FINAL REPORT

Prevention of Contamination of Rendered Meal and Tallow by Foreign Matter

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1.0 EXECUTIVE SUMMARY

The "Hierarchy of Controls" was applied to consider:

- Elimination i.e. improved segregation and waste practices.
- Substitution i.e. different materials of construction for devices.
- Engineered / Redesigned plant i.e. automated detection and removal equipment.
- Education i.e. posters and information for dissemination amongst upstream stake holders in the rendering supply chain.
- Encouragement i.e. incentivization.

A project team representing processors with rendering, two rendering aggregators, AMPC and All Energy Pty Ltd was formed. All members were from different geographic areas and covered ovine and bovine rendering. Composition requirements and client KPIs for meal and tallow were summarized. In addition to published quality parameters, of higher interest are customer specific requirements on contamination as simply stating "nil acceptance" is too simplistic an approach.

Industry wide data on rejection of material or claims for contamination are highly confidential, however anecdotal evidence suggests that the main sources of foreign material contamination for protein meal is coloured plastic and metal fragments whilst for tallow poly-ethylene (PE) is the main contaminant not listed in standard composition requirements.

Meat and bone meal (MBM) has a NIL ACCEPTANCE of toxic matter or chemicals prohibited by State laws against inclusion in stock feeds, or any substance harmful to animal health. For the types of polymers used within the red meat supply chain, the risk rankings for the polymers and monomers of the polymers used are low[1]. Hence, whilst polymers may pose a low risk of toxicity, state level feed requirements prohibit "industrial waste"[2]. Polymer based materials are not specifically listed as a contaminant, however an anecdotal example from Japan was that if a particular material (e.g. polymer) is present then it must be listed as an ingredient. Tallow contamination is predominantly due to LLDPE and LDPE due to the low melting temperatures.

A range of separation technologies were considered covering "wet" feed, dry meal, metals only and all contaminants. Simple payback periods ranged from 0.8 to 4.4 years, with high level recommendations being to target technologies that remove contaminants from the rendering feed as early as possible to protect equipment and to remove all contaminants (metals and plastics). Further advantages not quantified included maintaining reputation / good standing, additional product demand from off takers due to absence of contamination and evidence of use of best practices and higher product value due to absence of contamination and evidence of use of best practices.

Further, sensing and removal of a wider range of contaminants (i.e. more than metals) from wet render feed is highly innovative and, to the vendor's and author's knowledge, is not currently available "off the shelf". Hence, there is an opportunity for AMPC to consider supporting an innovative contaminants removal project that removes all contaminants before entering the rendering process.

A range of "off the shelf" devices are available that provide an "immediate" payback such as bungs and plugs

[1] https://ac.els-cdn.com/S0048969711004268/1-s2.0-S0048969711004268-main.pdf?_tid=2a0aae25-3e25-439b-9328-4490c97a23cf&acdnat=1520390599_ddb8fd3c9913baf500037cc2cc269418

[2] https://www.business.qld.gov.au/industries/manufacturing-retail/manufacturing/agricultural-products/feed-labelling

plus also clips being in development. Protein base bio-polymers have a chemical composition and colour matching that or similar to that of meal. As a second option, polymer made from organic, soluble and renderable materials are available that is food safe and fit for animal consumption. Thirdly, bungs/plugs made from paper are available and can be processed through the rendering process however anecdotally can leave flecs and/or remain intact after rendering. Fourthly, materials that are sources of highest contamination risk (LLDPE and LDPE films that melt into tallow) can be replaced with polymers with high melting points (e.g. polypropylene).

Including ferrous / metal material in devices was estimated to provide a 0.63 year payback for a typical beef operation and a 1.93 year payback for a sheep operation (i.e. abattoir with onsite rendering).

There is a strong economic argument for removing contaminants from the rendering feed as early as possible to protect equipment and to remove all contaminants (metals and plastics). Where a plant does not have an existing metal removal system, investing in a system to remove metal and magnetized devices can achieve a payback of 1 to 3 years. Automated detection and removal equipment utilizing near infra-red (NIR) can provide paybacks of 3 to 5 years. However, a NIR system can offer a higher net present value due to avoidance of metal and plastic contamination as well as showing utilization of best practice technology for dealing with a range of contaminants.

Recent data from a tallow aggregator suggests that low temperature renders are well below the 50 ppm polymer specification, high temperature renderers are now more recently below the 50 ppm levels whilst the service renders show evidence of remaining above the 50 ppm levels. Generally, low and high temperature rendering have feedstock from a single and controllable source whilst service renderers have less control over the feedstock.

2.0 INTRODUCTION

It is estimated that up to 45% of a slaughtered animal is processed by rendering, with rendered products (tallow and meal) contributing to around 8 – 10% of the revenue for a red meat processing facility with associated rendering. The specific aim of this project is to ensure that foreign objects do not enter the rendering process. The rendering process is an efficient and effective method to safely treat animal by-products to produce animal fats and protein meals. Rendering provides an essential service to the red meat industry (RMI) and is a critical element for improving the profit margin for the RMI. Rendering creates co-products used as ingredients in the manufacture of processed foods, stock feed, pet food and aquaculture feeds. Rendered products are recognized as a valuable sustainable feed stock and adds value to the meat producer.

The Australian rendering industry is currently frustrated with the amount of foreign matter and non-detectable (plastics) in their products. This has the impact of decreasing the quality of protein meals produced for the domestic and export markets. Incidents of foreign matter has led to customer complaints, product rejection, product claims and down grading of products. The source of foreign matter is through both systemic and random acts. The systematic issue arises for the use of NLIS identification tags and other non renderable materials used in animal stock management and processing aids. The random incidents are caused by either accidental or deliberate items being disposed of into the raw material. The problem is that the plastics present in the raw materials received from the abattoirs are not able to be detected and automatically removed (like a metal foreign body can be). This means they are forced to rely on education and people management to manually remove plastic ear tags/NLIS tags and plastic gloves used by operators in the abattoirs. Unfortunately, due to the nature of abattoir operation, training and communication of standard operating procedures are not 100% effective. Further, manual intervention cannot achieve 100% compliance of prevention of foreign bodies entering the product stream. Hence, an automated and engineered solution is suggested in conjunction with education.

The pet food industry is particularly affected by this contamination and has raised many complaints and concerns without real improvement occurring. The pet food industry is worth $1.7 billion and foreign body consumer complaints are currently costing one pet food manufacturer 200K + per year. The cost of a recall is $100K+ but could reach the multimillions easily through damage to a brands reputation. The presence of foreign matter is recognized as a serious risk to the feed industry and both the rendering and pet food industries jointly wish to positively address the issue.

Australia's rendering industry is worth about $1 billion for rendered product, domestically and exports. Demand for export tallow is around 250,000 to 300,000 tonnes per year. Singapore represents nearly 65 per cent of Australia's production for exports.[3] This currently equates to an export market of over $0.3 bil pa for tallow. Besides its main use for biodiesel, other uses for tallow include soap manufacturing and animal feed, with markets opening up in countries such as Taiwan, China, Korea, Nigeria and Pakistan.

By removing foreign matter from rendering raw materials the Australian red meat industry will be able to supply products that are fit for purpose, meet quality requirements and do not result in financial losses / claims for the industry. The benefits include:

- Maintaining Australia's "clean and green" image,
- Preventing end user concerns on RMI co-product quality,
- Preventing product rejection and customer complaint,

[3] http://www.abc.net.au/news/rural/2015-05-05/tallow-demand-bounces-back/6445126

- Avoiding financial claims,
- Example of continuing process improvement for clients and customers,
- Reduction in manual labor via removal of the issue (different material of construction) and/or an automated solution,
- Opportunity to support a new product (i.e. biodegradable polymer to replace low density polyethylene) via support and utilization of products made from blood meal (i.e. plugs made from red meat industry blood meal).

The potential for contamination of rendered products is present throughout the entire supply chain as shown in Figure 1 below. A customer complaint in China can impact a pet food manufacturer in the U.S.A. which can impact orders for Australian meal.

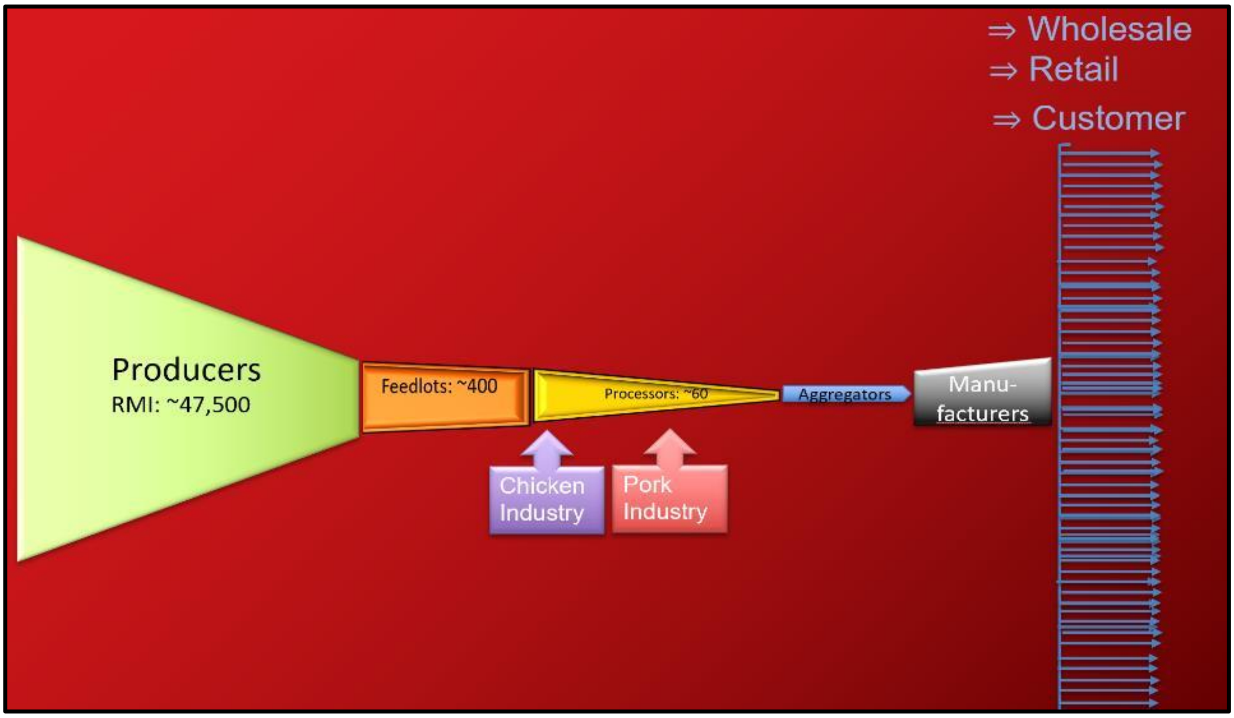

Figure 1: The potential for contamination of rendered products is present throughout the entire supply chain from production and feedlots (ear tags; boluses; ingested materials), processors (plastics), and contaminants aggregated from other industries.

3.0 PROJECT OBJECTIVES

1) Approach AMPC membership (in consultation with AMPC) to determine interest in project participation. Project team and subcontractor longlisting; baseline KPIs selected to be able to measure performance of this scope of works then to complete assay development with a suitable laboratory. Definition of source and type of contaminant.

2) Baseline KPIs measured to define current baseline / performance (e.g. type and concentration of contaminants). a suitable laboratory will be engaged, in consultation with AMPC, e.g. FTIR assays.

3) Develop an education program in consultation with AMPC that builds on previous works and communicates that foreign matter in raw material is unacceptable. Employers and employees require improved

understanding, training, and induction on the issue.

4) Education sessions and presentations.

5) Investigate the use of Mechanical separation / automated detection with associated quotes from market for trial / Proof of Concept i.e. via case studies or data sheets.

6) Investigate the use of different materials of construction (e.g. renderable) with associated quotes from market for trial / Proof of Concept i.e. via case studies or data sheets.

7) Measurement of impact / performance of above communication and education activities.

8) Final report and Snapshot submitted to and approved by AMPC, including recommendations for implementation of a trial / Proof of Concept for mechanical and/or material of construction.

4.0 METHODOLOGY

4.1 Options for Preventing Contamination – Hierarchy of Controls

The "Hierarchy of Controls" (Figure 2 below) can be used to determine the most feasible and effective solutions for controlling hazards. The control methods range from the most effective at the top to the least effective at the bottom. By following this hierarchy, organizations can reduce risks of incidents.

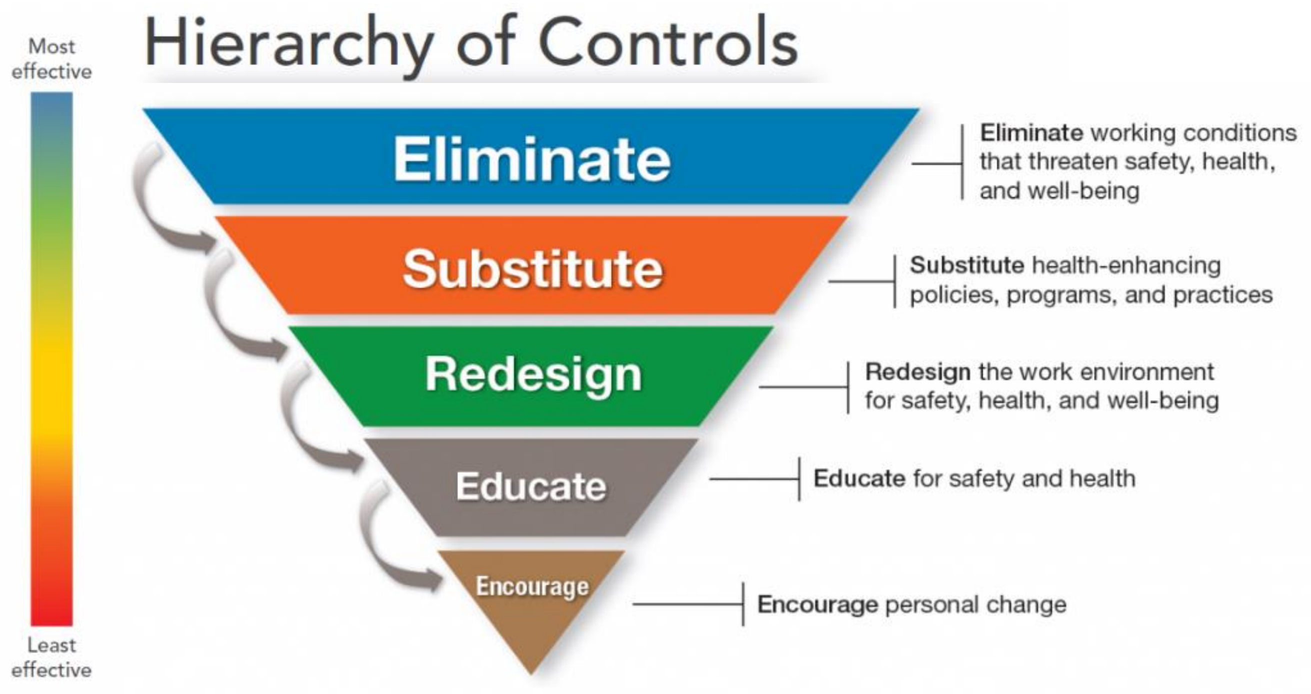

Figure 2: Hierarchy of Controls.

Using the hierarchy above, options could include:

[1] Eliminate: Mandating removal of sources of contamination from the entire supply chain. This could be state or national based legislation, mandates or guidelines to prevent certain materials / devices from entering the supply chain. Examples include banning LDPE and LLDPE to prevent melting into tallow; making submissions of behalf of the industry to regulating bodies e.g. Food Safety Modernization Act (FSMA)[4]; improved segregation and waste practices so that contaminants are not present in rendering feedstock.

[2] Substituting: Substituting all current devices with renderable, non-contaminating and/or non-toxic materials. Options include protein (Novatein[5]), starch or plant based devices; National Livestock Identification System (NLIS) design specifications to help drive change in tagging products (e.g. magnetize for easier removal; ensuring high melting points of material). Adept Ltd (NZ) has had some success with starch and paper but has been unsuccessful with potato starch, TPS-Plantic, PLA, and biodegradable polyesters/starch blends as whilst being biodegradable, are not renderable. Adept's soluble devices are stated as being able to dissolve "inside

[4] https://www.fda.gov/Food/GuidanceRegulation/FSMA/ucm359436.htm
[5] http://www.adurobiopolymers.com/Novatein

the paunch (zero impact on paunch waste stream”[6].

