Innovative approaches to adding value to vegetable waste - Phase II

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Simplot Australia Pty Ltd - Victoria

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MT06053

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Innovative approaches to adding value to vegetable waste – Phase 2

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MT 06053

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Report Purpose
The final report for project MT 06053 (Innovative approaches to adding value to vegetable waste – Phase 2) has been produced in fulfilment of the conditions of milestone 190: "Final report received by Horticulture Australia Ltd.". It includes information on the conduct of the work, the outcomes, and the business propositions that have resulted from the project.

Acknowledgement of funding sources and collaborating institutes.
Project MT 06053 was supported by funding from Horticulture Australia Ltd (HAL), and Simplot Australia Pty Ltd (SAPL). Technical expertise and research services were provided by Food Science Australia (FSA), New Zealand Crop and Food Research (NZCFR), and SAPL.

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Media Summary

The Australian vegetable processing industry is under increasing pressure from low cost alternatives, such as frozen broccoli florets from China, canned and frozen sweet corn from Thailand, and frozen peas and potatoes from New Zealand. Processing companies and their growers are looking at all areas of the supply chain for opportunities to improve efficiency. Adding value to the large volume of waste associated with vegetable and potato processing is a focus for Simplot Australia Ltd., and it has joined with Horticulture Australia to fund a project: "Innovative approaches to adding value to vegetable waste". This is the second of a three phase program, and builds on the strong progress made in Phase I. The project has a triple bottom line philosophy—outcomes must benefit society, the environment, and the balance sheet.

The project brings together scientists from Food Science Australia and New Zealand Crop and Food Research to work with Simplot to examine new technologies for adding value to vegetable waste.

A waste audit for processing plants in Bathurst, Devonport, and Ulverstone (Phase I) was used as the basis for evaluating available technologies. The technologies were spread across bio-energy generation, edible fibre and starch recovery, fish and animal food manufacture, extraction of bio-actives and biopolymers, and composting. The initial study identified four concepts for detailed analysis: conversion of potato waste to bio-energy, extraction of corn fibre and potato protein, and refinement of solid waste for pet food. A business case has been developed for each of four concepts: protein extraction from potatoes, fibre extraction from corn, bio-energy from anaerobic digestion of solid vegetable waste, and animal food pellets. The business cases are essential to secure large capital investments for pilot stages and commercial adoption, and will be presented to the Simplot Board of Management in July 2008.

Although the business cases are still under consideration, Stage II has clearly shown that strong opportunities exist to improve the efficiency and minimise the environmental impact of vegetable processing. Future R&D in this area will include the pilot testing of capital intensive technologies and the extrapolation of the technology to commercial situations.

Technical Summary

Nature of the problem

Vegetable and potato processing industries generate a large volume of waste. At best this waste is sold for very low returns as raw feed for animals, and at worst it incurs treatment and disposal costs. A new philosophy and new approaches are needed to obtain better financial and environmental outcomes from the waste associated with vegetable and potato processing. The challenge is to improve the competitiveness of the processing industry in Australia.

Science undertaken

The work involved:

- Engage FSA to further evaluate the business cases for 'specific protein extraction from potato waste' and 'fibre from corn core waste'.
- Analysis of a waste audit for processing vegetable (sweet corn, peas, beans, and broccoli) and potato industries based at Bathurst (NSW), Devonport (TAS), and Ulverstone (TAS). The audit included plant materials left behind at harvest, and solid and liquid waste streams associated with processing factories.
- Identification and investigation of technologies with potential to add value to the vegetable and potato waste. The technologies were spread across bio-energy generation, edible fibre and starch recovery, fish and animal food manufacture, extraction of bio-actives and biopolymers, and composting.
- Economic and environmental evaluation of the most promising opportunities to enable a business decision to be made.

Major research findings, industry outcomes, and recommendations

A strong financial and environmental case was built for three concepts:

1. 'Fibre from corn core waste': The return on investment (ROI) is estimated at 32%, with a pay back time of 4 years and an internal rate of return (IRR) of 25%. The projections indicate that the project will be cash flow positive after the first years of production.

2. 'Specific potato protein extracts from potato waste': The ROI of this project is estimated at 46%, with a payback time of 3.4 years and an IRR of 33.1%. The projected cash flow indicates that the project will be cash flow positive from the first year of production.

3. 'Pellets from waste to feed livestock': The ROI for the vegetable pellet is estimated at 148% and a payback time of less than 1 year. The cash flow also will be positive from the first year of production.

Industry must now evaluate the business cases for these concepts further and invest in the research and development required to address the technical and commercial challenges in a staged approach. The cost of the pilot and commercial developmental work will be significant.

A business case for the conversion of SAPL's solid waste streams into bio-energy (methane) was also developed. Three different options were explored and analysed but none of them was financially viable. The estimated ROI was either negative (income lower than operation costs) or very low (payback time of more than 16 years). However, industry should maintain a watch on financial and environmental factors affecting the viability of the technology. Global energy costs are volatile and imposts surrounding energy producing net carbon emissions are likely to be set.

The 3-stage approach (concept evaluation, technical development, and business case development) used by the project to develop technology to add value to processing waste proved to be successful. The project recommendations to industry are to:

- Engage FSA to further evaluate the business cases for 'specific protein extraction from potato waste' and 'fibre from corn core waste'.
- Engage CFR to further evaluate the business case for 'vegetable pellets from waste to feed livestock'.
- Invest in the research and development required to address the technical and commercial developmental challenges in a staged approach for one or more cases.
- Maintain a watch on financial and environmental factors affecting the viability of the case for bio-energy.
- Maintain a watch for emerging technologies with the potential to add value to vegetable and potato waste.

1 Introduction

The Australian vegetable and potato processing industry is under increasing pressure from low cost alternatives, such as frozen broccoli florets from China, canned and frozen sweet corn from Thailand, and frozen peas and potatoes from New Zealand. Supermarket chains are able to import a range of processed vegetables from low labour cost countries to place on shelfs at a low price next to well known Australian brands. Major food processors are now facing serious decisions concerning the viability of Australian factories using locally sourced raw material. Processing companies and their own growers are looking at all areas of the supply chain for opportunities to improve efficiency. SAPL is a large processor of potato, sweet corn, pea, bean, and brassica crops with factories at Bathurst (NSW), Ulverstone (TAS), and Devonport (TAS).

Large capital investments in new technologies to manage vegetable waste are likely to result from this work. These investments will add value to existing waste and improve industry competitiveness in Australia. The new technologies will also reduce the environmental footprint of vegetable and potato processing.

Background: In 2006 Simplot Australia (SAPL) quantified and qualified waste volumes associated with their processing sites. The major waste streams at these sites were:

Factory site:	Main waste streams
Bathurst	Corn cob cores and corn husks
Devonport	Beans, peas, carrots, broccoli, cauliflower
Ulverstone	Raw & processed potato flesh & potato peels

This examination found that close to 100kt of by-products (waste) were produced each year. In order to improve the economic and environmental outcomes of the waste streams, SAPL initiated a project ("Profitable Waste") in September 2006. The project has 3 phases:

Phase 1: *Compositional Analysis of vegetable waste products*[1]

Aim: to determine the functionality and value of the by-product or of extracted components.

Samples of the major waste streams were sent to New Zealand Institute for Crop & Food Research (CFR) for analysis, and the moisture, nitrogen (protein), fat, ash, selected vitamins and bio-actives, and minerals were measured:

- Corn cob cores, husks, and waste water slurry coming from the corn process
- Raw potato flesh + potato peel slurry
- Vegetable matter (beans, peas, carrots, broccoli and cauliflower)
- Broccoli and cauliflower field waste

Phase 2: *Technology evaluation (Current Project MT06053)*

The project was funded by SAPL and HAL, and technical expertise was provided by CFR and Food Science Australia. The aim of phase 2 was to identify and evaluate existing innovative technologies to add value to selected vegetable processing waste streams.

The division of concept evaluation tasks was made according to the specific technical abilities of each service provider. New concepts and technologies involved were aligned with the SAPL waste database, and examined for fit against the criteria of economic benefit and environmental sustainability.

[1] Note: this project phase was solely funded by SAPL and was not part of HAL fund for "Innovative approaches to adding value to vegetable waste – Phase 2".

Initial areas of interest included starch and fibre recovery, extraction of bio-actives, bio-fuel or bio-energy production, and the manufacture of fish and animal foods. All concepts were reviewed with a focus on existing technology, economic, and environmental feasibility. The final output of Phase 2 was in the form of a business plan designed to assist SAPL to make a business decision.

Phase 3 (future): *Implementation of new technology*[2]

The phase 2 business plans will be presented to the SAPL Board in July 2008, and the strategy for adoption will be based on the financial imperative of the business cases. This may lead to significant investments for the SAPL year beginning on the 1st of September 2008 to implement the sound cases.

[2] It is planned to commence the implementation phase in September 2008

2 Materials & Methods

The technical work was a collaborative effort involving SAPL, CFR, and FSA. Funding for the project was provided through a Voluntary Contribution arrangement between SAPL and HAL. SAPL provided the overall project leadership and management.

2.1 Phase 2 - Project structure

Phase 2 used three stages to identify waste management technologies for business plan development. The ideas/concepts were evaluated at the end of each stage, and were compared against technical, economic, and environmental criteria (Figure 1).

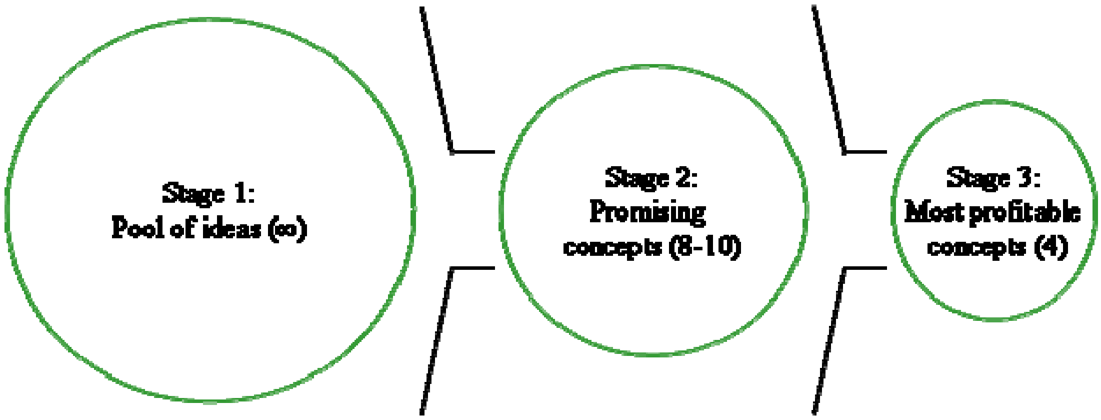


Figure 1: Elimination of ideas at the end of stage 1 & 2

2.2 Stage 1: Concept evaluation / ideation

Project outcomes and aims were discussed at an initial meeting with each service provider, and their expertise was evaluated to assist with the division of work. Data related to the SAPL waste streams (from phase 1) was provided. The service providers were asked to conduct internal brain storming and ideation sessions with their experts to ensure that a wide range of technologies were captured. The bulk of ideas/concepts were presented to SAPL at Stage 1 Workshops and ranked using the following score card:

	Score				
	1	**2**	**3**	**4**	**5**
Chance of technically success	Very low	low	Average	High	Very High
Length of development	> 36 month	24-36 month	12-24 month	6-12 months	≤ 6 months
Magnitude of impact per anno	< $ 0.5M	$ 0.5-1M	$ 1-2M	$ 2-3M	> $ 3M
Cost of processing	Very High	High	Moderate	low	very low
Capital costs	> $3M	> $2M	$1-2M	$0.5-1M	<$0.5M
Research Development costs	>300 k	200 - 300 k	100 - 200 k	50 - 100 k	< 50 k
ROIC (pay back period)	> 5 y	3 y	2 y	1 y	< 1 y
Level of Benefit (non profit)	Very low	low	Average	High	Very High
Implementation of Technology	very difficult	difficult	Moderate	easy	very easy

After the Workshops, SAPL analysed the concepts and discussed their respective ranking.

Time allocated for stage 1: 3 months (May – July 07)

2.3 Stage 2: Analysis of technologies

To assist service providers tailor the selected technologies to industry needs, SAPL provided additional information to the service providers:

- Data related to SAPL's vegetable and potato processes, such as equipment, capacity, seasonality, volumes, etc.
- Volume of other waste streams such as waste water, starch recovery etc.
- Detailed energy requirements for each site.
- Costs related to waste treatment, e.g. gas, electricity, water and waste water charges, caustic, transport, etc.
- Cost balance for current waste streams.
- Site plans of factories; accessibility of waste streams, available spaces for new technologies.

In addition, the service providers visited the plant sites to hold discussions with key SAPL staff. SAPL called meetings with the service providers to discuss progress at least once per month.

