracting, modifying, and processing raw ingredients into a finished product appears to be mostly kept as a trade secret. New products would likely take the same path and not register patent applications. Registering intellectual property requires some level of disclosure that may not protect a competitive position. However, it is recommended that professional patent advise is consulted at all stages of exploiting an opportunity. Decisions about the protection and management of intellectual property in this area may occur in the design and use of processing equipment, packaging design, product logos, colours and marketing designs.

Broth

EP2484231 METHOD FOR PRODUCING AN INTERMEDIATE PRODUCT FOR THE FOOD INDUSTRY FROM SLAUGHTERHOUSE BY-PRODUCTS (NIENSTEDT GMBH)

- producing intermediate products for the food industry from slaughterhouse by-products in the form of bones, non-usable flesh and offal components, preferably for producing products for preparing flesh-, fish- or poultry broths

Food ingredient

WO200400669 4 A METHOD OF PROCESSING ANIMAL BONE (BOOYSEN CHARLES)

- minced bone product produced by cooling, breaking, mincing and grinding, for use in the production of processed meat product such as baloney
- a suitable alternative or complement ingredient to mechanically deboned meat currently used in the meat processing industry
- the process of the invention can produce about 20-25 thousand kg of product per day and the entire cycle takes about 30 minutes
- at least 80% of the 460,000 kg of bone yielded daily during slaughtering of animals can be recovered and processed for human consumption by means of the method of the invention

Extraction of components/nutrients

WO2011108920 METHOD FOR PREPARING A PROTEIN EMULSION (MEATCO BV)

- preparing a protein emulsion from bone material by enzymatic hydrolysis
- the protein emulsion obtained can be used as food product or as semi-product in the production of foods or medicines

Among the entities in the previous sections:

- No published patents/applications were found by Coctio and Sonac on bone processing and products.
- Edward Someus of Terra Humana holds 8 patent families, of which two are relevant to biochar production, US5194069 “Method and apparatus for refinement of organic material” and US5261936 “Gas treating apparatus”, both expired now.
- CJ holds 4 patent families related to beef stock and extract from bones, with active filings only in KR.
- Michael Mucalo is named as a co-inventor on 5 patent families related to bone-derived biomaterial or implant.

CONSUMER MARKET INSIGHTS

Cattle by-products constitute between 20-30% of the live weight of an animal, but in their unprocessed state they are only worth 10-20 percent of the total value of the animal. This report provides a high level exploratory overview of the trends and opportunities that exist around cattle bone by-products and identifies opportunities to create high value bone-based products.

The methodology used combines stakeholder interviews with industry trends to produce high level opportunity themes. To get a sense of themes relative to by-products and the value chain they have been plotted on a two-dimensional matrix.

Based on qualitative interviews and emerging trends gathered along the value chain the research finds that there is likely to be opportunities around:

- As **people get older** they produce less collagen, which in turn leads to weakened bones, joints and ligaments. Early research shows promising signs that collagen hydrolosate can address some of these ageing issues.
- **High performance sportspeople** need protein to build muscle mass and for recovery. Trends indicate this segment prefers high protein concentrated foods rather than protein sourced via supplements. There is an opportunity to provide products with high concentration of natural animal protein that can be taken as part of their daily food intake.
- **Pet food owners** appears to be willing to increase their spending on premium food for the wellbeing of their pets. The by-products industry can work with the pet food industry to provide safe and highly nutritional products.
- **Health conscious consumers** are now demanding natural and organic food. This creates opportunities to provide a variety of products in the form of food ingredients, broths, gelatin and protein snacks that are chemical free, organic, and low in sodium.
- **Environmentally aware people** are increasingly demanding products that are good for the environment. **T**here appears to be large scale opportunities in and around bio chemicals, bio plastics, bio fuels and, in general, environmentally friendly bio production.
- **Production Processes.** Processors delivery large amounts of By-products to Renders in *"one big mess"* and opportunities exist around By-product separation processes that makes downstream production effective and efficient.

It is recommended that a deeper exploration of the opportunities listed above is conducted to better understand the viability of the opportunities in the value chain and how the business models will impact customers, distributors, processors, developers and investors.

Methodology

In line with design thinking methodology, the objectives for this project were to address and assess market and business models required for solution delivery (Viability). Development and viability (to all players in the value chain e.g. customers, distributors, processors, developers, investors) of the business model used to deliver the solution are critical to adoption/commercial success of the project. This project offers a

high-level exploration of trends and opportunities in the cattle bone by-products. The project uses a combination of expert views, stakeholder and consumer interviews along the value chain and combines that with analysis of industry reports, research papers and industry trends. In total, eight interviews were conducted with: a **nutritional health researcher**, an **elite sports researcher**, **three teenagers and sport enthusiasts**, a **middle-aged executive** (having lunch), a **meat processing QA manager** and an **executive from the Australian Renderers Association**. Descriptive and interpretive analysis was then used to categorise observations from interviews and combine those with trends to produce high level opportunity themes that are loosely plotted in a two-dimensional observation matrix. Note any references in this section can be found in the Further Readings sections of this document.