[3] Redesign: Engineered controls: magnetic / metal detectors [400 kg metal per 400 t meal]; near infrared detectors [$0.75mil cap ex; 190 kg plastic removed per week out of 90-100 t meal per week]; magnetizing all tags and devices. With regards to the cost benefit of engineered solutions, a technical specification will be developed for short listed vendors with an associated cap ex, op ex and benefits analysis. The project team considered the size of operations and recommend the following scenario: “typical” beef processor of 156,250 head per annum (625 head per day, 2 shifts per day, 5 days per week, 50 weeks pa).

[4] Education / processes / administrative controls. Will be undertaken as part of this project.

[5] Encourage: incentivization of contaminant reduction. Not considered within this scope of works as is on option for individual facilities to implement.

[6] https://cdn.shopify.com/s/files/1/0612/9909/files/ADEPT_Bovine_Throat_Plugs_5b1094f3-9e53-49c7-89a9-f8c1ae357608.pdf?14852286304409932127

4.2 Flow Diagram for a Rendering Facility

Approximately 42% to 45% by mass per animal is sent to rendering. Rendered products of tallow and meal can represent around 8 to 10% of annual revenue for a meat processor. Hence, it is important that rendered products achieve the maximum revenue possible for a red meat processor.

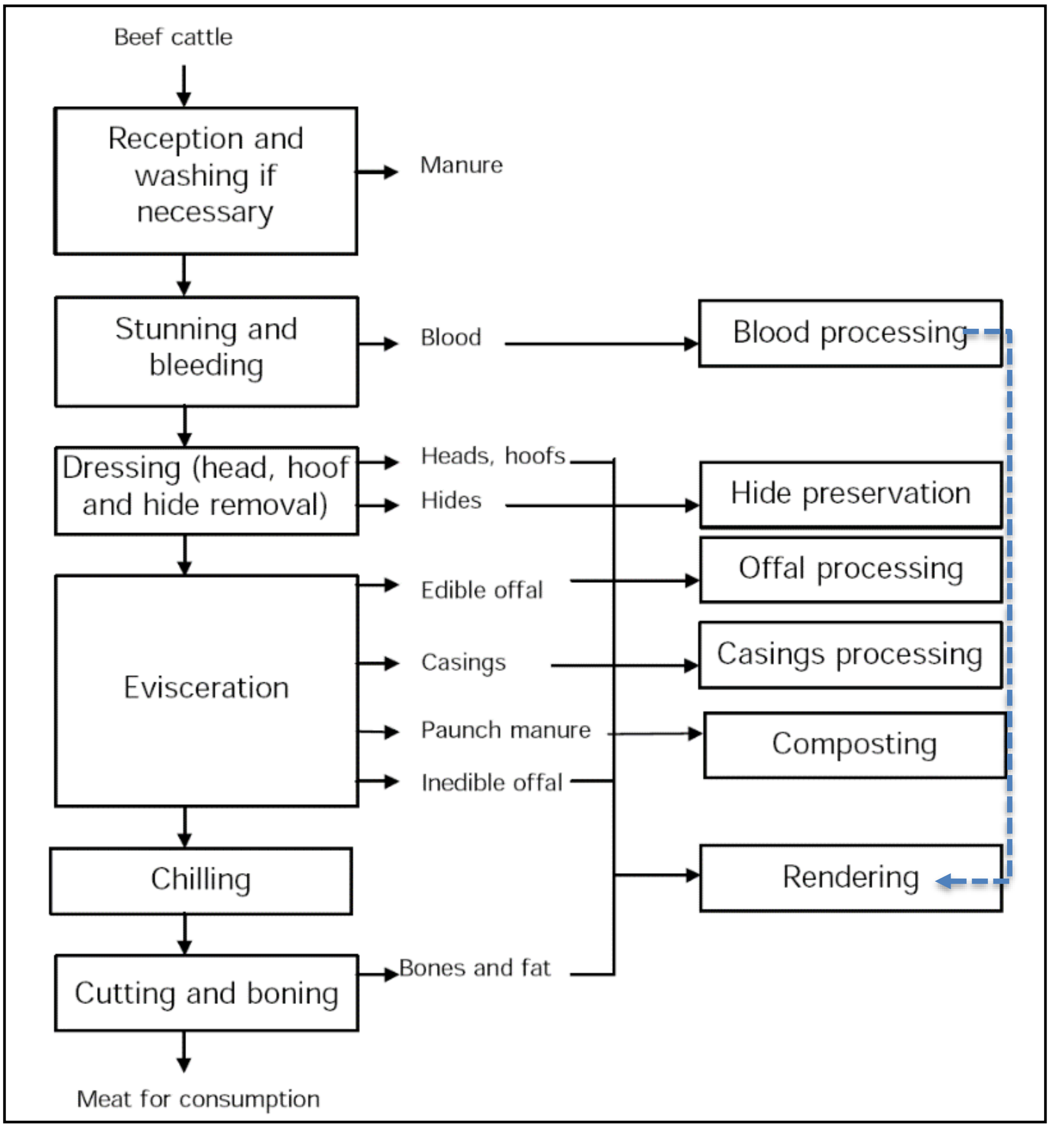

Figure 3: Meat processing block diagram. Source: Cleaner Production assessment in Meat Processing, Chapter 2 "Overview of Meat Processing".

4.3 Tallow Composition Requirements

The ARA Code of Practice for Hygienic Rendering of Animal Products V3.2 5th Revision (2017) defines foreign matter as plastic, metal, glass, wood or other physical contamination in raw material or finished product[7]. The code goes on to state that "Foreign matter in raw materials shall be controlled so that product safety and quality is not jeopardized by the presence of foreign matter including, but not limited to plastic, metal, glass or other material. There shall be a documented procedure for handling raw material"; "procedures for collection of raw material that explain precautions taken to minimize contamination of raw material by foreign objects such as plastic and metal (these precautions include inspection of raw material and use of metal detectors); tallow intended to be used for stock feed manufacture shall be processed to ensure the moisture and insoluble material (M&I) does not exceed 2% and shall be labelled according to legislation".

Sample Tallow specifications - Pure Beef Tallow for export (e.g. from a US commodity management firm):

FFA	1% maximum
MIU	1% maximum
FAC	11a maximum
R&B	0.4R maximum
Titre	42 deg C minimum
FFA –	Free Fatty Acids
MIU –	Moisture / Impurities / Unsaponifiable
FAC –	Fat Analysis Committee (colour scale) 1,3,5,7,9,11a
R&B –	Bleachability (test for soap) (.2-.3)
Titre –	melting/solidifies temperature

Client specific / anecdotal:

- Singapore: 50 ppm PE
- Japan: must list all ingredients
- Industry standard (1973): 200 ppm PE

4.4 Meal Composition Requirements

Sample high protein meal: GTA RING DRIED BLOOD MEAL CSPA-8 [8]
Colour: Preferably blackish in colour.
Odour: Nil acceptance of commercially offensive odours.
Texture: Grind shall be uniform and 100% shall pass through a 2.36mm screen. No more than 5% shall be retained on a 1.7mm screen.
Protein Minimum of 85% or as specified.
Fat Maximum 1.5%
Fibre Maximum 1%
Ash Maximum 6%
Moisture Minimum 4% / Maximum 10%
Total Digestible Protein Minimum 90%
Salt Maximum 1%

Sample low protein meal: ARA/SFMAA SPECIFICATION MBM 45 CSPA-7 [4]
Meat and Bone meal where nothing other than an approved antioxidant may be added to the product prior to delivery, shall conform in composition and quality with the most recent regulations pertaining to meat and bone meal published under the relevant Stock Feeds Act in the State in which the product is manufactured.

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[7] http://www.ausrenderers.com.au/index.php/downloads/category/3-standards?download=33:ara-code-of-practice-2011.

[8] Animal Proteins Standards 2015/16 Effective date: 01 August 2015 Page 1 of 13 Section 7 - ANIMAL PROTEINS 2015/2016 SEASON Developed by AUSTRALIAN RENDERERS ASSOCIATION AND STOCKFEED MANUFACTURERS ASSOCIATION OF AUSTRALIA.

Colour- light to dark brown
Texture – minimum 98% to pass through a 2.00mm (US Mesh No. 10 sieve) and 100% shall pass through a 5.00mm screen
Production to minimize level of microbiological contamination of the rendered product by the adoption of the ARA Code of Practice for Hygienic Production of Rendered Product.
Crude Protein – Minimum 45% on an “as is” basis.
Crude Fat – Maximum 15% on an “as is” basis.
Ash – Maximum 38% on an “as is” basis.
Crude Fibre – Maximum 3% on an “as is” basis.
Moisture – Minimum 4% Maximum 10%.
Salt – Maximum 1% on an “as is” basis.
Pepsin Digestibility Minimum 86% of the protein as determined by the method given in the official methods of analysis of the Association of Official Analytical Chemists (AOAC).
NIL ACCEPTANCE Toxic matter or chemicals prohibited by State laws against inclusion in stock feeds, or any substance harmful to animal health. The product must be free from rodent and insect infestation.

Client specific / anecdotal:

- Maximum of 2% iron content in meal.
- Japan based client: must list all ingredients
- The Animal Proteins Standards 2015/16 makes no mention of allowable polymer but has a nil acceptance of toxic matter or chemicals prohibited by state law.
- Presence of any coloured polymer.

4.5 Sources of Contamination

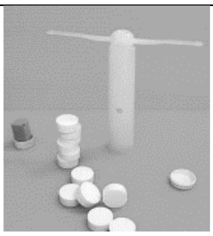
Table 1: Summary of contamination items found throughout the red Meat Industry (RMI) supply chain.

Item	Material of Construction	# per annum throughout Australia	$/unit [$ pa typical processor]	Tonnes per annum polymer	Image
Lamb/sheep clips	**Plastic, FDA food contact approved**	**30,593,660**	**$0.058/unit** **[$28,892 pa for a typical facility]**	**122.37**	
			$0.086/unit **[$43,125 pa for a typical facility]**		
(Or O-rings for oesophagus (sheep, cattle)	**Rubber**				
Lamb/sheep bungs	**100% recycled paper** [9]	**30,593,660**	**$0.079 / unit** **[$39,533 pa for a typical facility]**	**139.86**	
	Plastic, FDA food contact approved		**$0.12/unit** **[$60,000 pa for a typical facility]**		
Beef clips **(Weasand clip)**	**Polyoxymethylene (POM) plastic, also known as "acetal" or "polyacetal". Polyoxymethylene or "acetal" is an engineering thermoplastic used in precision parts requiring high stiffness.**	**7,639,824**	**$ 0.098 / unit** **[$14,696 pa for a typical beef facility]**	**53.48**	

[9] http://www.bunzl.com.au/catalogues/bfps/meat_processing/files/assets/basic-html/page12.html

Item	Material of Construction	# per annum throughout Australia	$/unit [$ pa typical processor]	Tonnes per annum polymer	Image
					
Beef bungs	100% recycled paper, waxed “breaks down in the rendering process”, FDA food contact approved	7,639,824	$0.525/unit [$78,750 pa typical beef plant]	61.12	
	100% recycled paper, unwaxed, “breaks down in the rendering process”, FDA food contact approved		$0.339/unit [$50,790 pa for a typical beef plant]		
	Plastic, FDA food contact approved		$0.314/unit [$47,113 pa for a typical beef facility]		
	Water soluble, FDA food contact approved (Note: anticipated to be a vegetable starch based material)		$0.251/unit [$37,688 pa for a typical beef facility]		
	Rice husk which “breaks down in the rendering process”				
Ear tags visual ear tag or an RFID ear tag.	polyurethane[10]	Up to 41.1 mil (30.6 mil beef, 7.6 sheep lamb, 0.9 mil cattle exported, 1.95 mil of			

[10] https://www.agriculturejournals.cz/publicFiles/80154.pdf

Item	Material of Construction	# per annum throughout Australia	$/unit [$ pa typical processor]	Tonnes per annum polymer	Image
		sheep exported and 0.01 mil goats.			
Rumen bolus	Ceramic + RFID				
Hormonal Growth Promotant (HGP)	Silicon rubber or; Compressed cholesterol / lactose, along with a metal ball (mild steel, carbon steel) for pellet implantation[11].				 Silicone rubber implants of different length (dose per day) and different silicone thickness (duration of payout). Left to right: Compudose 200, 100, 400.
Rumen medicinal bolus	3" long polymer device loaded with medicine for delivery for up to 12 months; wings to increase residence time mild steel spring for drug delivery.				 [12]
Gloves	Latex, nitrile, rubber, polyvinyl chloride and neoprene				
Vacuum / Cryovac packaging	Polyamide (PA; for puncture resistance) and PE for sealing. Prevention of oxygen permeability via polyvinylidene chloride (PVDC) and ethylene vinyl alcohol (EVOH).				

[11] Hormone growth promotants and beef production A best practice guide (2011).
[12] https://www.researchgate.net/figure/012-Components-of-the-housed-tablet-technology_fig18_278711417

Item	Material of Construction	# per annum throughout Australia	$/unit [$ pa typical processor]	Tonnes per annum polymer	Image
Veterinary gloves	HDPE/LDPE Film				
Bags and bin / carton liners	Typically made from high-density polyethylene (HDPE), low-density polyethylene (LDPE), or linear low-density polyethylene (LLDPE).				
Metal from feedstock and/or equipment	Steel, galvanized steel				Iron filings and metal pieces from equipment wear.
Wood / organics	Paper, ligno-cellulosic				
Face/dust masks and hair nets.	PP, mixed fibre material, Nylon, PE. Elastic (spandex, polyester, cotton, nylon or fibre blends) or rubber straps				

4.6 Cost-Benefit Analysis

This section outlines the method utilized for the cost-benefit analysis applied to tallow and meal when changes are made to preventing contamination with foreign materials.

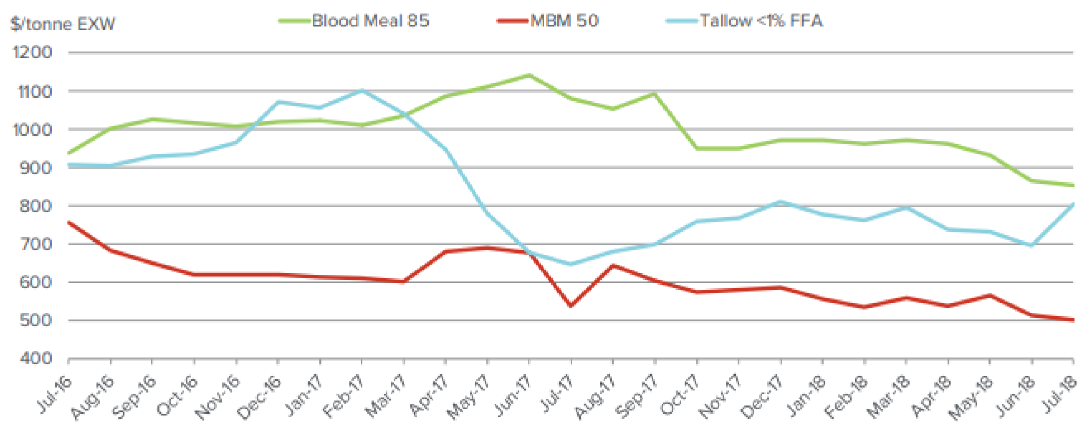
Assumptions: Figure 4 below shows a mass balance for a "typical" 625 head per day beef processing facility producing MBM50 and tallow <1% FFA created to enable completion of a cost-benefit analysis.

Due to the higher value of tallow compared to MBM, it is preferable for a processor to maximize the fat sold as tallow (as opposed to leaving a high % of fat in the MBM), hence fat in the MBM was modeled at a lower approximate bound.

Other key assumptions are outlined in Figure 5 (next page) which summarizes the mass balance.

4.7 Cost / Benefit Data

The following data from MLA[13] was utilized for the value of rendered products MBM50 and tallow ex-works.



	Average (July Data)	Range	Responses	Monthly Change	Annual Change
Bloodmeal 85	852.5	170	4	-0.01	-0.21
MBM 50	501.67	75	3	-0.02	-0.07
Tallow Ined.<1FFA	805		2	0.16	0.25
Tallow Ined.<2FFA	755	70	4	0.08	0.16
Tallow Ined.<4FFA	746.67	50	3	0.18	0.20

Price quoted is average price reported ex works$/tonne.