The service providers provided "back-of-the-envelope" capital and operation costs for all concepts to assist with the selection of technologies for Stage 3 business case development. Additional market research was conducted by SAPL for those concepts focusing on the extraction of specific components such as antioxidants, fibres, and proteins. Information about the Australian and international markets was difficult to obtain, and a SAPL marketing expert was used to conduct the market research. The report was provided to the service providers.

Time allocated for stage 2: 6 months (Aug 07 – Jan 08)

2.4 Stage 3: Business case development

SAPL provided a guideline for business case requirements at the beginning of stage 2 to guide the service providers. Business case requirements included:

- Introduction and background:
  - Background to project.
  - Current situation - impact of waste material on the business.
- Objectives: commercial, technical, and environmental.
- Evaluation of technology.
- Project Outcomes - Technology and Recommendations (detailed description of each concept):
- Waste description.
- Technology description.
- Outputs and likely volume/s.
- The process:
  - Optimal handling of waste pre-processing (and consequences).
  - Process flow.
  - Equipment needs.
  - Sensitivities.
  - Impact on current processes.
- Market information:
  - Market size.
  - Market need.
  - Market value of idea output/s.
  - Market competition.
  - Margins available in this market.

- Financials - full financial model of the idea including:
    - Sales.
    - Cost of production.
    - Other costs.
    - Net profit.
    - Capital costs.
- Non-financial benefits (environmental).
- Challenges and Risks (Technical and commercial).
- Technical development:
    - R&D plan and requirements.
    - Time-frames (including milestones and go/no go gates).
    - Development costs.

The business cases were presented at the end of April 08.

The time allocated for stage 3: 3 months (Feb – Apr 08)

Annotation: The SAPL "Profitable Waste" team will evaluate and discuss each of the business cases in detail. The recommendations will be presented to the SAPL Board of Management in July, based on the chance of success, and the economical, technical and environmental feasibility.

3 Results and discussion

3.1 Stage 1 – Concept ideation outcomes

The service providers conducted desk top research to develop waste management ideas tailored to vegetable and potato waste streams, based on a SAPL briefing document. The outcome of this research was presented at Workshop 1.

3.1.1 Ideas developed by Food Science Australia

Eight value-adding opportunities were researched and presented:

- Isothiocyanages and Glycosinolates from broccoli and cauliflower waste.
- Polyphenols from vegetable waste.
- Carotenoids from vegetable waste.
- Proteins and enzymes from vegetable waste.
- Dietary fibre from vegetable waste.
- Novel extruded food products from vegetable waste.
- Healthy French fry from vegetable waste.
- Structured ingredients from vegetable waste.

The opportunities were evaluated against a set of selection criteria and the scores used to rank each opportunity (Table 1). Dietary fibre from vegetable waste achieved the highest score, followed by novel extruded food products, and then healthy French fries. The extruded food products and healthy French fry opportunities were not pursued by SAPL as rough economic calculations found them to be unprofitable. The extraction of dietary fibre from vegetable waste, isothiocyanates and glycosinolates from broccoli and cauliflower waste, proteins and enzymes from vegetable waste, and polyphenols from vegetable waste were selected for further desk-top research and development by FSA.

Table 1: Sum of the scores for each of the eight opportunities presented by FSA in order of highest to lowest score.

Opportunity	Score Sum
Dietary Fibre	32
Novel Extruded food products	30
Healthy french fry	30
Isothiocyanates and Glucosinolates	25
Proteins and Enzymes	24
Polyphenols	22
Novel structured Foods	18
Carotenoids	2

3.1.2 Ideas developed by Crop & Food Research

The concepts presented by CFR at Workshop 1 were:

- Waste stream bio-transformation using invertebrates
- Create compost from waste vegetable materials.
- Create quality compost and worm casts from worm farms using waste vegetable material, and grow live worms to sell.
- Produce liquid fertiliser from waste vegetable materials.
- Grow live insects from waste materials and create a new protein product.
- Create vegetable pellets or cubes from waste to feed livestock.
- Create invertebrate and vegetable matter pellet combinations to feed to livestock, fish farms, etc.

- Minimise compliance costs for waste treatment by adding detritus feeding aquatic larvae to ponds.
- Test waste streams at different stages along the processing line for natural pesticides.
- Waste water recycling.
- Ingredient development.
- Bio-polymers.
- Bio-energy.

These opportunities were also evaluated and scored against the set of selection criteria (Table 2). Vermi-composting was removed from the list of ideas because large-scale facilities are not common and the technology is developmental. The manufacture of food ingredients from frozen vegetable waste was also excluded due to the small volume of food quality waste. To achieve a sharper focus, the ideas selected from each service provider were limited to five. The concepts selected for further analysis were: compost, liquid fertilizer, vegetable pellets, waste water recycling, and bio-energy.

Table 2: Sum of the scores for each of the presented opportunities by CFR in order of highest to lowest score

Opportunity	**Score sum**
Whole ingredients (froz veg waste)	**34**
Compost + worms	**32**
Compost	**31**
Liquid fertilizer	**30**
Veggie pellets	**29**
Recycling waste water	**29**
Bio-energy	**28**
Corn husks for pellet fires	**27**
Extract components (crude)	**23**
Live insects	**18**
Pellets high in protein	**18**

3.2 Stage 2 – Technical development outcomes

The research outcomes for each of the nine concepts were assessed at Workshop 2 for technical feasibility and economic benefit.

3.2.1 Concepts developed by Food Science Australia

Based on Stage I results and feedback from SAPL, FSA undertook desk top research and prepared additional information on four opportunities (dietary fibre, isothiocyanates and glycosinolates, proteins, and polyphenols from vegetable waste). This was presented at Workshop 2 and the concepts were assessed against the following criteria:

- Amount of waste available.
- Amount of product that could be extracted from the waste.
- Value of the products extracted from the waste.
- Approximate days and hours of production.
- Approximate size of each processing operation when processing 100%, 75%, 50% and 25% of the selected waste streams.
- Potential income generated.

In addition, SAPL conducted market research to evaluate the potential for the extracted ingredients. Following aspects were considered in this research:

- Market characteristics (globally and Australian).
- Market Opportunities.
- Market Growth and structure.
- Industry Forces.

- Resource requirements and fit with SAPL.
- Potential for SAPL.

After reviewing the information provided, SAPL selected two opportunities:

- The extraction of proteins from potato waste.
- The production of soluble and insoluble fibre from corn cores.
  -

In addition to information provided by FSA, a major driver of this decision was market research, which showed that large and growing markets exist for potato protein and corn fibre.

3.2.2 Concepts developed by Crop & Food Research Australia

CFR conducted desk top research for five opportunities based on the outcome of Workshop 1 (compost, liquid fertilizer, vegetable pellets, waste water recycling, and bio-energy). An external consultant (Waste Solutions Ltd) was engaged to develop the bio-energy concept in collaboration with CFR. Trial work was conducted at Devonport to evaluate the quality of different composted vegetable waste streams. The outcomes of this stage were presented at Workshop 2. The concepts were assessed against the same criteria as used for FSA (above).

SAPL selected two opportunities for business case development:

- Pelletising the waste streams into stock feed and pet food.
- Converting solid waste streams into bio-energy.

The non-selection of the waste water and composting concepts was driven by disappointing economic analysis results. At this stage of the process, pelletising and bioenergy appeared to have some economic fundamentals in place.

Note: the concepts chosen for business case development (FSA and CFR) covered all main waste streams at the three factory sites in Bathurst, Devonport and Ulverstone.

3.3 Business case 1 (summary) – Protein extraction from potato waste

3.3.1 Description of waste

Potato waste consists of a liquid and a pulp fraction. The liquid fraction has a relatively high amount of protein (2-3%), free amino acids, and salts, and the potato pulp fraction contains starch, cellulose, hemicelluloses, pectin, and proteins. More than 42,000 tons of potato waste is available for protein extraction and separation at the Ulverstone factory (Table 3). This consists mainly of raw and cooked potatoes, and peel. An analysis of the potato waste found an average protein content of 2.5%. The compositional analysis of these waste streams is presented in Table 4.

Table 3: Quantity of potato waste streams produced at Ulverstone suitable for protein extraction and separation.

Waste stream	Quantity (tons)
Raw and cooked potato waste	22,500
Peel (contains soil)	20,000

Table 4: Composition of the potato waste material produced at Ulverstone factory.

	Late season		Early season		Mid season	
	Potato waste	**Potato peel**	**Potato waste**	**Potato peel**	**Potato waste**	**Potato peel**
Moisture (%)	75.7	89.1	79.4	85.7	76.5	87.1
Protein (%)	2.28	2.5	2.5	2.5	2.5	2.5
Fat (%)	0.1	0.2	0.15	0.3	<0.1	0.2
Ash (%)	0.95	0.9	1.25	0.7	1	0.8

Potato tubers contain patatin as the major protein (approximately 70%) and protease inhibitors (PPI; about 30%), described by Pouvreau *et al*, 2001. Potato proteins are reported to have useful physical properties such as foam forming and stabilising properties, and good emulsifying properties over a wide pH range (Van Den Broek, 2004).

Some potato proteins have biological activity such as angiotensin-converting enzyme (ACE) - inhibition, antioxidant activity (Pihlanto *et al*, 2008), anti-carcinogenic activity (Pouvreau *et al*, 2001) and satiety effects (Hill *et al*, 1990).

3.3.2 Technology

The technology to extract proteins from potato waste streams in an un-denatured form is similar to that used in other food sectors such as the dairy industry. The protein content in potato is higher than in cheese whey (2.5% c.f. 0.6%), making it a suitable starting material for protein extraction. The process to extract and separate proteins from potato waste is depicted in Figure 2[3].

The waste stream is first pulverised to improve mass transfer and achieve good rates of protein extraction and solubilisation. In the solubilising stage, water is added from an existing waste stream from the factory to reduce the overall water consumption. This stream will also provide additional soluble potato proteins. The solid and liquid streams are next separated by decanting or filtration. The clarified liquid containing dissolved solutes, including the proteins, is run over adsorption substrates. Strategic elution protocols are used to fractionate the adsorbed proteins into patatin and PPI fractions. These two fractions are de-salted, concentrated, and then dried.

[3] This strategy will need to be researched to confirm the process and secure data for commercial design.

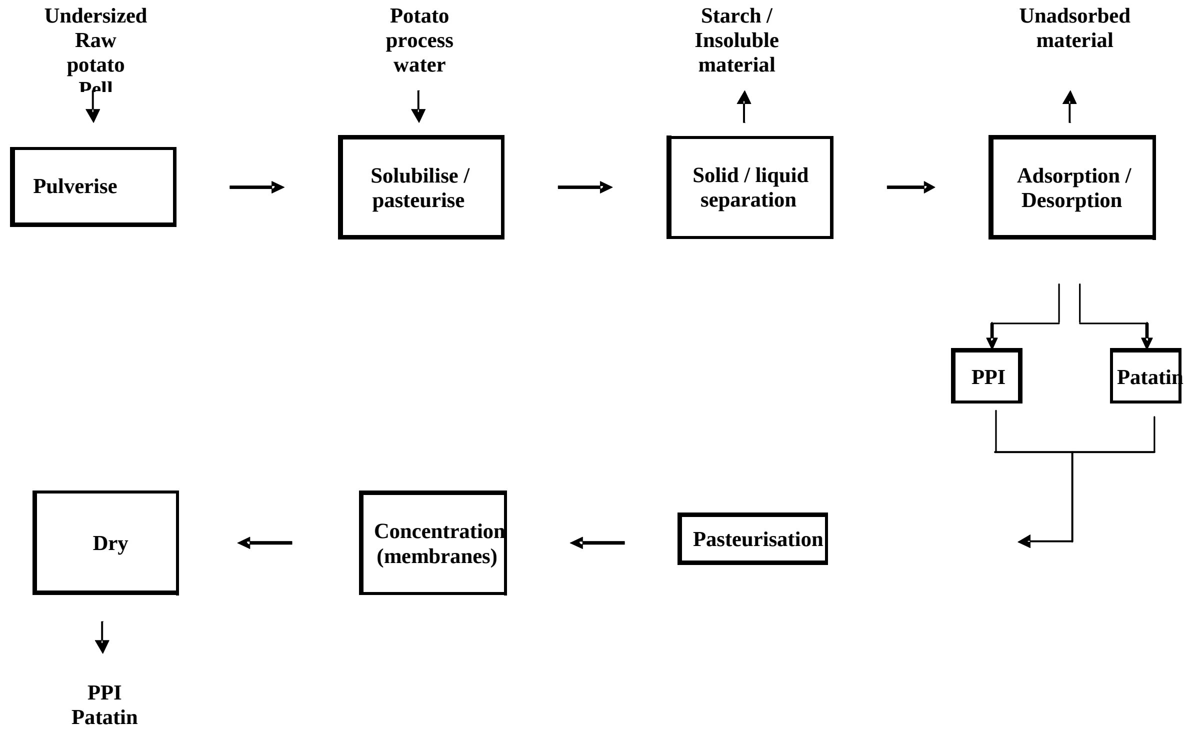


Figure 2: Extraction and separation strategy to process 42,500 t/year of potato waste and manufacture the potato protein ingredients, patatin and PPI.