Trend and opportunity matrix

The trend and opportunity matrix outlined below is a thematic plotting of observation from interviews, industry reports, research papers and trend scanning. The themes are plotted in an observation matrix that loosely identifies the value chain and edible and non-edible products.

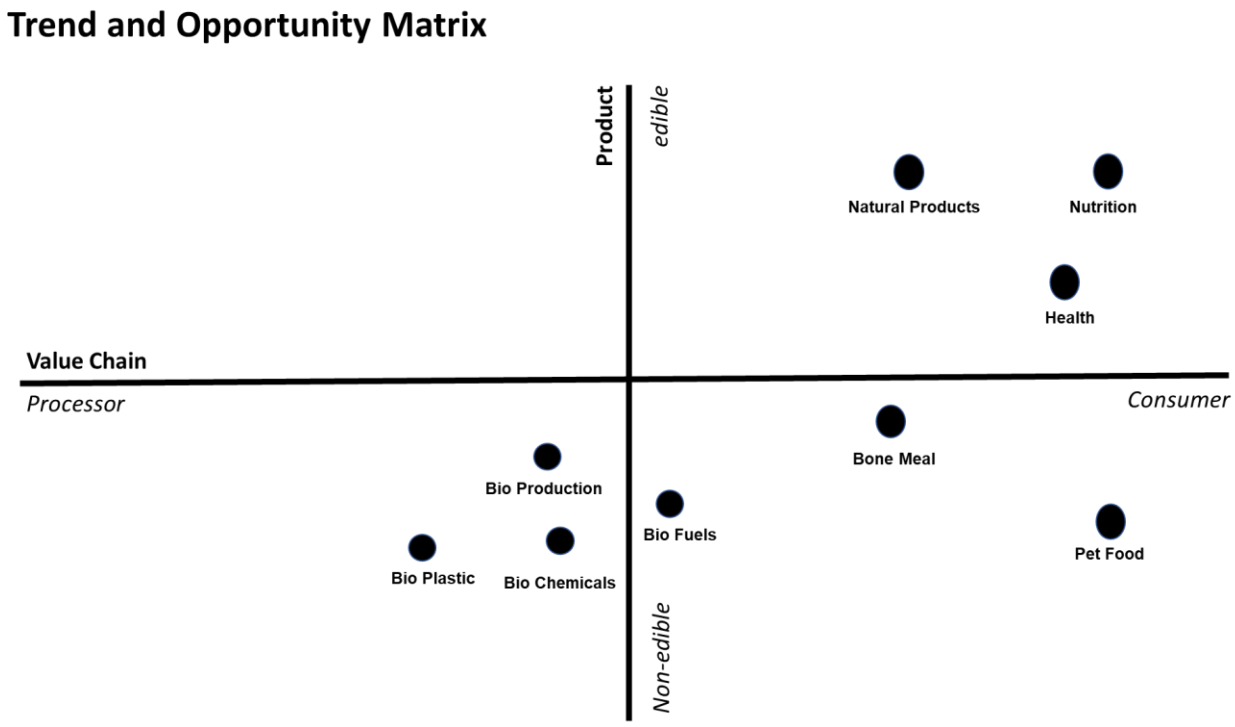


Figure 12 – Trend Opportunity Matrix

Health

Bones, horns and hooves are converted into protein hydrolysates products that have special application in sports medicine. The consumption of protein hydrolysates products allows amino-acids to be absorbed by the body more rapidly than intact proteins, thus maximizing nutrient delivery to muscle tissues. Also, according to a health expert, collagen is the*: "new kid on the block".* Collagen is extracted from

cartilaginous substances, including hides, bones and horns, with a large amount found in cattle ears and feet. Collagen by-products provide the raw materials for industrial processing and export into products such as skin care cosmetics, keratin, gelatin and as a tissue and bone agent in high performance sport.

Insights

- There is extensive research (See references 6, 9, 25, 26, 41, 54, 60, 71) to understand how collagen can improve human health. Collagen has proven to have properties for tissue, bone and ligament building and research shows that collagen combined with 30 minutes of exercise can significantly improve bone and ligament tissue. This goes in line with international research, which, apart from the benefits in tissue, bone and ligament building, has attributed benefits in recovery from resistance training and cardiovascular exercise and counteract signs of natural aging.
- The Australian Institute of Sport (AIS) is looking at collagen and its impact on building tissue in high performance athletes. This research uses a high-quality protein gel from GELITA for its analyses. Our interview revealed that AIS would like to work with Australian companies and MLA to develop products based on Australian sources of collagen.
- As people are getting older, there will be a need to increase muscle strength and bone strength as well as a need to keep tendons flexible. This will require different protein products than what is currently available on the market, which opens a potential very large opportunity for the Australian industry.
- GELITA, who was mentioned several times in our interviews, is a global leader in the manufacturing of collagen and various types of gelatin for diverse applications. This company according on a rendering executive: “uses a completely different process compared to typical Australian renderers”.
- Two of the people interviewed referred to GELITA and how protective they are of their products and production facilities: “they use a completely different process which is not a typical rendering process and all visitors must sign NDA’s before entering their manufacturing plant”.
- The Collagen Research Institute in Germany is an example of the interest that collagen has aroused within the medical community. They have partnered with GELITA to develop products that are distributed and sold as a medical product, not retail.