Figure 4: Trends in rendered products and detailed July 2018 rendered product pricing.

Annual maintenance for magnetic separation systems assumed at $8170 p.a. and is subtracted from the annual benefit (includes: lubricant / oil change, oil viscosity testing kit, Travelling Wiper Seals every 6 mths, Annual Major Overhaul carried out by Technician and parts, Annual Verification report to meet auditors / client requirements for HACCP certification, 14 hours p.a. for general maintenance / inspection by onsite staff).

[13] https://www.mla.com.au/globalassets/mla-corporate/prices--markets/documents/trends--analysis/co-products/mla_market-information-report-co-products_august_2018.pdf

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Mass balance - Rendering Plant

All Energy Pty Ltd

A	AEPL	28/09/2018	AEPL
Rev	REVISION DETAILS	DATE	DESIGNED

1. BASIS OF DESIGN

Assumptions:		
Average weight per head	kg/day	600
Percentage of each head to rendering (blood, bones, fat, head, etc.)		42%
Percentage each HSCW		40%
Percentage each head edible offal		7.00%
Percentage each head hides		5.00%
Percentage waste and losses		6.00%
Hours per day		16.00
Operating time - hours pa		4,000
Days per week		5
Weeks per annum		50
Days per annum		250
Head per day		625
Head per annum		156,250

Operating Assumptions

110 degree Celcius hot render
90% recovery of total solids to MBM
98% recovery of non MBM FOGs to tallow
2% losses of solids to stick water and evap
1 kg metal per tonne meal produced; Near infra-red (NiR) 0.044 % total rendering feed
2.1 kg plastic per tonne meal; Tomra
0.3% protein loss through NiR and Metal removal
8% % fat in MBM
1800 normal hepatic iron concentration is micrograms/g dry weight 0.180%

MBM50		Tallow (edible)	
ex works $/tonne	$ 501.67	ex works $/tonne	$ 805.00

Stream Description	Total plant inlet	Render Plant Feedstock	HSCW	Metal detector	Post-Metal Pre-NiR	NiR Material	MBM50	Tallow (edible)
Stream #	1	2	3	4	5	6	7	8
Temperature (°C)	37.0	37.0	37.0	37.0	37.0	25.0	25.0	25.0
Head per annum	156,250							
Volume Flow m^3/pa	100,734	42,308	40,294	19	42,290	39	9,905	5388
Volume Flow m^3/hr	25.18	10.58	10.07	0.005	10.57	0.010	2.48	8987
Mass Flow (tpa)	93,750	39,375	37,500	17.46	39,358	36.65	9218	4795
Mass Flow (kg/operational day)	375,000	157,500	150,000	70	157,430	147	36,873	19,181
Mass Flow (kg/hr)	23,438	9,844	9,375	4	9,839	9	2,305	1,199

Component Flows	Total plant inlet		Render Plant Feedstock		HSCW		Metal detector		Post-Metal Pre-NiR		NiR Material		MBM50		Tallow (edible)	
SOLIDS	tpa	mass %	tpa	mass %	tpa	mass %	tpa	mass %	tpa	mass %	tpa	mass %	tpa	mass %	tpa	mass %
Total Solids	27,263	24%	13,388	34%	13,875	37%	15.71	90%			36.65	100%	8,296	90%	4,771	99.50%
Volatile Solids (%VS/TS)	25,500	27%	10,710	27%		27%	8.7	50%			18.33	50%	194	2.10%		
Ash			5,040	13%									2,950	32.00%		
Crude Fibre	1,594	1.7	277	0.7%		1.7							277	3%	0	0
Protein (and minerals in feed)	5,453	20%	7,875	20.0%		25%	2	10.0%			3.67	10.0%	7,712	50%		
FOGs/Tallow			5,513	14%		12%	1.22	7.0%			2.57	7.0%	737	8%	4771	99.500%
Polymer											18.326	50%			0.96	0.005%
Metal							8.7	50%					184	2%		
Water			25,200	64%		63%	11.18	64%		64%	23.46	64%	922	10%	23.74	0.495%

Figure 5: Mass balance for a typical rendering plant.

4.8 Cost of Consignment Rejection

The following table provides a summary of calculations of financial benefits of removing contaminants from rendering feed / products. Anecdotally, two recent "rejection events" due to metal contamination in September 2018 cost a rendering operation $120,000 and $140,000 respectively in rejected product. For a "typical" beef facility this equates to 1.53% of revenue from a rendering project (meal and tallow aggregated). For a typical sheep operation, 1.53% of mela and tallow equates to $37,182 pa. However, companies should consider if historical claims and/or rejections associated with contamination have occurred and perform individualized CBAs on best available data.

Table 2: Costs of consignment rejection scenarios. Highlighted in the red box is the scenario utilized in the cost-benefit analysis.

Benefit Description	MBM50	Edible tallow	AGGREGATE
Revenue per consignment (40' container / ISO tainer)	$ 13,871	$ 16,100	$ 29,971
Revenue loss at 1% rejection for a "typical" facility	$ 46,245	$ 38,602	$ 84,847
Revenue loss at 1.53% rejection for a "typical" facility	$ 92,490	$ 77,203	$ 169,693
Revenue loss at 10% rejection for a "typical" facility	$ 462,450	$ 386,016	$ 848,466
Revenue loss at 50% rejection for a "typical" facility	$ 2,312,248	$ 1,930,081	$ 4,242,329
Revenue loss at 100% rejection for a "typical" facility	$ 4,624,497	$ 3,860,162	$ 8,484,658
Revenue loss at chemical tanker rejection (25,000 DWT)		$ 18,257,093	
Equipment maintenance and repair savings $ p.a. when contaminants removed from rendering feed	$27,000 p.a. (assumed)		
Loss of reputation / good standing due to contamination	Unable to be estimated		
Additional product demand / higher product value due to absence of contamination via use of best practices	Unable to be estimated / case-by-case basis		

5.0 PROJECT OUTCOMES & DISCUSSION

5.1 Contaminants Analysis

5.1.1 Microscopy – Meal

MBM50 (dried, milled blood and bone meal with 50% protein) was qualitatively considered under a light microscope. Images of the microscopy works are presented below.

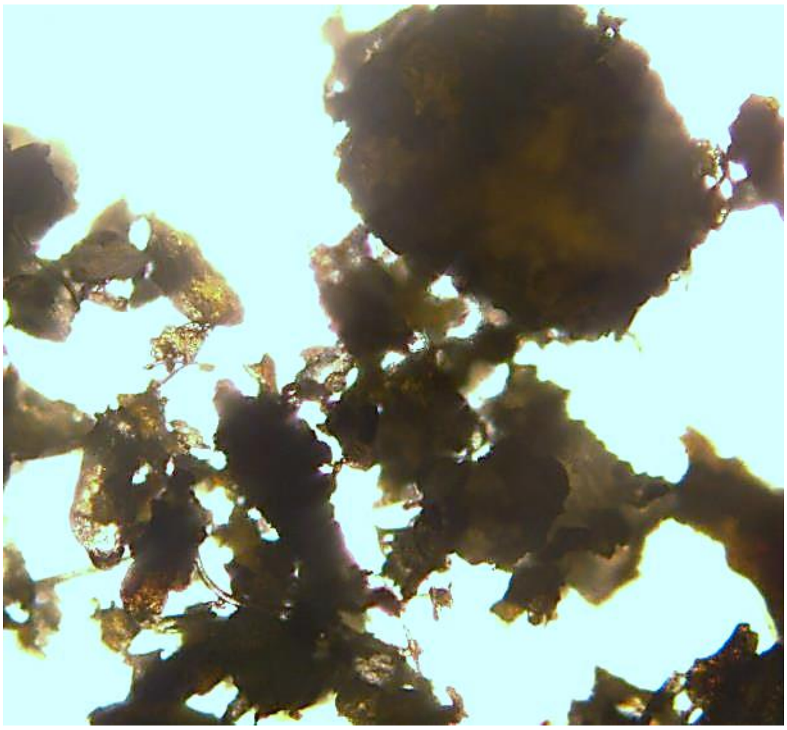


Figure 6: Light microscopy of MBM50 at x4 magnification. This image shows the presence of protein particles, hairs and bone material.

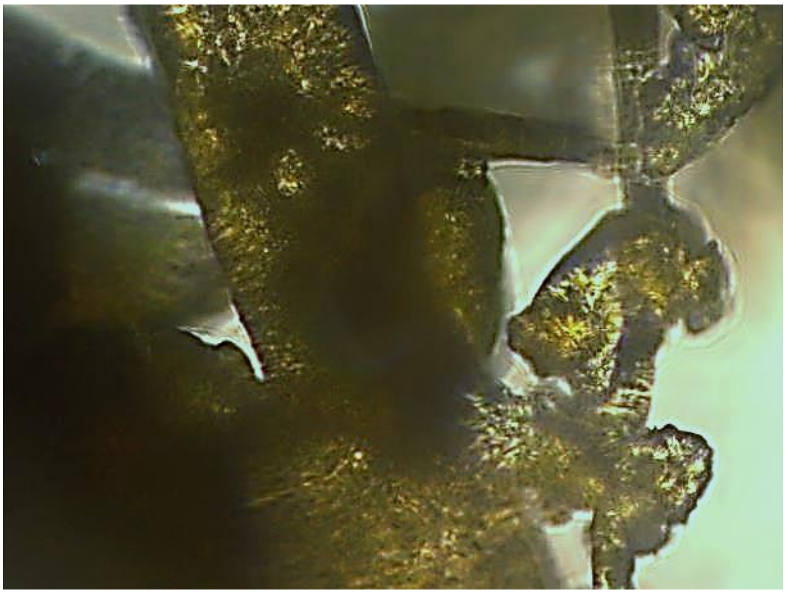


Figure 7: Light microscopy of MBM50 at x40 magnification. This image shows the highly crystalline and polymeric nature of protein and hair.

5.1.2 Fluorescent Assays – Meal

Previous research utilized staining with a fluorescent dye in order for any polymers present to be highlighted. The method required creating a Nile Red stock solution of 1 mg mL^{-1} in acetone and filtering through a 0.22 µm PTFE syringe filter[14]. The sample was then incubated for 30 minutes into a 10 µg mL^{-1} solution of Nile Red (i.e. deionised water was added to meal and the stock solution). The samples were then viewed using light microscopy at different magnifications.

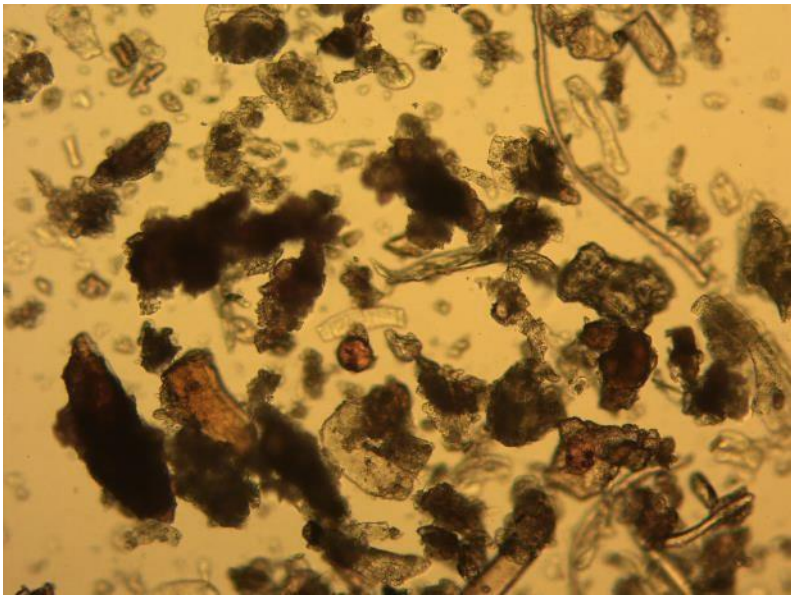


Figure 8: Light microscopy of MBM50 at x10 magnification after incubation in Nile Red for 30 minutes. This image shows how a range of materials, such as bone, also bonded non-covalently with the Nile Red dye which resulted in this assay being consider unsuitable for determining the presence of polymer contaminants.

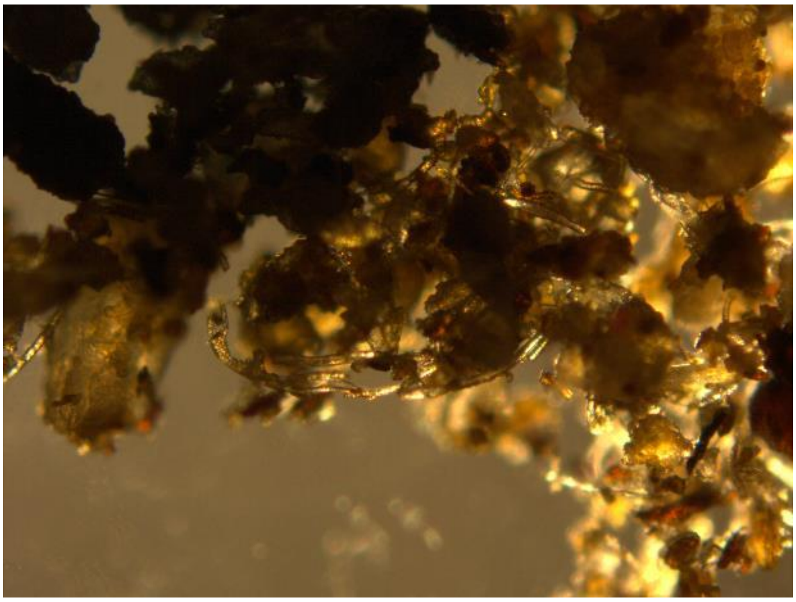


Figure 9: Light microscopy of MBM50 at x4 magnification after incubation in Nile Red for 30 minutes. This image again shows how a range of materials, such as bone, also bonded non-covalently with the Nile Red dye which resulted in this assay being consider unsuitable for determining the presence of polymer contaminants.

14 https://www.nature.com/articles/srep44501?utm_source=feedburner&utm_medium=feed&utm_campaign=Feed%3A+srep%2Frss%2Fcurrent+(Scientific+Reports)

5.1.3 Laboratory Analysis – FTIR of Meal

An FTIR spectra method was employed by Intertek Testing Services (Australia) Pty Ltd Building 1, 19-23 Paramount Road West Footscray, Victoria 3012.

Approximately 7.75g of tallow sample was dissolved in 100 ml of water filtered through a pre-weighed nitrocellulose filter. The filter was washed, dried and weighed again to determine insoluble content in the samples. Material retained on the filters were analyzed using FTIR (Fourier Transform Infrared) spectroscopy in ATR (Attenuated Total Reflectance) mode on the 03/07/18 in transmission mode. The amount of insoluble component was ~approximately 1-0.5% w/w. Little material was retained on the filter of the protein meal sample. Some particles were removed and analyzed by FTIR microscopy and were compared against a library spectrum. The strong signals at (~2918, 2850 and 175-1417 cm-1) are indicative of a carboxylate salt and may be typical of a fatty acid salt (e.g. soap). Remaining sharp signals at (~1025cm-1) matched phosphates and may be indicative of calcium phosphate (bone). No polymers / polyolefins were detected in the residue matrix.