Chromatographic separator (CSEP) technology is used in the process (above) to separate the proteins from the liquid stream. CSEP technology has been successfully used in the Victorian dairy industry to extract and fractionate proteins from dairy streams. It is a systems approach to continuous simulated moving bed chromatography (SMB). Figure 3 shows CSEP technology.

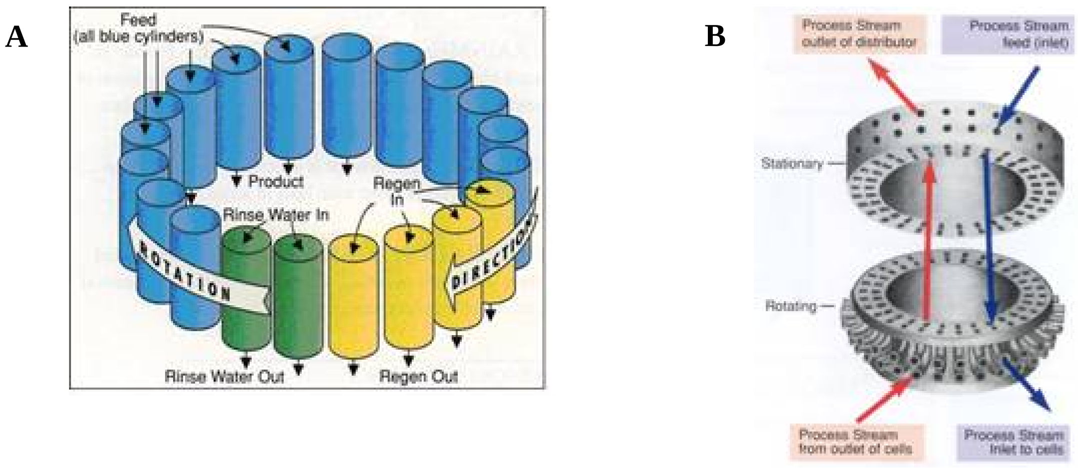


Figure 3: Illustration of CSEP technology showing the continuous nature of the technology (A) and the valve arrangement (B)

This technology is widely used in chemical and water treatment industries, but not in the food processing sector until the recent pioneering work of FSA to fractionate dairy protein and peptide.

The CSEP approach simplifies upstream and downstream processes and allows them to operate continuously; reducing the size of the equipment compared to operating traditional batch columns. The technology is commercially available and can process fluids over a very wide range of flow rates and hydraulic characteristics. CSEP technology uses mild processing conditions compared to other forms of separation, and materials are not subjected to high temperatures or to organic solvents, which improves their functionality. The functionality of CSEP-isolated products provides a point of differentiation against those manufactured by other processes.

3.3.3 Outputs and likely Volume

The Ulverstone site produces about 42,500 tons of potato waste annually, with an average protein content of 2.5% and solids content of 13%. This equates to about 1,100 tons of protein per year.

3.3.4 Market Information

The total protein market in the US was estimated at US$ 2.69 billion in 2004, growing at a compound annual growth rate of 6.3%, and projected to be US$ 3.95 billion in 2011. The main product category of the market is soy proteins, followed by dairy proteins. Solae LLC and Archer Daniels Midland are the two main producers of protein ingredients, accounting for 36% of the US market. In 2004, whey protein isolate (WPI) sold for US$ 5.95 – 6.60/kg, gelatine for US$ 5.50/kg, and soy protein isolate for US$ 6.15/kg. About 140 companies operate in the US protein ingredient market (Data from Frost and Sullivan; May 2005).

The price of dairy protein ingredients has increased over the past year and is likely to remain high for the next few years. Prices for dairy ingredients have risen by 10% (whey proteins) to 40% (caseinates) over the past year (Dairy reporter.com; 13/08/07). There are many reasons for this, including rising demand for dairy proteins globally, reduced protein production due to the drought in Australia and New Zealand, elimination of EU export subsidies to dairy farmers, and the increased cost of agricultural feed due to diversions to bio-fuel production (Dairy reporter.com; 13/08/07). The imbalance in the market for dairy proteins presents opportunities for the supply of proteins from other sources with similar physical and nutritional functional properties. The development of protein ingredients derived from potato is timely as an alternative to animal derived proteins, and as an alternative to soy proteins which have reported allergenic properties.

It is expected that the market for potato proteins will grow with the overall global demand for proteins, and also with promotional activities by Solanic (a potato protein manufacturer). Solanic is located in Holland and produces four ingredients based on potato proteins. SAPL is in a good position to manufacture potato protein ingredients and take advantage of the growing market.

3.3.5 Financials[4]

Table 5 shows the estimate for capital items to process the potato waste stream from Ulverstone. The cost includes a contingency of **20%** of equipment capital (excluding installation costs) for unforeseeable capital items. The estimate assumes that a building to install the process is available at Ulverstone, but an allowance is made for building modification (footings, plinths, drainage etc.).

[4] It should be noted that FSA is not a licensed financial advisory entity, and as such, it is recommended that independent financial advice be sought with respect to economic analysis of any products or processes.

Table 5: Capital costs estimate for a process to manufacture potato protein ingredients by processing 42,500 tons/year of potato waste.

Item		$
Milling/mincing equipment		250,000
Mixing/protein extraction (2X 5kL temperature control tanks with stirrers)		100,000
Solid / liquid separation		450,000
CSEP (**C**ontinuous Chromatographic **SEP**arator)		1,500,000
UF for protein concentration		250,000
Spray Dryer		1,000,000
Pumps and valves		100,000
CIP system		75,000
Initial resin charge		570,175
Instruments and control		100,000
Total equipment cost		4,395,175
Installation costs (% of equipment costs)	10	439,518
Electrical costs (% of equipment costs)	10	439,518
piping costs (% of equipment costs)	10	439,518
Civil costs (% of equipment costs)	5	219,759
Engineering & consultancy (% of equipment costs)	8	351,614
Start up costs (% of equipment costs)	2	87,904
Contingency (% of equipment costs)	20	879,035
Total capital cost estimate		**7,252,039**

The **process economics** of extracting protein from waste potato streams was evaluated using the following assumptions:

- Only 70% of the protein can be extracted, but technically a yield of >90% should be possible.
- Patatin fraction is 80% of the total protein in potato.
- Process plant operating period:
  - 20 hours/day production; 4 hours/day cleaning (CIP)
  - 7 days/ week operation
  - 48 weeks / year operation
- The sales value of patatin is $7,000/t and $18,000/t for potato protease inhibitor.

Table 6 shows the annualised income and operating costs of a plant to process 42,500t of potato waste.

Table 6: Annualised costs and earnings before interest, tax, depreciation and amortisation (EBITDA) for a plant to process 42,500 tons/year of potato waste.

	$/unit	Quantity	$
Labour (2/shift: total 8)	55,000	8	440,000
Water ($/kL)	0.41	121,972	50,008
Salt ($/ton)	270	3,362	907,797
Packing costs ($/ton)	60	766	45,979
CIP chemicals ($/day)	50	336	16,800
Resin (replaced over 18 months; $/L))	100	3,801	380,117
Membranes replaced over 18 months	125	380	47,515
Spray drying costs	125	766	95,789
Power costs (incl. membranes; $/kWh)	0.14	618,358	86,570
Maintenance (% of equipment costs)	1		43,952
Plant overheads (% of labour)	10		44,000
Laboratory analysis (% of labour)	5		22,000
Marketing and sales (% of sales income)	3		128,741
Operating costs			2,309,268
Contingency (% of operating costs)	10		230,927
Total cost of production			**2,540,195**
Cost of production ($/kg protein)			3.31
Income			
Patatin ($/ton)	7,000	613	4,291,368
Potato Protein Inhibitor ($/ton)	18,000	153	2,758,737
Total Income			**7,050,105**
Income (EBITDA)			**4,509,910**

The estimated costs of production include 10% contingencies for unforseen operating expenses. The operating cost includes the replacement of the resin and membranes after 18 months of operation, although it is expected to function for longer. The analysis indicates that the cost of production will be $3.31 per kilogram of protein.

Pea protein is estimated to return between $5.20 and $8.20/kg, and $8 and 10/kg for higher quality vegetable proteins. The estimate for functional protein ingredients is between $20-50/kg (Corinne Noyes 2008, Profitable Waste Report). Project budgets have used $7/kg sales of patatin, which is the mid price of the pea protein, and $18/kg for the functional protein ingredient.

Table 7 shows the projected cash flow and profitability for the production of potato protein. The cash flow assumes that any escalation in cost due to inflation will be off set by an increase in global protein prices. The project life is assumed to be 10 years for the evaluation.

The sale of protein products is assumed to increase over time, and in the first year only 60% patatin and 20% PPI will be sold, rising in each year until plant capacity is reached in 5 years for patatin and 6 years for PPI.

The return on investment (ROI) of the project is estimated at 46%, with a pay back time of 3.4 years and an internal rate of return (IRR) of 33.1%. The projected cash flow indicates that the project will be cash flow positive from the first year of production.

Table 7: Projected cash flow for the process to manufacture potato proteins at Ulverstone.

ROI (%)	**46.0**
PBT (Years)	**3.42**
IRR (%)	**33.12**

Year		0	1	2	3	4	5	6	7	8	9	10
Capital costs		-7,252,039										
Sales - Patatin (% of prodiuction capacity)			60	80	90	95	100	100	100	100	100	100
Patatin (tons/year)			368	490	552	582	613	613	613	613	613	613
Sales - Potato Protein Inhibitor (% of prodiuction capacity)			20	40	70	80	90	100	100	100	100	100
Potato protein Inhibitor (tons/year)			31	61	107	123	138	153	153	153	153	153
Income - Patatin ($/ton)	7,000		2,574,821	3,433,095	3,862,232	4,076,800	4,291,368	4,291,368	4,291,368	4,291,368	4,291,368	4,291,368
Income - Potato protein Inhibito ($/ton)	18,000		551,747	1,103,495	1,931,116	2,206,989	2,482,863	2,758,737	2,758,737	2,758,737	2,758,737	2,758,737
Total Income ($)			3,126,568	4,536,589	5,793,347	6,283,789	6,774,232	7,050,105	7,050,105	7,050,105	7,050,105	7,050,105
Expenditure												
Labour (2 people/shift @55,000/year)			440,000	440,000	440,000	440,000	440,000	440,000	440,000	440,000	440,000	440,000
Variable costs			975,686	1,300,915	1,463,529	1,544,837	1,626,144	1,626,144	1,626,144	1,626,144	1,626,144	1,626,144
Fixed costs			683,124	683,124	683,124	683,124	683,124	683,124	683,124	683,124	683,124	683,124
Operating costs			2,098,811	2,424,039	2,586,654	2,667,961	2,749,268	2,749,268	2,749,268	2,749,268	2,749,268	2,749,268
Contingency (%)			138,556	184,741	207,834	219,380	230,927	230,927	230,927	230,927	230,927	230,927
Total operating costs			**2,237,367**	**2,608,781**	**2,794,488**	**2,887,342**	**2,980,195**	**2,980,195**	**2,980,195**	**2,980,195**	**2,980,195**	**2,980,195**
Net cash flow		**-7,252,039**	**889,202**	**1,927,809**	**2,998,859**	**3,396,448**	**3,794,037**	**4,069,910**	**4,069,910**	**4,069,910**	**4,069,910**	**4,069,910**
Cumulative net cash flow		-7,252,039	-6,362,838	-4,435,029	-1,436,170	1,960,278	5,754,315	9,824,225	13,894,135	17,964,045	22,033,955	26,103,865

3.3.6 Non-financial Benefits

Non-financial benefits of undertaking the R&D and commercialising the protein manufacturing process includes reduced BOD in waste streams and improved sustainability of the potato industry. In addition, there will be improved industry awareness of technology to manufacture high value food ingredients from horticultural by-products.

3.3.7 Challenges and Risks

Technical risks include:

- Achieving complete solubilisation of the potato proteins.
- Challenges in achieving yields that are economic.
- Maintaining functional properties of the proteins during processing.
- Fractionation of the PPI from the proteins adsorbed onto the resin.
- Physical functionality of the patatin from Ulverstone may not as predicted.
- Developing a cost effective processes.
- Commercial risk includes:

- Expertise and experience in marketing protein ingredients.
- Gaining access to protein markets.
- Inability to achieve sales in terms of volumes and prices, especially PPI.

3.3.8 Technical Development

Stage I – R&D
Objective 1: Due diligence; review of public domain literature on potato proteins and proposed extraction and separation technologies to assess freedom to operate.
Milestone: Report produced for potato proteins and extraction/separation technology.
Timeframe: 2-3 months.