Health is an opportunity for MLA to explore as there is extensive research that confirms the benefits of collagen due to its attributes that improve tissue, bone and ligament building, benefits in recovery from resistance training and cardiovascular exercise and special properties that counteract signs of natural aging. Such health issues are aligned with the needs of a growing aging population. Moreover, there are emerging companies in the industry that have found innumerable uses of collagen not only for consumers but for a variety of industries. Additionally, there is willingness from research institutions to work with the industry to develop new products from collagen.

Nutrition

The analysis of industry reports, scientific literature and interviews with experts confirmed the benefits of bone by-products as a source of nutrients for humans. Insights revealed that bone by-products are rich in proteins that are of interest to high-performance sportspeople, a market that requires a higher variety of animal protein products that satisfy their needs.

Insights

- Research demonstrate that animal protein is much more effective in muscle recovery / building compared to vegetable protein. It seems that general consumers are aware of this and some of them associate the quality of animal protein with its high price in comparison to vegetable protein.
- High-performance sports physicians recommend to athletes the intake of animal protein via food over supplements and combine this with exercise to either build muscle prior to or post recovery from injury, surgery or cancer treatment and to achieve more natural and efficient uptake. This practice is recommended not only for more efficient results, but also because high protein taken via food does not require batch testing. Batch testing is done to make sure intake is not contaminated with banned substances and it can cost close to AU$500 per test.
- Some sports clubs recommend the consumption of proteins via food right after training and complementing with protein supplements, mainly in the form of protein bars and powder shakes.
- Exercise-mindful youth consumers do not like the taste of some protein snacks such as Jerky because it is too salty and full of fats. Protein supplements that they mix with breakfast give a bad after taste even though it is flavoured. They know protein is required to build and repair muscle, but they are not aware what type of protein are in the powder shakes.
- Because of abundant research that favours animal protein over vegetable protein, there are plentiful of protein products in the market, most of them supplements. Supplements are bought in sports shops and clubs recommend players only buy products accredited by the Australian Sports Anti-Doping Authority (ASADA).
- Nutrition is one of the main research topics of the National Renderers Association in the US.

Nutrition is an opportunity for MLA to explore since there is a strong interest from experts, such as scientists, nutritionists, and sports physicians, on the benefits of protein. Additionally, Australian organisations support research in this area.

Natural Products

In recent years, the meat industry has attempted to obtain more value from bone by-products. This is driven by a discovery of the importance of by-products as a source of nutrients for human benefit and social trends towards more natural products with no additives and flavour enhancers such as monosodium glutamate (MSG).

Insights

- The food industry has been taken by the increasing trend of clean label foods and it is driven by customers' desirability of natural products made with ingredients that they can understand and recognise.
- Some food advocates indicate that bone broth is a food that is easy to cook at home and which will make people more thoughtful about the ingredients that they are consuming.
- Some naturopaths, nutritionists and vets recommend chemical free products such as organic and low in sodium. Grass feed cows is also encouraged. (This applies for bone broth, gelatin, tallow, bone marrow, pet food).
- MSG is clearly an undesirable ingredient in savoury snacks.
- Global economic trends are characterised by consumers with rising disposable incomes that demand the creation of new markets, a shift towards local food, whole food and natural food, sustainably produced foods, seasonal produce and organics.
- Companies are re-assuring the message of natural food in their labels. Labels such as "organic", "low in sodium", "pasture raised cows" are gaining popularity.
- There has also been a significant response of the food industry to the new consumer demands by acquiring other companies with capabilities in the natural and organic segment. For example, Campbell's Ltd acquired Pacific Foods in response to the consumers' needs, seeing that the natural and organic segments are experiencing the fastest growth across all food segments. Givaudan (a major ingredient producer) acquired Vika (natural ingredients producer including natural stock), again signalling the importance of natural ingredients for the foodservice, but also the ready meals industry, which is growing at a very fast rate across the globe (35).

Natural products are an opportunity for MLA to explore due to the emerging trend of natural products that is driving the consumption of chemical free products such as organic, low in sodium and products that come from grass feed cows. This trend is reinforced to consumers by some nutritionist and food advocates. Companies are responding to this trend by adding labels in their packaging and by acquiring companies with capabilities in the natural and organic segments.