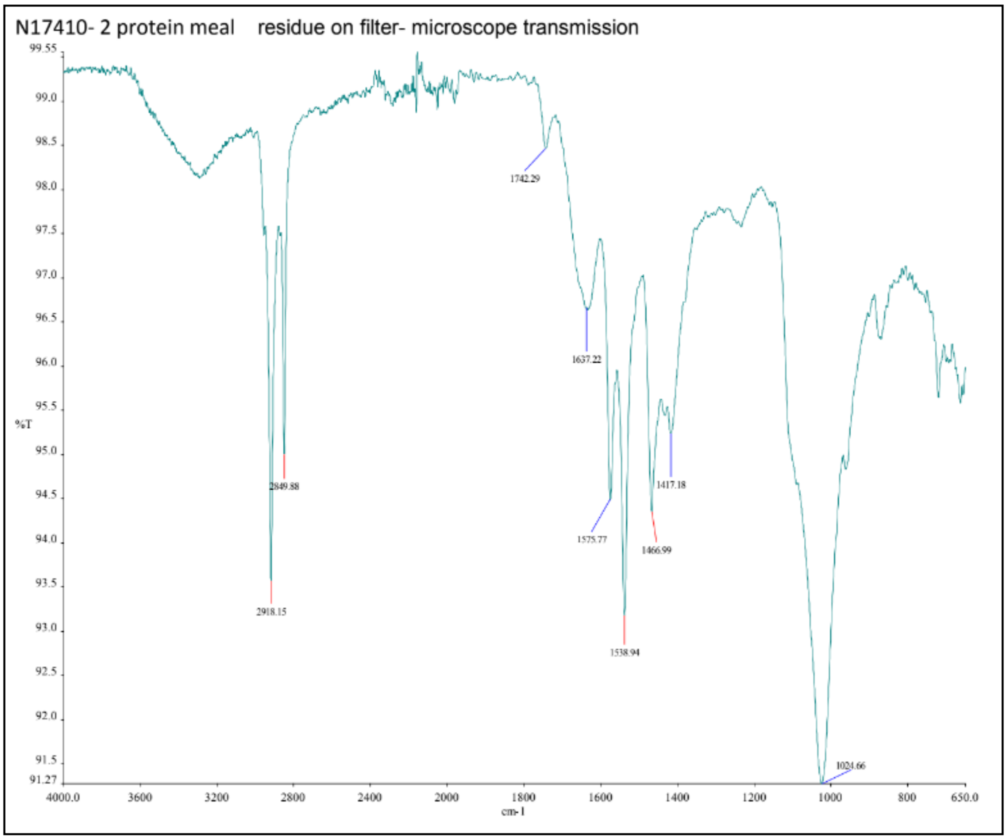


Figure 10: FTIR of insoluble material from MBM50. No polymers / polyolefins were detected in the residue matrix.

5.1.4 Microscopy – Tallow

Light microscopy was used to qualitatively inspect edible tallow samples for the presence of any flecs, discolouration or contamination, none of which was visible using light microscopy.

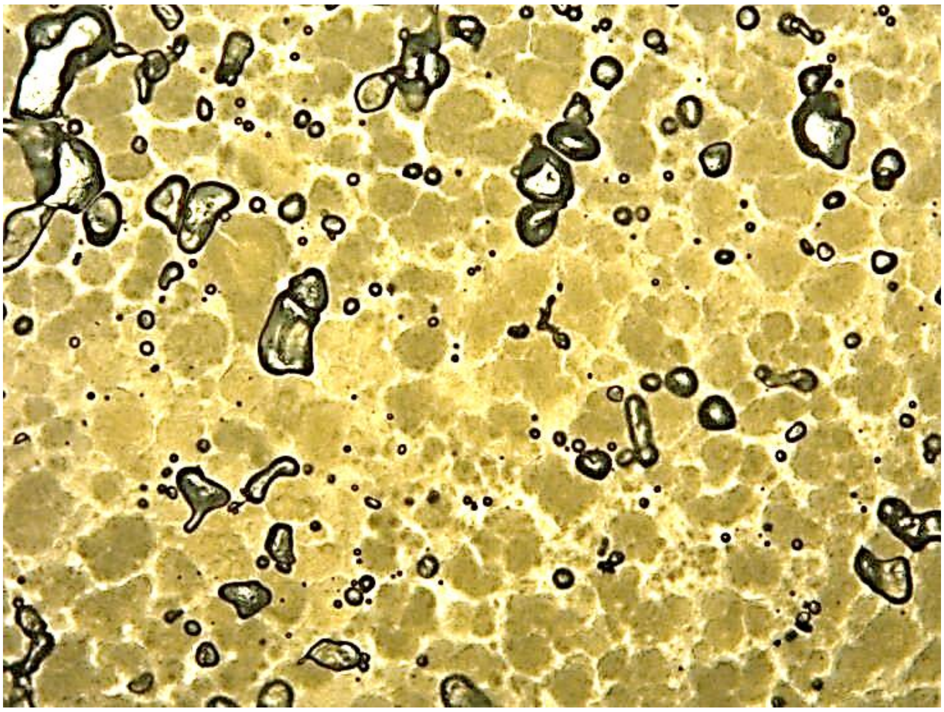


Figure 11: Light microscopy image of edible tallow at x4 magnification. Bubbles within the tallow can be clearly seen in the image.

5.1.5 Fluorescent Assays – Tallow

As for the meal, the Nile Red solution. Nile red has been found to be highly effective at identifying strongly hydrophobic particles such as PE, PP, PS and nylon-6. Weaker fluorescent was evident for PUR, PC, PVC and PET. As a result, Nile red was concluded to be a reliable, fast and cost-effective method for detecting small, highly hydrophobic microplastics. Polymers present in tallow are expected to be LDPE. However, unless reaggregation occurs then the polymer would be present as individual polymer chains, perhaps as small as the nanometer scale, dispersed throughout the tallow rather than being present in visible particles on the micron scale. As shown in the image below, no fluorescence was detected above background levels that could have indicated polymer contamination.

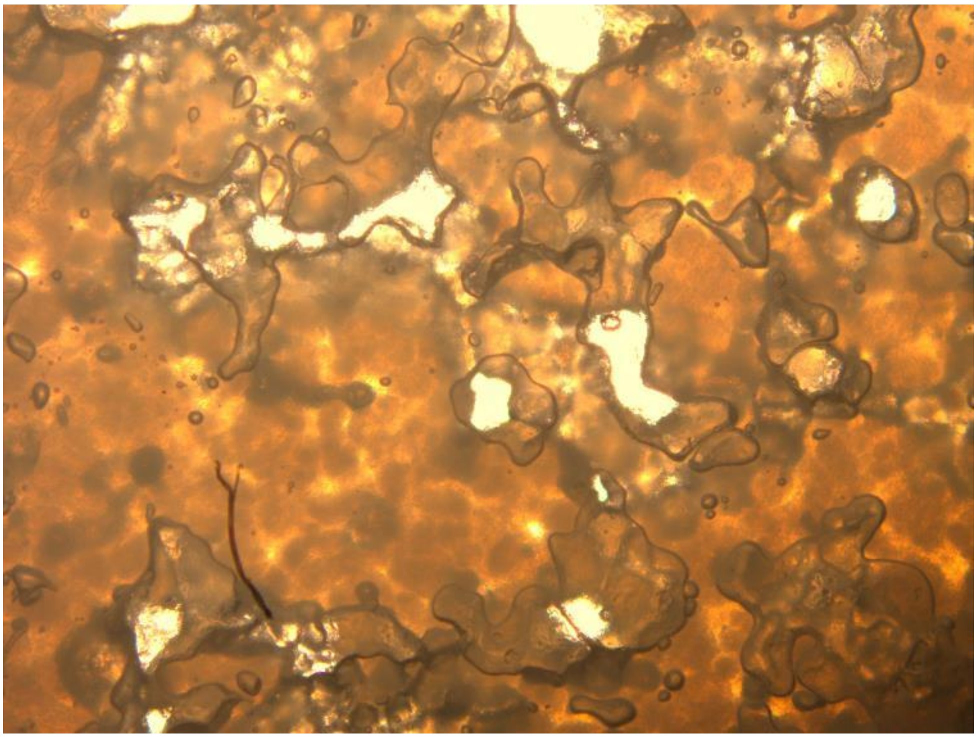


Figure 12: Light microscopy image of edible tallow with Nile Red fluorescent stain at x4 magnification. No particular contaminant particles were found against the background levels. Bubbles within the tallow can be clearly seen in the image.

5.1.6 Laboratory Analysis – FTIR of Meal

An FTIR spectra method was employed by Intertek Testing Services (Australia) Pty Ltd Building 1, 19-23 Paramount Road West Footscray, Victoria 3012.

Approximately 100 g of tallow sample was dissolved in 100 ml of Methylene dichloride filtered through a preweighed nitrocellulose filter. The filter was washed, dried and weighed again to determine insoluble content in the samples. Material retained on the filters were analyzed using FTIR (Fourier Transform Infrared) spectroscopy in ATR (Attenuated Total Reflectance) mode on the 03/07/18 in transmission mode. Insoluble sample component was < 1ppm, that is, very little material was retained on the fitter paper. Surface analysis of the filter- FTIR-ATR returned a similar spectrum to a blank filter paper (no material was detected). Under the optical microscope a number of small brown particles were observed. Two representative particles were analyzed by FTIR microscope. They retuned a broad FTIR spectrum in the main typical of protein based materials (~1645cm-1). A second signal(~1033cm-1) in the spectra may be indicative of inorganic silicate or carbohydrate based materials. The spectra were not consistent with the presence of micro plastics / polyolefins.

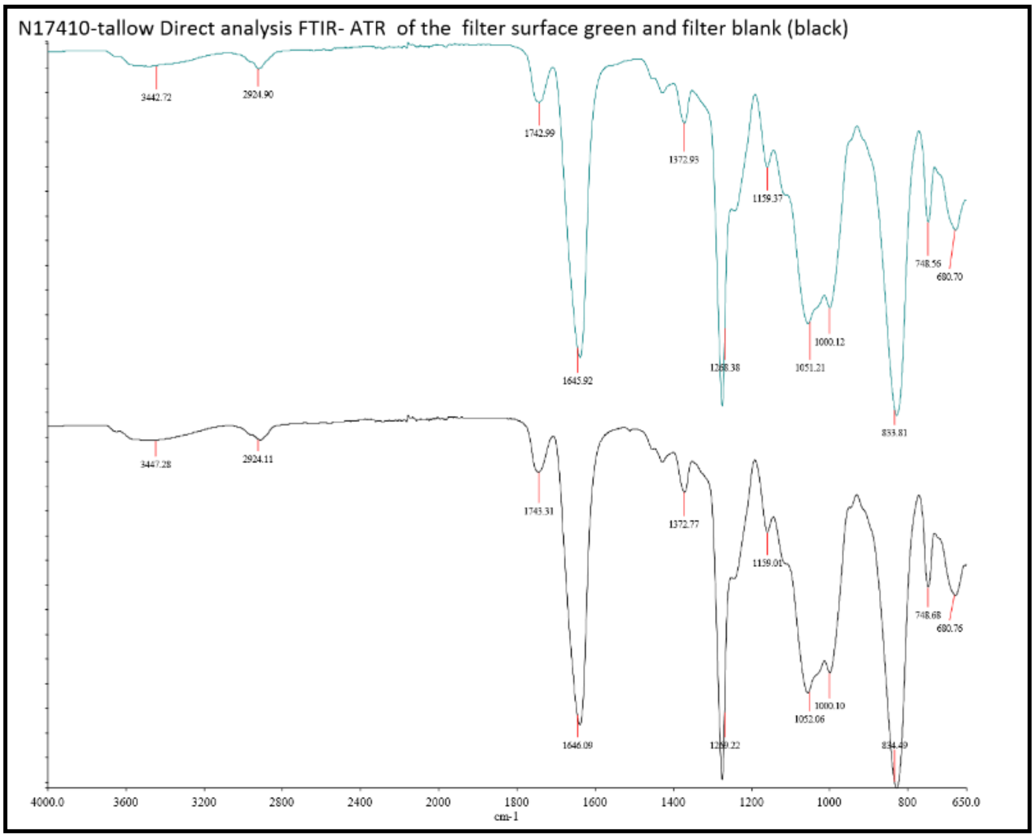


Figure 13: FTIR of insoluble material from tallow showing no contaminant was detected.

AMPC

5.2 Materials of Construction

5.2.1 Detailed Polymer Contamination Physical Characteristics

With its low melting temperature, the different forms of Polyethylene (PE) provide the greatest source of contamination within the rendering process. Melting temperatures are often a mean temperature and may be affected by molecular weight distributions, additives / contaminants, and rates of temperature change.

Table 3: Summary of polymer contamination melting points.

Contaminant		Contaminant Source	Melting Point (deg C)	Reference/Source
HDPE	High-density polyethylene	Bags, gloves, liners	126 -135	CHEMnetBASE, Polymers: A Property Database
LDPE	Low-density polyethylene		105 -115	CHEMnetBASE, Polymers: A Property Database
LLDPE	Linear low-density polyethylene		100 - 120	CHEMnetBASE, Polymers: A Property Database
PE	Polyethylene		135 - 142.6	CHEMnetBASE
PET	Polyethylene terephthalate	Bottles	267	
PVC	Polyvinyl Chloride	Gloves, Piping	212	
PVDC		Cryovac	200	
EVOH	Ethylene Vinyl Alcohol	Cryovac	280	
PP	Polyprop	Face/dust masks and hair nets.	160 - 165	https://www.blueridgefilms.com/polypropylene_film.html
acetal	Polyoxymethylene / polyacetal	Clips	175	
PU	Polyurethane	Tags	240 (Processing Temperature 227 – 260)	http://www.efunda.com/materials/polymers/properties
Wool		Feedstock	228-230 (ignition)	
Cotton		Personal Protective equipment (PPE)	250 (ignition)	
Rubber		PPE	260-316 (ignition)	
PA (synthetic polyamide; nylon)		PPE; Cryovac	220 (ignition)	
Nylon-6 / polycaprolactam		Multilayer packaging as an O2 barrier film	214	
Nylon 12 / PA12		Films for packaging. Added to PE to improve water vapor and aroma permeability.	178	

High temperature rendering (>100 ^{o}C, often reaching 110 to 130) tends to result in softening of PE at 80 oC with completely fluid PE from 100 – 126 oC (depending upon the density) versus low temperature rendering at 70 to 100 (routinely 88; resulting in PE not becoming fluid) to achieve phase separation between the fats and other rendered materials.

Discussions with biodiesel manufacturers raised the issue of polymer in tallow. One of the more interesting finds was, in addition to PE, the belief that nylon was a main contaminant. Whilst rendering occurs at temperatures above the melting points of nylon, nylon-6 has a glass transition temperature of 47 ^{o}C. The glass transition temperature is where a brittle plastic changes state into a viscous or rubbery state and polymer chains are able to slide past each other when a force is applied. Nylon is considered non-toxic and is used at concentration of up to 35% in face power formulations (nylon-12) and 20% in eyebrow pencil formulations[15].

At 25 ^{o}C PE has a density of 0.92[16] and nylon has a density of 1.1 to 1.2 compared to beef and mutton tallow with a density of approximately 0.86 to 0.94[17], hence it would be expected that PE is a reasonable stable colloid whilst nylon would settle out under gravity in a non-mixed tank.

[15] "Safety Assessment of Nylon as Used in Cosmetics", 2012, cir.safety.org, accessed 26 Sept 2018.
[16] "Qenos technical Guide", Qenos.com, accessed 26 Sept 2018.
[17] "Physical Properties of Fats and Oils", dgfett.de, accessed 26 Sept 2018.

5.2.2 Alternatives to Traditional Synthetic Polymers

Around 150 million tons of plastic are produced annually with production and consumption continuing to increase[18]. Several types of polymers are accidental contaminants that can end up in raw materials. Polyethylene film is particularly difficult to process as it can wrap around augers and, if sufficient film is present to bind the system, can cause damage to gearboxes. Upon thermal processing, polyethylene melts and remains with the fat where it creates problems with pumps and general downgrading of the value of the fat. Plastic particles of polyethylene and other polymers are detrimental in finished protein meals, especially for pet food-grade materials. Often brightly colored, these plastics are a source of concern to rendered product customers with visual evidence of contamination a major source for claim.

Previous works from 2013[19] found that of over 100 commercially available polymers, a biodegradable thermoplastic polymer made from corn can be melt-processed via rendering: a 4-week trial in 42 businesses using 0.88 mm liner and 57 businesses using 1.5 mm liner. No issues were found with the bags during usage or rendering (examination of raw material conveyors, raw material conveyor pumps, material grinders, production fat screens or filters, production fat centrifuges, fat work or finish storage tanks, production fat pipes or valves, or Rotex screens). for a variety of uses. The "poly count" test for polyethylene conducted at an independent testing laboratory revealed that purposely adding 6,000 of the biodegradable, corn-based liners to the rendering cooker did not increase poly count. In fact, one processing plant even reported a greater than 50 percent reduction in poly count.