Objective 2: Analytical methodology:
(a) Establish methods to analyse major potato proteins; including SDS-PAGE and HPLC.
(b) Establish methods to determine protease inhibitor activity of protein fractions (optional).
(c) Develop and/or adapt CCK assay to determine *in-vitro* CCK induction of potato protein fractions (optional).
Milestone: Validated analytical methods established.
Timeframe: 3-4 months.

Objective 3: Develop laboratory scale strategy to extract and separate protein from potato waste streams:
(a) Evaluate methods for maximum solubilisation of potato proteins from different waste streams.
(b) Evaluate commercially available GRAS status adsorbents for potato protein adsorption (maximum of 6 resins).
(c) Determine static and dynamic adsorption characteristics (effects of flow-rate, concentration, pH, mass transfer zone length) of the selected adsorbent and potato protein system.
(d) Determine hydraulic characteristics of the resin/potato protein system.
(e) Preliminary sizing of the CSEP system to achieve separation at pilot scale
(f) Conduct benefit cost analysis of a commercial process.
Milestone: Laboratory scale separation strategy and process economics established.
Timeframe: 6-9 months.

Objective 4: Up-scale the laboratory process to separate proteins from potato waste to pilot scale:
(a) Test CSEP configurations using laboratory adsorption data to adsorb and release proteins.
(b) Determine flow rates, resin bed movement rate, recycling rate of feed material, mass transfer zone length, resin:protein ratio in feed stream, fouling characteristics of adsorbent bed.
(c) Develop desorption protocols to fractionate the adsorbed proteins and investigate eluant recycling effects.
(d) Adsorbent inter-zone wash requirements.
(e) Determine flow rates in different chromatographic zones.
(f) Determine down stream product purification and concentration procedures.
(g) Determine CIP protocols.
(h) Determine performance of process over number of trials to validate process and product specifications.
(i) Produce up to 1kg of fractions using the pilot scale process.
(j) Analyse samples using methods developed in Objective 2.
(k) Refine benefit cost analysis of the commercial process.
Milestone: Cost-effective process to extract and separate proteins from potato waste streams established.
Timeframe: 6-9 months
Stage II - Technology transfer
Objective 5: Design and commission of commercial plant in collaboration with engineers:
(a) Provide information and technical advice during design, procurement and installation stages of the commercial plant.

(b) Transfer technology and train operators.
(c) Train/transfer analytical methods to laboratory staff.
Milestone: Technology successfully transferred, technical advice provided to engineers, operators trained.
Timeframe: Unknown, subject to SAPL internal process.

Objective 6: Commissioning of commercial plant:
(a) Commission commercial plant.
(b) Provide technical advice during initial commercial production period.
Milestone: Production of potato protein products.
Timeframe: Unknown, subject to SAPL internal process.

3.4 Business case 2 (summary) – Fibre from corn core waste

3.4.1 Description of waste

SAPL generates about 9,000 tons of sweet corn core waste per annum at the Bathurst factory, NSW. The literature reports that corn core contains a significant amount of cellulose, lignin, hemicellulose, small sugars, proteins and minerals (Table 8). The cellulose and lignin are classified as insoluble dietary fibres and the hemicellulose is classified as soluble fibre. In general, corn cores are reported to contain 49-57% insoluble fibre and 19-41% soluble fibre (dry basis). About 90% of the soluble fibre is reported to be xylan polysaccharides, which can be broken down by enzymatic hydrolysis or auto-hydrolysis to release xylooligo-saccharide with prebiotic activity and other small sugars. Prebiotic oligosaccharides can be incorporated into a wide variety of food products to enhance the growth of beneficial probiotic bacteria in the gut. With further R&D and commercialisation, the insoluble and soluble fibres in SAPL's corn cores may be used as dietary fibre in food and in neutraceutical products. In addition, the soluble fibres could be converted to xylooligo-saccharide (prebiotics) and used in functional food and neutraceutical products.

Table 8: Summary of corn core composition from a range of published scientific literature.

		Garrote 2002	*Garrote* 2007	*Yang* 2006	*Vazquez* 2006	*Nabarlatz* 2007	*Yang* 2005	*Zhu* 2006
Insoluble fibre [%]	Cellulose	34.3	36.7	35	26.6	38.5	35	36.8
	Lignin (acid-insoluble)	17.7	21.3	14	24.9	18.7	14	17.2
Hemicellulose [%]	Xylan	31.1	15.6	34.8	30.6	29.5	34.8	22
(soluble fibre)	Arban	3.01	1.68	3.05	2.83	3.3	-	3.5
	Acetyl groups	3.07	1.62	3.12	3.83	4	-	3.2
	Variety	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Geographic	Spain	Spain	USA	Spain	Spain	China	USA

The published composition of corn cores presented in Table 6 is that of mature dried corn cores. SAPL's corn cores are derived from sweet corn, which is immature, high in sugar, and high in moisture when compared to mature dried corn cores. Samples of Simplot's sweet corn cores were analysed in Phase 1 of the project. Due to discrepancies in insoluble and soluble fibre contents compared to the data found in the literature, additional analysis was conducted for total dietary fibre, insoluble fibre, and soluble fibre by two independent laboratories (Table 9). Results indicate that the soluble fibre content of Simplot corn cores is significantly lower than that reported in literature (0.3% vs 30% respectively). It is unlikely that the soluble fibre in SAPL corn cores can be economically extracted, and this business case focuses on the production of a total fibre (mainly insoluble fibre with a small amount of soluble fibre).

Table 9: Total insoluble and soluble dietary fibre content (% as is) of Simplot corn cores derived from sweet corn and super sweet corn (lab 2 data represents the average of 2 analyses).

	Total Fibre (% as is)	**Insoluble Fibre (% as is)**	**Soluble Fibre (% as is)**
Corn Cores (Lab 1)	15.5	15.4	0.1
Sweet Corn (Lab 2)	17.1	16.5	0.6
Super Sweet Corn (Lab 2)	14.2	14.0	0.2
AVERAGE	**15.6**	**15.3**	**0.3**

3.4.2 Technology

The process to extract fibre from corn core is expected to be relatively simple and low cost. It will involve various size reducing steps, drying, and sieving (Figure 4). Pilot trials will be needed to confirm this strategy and secure data for commercial design.

Corn cores are perishable and they should be processed immediately after production. The process depicted in Figure 4 and associated equipment sizes (Table 8) assume that corn cores will be available on a continuous basis from early January through to mid April (4 months), and that they will be processed continuously during this period. Using this process the impact on current corn processing will be minimal.

The major product will be crude corn core fibre. To ensure the insoluble fibres are suitable for incorporation into food products, a secondary size reduction step may be required before drying. Further research will determine the optimal size reduction conditions to produce fibre suitable for use as a food ingredient.

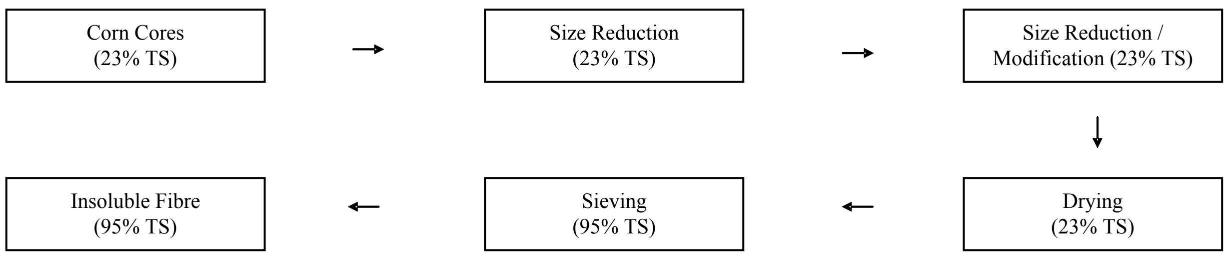


Figure 4: Process flow diagram of theoretical corn core fibre production plant.

3.4.3 Outputs and likely Volume

Based on the average amount of fibre in Simplot corn cores (15.5%, Table 7), and a solids content of 22.8%, the maximum amount of fibre product that can be produced is estimated to be 1,080 tons per annum. This assumes a loss of 50% throughout the manufacturing process. Table 8 summarises the type and size of equipment that maybe required and the amount of fibre produced when processing 100%, 75%, 50% and 25% of total corn core waste (~9,000 tons/year fresh weight). When undertaking calculations it has been assumed that the plant will operate continuously (24 hours a day) for four months of the year.

Table 10: Estimation of equipment type and size required when processing 100%, 75%, 50% and 25% of SAPL's total corn core waste (9,000 tons).

Process Step	Equipment	Amount of Corn Core Processed			
		100%	**75%**	**50%)**	**25%**
Size Reduction	Knife Mill (kg / h) (23% TS in corn cores)	4,020	3,010	2,010	1,000
Size Reduction / Modification	Hammer Mill (kg / h) (23% TS in feed)	4,020	3,010	2,010	1,000
Insoluble Drying	Drum dryer (kg evap / h) (23% TS in feed)	2,950	2,210	1,470	740
Sieving	Sieve (kg / h) (95% TS in feed)	1,070	800	540	270
FIBRE PRODUCT	**95% Total Solids (kg / h)**	**480 kg / h**	**360 kg / h**	**240 kg / h**	**120 kg / h**

3.4.4 Market Information

Dietary fibres are defined as soluble and insoluble fibres which resist digestion by human enzymes in the small intestine and pass into the large intestine, where they may or may not be fermented by gut bacteria. Dietary fibres have a number of beneficial physiological effects including laxation, risk reduction for some cancers, reduction in blood cholesterol, and modulation of blood glucose. Dietary fibres not only offer human health benefits, they also provide food structure or functionality for dairy, beverage, and bakery food products. For example, insoluble fibres are used as anti-caking agents, bulking agents, low calorie/no calorie agents, water absorbers, and to increase the fibre content of bakery, cheese, spice, and cereal foods. Soluble fibres are employed as stabilisers, gelling agents, fat replacers, and encapsulates in a range of meat, bakery, beverage, dairy products.

It is evident that the western diet is deficient in fibre. Nutrition professionals believe that Americans consume about only 15 grams per day, which is half the dietary reference intake (DRI) of 28-35 grams per day. To increase consumption of dietary fibre, many food companies are fortifying products with fibres such as cellulose powders and oat fibres. The drivers increasing fibre production and use are:

- Increasing interest of the population in nutritionally healthy products.
- Emphasis on organically and non-genetically modified foods.
- Increased public knowledge on the health benefits of fibre.
- Growing amount of clinical studies on fibre.
- Response to 2005 dietary guidelines.

In 2004 the USA market for fibre was valued at $192.8 million. Revenues are projected to grow to $487.0 million by 2011, with a compound annual growth rate of 14.2% (Figure 5). Insoluble fibres dominate the total fibre market; however the growth of soluble fibres is predicted to be greater than the growth of the insoluble fibre market in the near future (Frost and Sullivan, 2006). The price for insoluble and soluble fibres in 2004 averaged US$1.85/kg and US$4.19/kg, respectively.

In 2004, the European market for insoluble fibre was valued at €160.9 million, down from €169.4 million in 2001. This decease in market value was due to a decrease in the average price of insoluble fibres from €1.38 per kg to €1.26 per kg. In 2011 the European insoluble fibre market is expected to reach €140.2, with a compound annual growth rate between 2005 and 2011 of -1.9% (Figure 6).

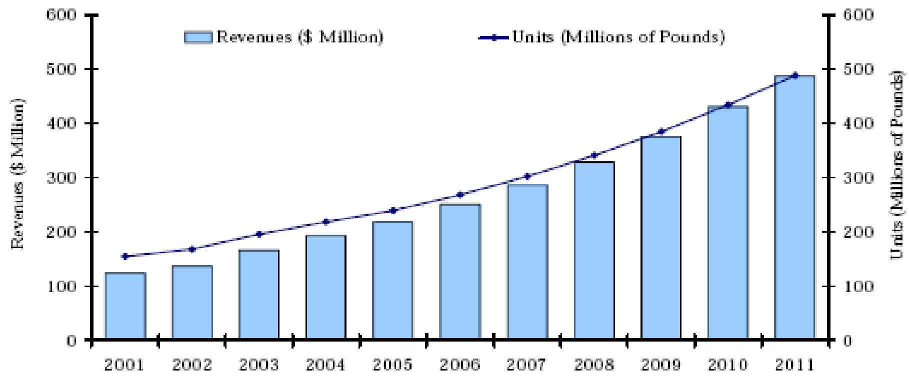


Figure 5: USA total food fibre market unit shipment and revenue forecasts between 2001 and 2011 (source: Frost and Sullivan, 2006).