Pet Food

Bone by-products provide a source of nutrients not only for humans but also for pets. Pets have become a special companion in a more individualised society. Therefore, there is an increasing interest within pet owners to provide high quality food to their pets - food that is free from chemicals, high in nutrients that improves pets' health. However, there are increasing concerns about food safety in the pet food industry.

Insights

- One of the drivers of prepared animal and bird feed manufacturing industry in Australia is the rising of disposable incomes and increased spending on premium pet food. This is associated with

the individualisation of society as pets have become an exceptional company for singles and are important family members.

- Some vets recommend chemical-free products such as organic and low in sodium. Products that come from grass-fed cows are also encouraged.
- Wet pet food is likely to get more attention and product development interest because of the ongoing problem of pet obesity. Wet food is high in water and helps pets feel more satisfied faster.
- There is an increasing demand for specialty pet products such as functional foods, for example, to help digestion, improve performance of immune system and joint care.
- There is an interest from rendering companies to work together with pet food manufacturers to support them in demystifying the myths around quality and safety of meat meal. Rendering companies are making efforts to provide safe and highly nutritional value products.

Pet food is a key opportunity for MLA to explore due to increased spending on premium pet food as pets have become special company for an increasingly individualised society. As pets have become an important family member, owners care more about natural sources of raw materials and food that provides nutrients and contributes to the pet's health. Moreover, the pet food industry is facing an unfavourable consumer perception that the rendering industry wants to demystify with their efforts to provide safe and highly nutritional value products.

Bone Meal

Historically, bone meal has been used for fertilisers and farms animal feed. However, it is associated with the proliferation of BSE and its use has been banned in many countries. Considering that a high proportion of the production of rendering plants is bone meal, it is important to find new uses for this by-product other than disposing of it into landfills.

Insights

- Some countries have a no bone restriction due to BSE (mad cow disease).
- Recent research claims that bone meal might have new industrial applications:
    - It has special properties to adsorb copper (II) and zinc (II) from aqueous solution.
    - In the production of biodegradable plastic with no presence of BSE infectious agents.
    - In the production of plastic material to use as dog chew.
    - Combination of bone meal with other kind of biomass to produce high quality fertiliser.
    - To extract phosphorus.
    - As a new low-cost adsorbent for the removal of dyes from wastewater.

- There is an extensive production of meat and bone meal around the world. The meal from cows had to be treated with harsh chemicals to destroy any BSE and then put into special landfills. In some countries there are no disposal facilities, therefore, meat and bone meal (MBM) are exported for destruction at huge expense.
- The National Renderers Association in the US is currently researching in non-feed uses for rendered products.

Safe uses of bone meal are an opportunity for MLA to explore since the outbreak of bovine spongiform encephalopathy has led to the creation of new laws banning the use of bone meal in ruminant feed in the United States and in any farm animal feed in the European Union. This situation, combined with an excessive production of bone meal, has encouraged the continuous search and development for alternative uses.

Sustainability

Information from interviews and signals from trend scanning indicate that there is emerging by-product bio-themes. These small themes are here combined under a sustainability heading.

The rendering industry plays an important role not only in the economy, but also in the environment, as it recycles most of the meat by-products and processes them to provide new valuable uses. The rendering industry could obtain marketing advantages if it not only produced sustainable products, but also if it demonstrated that it follows sustainable practices.

Insights

Bio Fuels

- There are some regulations that have encouraged or discouraged the consumption of meat by-products. In the UK, there is legislation that banned the use of tallow as a fuel alternative, which was widely regarded as being nonsensical. US regulations, such as California's Low Carbon Fuel Standard (LCFS), and similar programs in Oregon, Canada, and around the world are driving global demand for carbon reduction in transportation fuels. As this demand increases, the need for fats, oils and greases (FOG) and other biomass feedstocks will also increase.
- Non-ester renewable hydrocarbon diesel (RHD) has rapidly entered the fuel markets in recent years, increasing demand on global supplies of rendered fats and oils.
- Half of Australian's non-edible tallow production goes into the production of biofuels in Singapore. There used to be a biofuel industry in Australia, but this has ceased due to the lack of Government subsidies.

Bio Plastics

- Recent research states that bone meal might have new industrial applications in the production of biodegradable plastic with no presence of BSE infectious agents.

- There is extensive R&D work being done in the US (Australian Renderers Association sponsors some of this work) looking at high protein foods and bio-degradable plastics, which is a big issue in the industry.

Bio Production

- One of the research focus of the National Renderers Association in the US is related to waste water and plant management and how they can be even more sustainable.
- One of the reasons of more consolidation in the rendering industry is the economies of scale, since rendering is very capital-intensive, including the additional costs associated with air-pollution control. For this reason, efforts around sustainability are very important for the industry.

Bio Chemicals

- The commitment with sustainability of some rendering companies have encouraged them to open new markets with the development of performance additives for new biodegradable surface cleaners.