Further work in 2015[20] conducted a study for the industry and after investigating 70 polymers, identified a biodegradable thermoplastic polymer made from corn known as Mater-Bi. This polymer is a natural, edible product from the Italian company Novamont. It is made from a by-product of the biorefinery process and is comprised of corn starch, cellulose, glycerin, and natural fillers. Mater-Bi is approved by the Food and Drug Administration for food contact. 3.0 mm thickness gloves were found to be optimum with no ripping or tearing during use. The gloves had excellent chemical resistance properties and worked well in real world trials in four poultry processing facilities in Florida. During the trial, 750 gloves were deposited in the raw offal material for rendering. Hurley's last trial was conducted over the 2014 holiday season when various poultry processing facilities in the Southeast utilized the gloves. Survey results are equal to or better than the gloves currently utilized at these facilities. Replacing standard gloves with gloves made from the Mater-Bi biodegradable polymer will benefit the rendering industry and allow production of higher-quality rendered products without the hazard of plastic polymer fragments in finished animal fats and proteins.

[18] Journal of Polymers, Volume 2014 (2014), Article ID 427259, http://dx.doi.org/10.1155/2014/427259
[19] http://www.rendermagazine.com/articles/2013-issues/october-2013/a-renderable-solution/
20 http://www.rendermagazine.com/articles/2015-issues/february-2015/renderable-gloves/

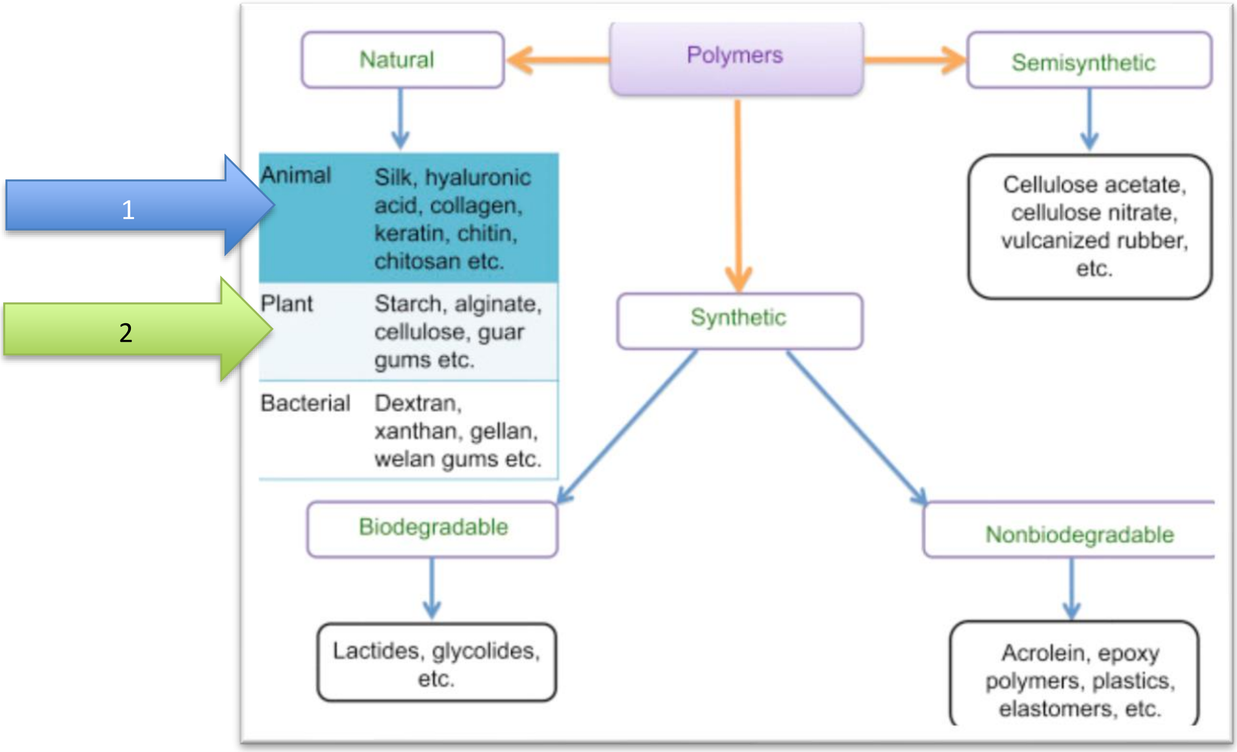


Figure 14: Polymer classification [21]. (1) Protein based; (2) Plant (3) Food safe based material). Food safe and non-toxic is on a case by case basis.

Natural Polymers and biopolymers are a group of naturally occurring polymers including cellulose, starch, lignin, chitin, and various polysaccharides. These materials and their derivatives offer a wide range of properties and applications which are readily biodegradable, although the rate of degradation is generally inversely proportional to the extent of chemical modification; options include (with the number of options available on the market in brackets): adhesion proteins (2), carbohydrates and starches (4), cellulose (40), chitosan and chitin (12), dextrans (100), gelatin (6), high-purity collagen (4), lignins (7) and polyamino acids (116)[22]. This is the general class of polymers most likely to provide current or future renderable material devices.

Biodegradable polymers contain polymer chains that are hydrolytically or enzymatically cleaved, resulting in soluble degradation products. Biodegradability is particularly desired in biomedical applications, in which degradation of the polymer ensures clearance from the body and eliminates the need for retrieval or explant. Biodegradable polymers have applications in controlled/sustained release drug delivery approaches, tissue engineering scaffolds, temporary prosthetic implants[23]. Options for biodegradable polymers include (with the number of options available on the market in brackets) synthetic (e.g. poly(lactide), poly(glycolide) and their copolymers; this class of polymers are considered less suited to renderable devices as they do not degrade

21 "Recent Developments in Polymer Macro, Micro and Nano Blends Preparation and Characterisation", 2017, Pages 57–74, Hybrid composites using natural polymer blends and carbon nanostructures: Preparation, characterization, and applications, A. Anumary1, 2, M. Ashokkumar1, P. Thanikaivelan2, P.M. Ajayan1

22 https://www.sigmaaldrich.com/materials-science/material-science-products.html?TablePage=16371327, accessed 1 Oct 2018.

23 Nair, LS et al. Prog Polym Sci, 2007, 32, 762-798.

readily during typical rendering conditions) and natural / bio-polymers (listed above)[24]: Lactide and Glycolide Polymers (85), PLGA Microspheres and Nanoparticles (12), Biodegradable Block Copolymers (52), Caprolactone Polymers (38), Chitosan (13), Hydroxybutyric Acids (4), Polyanhydrides and Polyesters (7), Polyphosphazenes (16), Polyphosphoesters (3), Lipodisq (8).

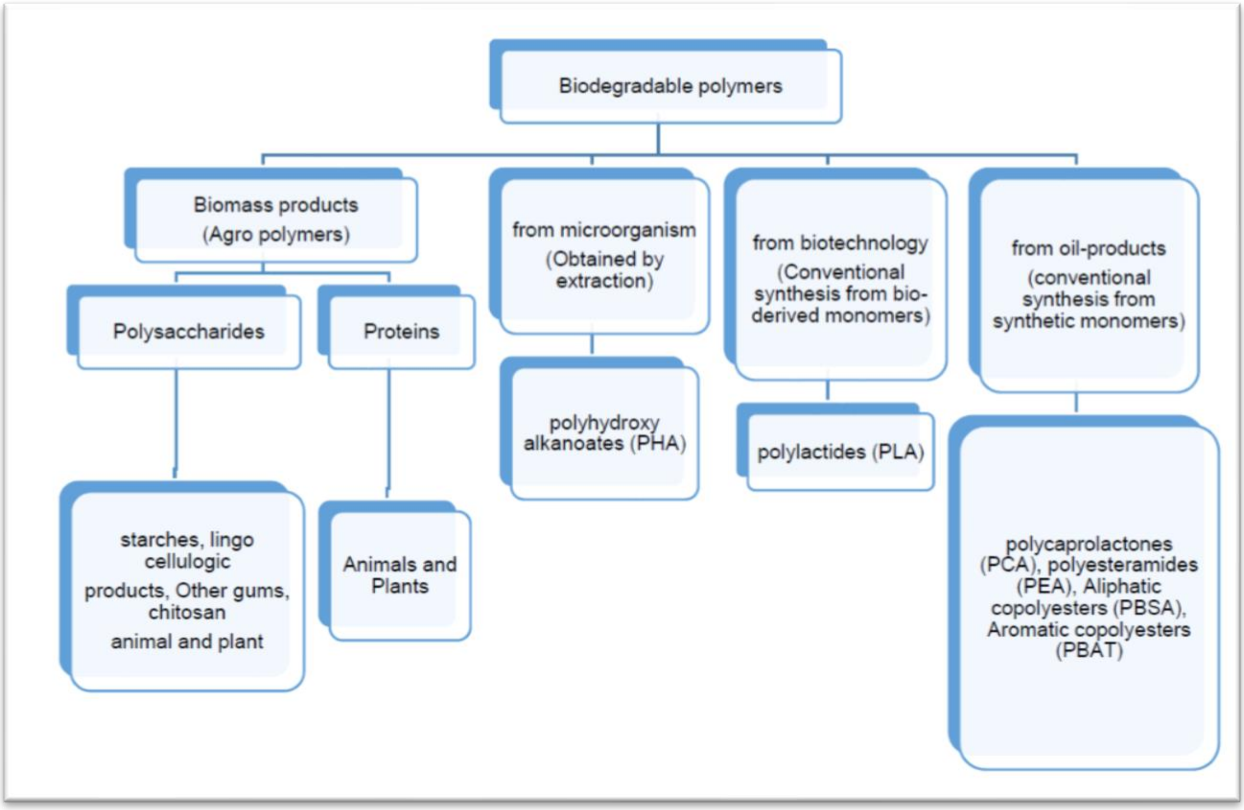


Figure 15: Biodegradable Polymer classification[25]

Biodegradable polymers: not sufficient information and/or not pertinent to this project as these polymers tend to not be renderable.

Edible polymers: are classified as polymers where the polymeric material can be easily ingested by humans or animals in whole or part and are harmless to health.

Components used for the preparation of edible polymer can be classified into four categories: hydrocolloids, polypeptides, lipids, and composites. Hydrocolloids are often called hydrophilic polymers, of vegetable, animal, microbial, or synthetic origin, that generally contain many hydroxyl groups. Hydrocolloid films have good barrier properties of oxygen, carbon dioxide, and lipids but not to water vapor (refer Table 1). Most hydrocolloid polymers also possess mechanical properties suitable for fragile foods (refer Table 2). Protein-based edible polymers have impressive gas barrier properties compared with those prepared from lipids and

[24] https://www.sigmaaldrich.com/materials-science/material-science-products.html?TablePage=20202255, accessed 1 Oct 2018.
25 Luc Avérous, Eric Pollet, (2012). Environmental silicate nano-biocomposites. London: Springer. ISBN 978-1-4471-4108-2.

polysaccharides. In the food packaging sector, starch-based material has received great attention due to its biodegradability, it is edible, starch is commonly available and abundant, the low cost, nonallergic, ease of use and thermoprocessability[26].

Table 4: Water vapor permeability (WVP) properties of different polymers[27].

Film formulation	WVP ($g\ m^{-1}\ s^{-1}\ Pa^{-1}$)
Corn zein	5.35×10^{-10}
Corn zein plasticized with glycerol	8.90×10^{-10}
Fish skin gelatin	2.59×10^{-10}
Whey protein plasticized with sorbitol	7.17×10^{-10}
Wheat gluten plasticized with glycerol	7.00×10^{-10}
Gelatin (obtained from pigskin) plasticized with sorbitol	1.6×10^{-10}
Amylose	3.8×10^{-10}
Corn starch plasticized with glycerol	2.57×10^{-10}
Corn starch plasticized with sorbitol	1.75×10^{-10}
Amylomaize starch plasticized with sorbitol	1.21×10^{-10}
Hydroxypropyl methylcellulose withplasticizer and oil	1.90×10^{-10}
Amylomaize starch with sorbitol andsunflower oil	9.7×10^{-11}
Methylcellulose	8.70×10^{-11}
Methylcellulose 3%	$8.4–12.1 \times 10^{-11}$
Chitosan 2% (unknown source)	$3.66–4.80 \times 10^{-11}$
Chitosan 3%	$6.19–15.27 \times 10^{-11}$
Cellophane	8.4×10^{-11}
PVDC	2.22×10^{-13}
LPDE (low density polyethylene)	9.14×10^{-13}
HDPE (high density polyethylene)	2.31×10^{-13}

26 E. Salleh, I. I. Muhamad, and N. Khairuddin, "Structural characterization and physical properties of antimicrobial (AM) starch-based films," World Academy of Science, Engineering and Technology, vol. 3, pp. 7–25, 2009.
27 M. E. Embuscado and K. C. Huber, Edible Films and Coatings for Food Applications, Springer, London, UK, 2009.

One exciting development is the use of waste water (e.g. cassava starch production wastewater) for growing bacteria (*Bacillus tequilensis*) that produce polyhydroxyalkanoate (PHA)[28].

Table 5: Tensile strength and elongation at break properties of hydrocolloid polymers 29,30.

Polymer	Tensile strength (TS) MPa	Elongation at break (*E* %)
Cellulose derivatives	44–65	10–50
Collagen	1–70	10–70
Chitosan	10–100	20–80
Gelatin	25–140	7–22
Starch	35–46	1.7–3.4
Soy protein	3.7–4.5	152–160
Lentil protein	4-5	58–70
Whey protein	2.5–3.0	15–18
Peanut protein	3-4	147–150
Mung Bean	5.70–6.51	32–40
Low density polyethylene	16–18	>1000
Oriented polypropylene	50–60	73–100
Polyethylene terephthalate	81–85	19–25
Polyvinylidene chloride	65–75	18–23

There are minimal guidelines and/or regulations around the allowable amounts of polymers in any literature. Australian and New Zealand Guidelines for Fresh and Marine Water Quality[31] has no data on polymer contamination. Under “Oils & Petroleum Hydrocarbons” the guidelines state “Insufficient data to derive a reliable trigger value.”

For the types of polymers used within the red meat supply chain, the risk rankings for the polymers and monomers of the polymers used are low[32]. The sorption of persistent organic pollutants to plastic particles, may pose additional problems for marine organisms that ingest plastic particles. Mato et al. (2001) found 100,000–1 million times higher concentrations of PCBs and DDE in marine polypropylene pieces than in the surrounding seawater.

28 https://www.researchgate.net/publication/275530080_Production_of_PHA_from_Cassava_Starch_Wastewater_in_Sequencing_Batch_Reactor_Treatment_System [accessed Mar 28 2018].
29 S. Saremnezhad, M. H. Azizi, M. Barzegar, S. Abbasi, and E. Ahmadi, “Properties of a new edible film made of faba bean protein isolate,” Journal of Agricultural Science and Technology, vol. 13, no. 2, pp. 181–192, 2011.
30 O. Skurtys, C. Acevedo, F. Pedreschi, J. Enronoe, F. Osorio, and J. M. Aguilera, Food Hydrocolloid Edible Films and Coatings, Food Science and Technology, Nova Publisher, 2010.
31 http://www.agricultue.gov.au/SiteCollectionDocuments/water/nwqms-guidelines-4-vol1.pdf
32 https://ac.els-cdn.com/S0048969711004268/1-s2.0-S0048969711004268-main.pdf?_tid=2a0aae25-3e25-439b-9328-4490c97a23cf&acdnat=1520390599_ddb8fd3c9913baf500037cc2cc269418

5.2.3 Literature review of Available Biopolymers

Presented below is an industry wide scan of non-traditional polymers, that is, polymers that are biodegradable and/or made from biological feedstocks that could be suitable for use in RMI device manufacturing.

Table 6: Examples of biodegradable and edible polymers.

Polymer Classification	Company / Product	Ingredients	Melting Point (°C)	Young's Modulus (MPa)	Applications	Advantages	Dis-advantages
Fossil and biodegradable	Polybutylene succinate (PBS)	Succinic acid and 1-4-butanediol	115 °C	3200	• Similar properties to polypropylene • Films e.g. mulching bags • Bags • Boxes	• Biodegradable via microbes • Ingredients can come from petro-chemical and biological sources.	• Biodegradation of fossil based polymers can be slow: longer than composting times hence are less suited to operations associated with the RMI.
Non-fossil and Biodegradable	Cardia Bioplastics / Cardia Compostable B-F[33]	• Thermoplastic starch (TPS), biodegradable polyesters and natural plasticizers. • Resin derived from renewable resources such as non-GMO corn-starch.	90 - 130		• Compostable bags • Shopping bags • Garbage bags • Leaf litter bags • Green bin liners • Produce and meat liners	• Certified biodegradable in professionally managed composting facilities. • Does not contain any non-degradable polymers such as PE, PP, PS, and PVC. • Independent university tests on substance prove no harmful residue left.	• Needs to be stored and handled in cool and dry environments and without exposure to direct sunlight.
	NatureWorks / Ingeo™ Biopolymer 2003D [34]	• Polylactide acid (PLA) resin derived from renewable resources such as corn starch.	150 - 180	3500	• Dairy containers • Food service ware • Transparent food containers • Hinged-ware • Cold drink cups	• Biopolymer used for thermoformed, coating, injection mold, blow molded, and fiber applications. • Polylactide acid looks and behaves like polyethylene and polypropylene. • Making PLA saves 2/3 the energy needed to make traditional plastics. • PLA produces about 70% less greenhouse gases, during degrading, than	• Less suited to RMI devices due to high stability. • Long biodegradation times.