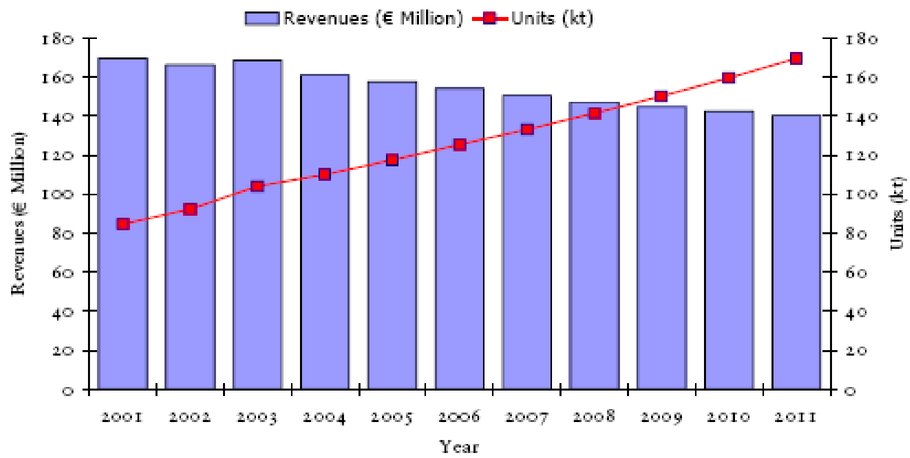


Figure 6: European insoluble food fibre market unit shipment and revenue forecasts between 2001 and 2011 (source: Frost and Sullivan, 2006).

3.4.5 Financials[5]

The capital cost estimate to process the corn core waste stream produced at Bathurst is shown in Table 11. The estimated capital costs include a contingency of 20% of equipment costs for any unforeseeable capital expenditure

The capital costs estimate assumes that a building to install the process is available at Bathurst, but an allowance for building modification for footings, plinths, drainage etc is included.

[5] It should be noted that FSA is not a licensed financial advisory entity, and as such, it is recommended that independent financial advice be sought with respect to economic analysis of any products or processes.

Table 11: Capital costs estimate for a process to manufacture fibre from 9,000 tons/year of corn core.

Item		**$**
Size Reduction Knife Mill	1	400,000
Size Reduction Hammer Mill	1	400,000
Drum dryer	1	750,000
Sieve	1	200,000
Instrument and control	1	50,000
Total equipment costs		**1,800,000**
Installation costs (% of equipment cost)	10	180,000
Electrical cost (% of equipment)	10	180,000
Material transfer costs (% of equipment)	10	180,000
Civil costs (% of equipment)	5	90,000
Engineering and consultancy (% of equipment cost)	8	144,000
Start up costs (% of equipment costs)	2	36,000
Contingency (% of equipment cost)	20	360,000
TOTAL CAPITAL COST ESTIMATE		**2,970,000**

The process economics of extracting fibre from the corn cores was evaluated using the following assumptions:

- That only 50% of the fibre can be extracted for use as a food ingredient.
- Process plant operating period:
  - 24 hours/day
  - 7 days/ week
  - 16 weeks / year
- The sales value of corn core fibre has been taken as $1,850/ton ($1.85 / kg).

The annualised income and operating costs of a plant to process 9,000 tons of corn cores and produce 1,080 tons of corn core fibres are shown in Table 12. The estimated costs of production include 10% contingencies for unforseen operating expenses. The estimated production costs analysis indicates that the cost of production per kilogram of fibre is $0.64. The fibre price ($1.85/kg) is a conservative estimate of achievable prices for this stage of project evaluation.

Table 12: Annualised cost and earnings before interest, tax, depreciation and amortisation (EBITDA) for a plant to process 9,000 tons/year of corn core waste.

Item	Quantity	$ / Unit	$
Labour (1/shift: total 4)	4	55,000	220,000
Power costs ($/kW/h)	241920	0.14	33,869
Drying cost ($/ton)	1,000	175	175,000
Packaging & handling cost ($/ton)	1,000	40	40,000
CIP chemicals ($/day)	112	50	5,600
Maintenance cost (% of capital equipment)	1		18,000
Plant Overheads (% of direct labour)	10		22000
Laboratory analysis (% of direct labour)	5		11,000
Marketing and sales (% of income)	3		59,940
Operating Costs			624,209
Contingency (% of operating costs)	10		62,421
TOTAL COST OF PRODUCTION			**686,630**
Cost of production ($/kg)			0.64
Corn core fibre ($/ton)	1,080	1,850	1,998,000
TOTAL INCOME			**1,998,000**
INCOME (EBITDA)			**1,311,370**

Table 13 shows the projected cash flow and profitability of the process to produce corn core fibre. The cash flow assumes that any costs escalation due to inflation will be offset by any increase in global fibre price. The project life is assumed 10 years for the profitability evaluation.

The sale of fibre products is assumed to increase over time, and in the first year of production only 60% of corn core fibre will be sold, increasing over time to reach plant capacity in 5 years. The return on investment (ROI) of the project is estimated at 32% with a pay back time of 4 years and an internal rate of return (IRR) of 25%. The projected cash flow indicates that the project will be cash flow positive after the first years of production.

Table 13: Projected cash flow for the process to manufacture fibre from corn cores at Bathurst, NSW.

Year		0	1	2	3	4	5	6	7	8	9	10
						ROI (%)		**32**				
						PBT (Years)		**4.0**				
						IRR (%)		**25**				
Capital costs		-2,970,000										
Sales - Fibre (% of prodiuction capacity)			60	70	80	90	100	100	100	100	100	100
Corn Core Fibre (tons/year)			648	756	864	972	1,080	1,080	1,080	1,080	1,080	1,080
Sales - Fibre (% of prodiuction capacity)			60	70	80	90	100	100	100	100	100	100
Income - Fibre ($/ton)	1,850		1,198,800	1,398,600	1,598,400	1,798,200	1,998,000	1,998,000	1,998,000	1,998,000	1,998,000	1,998,000
Total Income ($)			1,198,800	1,398,600	1,598,400	1,798,200	1,998,000	1,998,000	1,998,000	1,998,000	1,998,000	1,998,000
Expenditure												
Labour (1 people/shift @55,000/year)			220,000	220,000	220,000	220,000	220,000	220,000	220,000	220,000	220,000	220,000
Variable costs			304,601	355,368	406,135	456,902	507,669	507,669	507,669	507,669	507,669	507,669
Fixed costs			116,540	116,540	116,540	116,540	116,540	116,540	116,540	116,540	116,540	116,540
Operating costs			641,141	691,908	742,675	793,442	844,209	844,209	844,209	844,209	844,209	844,209
Contingency (%)			37,453	43,695	49,937	56,179	62,421	62,421	62,421	62,421	62,421	62,421
Total operating costs			**678,594**	**735,603**	**792,612**	**849,621**	**906,630**	**906,630**	**906,630**	**906,630**	**906,630**	**906,630**
Net cash flow		**-2,970,000**	**520,206**	**662,997**	**805,788**	**948,579**	**1,091,370**	**1,091,370**	**1,091,370**	**1,091,370**	**1,091,370**	**1,091,370**
Cumulative net cash flow		-2,970,000	-2,449,794	-1,786,797	-981,008	-32,429	1,058,941	2,150,312	3,241,682	4,333,052	5,424,423	6,515,793

3.4.6 Non-financial Benefits

The work will improve the sustainability of the sweet corn industry. The local industry will be exposed to a range of new technologies, particularly those associated with the manufacture high value food ingredients from horticultural products.

3.4.7 Challenges and Risks

The technical risks associated with this opportunity include:

- Reducing the particle size of the fibre so that it can be incorporated into food products.
- Defining conditions to produce corn fibres that have good functional properties in food systems.
- Substantiating the benefit (physical and biological) of corn fibres over other fibres currently on the market and utilised widely by the food industry.
- Maximising the yield of fibre from corn cores.

The commercial risks associated with this opportunity include:

- Australia is a small producer of corn cores when compared to other countries (e.g. USA and South America).
- Other corn processors throughout the world developing the technology to manufacture and market corn core fibre.
- Corn core fibre failing to replace established fibre products or to establish new markets in the food industry.
- The price of food fibres decreasing and making corn fibre production uneconomical.
- Inability to achieve sales volumes and expected prices.

3.4.8 Technical Development

Stage I – R&D

Objective 1: Due diligence; review of public domain literature on corn core fibre and production technologies to assess freedom to operate.

Milestone: Report produced for corn core fibre and manufacturing technology.

Timeframe: 2-3 months.

Objective 2: Analytical methodology:
(a) Establish analytical methods to analyse corn core fibre.
(b) Establish methods to characterise fibre quality, including particle size, water, and oil absorption capacity, swelling capacity, viscosity, colour, flow ability (anti-caking), and others as necessary.
Milestone: Validated analytical methods established.
Timeframe: 3-4 months.

Objective 3: Develop laboratory scale strategy to extract fibre from corn core waste:
(a) Evaluate commercial methods for particle size reduction.
(b) Evaluate the effects of temperature, moisture content, acids, bases, and pH on fibre quality using the analytical techniques established in objective 2.
(c) Preliminary sizing of the corn core fibre processing plant to achieve production at pilot scale.
(d) Conduct benefit cost analysis of a commercial process.
Milestone: Laboratory scale separation strategy and process economics established.
Timeframe: 6 months

Objective 4: Up-scale the laboratory process to pilot scale:
(a) Optimise the fibre production process at pilot scale and examine the effect of processing conditions (size reduction, drying, and sieving) on corn core fibre quality using the methods established in objective 2.
(b) Determine the process performance in pilot trials. Refine the benefit-cost analysis of a commercial process.
Milestone: Cost-effective process to produce fibre from corn core waste established.
Timeframe: 6 months

Objective 5: Using the size reduction, drying, and sieving protocols established in objectives 4 and 5, manufacture at least 5kg of corn core fibre for evaluation in a range of food products.
Milestone: At least 5kg of corn core fibre manufactured at pilot scale.
Timeframe: 1 Month

Objective 6: Corn core fibre provided to potential customers for evaluation in their product lines, including breads, biscuits, cakes, drinks, and cereal products.
Milestone: Corn core fibre produced at pilot scale evaluated in a range of food products.
Timeframe: 4 months

Stage II - Technology transfer
Objective 7: Design of commercial plant in collaboration with engineers:
(a) Provide information and technical advice during design, procurement, and installation stages of the commercial plant.
(b) Transfer technology and train operators.
(c) Transfer analytical methods and train laboratory staff.
Milestone: Technology successfully transferred, technical advice provided to engineers, operators trained on the fibre production equipment.
Timeframe: Unknown, subject to SAPL internal process.

Objective 8: Commission commercial plant:
(a) Commission commercial plant.
(b) Provide technical advice during initial commercial production period.
Milestone: Production of corn core fibre.
Timeframe: Unknown, subject to SAPL internal process.

3.5 Business case 3 (summary) – Bio-energy

This case examines the potential value of the energy released when the waste decomposes, in the residual organic matter that remains after decomposition, and in the nutrients. The SAPL waste streams from vegetable processing contain large volumes of matter suited to biological or thermo-chemical transformation to energy, and also nutrients that can be concentrated into fertiliser products. Transformation of wastes to energy is possible using several quite different technologies.

The waste streams from the Devonport, Ulverstone and Bathurst processing plants can be categorised as follows:

- Category 1: potato flesh and peel slurry; beans, carrots, & peas from the freezing line and broccoli & cauliflower field residues.
- Category 2: high Chemical Oxygen Demand wastewater from potatoes and other vegetables
- Category 3: frying oil when replaced.
- Category 4: filter paper with frying oil.
- Category 5: sweetcorn cobs and husks.
- Category 6: cardboard, paper, wooden pallets.

These wastes have been quantified from Simplot records and their composition analysed. All of these categories are putrescibles (readily degradable by micro-organisms), however the more lignocellulosic materials in Category 6 (wood wastes) require greater pre-treatment.

Technologies currently or soon to be available for waste transformation include:

- Fermentation to bioethanol.
- Pyrolysis to bio-oil (and follow-on transformations), with fertiliser co-products.
- Gasification (and follow-on transformations to liquid fuels), with fertiliser co-products.
- Anaerobic digestion to biomethane (and follow-on transformations to liquid fuels), with fertiliser co-products.

The first three technologies were dropped from consideration at Workshop 2 after discussions between SAPL and CFR[6]. The workshop found that fermentation to bioethanol, pyrolisis to bio-oil, and gasification would not be economic, even at current high oil prices. Anaerobic digestion was shown to provide the best potential economic and practical outcomes.

3.5.1 Description of waste

The anaerobic digestion process is able to use a wide range of putrescible wastes; including Waste Categories 1 through 5 (see definitions above). Categories 1 and 5 will make up the largest part of the suitable wastes from the Simplot plants. Categories 3 and 4 (waste oil and filter paper), which are unsuitable for other technologies, are good feedstock sources for anaerobic digestion. Table 14 shows solid waste volumes expressed as FW (tonnes pa).

Table 14: Annual solid waste volumes at SAPL. Also expressed as kg/day of chemical oxygen demand (COD), assuming waste supply to be evenly distributed over 330 days pa.

Site	Tonnes FW/yr	kg COD/day
Devonport	4 000	2 000
Bathurst	14 700	6 600
Ulverstone	41 000	43 000

[6] Waste Solution Ltd, Dunedin, New Zealand, was consulted to conduct in collaboration with CFR the research on bio-energy

The chemical oxygen demand (COD) is the measure that determines potential biogas production. The values in Table 11 are daily averages, and assume even seasonal supply. While this is true at the Ulverstone potato plant, the other two factories are much more seasonal.