Sustainability is larger theme for MLA to explore because of the need to reduce carbon emissions and have environmentally friendly products. This situation has encouraged rendering companies to not only have a more sustainable production processes, but also to create new products that can potentially reduce the use of chemicals and the harm caused to the environment.

Recommendations from consumer insights

Based on qualitative interviews and emerging trends gathered along the value chain the research finds that there is likely to be opportunities around:

- An increasingly older population is potentially a very large opportunity for bone-derived products. Older people produce less collagen, which in turn leads to loss of muscle mass, weaker bones and less flexible tendons. This will require the development of different protein products to what is currently available in the market. Collagen has demonstrated to have the properties to fight these problems in the senior population. There is also willingness from research institutions to work with the industry to develop new products from collagen, which is motivation to pursue this recommendation.
- High performance sportspeople are a market of interest. They need sources of protein that help them to build muscle mass and recover from intense exercise. They prefer protein in food instead of supplements as it is better and avoids having to take an expensive batch test. Therefore, there is an opportunity to provide this segment with more natural sources of animal protein that they can take as part of their meals and a higher variety of protein snacks and supplements with good taste that can complement their diet regimen.

- Pet food owners are another interesting target market. Pets have become the ideal company in an increasing individualised society, which is willing to spend in premium pet food for the wellbeing of their pets. This situation has aroused an interest for chemical-free food and treats that are safe to eat and do not cause harm to pet's health, food that provides nutrients, functional foods to counteract specific health issues for example digestion, problems in the immune system and joint care. To target this market, it is important to work closely with the pet food industry.
- Health conscious foodies who demand natural and organic food are an important market to target. Even though this type of market is increasing, their options are still limited in the market. This creates an opportunity to provide a variety of products in the form of food ingredients, broths, gelatin, but most importantly in the form of snacks which are not sufficiently explored in the rendering industry according to this research. These products should have the characteristics of being chemical-free, organic, low in sodium and products from grass-fed cows.
- Environmentally aware consumers and new regulations should be considered as opportunities. Stronger focus on climate change are now underpinning production of more environmentally friendly products and services. This aligns with the efforts of the rendering industry to support more sustainable production process for the development of more environmentally friendly products. Therefore, there is an opportunity to introduce products in the form of bio chemicals, bio plastics, bio fuels and bio production.

Production processes. Most of Australian rendering plants get their products from cattle processors with bones, fat, cartilage, ligaments, etc in *"one big mess"*. Given the increasingly specialised production there may be opportunities in exploring how by-products can be separated in the production process.

TOP OPPORTUNITIES

This project sought to highlight any clear opportunities that may have application within the Australian meat processing context. This section of the report lists those opportunities identified and provides some commentary around potential application, value and next steps.

Opportunity 1: Modular bone by-product processing - Coctio

Qualitative interviews and emerging trends have identified a range of potential product offerings using bones as a raw feedstock. Coctio, is one example of a company that offers turnkey processing solutions that could be utilized to realize the productization of natural label food items such as bone broths, sauces, soups, and ready meals all from animal bones. Coctio designs versatile modular units, up to a complete manufacturing line, that can be used as essential infrastructure to execute a sustainable business model. Coctio also supply also includes industrial drying systems in all sizes for drying and further processing of cooked bone leftovers into dried meat protein and powder ingredients. A small, modular line to produce clean label bone broths, soup and sauce preparation in shown in the Figure 13. Figure 14 shows actual red meat bone based products currently available in Europe, produced on a Coctio production line. These products should be tested specifically against Australian consumer preferences to determine the interest. Separately, the Coctio modular process that could be utilized to extract value from the raw bone feedstock should be explored more deeply in the context of the Australian meat processing value chain.