33 http://www.cardiabioplastics.com/products/bioproducts
http://www.cardiabioplastics.com/uploads/110317_CBP_TECHNICAL_DATA_SHEET_-_Compostable_B-F_V3.pdf
34 https://www.natureworksllc.com/~/media/Files/NatureWorks/Technical-Documents/Safety-Data-Sheets/NA-ENG/SDS_NatureWorks_Ingeo-2003D_pdf.pdf
https://www.natureworksllc.com/~/media/technical_resources/technical_data_sheets/technicaldatasheet_2003d_ffp-fsw_pdf.pdf

						traditional and biodegradable plastics.	
	Plantic™ / Plantic™ HP [35]	• Corn-starch	166		• Suitable for food contact applications	• Contains up to 85% renewable content. • Completely biodegradable and home compostable. • Uses up to 40% less energy compared to conventional polymers. • Reduces carbon dioxide emissions. • Cost competitive compared to conventional counterparts. • Long term longevity raw material cost (corn prices more stable compared to rising petrochemical derived plastic costs).	• Requires blending with non-renewables to achieve barrier properties for food
	Showa Highpolymer Co. / Bionolle 1000 [36]	• Polybutylene succinate (PBS) polyester resin	114	470 (MD) 540 (TD)	• Mulching film • Trash bag • Plant pot • Filament • Yarn • Net • Bottle • Gloves • Containers	• From a biological source. • Melting point above low temperature rendering.	• Low melting point (<130 °C) makes this polymer less suited to industry-wide RMI devices
	Showa Highpolymer Co. / Bionolle 3000 [37]	Polybutylene succinate/ adipate (PBSA) resin	94	320 (MD) 340 (TD)			
Edible	Loliware [38]	• Organic cane sugar • Organic tapioca syrup • Filtered water • Seaweed (agar-agar) (hydrocolloid) • Citric acid, colouring agents, flavouring agents (derived from fruits and vegetables) • Shellac and beeswax (coating)	~64 °C		• Biodegradable cups and straws.	• Eco-friendly • 12 month shelf life (Sealed in original package) • Edible • Compostable in 60 days. • Can contain frozen, chilled or room temperature drinks and desserts.	• Not yet commercially available. • Cannot contain substances that are higher than room temperature. • Low melting point could make it unlikely for RMI, but if it does not contaminate tallow, could be easily rendered into meal.
	Aduro/ Novatein [39]	• Blood meal up to 65% (depending upon blend and materials properties required)	~150 – 170 (degrades at 200 °C)		• Agricultural, Horticultural. • Red meat industries.	• Combination of environmentally friendly chemicals used to develop proteins processability so that it can be extruded before degradation.	•

35 http://www.plantic.com.au/product/plantic-hp

36 http://showa-denko.com/wp-content/uploads/2015/03/Bionolle_2015.pdf

37 http://showa-denko.com/wp-content/uploads/2015/03/Bionolle_2015.pdf

38 https://www.loliware.com/pages/faq; http://www.freepatentsonline.com/y2016/0324207.html

39 http://www.adurobiopolymers.com/Novatein

						• Can solve a manufacturing problem. • Provide a competitive edge or marketing opportunity not found anywhere else. • Manufactured inexpensively and easily. • Expected end life disposal costs are lower, material biodegradable and compostable.	
	Biotech / Bioplast TPS[40]	• Polymer Solid Acid Composite (PSAC) derived from pure food sources such as starch.	152 °C[41]		• Short life packaging. • Single-use products. • Food packaging • Thermoformed products • Injection moulded products • Dissolvable products	• Recyclable. • Soft touch • Can be coloured with masterbatches. • Thermoformable • Dissolvable in hot water. • Contains 100% renewable raw materials and biobased carbon. • Exhibits good permeability to water vapor, but also provides good barrier to oxygen and carbon dioxide. • Made from pure food ingredients. • Due to composition, material is edible, digestible, water soluble and readily biodegradable.	• Not maintainable in hot environment and needs to be kept dry, cool and bagged. • Should be used within 3 months.

40 http://www.biotec-group.de/160922BroschBioplastTPS_EN_Web.pdf

41 https://www.researchgate.net/publication/325957212_Mechanical_Thermal_and_Biodegradable_Properties_of_Bioplast-Spruce_Green_Wood_Polymer_Composites, accessed 1 Oct 2018

5.2.4 RMI devices made from protein based biopolymer

Polymer pellets made from RMI blood meal, product name of "Novatein" are available for purchase from Aduro Biopolymers from New Zealand. These could be formed into any device; however, it is possible to purchase the sheep / bobby bungs ($0.065 each) with bovine throat plugs having been trialed ($0.10 each, dependent upon volumes). Ovine / bobby weasand clips are nearing completion and will then be followed by beef clips.

Moisture according to AS method at 105 oC averaged 15.05%. Average starting weight of 7.41g per plug. At 160 ^{o}C mass loss against ambient was 16.81% with some minor signs of deformation especially around tip (refer after and before images below) however, all in all, quite stable at higher temperatures. Most rendering processes reach 130 ^{o}C. The testing on the device at the elevated temperatures confirms that plugs are not expected to melt into the tallow fraction. After extended drying at 160 ^{o}C, the device becomes brittle and fragile, which should assist in the milling. The device does not create hard shards of plastic, but rather is somewhat malleable.

Based on availability, it is noted that the cost-benefit analysis is based on current sheep bung pricing with the estimates for beef clips and beef throat plugs based on predicted market prices. The above *renderable sheep bung device* is available for $0.065 per device compared to the base case of a *synthetic polymer sheep plug* at $0.056 hence for a 500,418 small stock pa facility the annual additional cost is $4,586 pa. Further, as the material is made from protein an additional $1,756 of revenue may be attributed to the mass of the device. Equating to $2,830 pa in additional costs. Assumes an avoided revenue loss of 1% of annual production for a typical sheep facility (500,418 small stock pa) valued at $24,302 pa, the annual overall savings equate to $21,472 pa.

The *renderable beef clip* at an assumed $0.12 each compared to the current *synthetic polymer beef clip* at $0.098 each would cost $43,438 pa more with additional meal of sale providing $207 pa equating to $3,230 pa in costs. The summary table assumes an avoided revenue loss of 1% of annual production for a typical beef facility (156,250 head pa) valued at $84,847 pa. The annual overall savings equate to $81,616 pa.

The *renderable beef throat plug* at an assumed $0.10 each compared to a *synthetic polymer beef plug* at $0.314 each would save $33,438 pa with additional meal of sale providing $414 pa equating to $33,852 pa in costs. The summary table assumes an avoided revenue loss of 1% of annual production valued at $84,847 pa; the annual overall savings equate to $118,699 pa.

5.2.5 Laboratory Analysis – Protein Based Device Before and After Heat Treatment

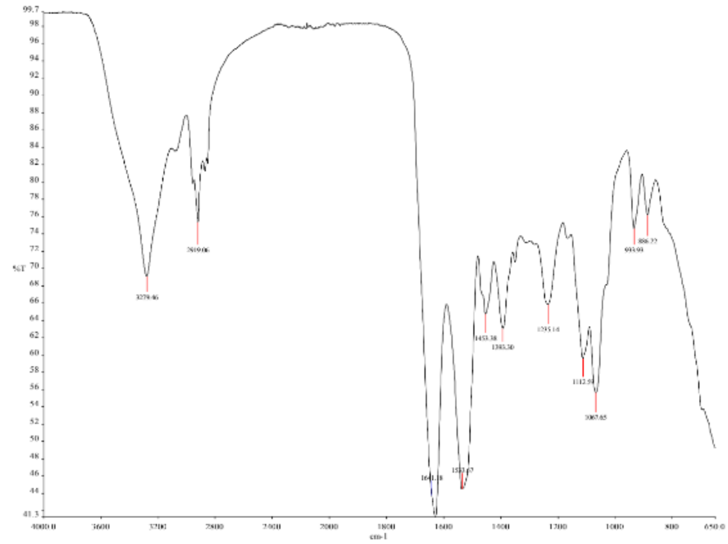
An FTIR spectra method was employed by Intertek Testing Services (Australia) Pty Ltd to determine the chemical composition of a sheep plug device made from blood meal proposed for use as a plug in the red meat processing industry. The composition of these devices is as follows: 15 – 18% moisture, 65% protein meal and 16% additives (e.g. extrusion lubricants, binders, chemical property modulators, etc.). On a dry basis, this is ~80% protein and ~20% additives. Of note is that if it is intended for this material to be left in the meal, then the additives may need to be added to the formal ingredients list.

Under optical microscope both the samples appeared to have a deposit on the surface. Care was taken to cut an analytical sample from under the surface, to represent clean polymer. The ambient sample gave a relatively clear spectrum. A key feature of the spectrum was amide signals. These signals match a range of polymers including nylon, derivatives of polyacrylamide and urea based resin as well as protein-based materials. The signals were broader than that observed for a typical nylon sample, indicating a broad mix of polymeric materials such as seem for polymer samples. The highest Hit Quality Index (HQI) results were for amide containing polymers of Polyamide-7 and Poly(N-n-Octadecylacrrylamide). Examples of naturally occurring polyamides include proteins such as wool and silk. Artificial polyamides include nylons.

The dried device sample gave a similar (or related) spectrum to the ambient sample. The spectrum was further broadened than that for the ambient device suggesting degradation had occurred. The highest Hit Quality Index (HQI) results were for “Cascamite” (a urea containing glue) and Polyamide-2,4.

Mixing the samples with protein meal would still return a spectrum typical of protein, according to the analytical experts.

Figure 17: Sheep plug at ambient storage (left) and after exposure to 160 °C heat. The plug did not melt; however, the device was highly brittle and dry.



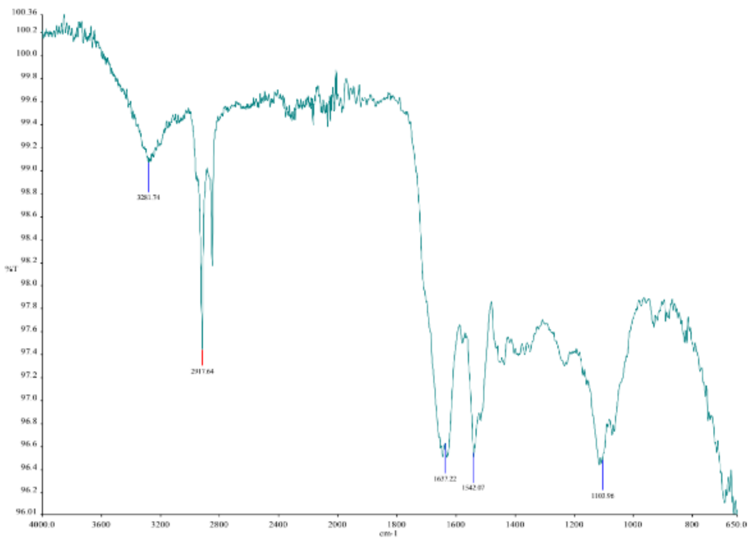


Figure 18: FTIR results for a sheep plug stored at ambient conditions (black trend, above) versus a device after exposure to 160 °C heat (blue trend, below). The wider spectrum for the dried device indicates some degradation / chemical change in the polymer but not complete degradation.

5.2.6 RMI devices made from plant material biopolymer

The main plant materials used are plant based such as paper and starch (or blends containing carbohydrate / starch / cellulose), with paper often being offered as waxed (more expensive but maintains shape in moist environments) and unwaxed (lower cost).

Poly lactic acid (PLA) whilst compostable, does not degrade during rendering hence was not considered a viable long term option for the RMI. The soluble options is claimed by the manufacturer to be functional long enough to complete the task as a bung / plug then degrades quickly in process conditions on plant i.e. heat, movement and moisture. The constituents of the final product are food safe, fit for animal consumption (pet-food savings and rendering by-products) as well as compliant to all global regulatory standards, it is processable (i.e. able to be injection moulded at high speed in multi-cavity hot runner tooling) and has mechanical properties similar to that of conventional thermoplastics by using fillers in a water soluble matrix.

The material has zero non-organic material in rendering by-products. However, starch and paper effectively contain no protein, hence whilst they may be "organic" and "renderable" they effectively present as ash and do not contribute to the protein percentage. Hence, no value as meal is assigned to these devices.

The two main offerings in the market tend to be:

[1] "soluble", often made from a starch / carbohydrate material. As an example, a *soluble sheep plug* at a quoted $0.112 each compared to the current *synthetic polymer sheep plug* at $0.056 each has an annual additional cost of $27,940 pa. Assumes an avoided revenue loss of 1.53% of annual production for a typical sheep facility (500,418 small stock pa) valued at $37,182 pa. As an example, a *soluble beef throat plug* at a quoted $0.251 each compared to the current *synthetic polymer beef throat plug* at $0.314 each has an annual cost saving of $9,844 pa. Assumes an avoided revenue loss of 1.53% of annual production for a typical beef facility valued at $130,000 pa.

[2] paper often referred to as "biodegradable". As an example, a *paper sheep plug* at a quoted $0.079 each compared to the current *synthetic polymer sheep plug* at $0.056 each has an annual additional cost of $11,592 pa. Assumes an avoided revenue loss of 1.53% of annual production for a typical sheep facility (500,418 small stock pa) valued at $37,182 pa.

As an example, a *waxed paper beef throat plug* at a quoted $0.525 each compared to the current *synthetic polymer beef throat plug* at $0.314 each has an annual additional cost of $32,969 pa. Assumes an avoided revenue loss of 1.53% of annual production for a typical beef facility valued at $130,000 pa.

As an example, a *unwaxed paper beef throat plug* at a quoted $0.339 each compared to the current *synthetic polymer beef throat plug* at $0.314 each has an annual additional cost of $3,906 pa. Assumes an avoided revenue loss of 1.53% of annual production for a typical beef facility valued at $130,000. pa.

5.2.7 Changing RMI devices from a low melting point to a higher melting point polymer

Based on a review of melting points, to prevent LLDPE, LDPE and perhaps HDPE / nylon (blend) contamination in tallow there appears motivation to consider an industry wide movement away from LLDPE, LDPE and blends towards polymers with melting temperatures above 130 °C (e.g. PP). Polypropylene (PP) films can be blown or cast and can provide high temperature resistance (melt point 160 to 165 °C), higher stiffness and tensile strength (than LDPE), better clarity than LDPE, availability in different thicknesses and colours. The main drawback is the lower barrier properties for the same thickness (refer Table below[27]), however this impact can be reduced by using a thicker film.

Table 6: Properties of polypropylene (PP) compared to low density polyethylene (LDPE).

Property at 1.0 mm film thickness [42]	PP - Cast	PP - Blown	LDPE
Tear Strength	Better	Good	Best
Modulus (stiffness)	Better	Best	Good
Low Temp Impact Resistance	Better*	Good	Best
Dimensional Stability	Best	Good	Better
Haze	Better	Best	Good
Heat Sealing	Better	Good**	Best
Barrier	Better	Best	Good
Area Factor (Yield)	Best	Better	Good
Haze (%)	2 – 3.5	1 – 2	5+
Gloss (%)	86 - 89	88 – 92	75 - 80
Modulus/Stiffness (kpsi)	75 - 130	350+	<55
Impact (Glass Transition Temp. °C)	3	4	-7
Area Factor (yield - in^2/lb)	31,000	30,500	29,800
Tensile Strength (psi)	7,000	15,000	3,000
Barrier: O2 (cc/100 in^2/day)	220	120	500
H2O (gm/100 in^2/day)	0.8	0.4	1.3

[42] https://www.blueridgefilms.com/polypropylene_film.html, accessed 1 Oct 2018.