Following the site feasibility assessments in Tasmania, the focus was mainly on the Devonport site, where digester construction space was determined to be available. The monthly variation of waste processed at Devonport is illustrated in Figure 7. This shows that the volume (expressed as tonnes per month) is concentrated into five months, and peak production only lasts for two months.

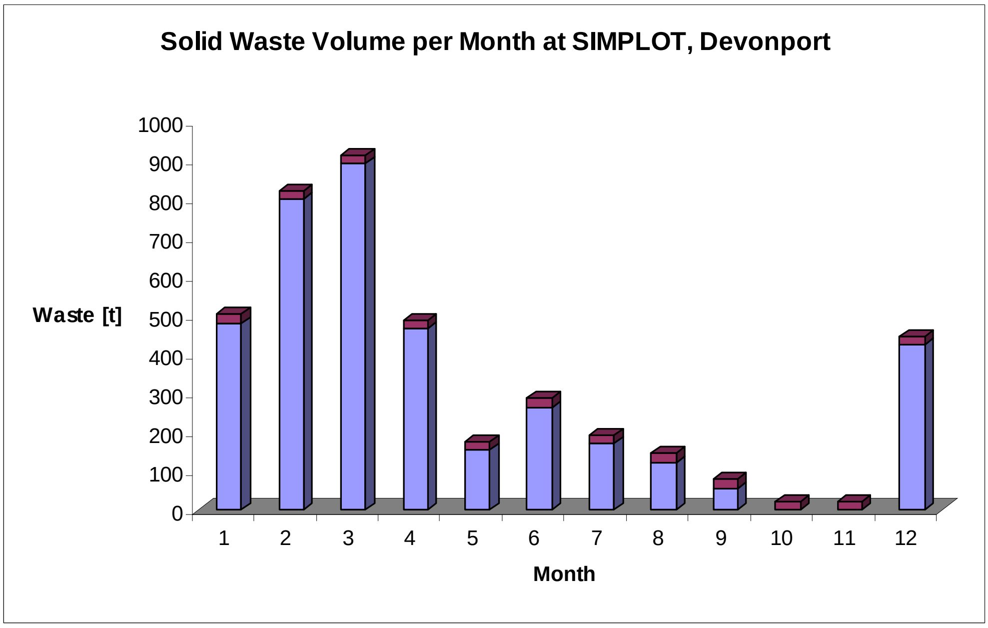


Figure 7: Monthly solid waste volume at Devonport. Blue: raw vegetable waste. Purple: processed waste.

Following three scenarios are conceivable for Tasmania:

Option 1: Use of 4,000 tonnes pa of Devonport wastes in an on-site digester.

Option 2: Use of 7,500 tonnes pa, where the Devonport waste is supplemented with 3500 tonnes pa of Ulverstone solid waste in an on-site digester at Devonport.

Option 3: Use of all waste streams coming from the Devonport and Ulverstone factories in an off-site anaerobic digestion plant near Ulverstone.

The aim in Option 2 is to keep the digester fully fed for most of the year at a rate near that of the peak months' supply of Devonport wastes, except in months with a natural gas heating requirement lower than potential bio-methane production, such as October. Both options are illustrated in Figure 8, with the waste volume in tonnes per day, expressed as the monthly average.

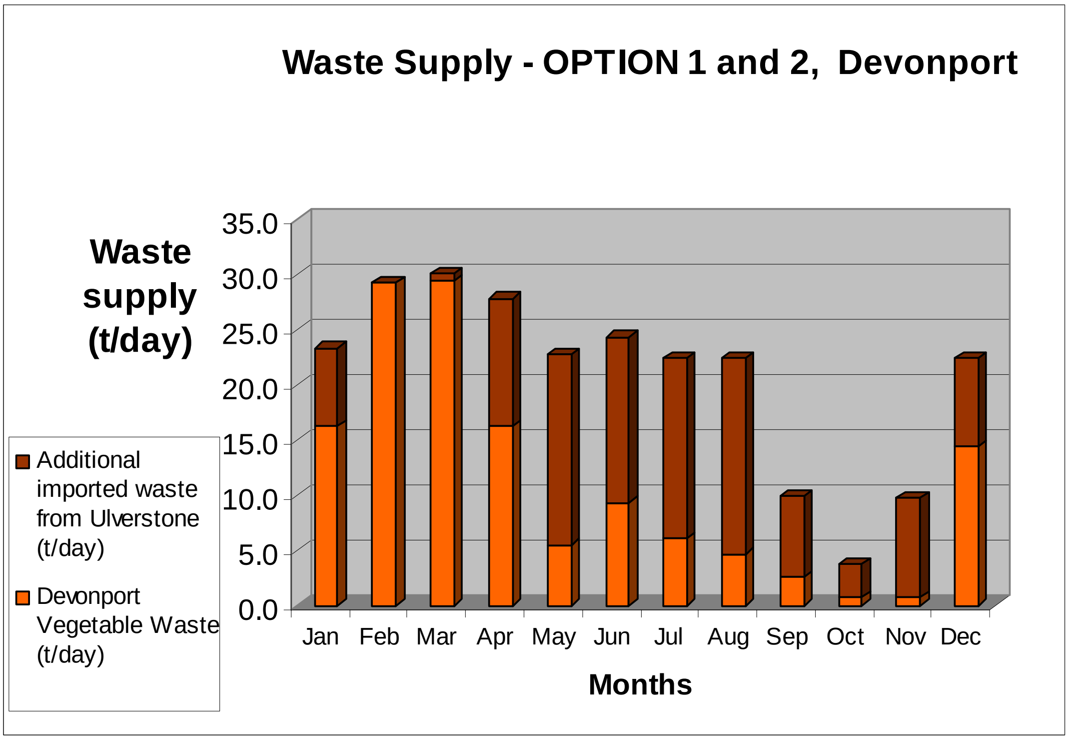


Figure 8: Projected waste supply for a digester facility at Devonport: 4,000 t/pa vegetable waste from Devonport, "topped up" with 3,500 t/pa potato waste from Ulverstone.

3.5.2 Technology

Anaerobic digestion has been associated with municipal sewage sludge or manure stabilisation technology which is related to faecal matter and odorous feed materials. However, since the 1970s, a technical revolution has occurred to allow a broader industrial application. This has been built on an improved understanding of the underlying process and biological reactions in anaerobic digesters.

Anaerobic digestion is now an established technology for the treatment of vegetable processing waste, solid organic waste, and wastewater. In 2003, Europe had more than 150 solid waste digester plants operating at 3,000 – 100,000 t/annum of solid waste (de Mes, et. al., 2003). Only organic material with a comparatively low content of woody residues (lignin) can be successfully treated. Vegetable processing waste falls into this category. The final product is biogas: a mixture of methane (55-75 vol %), carbon dioxide (25-45 vol %), and traces of ammonia (NH_3), hydrogen sulphide (H_2S), and di-nitrogen (N_2). The heating value (LHV: MJ/m^3) of biogas is typically low, but depends on the chemical characteristics of the waste materials and the process conditions. Biogas with 65% methane and 35% CO_2 has a LHV of 21.7 MJ/m^3 at 20ºC and 100 kPa, and 23.2 MJ/m^3 at 0ºC, 100 kPa.

Anaerobic digestion preserves the nutrient content (N, P, K, S) in the waste. The digestion residue is a dilute slurry with about 1-2 % suspended solids, which is often thickened and dewatered to a spade-able biosolids cake (20-25% solids content) and a digestate liquor. The digestate liquor contains about 70-90% of the nitrogen and 50-70% of the phosphorous of the original waste. The dewatered biosolids cake has a nutrient content of about 5.0:1.0:0.5 % of dry matter (N:P:K) and is comparable to quality compost.

The operation of modern anaerobic digestion systems for solid waste (maceration, pumping, mixing, dewatering) consumes electrical energy in the order of 10-15 % of the of the raw biogas energy content (de Mes, et. al., 2003, Hartmann, 2006). Digester heating requirements for solid waste digesters are also in the order of 10-15% of the biogas energy content. Large digester plants may be run using combined heat & power production (CHP, cogeneration) from a portion of the biogas, and the surplus biogas (about 50 % of that produced) can be sold to other gas users (e.g. factory boiler) or the natural gas (NG) grid (after gas clean-up). The full life cycle analysis of modern anaerobic digestion systems shows that energy output/input ratios can exceed 3:1 – 5:1 (including energy use in construction, operation and demolition).

The Ulverstone and Devonport factories have comparatively low electricity and high natural gas costs. Analysis of these factories found that an approach based on cogeneration and power sales (high CAPEX and lower revenue) is a poor option. The best use (lower CAPEX and higher revenue) of the surplus biogas is at the factory boiler, where it will replace expensive NG.

A summary of the advantages of anaerobic digestion (de Mes, et. al., 2003):

- Provision of surplus usable fuel through methane recovery.
- Anaerobic treatment processes generally consume little energy.
- Facilitation of biosolids dewatering.
- Comparatively low malodour end-products (biosolids cake and treated liquor).
- Significant reduction of residual solids mass to be handled. Biosolids mass is only 10-30% of that produced in alternative aerobic treatments (e.g. composting).
- Almost complete preservation of N, P, K fertiliser value in the digestion residue.
- Modern anaerobic wastewater treatment processes can handle very high organic loading rates exceeding 30 kg COD/m^3 per day at 30-35ºC and up to 50 kg COD/m^3 per day at 40ºC. This reduces the digester volume, CAPEX, footprint, and retention time about 10-fold when compared to traditional municipal sewage sludge and manure digester systems.
- Anaerobic sludge can be preserved in the digester tank for a prolonged time making seasonal operation of anaerobic digestion plants a simple task.
- Construction cost can be kept low with use of modern technology.
- Space requirements are lower than in composting or aerobic wastewater treatment systems for a comparable waste load. For example, a fully integrated anaerobic digestion facility for 80 000 t/pa of solid food processing waste with cogeneration and fertiliser dewatering and drying facilities can be built on a site with an area of less than 1 ha (Thiele, 2000; Hearn and Thiele, 2004).

The major disadvantages of anaerobic digestion are:

- A high sensitivity of the biogas producing microbes to a large number of chemical compounds. In many cases, the microbes are capable of adapting to these compounds.
- The first start-up of a digester facility without adequate amounts of adapted seed sludge can be slow due to the low growth rate and growth yield of biogas producing microbes.
- The anaerobic treatment of waste with sulphurous constituents can result in odours due to the formation of sulphide. An effective solution is to treat all odorous air building in an aerobic biofilter and to employ micro-aerobic post treatment of the digestate liquor to convert sulphide to elemental sulphur.

3.5.3 Outputs and likely volume

Three scenarios are conceivable for Tasmania:

- **Option 1** is a digester at the Devonport plant using only its own waste stream of 3,600−4,000 tonnes pa.
- **Option 2** shares the same site and operational layout, but the digester is larger to match the waste supply from peak months. The supplemental waste supply for the other months would come from the Ulverstone plant. The WSL report shows the monthly supply needed both to achieve a steady waste supply and to match biogas

production to the NG needs of the factory. This would use 3,500 tonnes pa of Ulverstone waste. A process for Option 2 is provided below.

- **Option 3** employs a larger anaerobic digestion plant at a site near Ulverstone. The Ulverstone factory would be the preferred Tasmanian site for a digester, since both the volume and quality of the solid wastes are higher there. However there is not enough space for a solid waste anaerobic digestion plant. The anaerobic digestion plant would be located to minimise waste haulage from the Ulverstone and Devonport factories. This option makes the best use of the available waste and could be designed for wastes from sources other than SAPL. Option 3 would use 31 000 tonnes of Ulverstone potato flesh and peel plus the full waste stream of the Devonport plant. Since the Ulverstone plant is fired with coal, the value of biogas assumes there would be a large user of gas located nearby.

Description of Option 2:

The proposed process arrangement for the integration of the digester facility into the Devonport factory operation is shown in Figures 9 and 10 below.

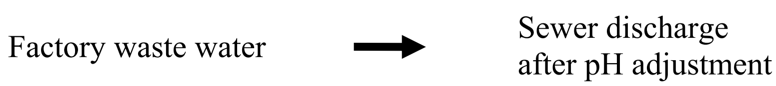


Figure 9: Conceptual process arrangement in the base case (BAU) at Devonport.