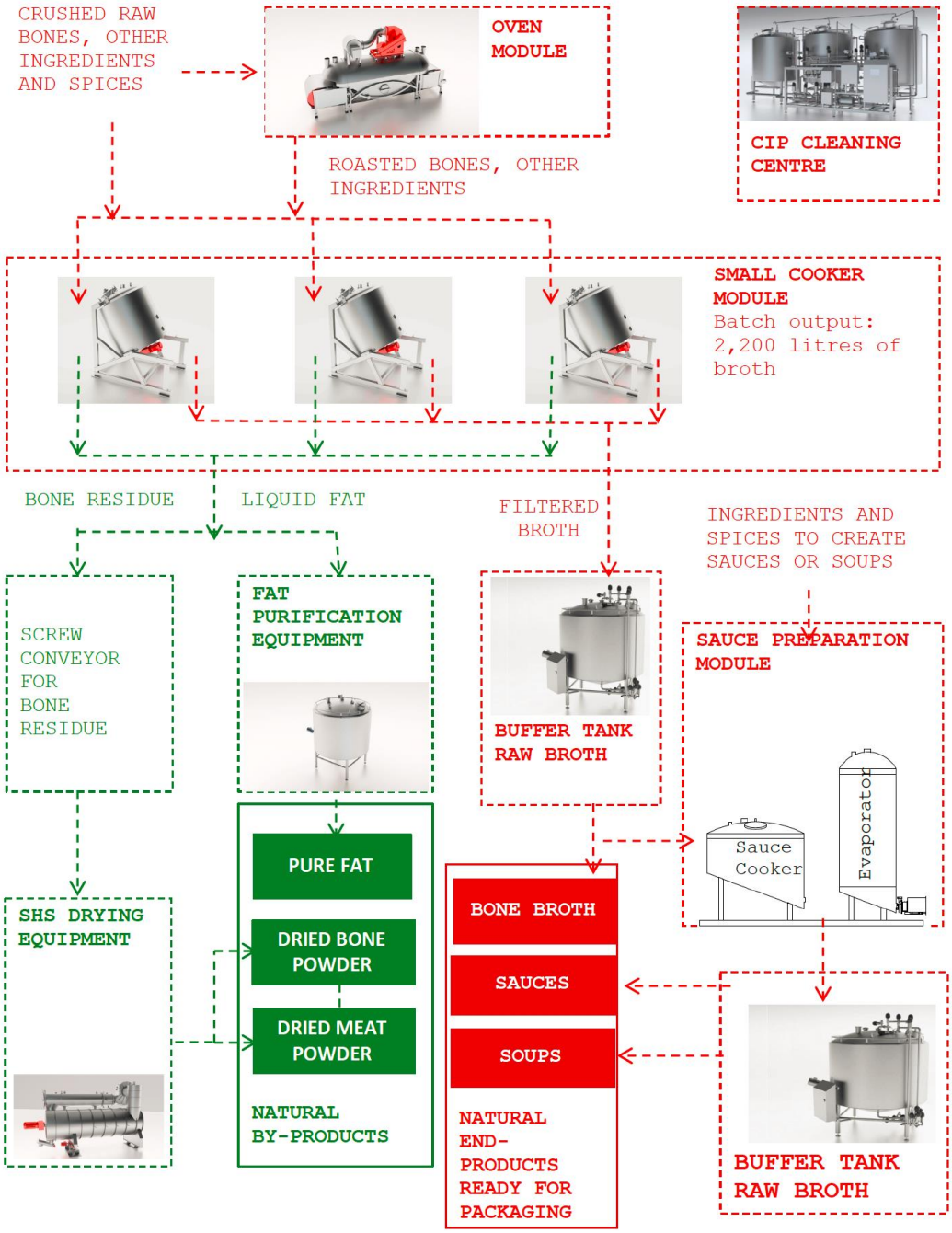


Figure 13 **–** Modular arrangement to produce broths, soups, and sauces.

	**TRUEfoods / UK** Beef: 0,79€ per 100ml Ingredients: spring water, beef bones (28%), chicken bones, calves' feet, onion, carrot, tomato puree, garlic, thyme, black peppercorns, bay leaves Chicken: 0,72€ per 100ml Ingredients: spring water, chicken bones (35%), onion, carrot, tomato puree, garlic, thyme, black peppercorns, bay leaves Veal: 1,80€ per 100ml Ingredients: spring water, veal bones (28%), chicken bones, calves' feet, onion, carrot, tomato puree, garlic, thyme, black peppercorns, bay leaves
	**Brox / Germany** Beef: 1,40€ per 100ml 18hrs cooking time; ingredients: water, beef and bones (90%), onions, carrots, apple cider, thyme, parsley, stone salt, laurel, white mountain pepper Organic chicken: 1,40€ per 100ml 6hrs cooking time
	**Prêt-à-Manger (fast food chain) / International** A leading global fast food chain, prêt-à-manger (350 stores), has launched bone broth as a drink in 28 of its stores in London. The retailer's bone broth costs £1.95 (or €2,30) and is made from bone and meat from grass-fed cattle.
	**Jarmino / Germany** Beef: 1,28€ per 100ml Ingredients: water, beef bones, vegetable broth (with onions, carrots, celery, leek, ginger, garlic, coriander), salt, apple vinegar, pepper, muscat *from controlled ecological cultivation Chicken: 1,28€ per 100ml Ingredients: water, chicken carcasses, vegetable broth (with carrots, onions, celery, leek, parsley, sage, bay leaves, chilli), salt, pepper *from controlled ecological cultivation

Figure 14 – Red meat derived bone products

This report has also highlighted the growing amount of environmental challenges that the red meat processing industry faces by considering bone waste as a low value by-product (After slaughter, one animal produces about 18 weight% bone residues of its total live weight), with the most common practice being to dispose of bone residues in landfills and rendering plants to be made into meat and bone meal for animal feed, fertilisers and bulk pet food ingredients. A selection of higher value products to those traditionally made, would make better use of the naturally beneficial and nutritious components of the bone, and provide higher profit margins to the entrepreneur and/or meat processing facility. In Australia, the current practice of transporting bones and bone residues vast distances for disposal or conversion into relatively low value products, is unsustainable. This opportunity should be explored with on-site directly with meat processors, or by innovative start-ups ideally located near to a meat processing facility.