5.2.8 Adding magnetic material to devices.

Magnetizing materials would then rely on separation technologies. Summarized in the following table are technology classes available and associated vendors for providing engineered solutions for the removal of contaminants from rendering feedstock. This option has been tested and can magnetizing agent is available however the supplier (Magnattack) suggests further R&D is required before complete roll-out into all devices (refer below).

A further advantage of magnetic separation is the prevention of damage to equipment downstream. A case study was provided for a DIMPLE-MAG™ MAGNETIC EXTRACTION SYSTEM at an Australian winery where metal contaminants such as wire and vine fencing staples, and small-medium sized tools such as hammers and brackets, enter the grape receivals area and cause significant damage to downstream equipment. The Dimple-Mag™ Extraction System consists of a specially designed Magnetic Plate paired with a high-intensity Magnetic Separation Bar. The configuration of the system improves the capture of magnetics without hindering product flow or compromising product coverage as experienced with conventional bar/grate magnets. The customer also noticed a significant improvement in the condition of sensitive assets downstream such as the bag press, de-stemmer, lacerated knife valves, pumps, etc. The estimated value of a magnetic separation system was $27,000 pa. For a rendering plant, it is expected that screens on the hammer mills, screw conveyors / augers, rotating equipment, prevention of clogging, wear, rupture and/or damage to pipeworks, valves and other infrastructure as well as avoided downtime.

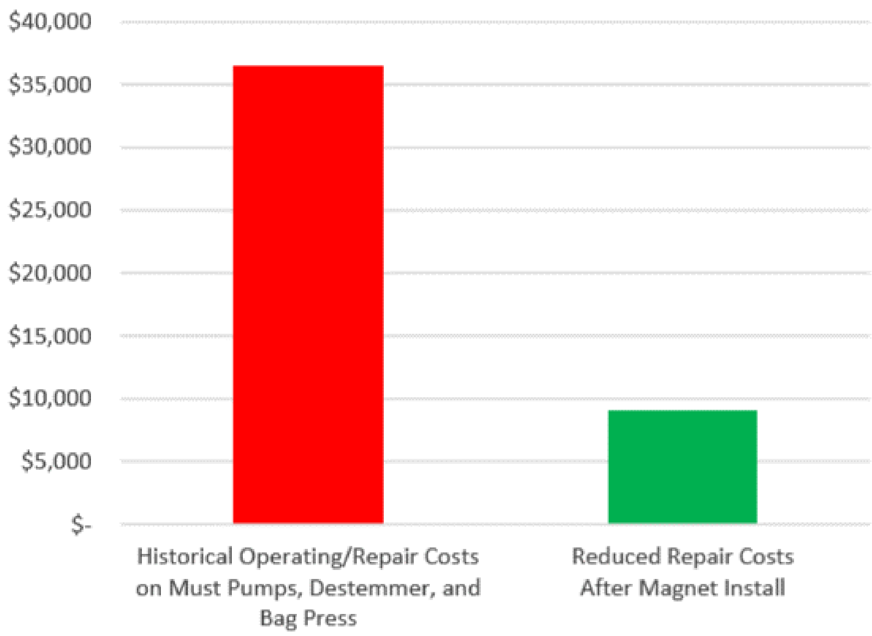


Figure 19: Case study in equipment protection from an Australian winery.

To maximise the benefit of removing magnetize materials, it is preferable to remove materials as early in the process as possible, hence capital costs for a wet separation system was assumed (Magnattack TMI-100.140/UC; refer table below).

Table 7: Summary of a system for removing metals from wet rendering feedstock.

	Magnattack TMI-100.140/UC
Removes	• Magnetized material • Work hardened stainless steel • Magnetic stone particles • Wear iron • Tramp metal • Some removal of metal containing devices
Capacity	10 tph
Size	Machine protection: W: 1200 mm D: ~2200 mm H: ~2400 mm Ground mounted.
Unit operations included and associated quote	Oil cooled electro magnet (incl. first oil fill), design, controls, control and transformer cubicles, manual: $58,450
Exclusions	• 415V/3P cabling • Support legs for magnet • Surrounding chute • Support frame for magnet and control box • Installation • Collection bins
Conformance	0909MAGSEP 1-2010 Standard
Equipment supply costs	$ 58,450
Estimated Total Installed Capital	$ 91,270 (accounting for an estimated amount for exclusions)
Warranty	12 months from receival
Notes	No ferric metals within 500 mm. 15 yr life of plant.
Delivery	6 – 8 weeks

Magnattack™ Global have, with Active Magnetics research input, completed some successful trials as part of a closely controlled rotor moulded project and found that magnetizing devices is a viable option for removal of magnetized contaminants. There are a number of aspects that need carefully controlled R&D to ensure reliability of the finished product to the end user, specifically:

How the MAGNATTACK™ Activator affects the set parameters of mass production for injection molding.

- Potential interference of the MAGNATTACK™ Activator with electronic chips that may be part of ear tags.
- Ensuring MAGNATTACK™ Activator incorporated into moulded products is compatible for activation reaction to the magnets and metal detectors found in a rendering
- Specified quantity of powder or liquid magnetising additive within a prescribed tolerance to be added to each batch to avoid interference with molding process.
- Tightly controlled and proven procedure to manage dispersion of MAGNATTACK™ Activator right up to the molding process.

MAGNATTACK™ Global estimates a product development budget of $150,000 to $200,000 to advance the molding technology for a participating molding company of which a proportion would be consulting fees for any further research needed from Active Magnetics Research Pty Ltd. Magnattack would retain ownership of background IP. Cost-benefit analyses (CBAs) presented in section 4.9 are for an individual rendering operation hence this development budget is assumed to be a "centralized" cost before a magnetizing agent / magnetized products are available in the market hence this product development budget is excluded from CBAs for individual rendering operations.

Devices are compared to a base case or "business as usual" case of an equivalent synthetic plastic device currently available for the RMI as outlined below in Table 9.

Table 9: Cost-benefit analysis of synthetic polymer devices compared to devices of different materials of construction.

Device	$ pa device saving	$ pa additional meal revenue	Avoided revenue loss (assumed at 1.53% of annual production)	Equipment protection	Equipment maint-enance costs p.a.	Annual revenue / cost saving	Capex ($)	Payback (years)	Notes
Renderable beef throat plug	$33,438	$ 414	$ 130,000	Avoided PE fouling (difficult to quantify; assumed $0)	NA	$163,852	NA	Immediate	Same colour as meal
Renderable beef clip	-$3,438	$ 207	$ 130,000	As above	NA	$126,769	NA	Immediate	Same colour as meal
Renderable sheep bung	-$4,586	$ 1,756	$ 37,182	As above	NA	$34,352	NA	Immediate	Same colour as meal
Paper sheep bung	-$11,592	NA	$ 37,182	As above	NA	$25,590	NA	Immediate	Different colour to meal
Soluble sheep bung	-$27,940	NA	$ 37,182	As above	NA	$9,242	NA	Immediate	Different colour to meal
Soluble beef throat plug	$9,844	NA	$ 130,000	As above	NA	$139,844	NA	Immediate	Different colour to meal
Beef Biodeg beef plug waxed paper	-$32,969	NA	$ 130,000	As above	NA	$97,031	NA	Immediate	Different colour to meal
Beef Biodeg beef plug unwaxed paper	-$ 3,906	NA	$ 130,000	As above	NA	$126,094	NA	Immediate	Different colour to meal
Magnetitic sep. system weasand clip: beef rendering	-$4,594	NA	$ 130,000	$ 27,000	$ 8,170	$144,236	$91,270	0.63	Separation efficiency relies upon exposure of contaminants to electro-magnet hence even spreading is required.
Magnetitic sep. system weasand clip: sheep rendering	-$8667	NA	$ 37,182	$ 27,000	$ 8,170	$47,344	$91,270	1.93	

5.3 Separation Technologies

5.3.1 Summary of Separation Technology Options

Summarized in the following table are technology classes available and associated vendors for providing engineered solutions for the removal of contaminants from rendering feedstock.

Table 3: Separation Technology Options Summary

Technology Class	Contaminants removed	Vendor	Contact	RFQ	Exp. with food	Exp. with Aus RMP
X-ray and imaging software technology	metal, stones, pits, glass, high density plastics removal. [Wagner "magmeat"]	Tomra[43]	[1] www.tomra.com Supplier in Australia is DKSH. This technology is recommended for stones and glass hence less suitable for RMI.	Date sent RFQ: 27/7/2018 Submitting a written proposal.	Y	Y
Pulsed LED, camera and NIR (Near InfraRed)	Targeted spectroscopy with 1 mm precision.	Tomra	Jeff Goodwin, jeff.goodwin@dksh.com 0438 106 048 Dry: standalone NIR Tomra system for metal and plastic out of meal. Wet: Tomra sensors + DKSH conveyor and ejection.	Date sent RFQ: 27/7/2018 Submitting a written proposal.	Y	Y
		Steinert[44]	[2] steinert.com.au Hefner@steinert.com.au sales@steinert.com.au 03 8720 0800	RFQ sent 27/7/2018 Response: Does not operate in food processing industry; cannot offer expertise or applicable equipment for RMI.	N	N
Ballistic / controlled air separator	Waste sorting	McDonald International Ltd[45]	[3] http://archive.mcdonaldint.com reception@mcdonaldint.com info@mcdonaldint.com	RFQ sent 27/7/2018 No response received.	N	N
Magnetic separators	Metals	magnattackglobal.com	[4] Calvin.ruddiman@magnattackglobal.com	RFQ sent 27/7/2018 Proposal received.	Y	Y
	Stainless steel.	Wagner Magnet	[5] wagner-magnete.de info@wagner-magnete.de Aus rep is DKSH, see above	RFQ sent 27/7/2018 No response received.	N	N
	Ferrous and non-ferrous	JDM Recycling Equip (can also do optical, NIR, XRF, controlled air)	[6] t.levien@jdmaust.net.au (personnel could have changed in last 3 yrs) P: 07 3807 9327 M: 0427 352 734	RFQ sent 27/7/2018 No response received. Does not operate in RMI.	Y	TBA
Recycling industry	Multi-stage: Optical / air nozzle systems, floatation, X-ray (material and/or colour)[46], and density [47]	MSS Optical	[7] http://www.mssoptical.com/ www.cpgrp.com	Date sent RFQ: 26/7/2018. Response: Not suitable; don't offer configuration of wash-down type quality (i.e. stainless steel etc.).	Y	N
		Paprec France	[8] https://www.paprec.com	No response received.	N	N
Ballistic separation	Separation of complex streams using multiple stages	DKSH	[9] Geoff Goodwin Rep for Tomra, see above	Date sent RFQ: 26/7/2018 Confirmed submitting proposal		

[43] https://www.tomra.com/en/sorting/food/sorting-equipment/ixus-bulk
[44] https://steinertglobal.com/au/magnets-sensor-sorting-units/sensor-sorting/nir-sorting-systems/unisort-black/
[45] http://archive.mcdonaldint.com/waste-management-systems/ballistic-separator
[46] http://www.mssoptical.com/wp-content/uploads/2014/05/mss_CIRRUS1.pdf
[47] https://www.paprec.com/en/understanding-recycling/recycling-plastic/sorting-plastic-waste

Technology Class	Contaminants removed	Vendor	Contact	RFQ	Exp. with food	Exp. with Aus RMP
Camera / laser sorter	Separates complex streams based upon color, size, shape, and structural properties	key.net/product-finder-page: Optyx, Python, Spyder.	[10] Alex Austin M: 0417 334 262 E: aaustin@key.net	RFQ sent 27/7/2018 Response: Reviewed more detailed information, declined to submit proposal as no sorters running this stream and significant difference to current ability. Will take time to characterize material and sensor issues; welcome opportunity to look in the future, unable now.	Y	N

5.3.2 Case Studies

Case study #1: MAGRAM

Testimonial

"We experienced customer issues with metal including drenching capsule spring pieces. MAGNATTACK™ Global assisted us and came up with the MAG-RAM™ system which allowed us to remove these metal contaminants and I have no hesitation in recommending this equipment to the rendering industry.

It has been a great investment which has undoubtedly proved its worth over nearly 3 years. There has been negligible maintenance. Since we load out of the MAG-RAM™ into skips in a driveway, we invented a vacuum cleaner system to suck away the metal fragments and deposit them in a vacuum drum beside the driveway. MAGNATTACK™ appreciated what we did and now have a pneumatic transfer option of their own as standard.

I must say the MAG-RAM™ self-cleaning separator has given us assurance that we have a safer, much cleaner and more valuable product than before. Highly recommended innovation!"

Scott Newton — Southern Meats

Figure 17: MAGRAM installed in situ.

Case study 2: TOMRA

FOOD SORTING TECHNOLOGY BY TOMRA

TOMRA provides a range of technologies for sorting and removal of foreign material and offers range of different sensor technologies for food sorting at **high speeds with capabilities for measuring** material, shape, size, geometry, color, defect and damage characteristics, and location of objects. Fine-tuning of the sorting machine is required for components including sensors, electronics, software, and ejection modules. Sensing options that may be applied to detection and/or removal of contaminants from rendering feed or products include:

1. Interactance spectroscopy (QVison): Utilizes Near-InfraRed (NIR) light and penetrates far into materials to measure fat, moisture, protein and collagen simultaneously and in real-time, delivering highly accurate and consistent results. The hygienic and robust analyzer up to 20 mm, and measures across the full 500 mm width of its conveyer belt. The design is open, so all surfaces can be visually inspected. The QVision is able to analyze up to 30 tons of meat per hour, making it an ideal choice for high volume processors.

*Figure 18: Standalone **QVison** system for processing 30 tons per hour. L: 2,900 mm, W: x 1,115 mm, H: 1,910 mm. Power draw: 0.5 kW, Compressed air: 50 L/min.*

CUSTOMER TESTIMONIAL #1: cold meat production line at **Salaisons Jouvin** to ensure consistent and uniform product quality as well as cutting costs, guaranteeing the uniformity demanded by customers in order to satisfy consumers. Link: https://www.tomra.com/en/sorting/food/case-studies/salaisons-jouvin

CUSTOMER TESTIMONIAL #2: TANN Marchtrenk, Austria's largest producer of meat products, uses the TOMRA QVision as part of its innovative fat analysis. As a result, the in-line fat analysis process is improved and optimized to deliver a uniformly high-quality product.

Link: https://www.tomra.com/en/sorting/food/case-studies/tann-marchtrenk

2. X-Ray scan and sorter: Product passes on a horizontal conveyor belt between an industrial x-ray source and an x-ray detector. X-rays are absorbed by the product and by the foreign bodies. The absorption rate is higher for denser or thicker objects. When foreign bodies are detected, they will be rejected by powerful air guns. This technology is well suited to sorting of metal, stones, pits, glass and high density plastics from nuts, dried fruit, fruit, seafood and whole potatoes. This technology may be suitable for contaminants removal from a wet rendering feed.

CUSTOMER TESTIMONIAL link: https://www.tomra.com/en/sorting/food/case-studies/sun-valley-raisins

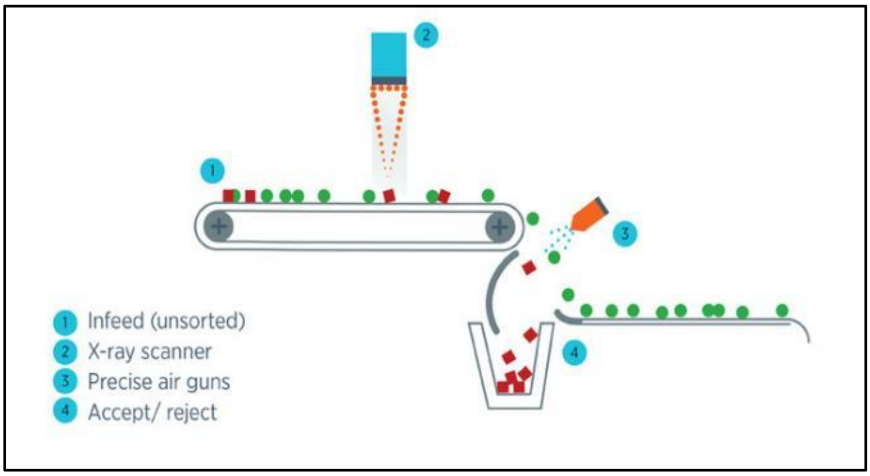


Figure 19: Standalone IXUS system and diagrammatic separation system. L: 2,435 mm, W: 1,785 mm, H: 2,320 mm. Power draw: 1.5 kW, Compressed air: 6 – 7 bar.