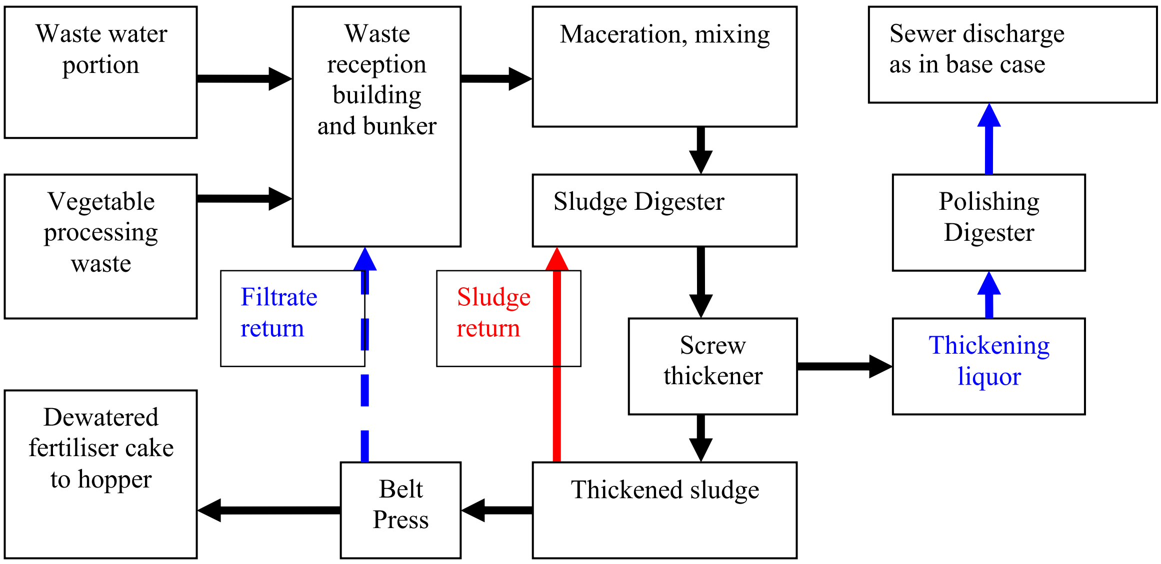


Figure 10: Process arrangement of major operations for the integrated digester facility at Devonport.

Parasitic thermal load and surplus biogas of the digester facility

The Option 2 biogas facility has a projected total gross annual biogas production of 21,700 GJ/annum (920,600 m^3/annum at 65% methane) from 7,500 t/annum vegetable waste with a monthly distribution shown in Figure 7. The thermal energy needed for digester heating is estimated at 15% of gross biogas or 138 000 m^3/annum biogas. No surplus biogas is available in month 10 because all biogas will be used to heat the idling digester in the down season.

Parasitic Electrical Load of the Digester Facility

The electric energy consumption of a typical biogas plant is: 38% for stirrers, 26% for heating, 2% for pumping and maceration, and 8% for solids introduction. The total parasitic electrical load for the digester is typically 10−16% of the gross energy produced (de Mes et al. 2003; Hartmann 2006; Thiele 2008a). For Option 2 it is estimated that about 350,000 kWh/annum will be consumed. The maximum electrical load is estimated at 200 KW.

Expected natural gas replacement in the factory boilers

The expected annual surplus biogas available for factory boiler operation is 770,000m^3 biogas/annum or 17,700GJ/annum.

Seasonal start-up of the digester facility

The digester will be 2/3 emptied at the end of the season, and mixed liquor discharged to the belt press. This will reduce the heating requirements and to generate waste receiving capacity in the digester tank for the start of the new processing season.

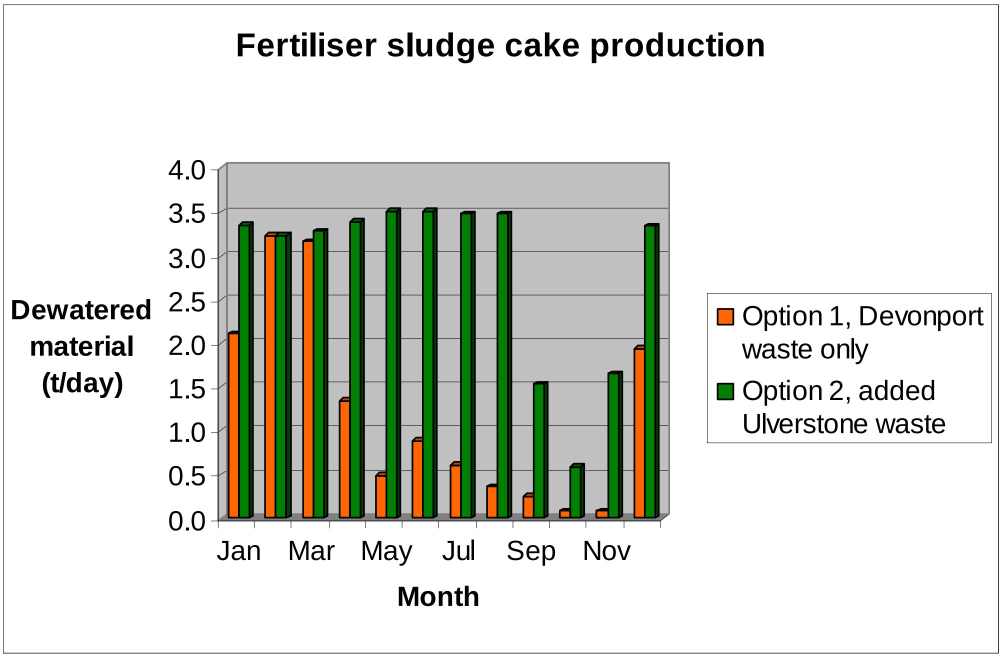
Production of fertiliser sludge cake and digester liquor

An Option 2 biogas facility has a projected fertiliser sludge cake production of 1,050t/annum when receiving 7,500t/annum vegetable waste, with a monthly waste distribution shown in Figure 7.

Indicative space requirement of the digester facility

The digester facility should fit on a rectangular site with a footprint of 5,000 m^2. Depending on the shape of the area available and geotechnical survey data, it may be possible to arrange tanks, buildings, and in ground digesters to achieve a smaller footprint.

Figure 11 shows that vegetable processing waste volume is reduced by about 90% by anaerobic digestion, leaving a residue weight of 3−4 t/day. This compares well to a scenario where the incoming vegetable processing waste (30 t/day) would be sent to land fill or composting[7].



[7] The wet fertiliser cake from the digestion facility could still be included as nutrient source in composting operations and approximately 90% reduced transport costs for any bulking material needed for a subsequent fertiliser cake composting and marketing of the finished compost product

Figure 11: Projected fertiliser sludge cake production for a digester facility at Devonport processing 4,000t/annum vegetable waste from Devonport (Option 1) or co-processing 4000t/annum Devonport waste + 3500t/annum potato waste from Ulverstone (Option 2). Note that anaerobic digestion has reduced the dewatered solid waste mass approximately 10 fold from 30 t/day to 3–4 t/day wet weight.

The other fertiliser co-product is the digester liquor, which contains the soluble nutrients, mainly N and K. This is quantified for Options 1 and 2 in Figure 12.

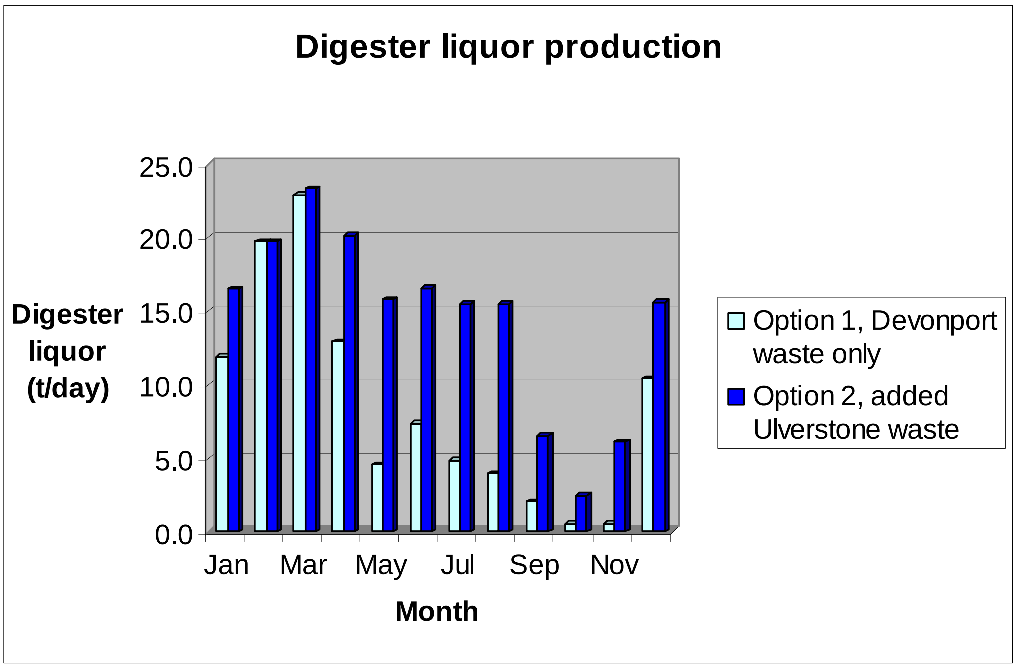


Figure 12: Projected net digester liquor production for a digester facility at Devonport processing 4,000t/annum vegetable processing waste from Devonport (Option 1) or 4,000t/annum Devonport waste + additional 3,500t/annum potato processing waste from Ulverstone (Option 2). Note that the values given are the difference between the daily amounts of re-used factory wastewater and the total daily amount of produced digester liquor.

The application of the anaerobic digestion process for the Bathurst plant in NSW has seasonal similarities to Option 1 for the Devonport plant. The volumes of sweet corn cobs and husks (Table 14 above) are only sufficient to supply a digester during the 4 month processing season. The seasonality of the waste stream poses a financial challenge to operate the anaerobic digestion plant profitably. It would require a supply of nearby putrescible wastes at no cost. The cobs and husks are high in lignin, and a pre-treatment phase would be needed prior to digestion. This might also be addressed by co-digestion with other waste products.

Energy (bio-methane) outputs

Table 15 shows biogas quality, yield, and energy outputs, based on the average COD/day values.

Table 15: Estimates of methane and daily energy production at the three plants, assuming the total annual waste supply was distributed over 330 days.

Site	% methane in biogas	Bio-methane yield (m^3/day)	Energy output (GJ/day)
Devonport	60 + 5	700	25.0
Bathurst	60 + 5	1 900	67.6
Ulverstone	70 + 5	15 000	534.0

Methane yields are net, after assigning 15% to heat the digester. Yield volumes were converted to an energy basis using a factor of 35.6 MJ per m^3.

Table 16 shows the direct calculations for energy output from the three options in the WSL report.

Table 16: Net bio-methane production (after 15% use by the digester) and energy from different waste streams. Scenario 1: Devonport waste only. Scenario 2: Devonport waste with added Ulverstone waste. Scenario 3: Large "off-site" digester with all waste from Devonport and Ulverstone.

Scenario	Bio-methane yield (m^3/day)	Energy output (GJ/day)
1	700	25
2	2378	55
3	8805	208

3.5.4 Market information

Vegetable wastes are ideal for anaerobic digestion. The environmental effects can be managed at very low levels. Anaerobic digesters have the potential to add value (Cox & Souness 2004) through:

- Reducing environmental impact.
- Reducing energy costs through biogas to heat and electricity.
- Developing a secure gas supply and price hedge.
- Producing useful organic fertilisers.
- Creating synergies with local primary producers.

The most significant of these drivers for digesters have in the past related to the economic issues of waste disposal rather than energy production. Energy issues are now coming to the fore. Natural gas prices will continue to rise as demand increases and coal is affected by carbon charges.

The internal market options for biogas include direct heating, fuelling gas turbines for electricity generation, fuelling stationary engines (including Stirling engines), and use as transport fuel. The current situation favours direct heating, followed by stationary engines.

If the cost of fuels for stationary power lags the rising cost of transport fuel, there may be an opportunity to market biogas as transport fuel. Vehicles could easily be altered to run on bioCNG or liquefied bio-methane. There are two new technologies that would greatly facilitate the cryogenic liquefaction process, which is now used in the EU, where high volume tanks are used to hold gas at much lower pressure than CNG tanks. This promotes the use of bio-methane in light vehicles. The caveat for any intended use in engines is that biogas must be purified to bio-methane, which is not always required for direct heating use.

Fertiliser market

The future fertiliser price is expected to shift in parallel with the energy market. If a high value is placed on carbon emissions, fertiliser or compost made from digester sludge and liquor will be able to gain carbon credits by displacing N fertiliser made from natural gas. This could make the vegetable waste more valuable when marketed as fertiliser than as livestock feed.

There are cost advantages to integrating composting with anaerobic digestion of wastes. Transport costs for any bulking material needed for a subsequent fertiliser cake composting would be reduced by about 90%.

3.5.5 Financials

Option 1 must be modified due to the very seasonal waste supply. Instead of using daily average supply to gauge the needed tank size, the peak volume months were used, and the system size and capital costs are the same as Option 2.