Next steps include, but are not limited to:

- Business opportunity assessment for a high value product manufacturer located at the site of Australian meat processors or nearby. The work should employ a design-led thinking methodology to investigate viability (e.g. local and global market trends and forces, economics of currently available solutions such as those offered by Coctio), feasibility (e.g. key technology capabilities & limitations) and desirability (e.g. customer/stakeholder needs) components.
- Map the industry / sector to identify key partners, competitors, stakeholders, and customers.
- Test business assessment and customer needs hypotheses with key stakeholders and potential investors.

Opportunity 2: MLA Partnerships with Australian Institute of Sport (AIS) and Beyond

Our consumer survey has indicated a strong willingness by the AIS to partner with MLA to provide expertise and sample subjects to test the efficacy of any bone based products directed at sports recovery or performance. It is expected that there are many other similar groups that would express a similar interest in partnering and/or investing with MLA on general themes or specific projects. Given the well-known trend of declining red-meat consumption in Western society, and the little-known existence of any red-meat based (including bone) products amongst the community, it is important that MLA actively look for opportunities to engage and educate the consumer by utilizing an extended network or partnerships. Partnering at different levels in a various consumer groups lifestyle, will help deliver a more sustained and clear message about the virtues of red meat and red meat based products.

Next Steps include:

- Understanding of the opportunity with the AIS and further development of a relationship. The authors of this report can be used to initiate a discussion.
- Develop a list of similar organizations, associations, & companies in Australia and globally that might provide benefit to the objectives of MLA. Specific objectives and understanding of how the potential partner may be able to assist should be understood and investigated.
- This approach represents a specific opportunity in the sense that careful diligence with the AIS and other commercial partners will identify the types of businesses (such as those identified in

the previous sections) that could be partnered with to exploit opportunities in the Australian red meat context.

Opportunity 3: Product Concept “Osteofizz” or “Protein Punch”

The raw product from dry bones has a desirable nutritional composition to be beneficial as an easy to consume nutritional supplement. The concept could have embodiments as a carbonated tablet or powdered product that is mixed into water, milk or similar such as Metamucil or Berocca, that would provide superior nutrition and clinically proven results when tested in humans. A new product offering would also benefit from being “natural” and “minimally processed” in contrast to these “formulated products”. Possible target markets for such a product could be the older population, individuals with specific conditions, and high-performance sportspeople recovery.

Figure 15 – Well known Berocca, representing the product format of a bone derived supplement product concept

Ingredients of Berocca

Citric acid, sodium hydrogen carbonate, vitamin C, magnesium sulphate, mannitol, calcium carbonate, magnesium carbonate, flavouring, sodium carbonate, niacin, sweeteners, salt, zinc citrate, colour, pantothenic acid, maltodextrin, riboflavin, thiamin, acacia gum, vitamin B6, partially hydrogenated soybean oil, sugar, trisodium citrate, antifoaming agent (polysorbate 60), Folic acid, Vitamin E, Biotin, Vitamin B12.

Key ingredient issues that may be addressed by developing a product derived from on natural bones

Calcium Carbonate – This is the least absorbable form of calcium.

Gelatin – It is unclear of the source of the gelatin, however red meat bones provide an excellent natural source of gelatin.

As mentioned in the previous section, bones can be readily converted into protein hydrolysates products that have special application in sports medicine. The consumption of protein hydrolysates products allows amino-acids to be absorbed by the body more rapidly than intact proteins, thus maximizing nutrient delivery to muscle tissues.

Next steps include:

- Design-led thinking methodology to rapidly survey the potential of the above product concept or others by addressing viability (e.g. local and global market trends and forces, economics of currently available products), feasibility (e.g. key technology capabilities & limitations) and desirability (e.g. customer/stakeholder persona identification and engagement to determine needs).
- Depending on the outcomes, further work might involve product manufacturing and scale-up, detailed cost analysis, partner identification, development plans and budgets etc, for high priority product concepts.
- A complete business case for each product concept would need to be tested against customer needs hypotheses and potential investors.

Opportunity 4: Collagen from Bones

Collagen is the *"new kid on the block".* Collagen is extracted from cartilaginous substances, including hides, bones and horns, with a large amount found in cattle ears and feet. Collagen by-products provide the raw materials for industrial processing and export into products such as skin care cosmetics, keratin, gelatin and as a tissue and bone agent in high performance sport.

Partnering options should be explored with Gelita, who are a world leader in manufacturing and marketing collagen proteins. Gelita appear to be in possession of world best collagen extraction and

processing technology. This information is not available via a desktop research project. This information should be better understood for the benefit of the Australian red meat industry.