5.3.3 Cost-Benefit Analysis: Separation Technology

Submission #1: Magnattack Electro Magnet for Machine Protection

Magnattack Global submitted drawings and information for a metal fragment contamination control system for a typical rendering plant as described in the technical specification, on 10 August 2018. The technical specification allowed for 18 tonnes pa of metal contamination overall. For the first submission, the source of this metal contamination was considered to originate tramp Iron and wear Iron introduced via equipment wear and tear within the plant.

This magnet has deep field coverage pre hammer mill or pre hogger for protection against larger tramp iron objects likely to cause significant damage and wear on assets downstream. Only a percentage of metal wires or fine metal slithers can be separated at this point due to the nature of the product flow and the limitations of a deep field electro magnet however the primary duty of this magnet is for protection against bolts and larger objects impacting machinery downstream.

Contact: Calvin Ruddiman, TECHNICAL SUPPORT, MANAGER AU, calvin.ruddiman@magnattackglobal.com , P + 61 2 4272 5527 M + 61 437 710 311, 16 Prince of Wales Avenue, Unanderra, NSW 2526.

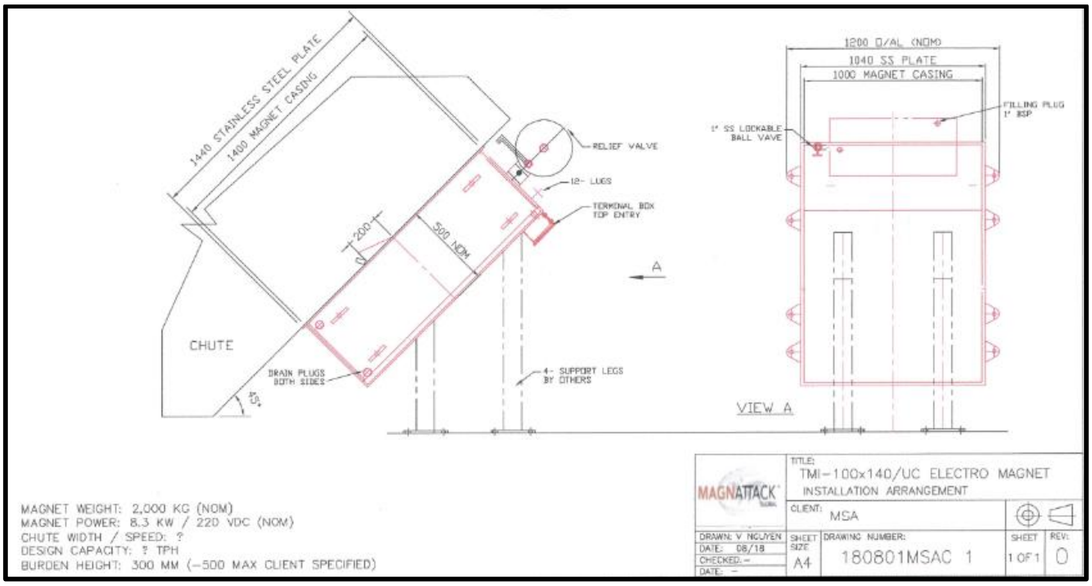


Figure 20: Magnattack TMI-100.140/UC.

Positioning the Magnattack unit at the front of the rendering process provides the following advantages:

- Protects unit operations downstream such as augers, screws, conveyors, mills and other equipment.
- Removes contaminants from both tallow and meal.
- Provides an opportunity to remove both metal and devices that are "magnetized" (i.e. plastic ear tags, bungs and clips that contain metal powder and/or sufficient metal content to be removed via a magnet / electro-magnet.

Submission #2: MAGRAM for final product security

The magnet for final product security requires a high intensity surface strength 10,000 gauss self-cleaning magnet to effectively retain the very fine fragments in the finished product such as wires and slithers that may be introduced during processing or have escaped the deep field magnet upstream. The final magnet is the Critical Control Point for metal fragment contamination, hence it is important that this unit meets relevant certification especially to meet the requirements for export and pet food ingredients. The Mag-Ram™ system is manufactured in conformance to the 0909 MAGSEP 1-2010 international magnet standard and USDA requirements for auditors and clients.

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Figure 21: MAGRAM RE80 self-cleaning pneumatic separator installed in situ.

Submission #3: DKSH – ejection of contaminants from a wet stream using sensors and a conveyor with air jets.

This solution combines a DKSH separation device with a Tomra sensor to remove contaminants from wet rendering feed. This approach provides the following advantages:

- Protects unit operations downstream such as augers, screws, conveyors, mills and other equipment.
- Can remove metal, stones and high density plastic from both tallow and meal.
- Provides an opportunity to remove both metal and devices that are "magnetized" (i.e. plastic ear tags, bungs and clips that contain metal powder and/or sufficient metal content to be removed via a magnet / electro-magnet.

Tomra: ARA. Costs if there are contaminants and a rejected load, or a court case if contaminants are traced back to a particular plant.

Perth: first plant to run a contaminant removal system for rendering feed. Render feed was a novelty for the German plant.

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Submission #4: Tomra - Removal of metals and plastic from a dry stream

This solution is a standalone solution using Tomra equipment to remove contaminants from a dry stream only (i.e. free flowing meal) using a strong magnet (electro-magnetic for ferrous, stainless steel materials and other metals) and NIR with air jets for polymers.

Note: DKSH is the Australian distributor of tomra equipment.

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Submission #5: Wagner - Removal of metals from a dry stream

The Wagner device achieves an "extreme depth effect" to remove ferrous and stainless steel metals but cannot remove aluminum or brass. Magnet diameter: 400 mm with a working width of 400 to 3000 mm, with 1800 mm recommended for this application.

Wagner is distributed by DKSH in Australia.

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Figure 23: Ferrous and stainless steel Separator 0432NV. Not able to remove aluminum or brass.

Annual maintenance for separation systems was assumed at $8170 p.a. and is subtracted from the annual benefit (includes: lubricant / oil change, oil viscosity testing kit, Travelling Wiper Seals every 6 mths, Annual Major Overhaul carried out by Technician and parts, Annual Verification report to meet auditors / client requirements for HACCP certification, 14 hours p.a. for general maintenance / inspection by onsite staff).

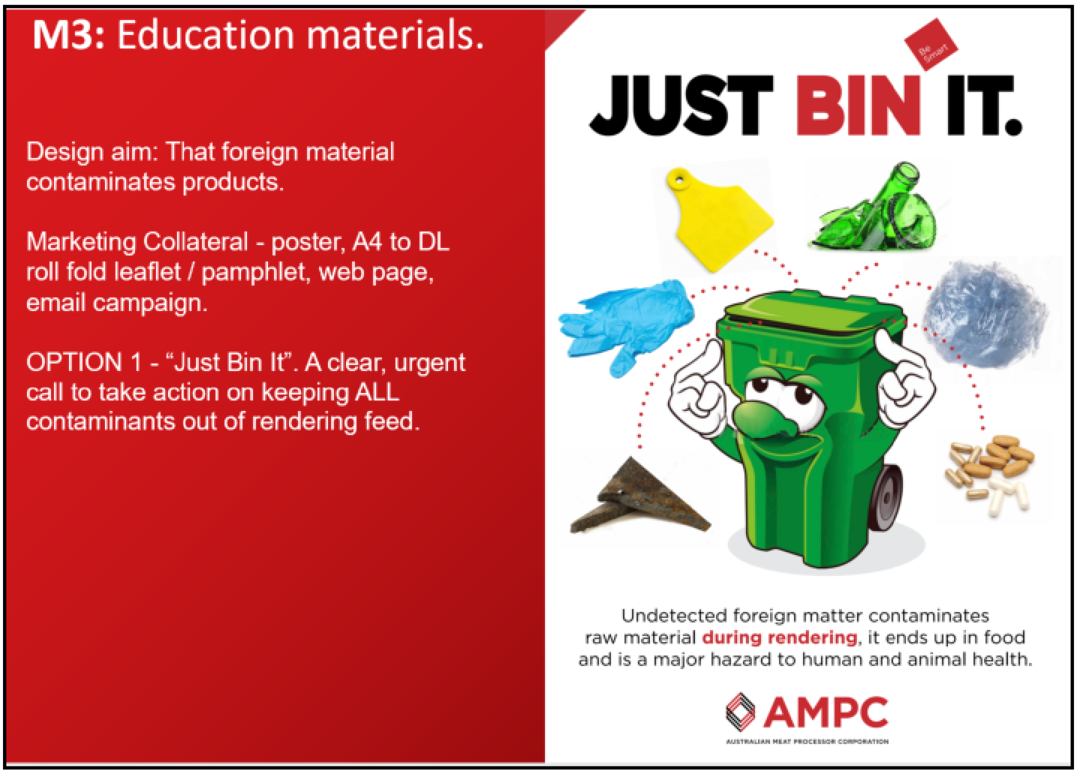
5.3.4 Summary of Contaminant Separation Equipment

	#1 Magnattack TMI-100.140/UC	#2 MAGRAM RE80	#3 DKSH – wet feed	#4 Tomra – dry feed	#4 Wagner – dry feed
Removes	• Work hardened stainless steel • Magnetic stone particles • Wear iron • Tramp metal • Some removal of metal containing devices	• Magnetic stone particles • Capsule springs post-milling • Other metal present in meal	Higher density and thicker objects: • metal • stones • glass • high density plastics	• Magnet and electromagnet for metals • NIR for polymers.	• Magnet and electromagnet for metals
Capacity	10 tph	40 tph load out chute		30 tons per hour	
Size	Machine protection: W: 1200 mm D: ~2200 mm H: ~2400 mm Ground mounted.	Product security: W: 500 mm D: 1605 mm H: 175 mm Mounted as required (i.e. mid-stream; above hopper)	L: 2,435 mm W: 1,785 mm H: 2,320 mm.	L: 2,900 mm W: 1,115 mm H: 1,910 mm.	L: 2,779 mm W: 2,460 mm H: 1,050 mm. 1,250 kg
Unit operations included and associated quote	Oil cooled electro magnet (incl. first oil fill), design, controls, control and transformer cubicles, manual $58,450	MAGRAM RE80, Top and bottom matching flanges, manual, standalone timing controls (incl. transformer, timing control panel and cubicle), venturi contaminant collection system.	Power draw: 1.5 kW, Compressed air: 6 – 7 bar.	Power draw: 0.5 kW, Compressed air: 50 L/min.	Integrated control and signals. Power draw: 1.5 kW, 415V. Compressed air: 50 L/min. Incl. import duty, insurance & sea freight.
Exclusions	• 415V/3P cabling • Support legs for magnet • Surrounding chute • Support frame for magnet and control box • Installation • Collection bins	• Top and bottom adaptors. • Standard 240V power cabling to control box. • 60 PSI operating air pressure. • Installation. • Collection bins.			• Unloading and positioning insurance. • 415V cabling • Installation • Collection bin

	#1 Magnattack TMI-100.140/UC	#2 MAGRAM RE80	#3 DKSH – wet feed	#4 Tomra – dry feed	#4 Wagner – dry feed
Conformance	0909MAGSEP 1-2010 Standard				
Equipment supply costs	$ 58,450	$ 47,393			$148,000.
Estimated Total Installed Capital	$ 91,270 (accounting for an estimated amount for exclusions)	$ 62,093	$790,000	$590,000	$186,920
Warranty	12 months from receival	3 yrs on magnetic strength; 2 yrs on mechanicals excl. metal fatigue. No warranty on seals, gaskets or wear items.	Typically 12 – 24 months (TBC). Additional insurance coverage / support beyond the standard warranty period is available.		12 months from date of installation and no later than 18 months ex works German
Notes	No ferric metals within 500 mm. 15 yr life of plant.	15 yr life of plant.			
Delivery	6 – 8 weeks	4 – 6 weeks	TBC	TBC	18 – 20 weeks.
Location	Incoming feed	Dried meal outfall	Incoming feed	Dried meal outfall	Dried meal outfall
Benefits	Removal of metal contaminants and machine protection	Removal of metal contaminants from final meal	Removal of contaminants (Metal, stones, plastic) in feed and machine protection	Removal of metal and plastic contaminants from final meal	Removal of metal contaminants from final meal
Avoided revenue loss $ p.a.	$ 70,855 (1.53% avoided rejection metal in meal only)	$ 70,855 (1.53% avoided rejection metal in meal only)	$200,855 (1.53% avoided rejection metal and 1.535 plastic in meal; 1.53% plastic in tallow)	$ 130,000 (1.53% avoided rejection meta in meal; 1.53% avoided plastic in meal)	$ 70,855 (1.53% avoided rejection metal in meal only)
Equipment protection / avoided maintenance $ p.a.	$27,000 (i.e. augers, screws, mills, pipework, fixtures)	NA (final product protection only)	$27,000 (i.e. augers, screws, mills, pipework, fixtures)	NA (final product protection only)	NA (final product protection only)
Estimated benefit $ p.a. (accounting for opex)	$ 89,685	$ 62,685	$ 227,855	$ 121,830	$ 70,789
Simple payback	1.02 years	0.99 years	3.6 years	4.84 years	2.98 years

5.4 Educational Materials

After creating five themes and receiving feedback from the Project Control Group and the ARA, two themes were further developed and refined as shown below. Approval by AMPC is required before wider dissemination.



6.0 CONCLUSIONS/RECOMMENDATIONS

The most critical sources of contamination were considered to be those presented in Figure 24 below. Operators throughout the supply chain should pay particular attention to these sources of contamination.

Figure 24: Main sources of contaminant in rendering meal and tallow.

RMI staff and other workers within the RMI supply chain must be given clear instructions during induction and re-training to not put any plastic or other such contaminants in rendering feedstock, that the only place for these materials are in the bin. There is anecdotal evidence that without clear direction, a worker may not be aware that waste can end up in render if not placed in the correct bin.

Microscopy can provide indicative images of meal and tallow however this qualitative method is not expected to provide any advantages above simple visual inspection. The use of a fluorescent dye is not considered viable due to the dye binding to a range of material in the meal and the polymer being too distributed / diffuse in the tallow. Further, as the dye binds to hydrophobic materials the dye appears to remain present through the tallow thereby decreasing the ability to detect heightened fluorescence.

Fourier Transform Infra-Red (FTIR) was found to be the most suitable assay for determining the presence and type of contaminant.

When considering the controls hierarchy, if a device must be used FTIR analysis shows clear advantages in targeting devices utilizing a protein base bio-polymer that has a chemical composition and colour matching that of meal. On a dry basis, this is ~80% protein and ~20% additives. Of note is that if it is intended for this material to be left in the meal, then the additives may need to be added to the formal ingredients list.

A range of “off the shelf” devices the provide an “immediate” payback are currently available such as bungs and plugs plus also clips being in development. There appear advantages in targeting devices utilizing a protein base bio-polymer that has a chemical composition and colour matching that or similar to that of meal. As a second option, polymer made from organic, soluble and renderable materials are available that is food safe and fit for animal consumption. Thirdly, bungs/plugs made from paper are available and can be processed through the rendering process. Fourthly, materials that are sources of highest contamination risk (LLDPE and LDPE films that melt into tallow) can be replaced with polymers with high melting points (e.g. polypropylene).

Including ferrous / metal material in devices was estimated to provide a 0.63 year payback for a typical beef operation and a 1.93 year payback for a sheep operation (i.e. abattoir with onsite rendering).

There is a strong economic argument for removing contaminants from the rendering feed as early as possible to protect equipment and to remove all contaminants (metals and plastics). Where a plant does not have an existing metal removal system, investing in a system to remove metal and magnetized devices can achieve a payback of 1 to 3 years. Automated detection and removal equipment utilizing near infra-red (NIR) can provide paybacks of 3 to 5 years. However, a NIR system can offer a higher net present value due to avoidance of metal and plastic contamination as well as showing utilization of best practice technology for dealing with a range of contaminants.

Further advantages that could provide financial benefits but are not able to be calculated due to the case-by-case and/or subjective nature are:

- Loss of reputation / good standing due to contamination
- Additional product demand from off takers due to absence of contamination and evidence of use of best practices
- Higher product value due to absence of contamination and evidence of use of best practices.
- Protecting in-house rendering equipment from polymer fouling / damage.

8.0 BIBLIOGRAPHY

References are supplied as footnotes throughout the report.