GELITA
Improving Quality of Life

Coordinated from the headquarters in Eberbach, Germany, GELITA provides customers around the world with products of the highest standard, comprehensive technical expertise and sophisticated solutions.

Within the range of collagen proteins, GELITA supplies collagen peptides with proven body-stimulating capabilities, tailor-made gelatines and non- or partly- water soluble collagens. Collagen proteins from GELITA are the perfect match for this as they fulfil these requirements, a plus being the fact that they are foodstuffs. More recently, GELITA has intensified its research in developing solutions for physical mobility, body toning and beauty from within, a trend identified in this reports consumer research.

Opportunity 5: Alternative phosphate source

Phosphates are the naturally occurring form of the element phosphorus, found in many phosphate minerals. The largest global producer and exporter of phosphates is Morocco. Within North America, the largest deposits lie in the Bone Valley region of central Florida, the Soda Springs region of south-eastern Idaho, and the coast of North Carolina. Smaller deposits are located in Montana, Tennessee, Georgia, and South Carolina. The small island nation of Nauru and its neighbour Banaba Island, which used to have massive phosphate deposits of the best quality, have been mined excessively. In 2007, at the current rate of consumption, the supply of phosphorus was estimated to run out in 345 years. Only six countries control 98% of the world's phosphate reserves, with 85% of the total in the Western Saharan state of Morocco. This makes access to quality fertilizer products in Australia and other parts of the world subject to geo-political and supply risk.

Phosphate from bone by-product represents an alternative source, utilising am existing waste stream. Terra Humana Ltd technology may be suitable for the recycling and recovery of phosphorus from animal

by-products, thereby providing a niche fertilizer play in Australia. The specific product manufactured using Tera Humanna equipment and knowhow is **ABC (Animal Bone bioChar) BIO-PHOSPHATE:** a safe horticultural biochar product for **natural recovered organic Phosphorus supply (>30% total Phosphate as P_2O_5)**, plant growth promotion and bio-control against soil borne plant pathogens in low input- and organic farming cultivations. **ABC BIO-PHOSPHATE** effects have be validated in several open field and green house cultivation trials in Germany, Denmark, Netherlands, Italy, Hungary, and Switzerland under different temperate climatic and soil conditions.

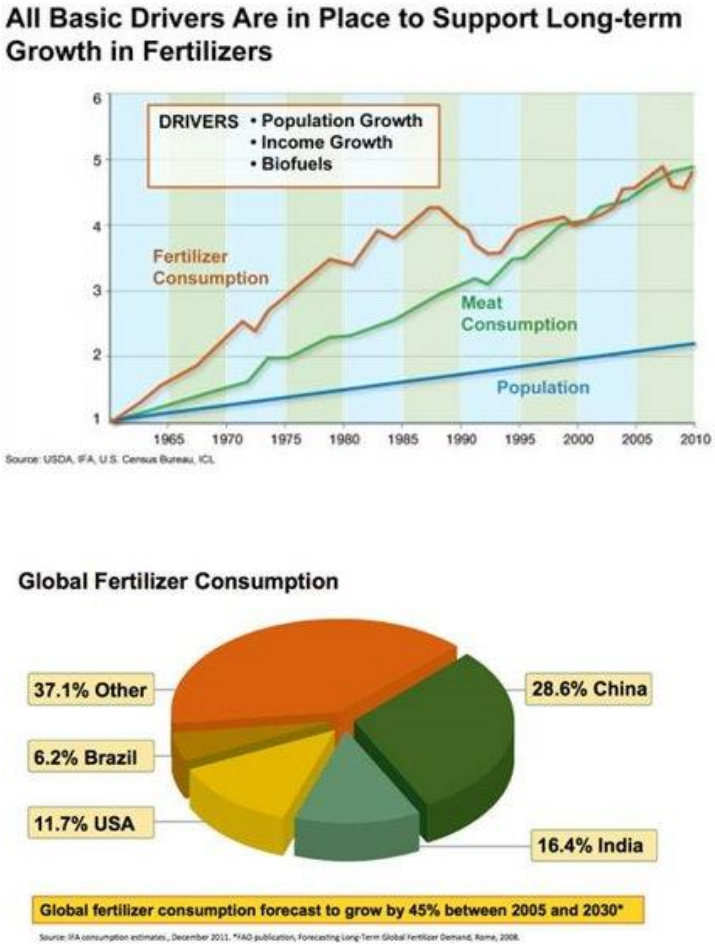


Figure 16 – The case for a booming phosphate economy

Phosphorus is strategic key element of the food crop and animal production in agriculture and analysts have widely reported that rock phosphate prices with increase significantly over the coming decades. In Europe for example, >95% of phosphate used in fertilizers is imported, and it is globally recognized by all western economies as a critical raw material.

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