Table 17: Comparative costings of Options 1, 2 and 3

Site	CAPEX	OPEX	Income	EBITDA	ROIC
Devonport Option 1	$2.7m	$150k	$77k	<$0	negative
Devonport Option 2	$2.7m	$196k	$175k	<$0	negative
Ulverstone Option 3	$6m	$644k	$681k	$37k	>16 y

The current annual value of bio-methane for Option 1 is $77k. This rises to $175k for Option 2, still less than operating expenses. Option 3 will yield 68,800 GJ p.a., worth $681k. Based on production prices for biogas in the EU, the cost is likely to fall between $10−20 per GJ. The cost of production of biogas for Option 2 would be at the high end of that range. The reason has less to do with the small scale of the anaerobic digestion plant than with the absence of cost offsetting by 'negative cost' wastes as biogas feedstock. Natural gas prices in Australia also remain lower than in many countries.

The prerequisites that Waste Solutions Ltd suggests for economically viable anaerobic digestion operation with vegetable waste are:

- Establishment of proper buffer zones to residential areas.
- Supply of vegetable processing waste at zero cost or negative cost.
- Consistent waste supply.
- Good biodegradability and quality of the waste.
- Low sulphur content in the waste.
- High extent of biogas utilisation.

Most of these criteria appear to be in place for Option 2. For example, handling of digester sludge and liquor has low process costs and could include offsetting sales income from sludge. A serious technical problem is the inconsistent waste supply, although this can be addressed by transporting waste from Ulverstone. A larger obstacle is the value of the waste used, which is currently sold as stock feed. Combined with the freight cost, the supply of additional waste is a strong net cost.

Although methane fuel can be produced at a low marginal cost, the overall financial result is unfavourable under the current set of conditions. Future price rises in natural gas or higher carbon market prices (with carbon credits for biogas production) may give a more positive result.

In conclusion, the operation of a vegetable processing waste digester facility is not economically sustainable at current natural gas fuel price levels and low carbon imposts.

3.5.6 Non-financial benefits

These include:

- Facilitate plant expansions.
- Brand image and maintaining market share where product sustainability is demanded.
- A large reduction (90%) in waste volume.
- Creation of carbon credits for fossil fuel substitution
- A linkage to a nitrogen capture technology to mitigate nitrous oxide formation when applied to soils that are intensively grazed.

3.5.7 Challenges and risks

The risks for adopting anaerobic digestion are smaller than the other bio-energy options due to the greater commercial experience with the anaerobic technology. There are operational challenges, such as keeping a reasonably homogenous feedstock supply and maintaining a consistent supply volume. Where the feedstock supply is seasonal, contingency sources must be secured and the feedstock transitions managed well (Cox & Souness 2004). One option is to make silage from the vegetable waste and hold it for use during supply gaps. The large scale generation of biogas to produce electricity or vehicle fuel introduces challenges associated with the freight of feedstock.

Currently an investment in an anaerobic digester would not pay, given the costs associated with the waste supply. However the commercial risks will change over time. If waste costs become negative (such as avoided landfill charges) and/or if natural gas prices rise, then the commercial risk would be lower. The main risk associated with replacing natural gas with biogas within a processing plant is that the cost of biogas production may exceed the price of purchased energy. A similar risk exists for the development of a fuel product for external sale.

3.5.8 Conclusions and recommendations

The amount of potato processing waste (3,500 tonnes/annum) required to balance seasonality effects is only about 10% of the available potato processing waste from Ulverstone. However, Waste Solution Ltd recommends not proceeding with the planning of a vegetable solid waste digester facility under the current economic fundamentals. The sale of waste as stock feed makes economic sense as long as this market is available.

The overall situation can be viewed in terms of the cost of producing bio-methane for Option 2. The current cost of energy produced could be as high as $20/GJ, and a reconsideration of the situation may be made when the natural gas price reaches that level.

3.5.9 Additional assessment of anaerobic wastewater treatment of separated high BOD wastewater streams

An assessment of anaerobic waste water treatment was additionally conducted and separately funded outside of this project by Simplot; completed in June 2008. The outcome of this assessment provides a potential benefit to the Australian vegetable and potato processing industry hence some data will be disclosed in this report.

As mentioned previously the anaerobic treatment of wastewater is not financially attractive due to the low BOD concentration of the factory wastewater effluent. This low BOD is related to the combination of low volume high BOD and high volume low BOD wastewater streams. The breakdown of wastewater flows at the Devonport factory indicated the possibility to separate a high BOD water stream from other low BOD waste water. Simplot assigned WSL to evaluate the option using UASB digester technology to treat the high BOD blancher effluent. The option proved to be economically and environmentally feasible due to:

- Fewer chemicals required to adjust pH of wastewater. This is related to the low amount of remaining acids (soluble mineral acids, organic acids) in the final factory discharge. Additional, bicarbonate caustic is a by-product of anaerobic wastewater treatment, which when combined with the high volume low BOD wastewater will neutralise organic acids prior to discharge.
- Overall reduced BOD load and costs for discharge of the combined wastewater. Optimised anaerobic treatment of segregated high concentrated streams typically removes more than 90% of the soluble BOD.
- Production of biogas as boiler fuel substituting natural gas (requires replacement of natural gas burner).
  •

The following process parameters and outcomes were estimated based on Devonport factory data (laboratory tests were not conducted):

Parasitic thermal load and surplus biogas of the digester Facility

Heating of the UASB digester influent is not required as the blancher wastewater temperature averages 50°C and higher. It is assumed that 90% of the biogas from the UASB disgester is used on a continuous basis for factory boiler operation.

Parasitic electrical load of the digester facility

The parasitic electrical load of the digester facility is minimal. Three pumps are the main power consumers (digester feed and recycle pump, and heat exchanger feed pump). Additional power is required for automation and controls. In the peak season (see Figure 8) a parasitic electrical load of approx. 500kwh/day is estimated; 200kwh/d for the rest of the year.

Expected natural gas replacement in the factory boilers

The estimated surplus biogas available for factory boiler operations is 15,000 GJ/y.

Seasonal start-up of the digester facility

The digester will be started with up to 1/3rd of the design load 2 days prior to receiving the full load. At the end of the season the digester will passively cool down.

Production of fertiliser

The fertiliser production from the wastewater treatment is marginal. A total of about 400t/y granular sludge is expected.

Indicative space requirement of the digester facility

The digester facility will fit on a rectangular site with a footprint of about 400m^2. The optimal arrangement of tanks, blowers, pumps and biogas flare may safe space.

Indicative methane yield of the digester facility

An indicative gross methane yield of the digester facility is estimated in the vicinity of 19 MJ/kg BOD_5 removed.

Indicative mass balance of the digester facility

Due to the limited amount of representative wastewater flow and composition data, a month by month digester facility mass balance cannot be presented. Based on an annual input of 213Ml wastewater it is estimated to produce 900t biogas and 400t surplus sludge.

Financials

The estimated capital cost for a full-scale anaerobic digester is in the order of $1.8m (subject to specific requirements at Devonport). Necessary adjustments of current equipment are estimated at $100k. The gross revenue includes cost savings for natural gas, chemicals & BOD discharge (future costs for carbon credits are not included). Based on the value proposition below the implementation of an anaerobic digester becomes economically and environmentally very attractive, particularly with respect to future carbon restraints.

Table 18: Value proposition for full-scale anaerobic wastewater treatment at Devonport

Gross Revenue	*$642 k*
Operating Costs	*$80 k*
Net Income	*$562 k*
Capital costs	*$1,900 k*
IRR	*10.0 %*
Payback time	*4 y*

Recommendations
It is recommended to implement of a dedicated blancher wastewater digester facility at Devonport (vegetable processing plant). Prior to full-scale digester design and installation, the following activities are recommended to refine the full-scale process design:

- Laboratory based tests with the actual blancher waste water
- Attain actual flow and composition information including elemental composition, bio-toxicity to digester cultures and interference with UASB digester operation
- Conduct pilot scale process trials (2m^3 containerised UASB facility) for at least 4 months to obtain operation data and demonstrate process stability and effectiveness under realistic high BOD blancher wastewater conditions

3.6 Business case 4 (summary) - Pellets from waste to feed livestock

3.6.1 Description of waste

All vegetable waste from Devonport and Ulverstone plants can be recycled as pelleted feed for animals. The pelleting process will follow similar specifications as for human food products. The main raw material ingredients used in the manufacture of compound animal feeds include cereal and legume grains, vegetable and animal protein meals, cereal milling co-products, and minerals and vitamins. Feed additives may be included for specific purposes. Waste products from starch processing and grains, pastas, rice hulls etc. also have the potential to act as natural binding agents. The use of oil in formulations depends on the nutritional needs of the animal, but typically 1−2% can be added to pelleted products (about 20 L per tonne). Soya oil is often used due to its low cost. Recycled vegetable oils have been used in the past, but further processing is often required which deters feed manufacturers. Alternative fat sources are always considered, with quality standards set by feed manufacturers rather than government regulations. There is little interest in recycled oils from fried foods because of the quality of the trans-fat portion. Feed manufacturers prefer to use top grade rendered tallows and oils from processed poultry, which are more expensive due to the heat treatment required to create them. Competition in the feed industry is high and manufacturers employ animal nutritionists to create new, improved recipes. The SAPL vegetable waste materials may fit well in pellet recipes created for ruminant industries, such as dairy, beef, calf, deer, sheep, and goats. Ruminant feeds may also provide an opportunity for re-using frying oils.

3.6.2 Technology

The pellet mill is the most costly and important piece of equipment to purchase and run. Well designed pellet mills ensure all the stock feed is consistent so each pellet contains the correct feed formulation intended. A pellet mill works by feeding powdered material into the rolls of the mill.

The material is then forced through the die and is compressed into a pellet. A set of blades cut the material to a desired length after the material is extruded through the die.

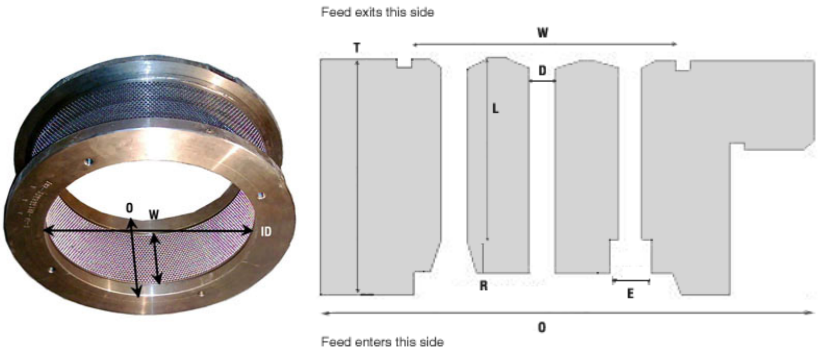


Figure 13: Example of a pelleting die and where feed enters and exits the die.

A diverse range of machinery has been developed for this purpose, and there is much controversy between different equipment manufacturers as to which type is the most effective (Figure 14).

Figure 14: Various types of pelleting machines available on the market.

Most pellet mills have conditioning units mounted above them where liquids such as water in the form of steam, and molasses can be added to improve pellet quality. To optimise pellet strength the moisture content of the raw materials must be 14−18%. From the conditioner, the feed falls into the centre of the pelleter where two or more rollers and feed ploughs push the material through the holes of the die plate. Usually the die plate itself rotates, and on its outer-side stationary knives cut the pellets to a pre-set length. From there, they are transferred to a cooler/drier to remove the heat which is generated during the pelleting process. The moisture content of the final pellets is then reduced to ~12% for proper storage and handling.

Coolers and dryers are employed to reduce the moisture content. Horizontal type coolers convey the pellets on a perforated steel mesh or moving belt through which a cooling air stream is passed. The horizontal method is best for 'sticky' dry pellets or for moist feeds. Heat is applied to the air supplied to horizontal driers for reducing the high moisture contents of moist feeds to those of dry pellets for storage. This type of drier is standard in the production of noodles and spaghetti and other pasta. The double pass is more efficient than the single, since it requires less airflow per ton of finished feed. In situations where a conventional cooler will not provide adequate moisture removal a dryer will be required.

Ribbon mixers are the most suitable for the vegetable waste stream ingredients (Figure 15). These are available in sizes suitable for mixing a few kilograms or of dealing with several tons of ingredients.

Figure 15: Horizontal ribbon and paddles mixers used to mix feed ingredients.

The process

The isolation of clean and dirty vegetable waste streams will generate a higher quality end product. The process involves:

- Production or purchase of raw materials to match the minimum quality standards.
- Sourcing registered feed additives (Australian Pesticide and Veterinary Medicines Authority (APVMA) approved).
- Formulation of the feed to meet the nutrient requirements for each class of livestock.
- Conversion of the raw ingredients into feedstock via milling, batching or weighing the raw ingredients according to formulation, and mixing to provide a consistent compound.
- Creation of a mash/meal or pellet.
- Sampling and testing the finished products to ensure they meet the minimum quality standards set by the Australian authority.
- Delivery of the bulk final products to large livestock producers or in bags to smaller scale producers and livestock owners.

• Process flow

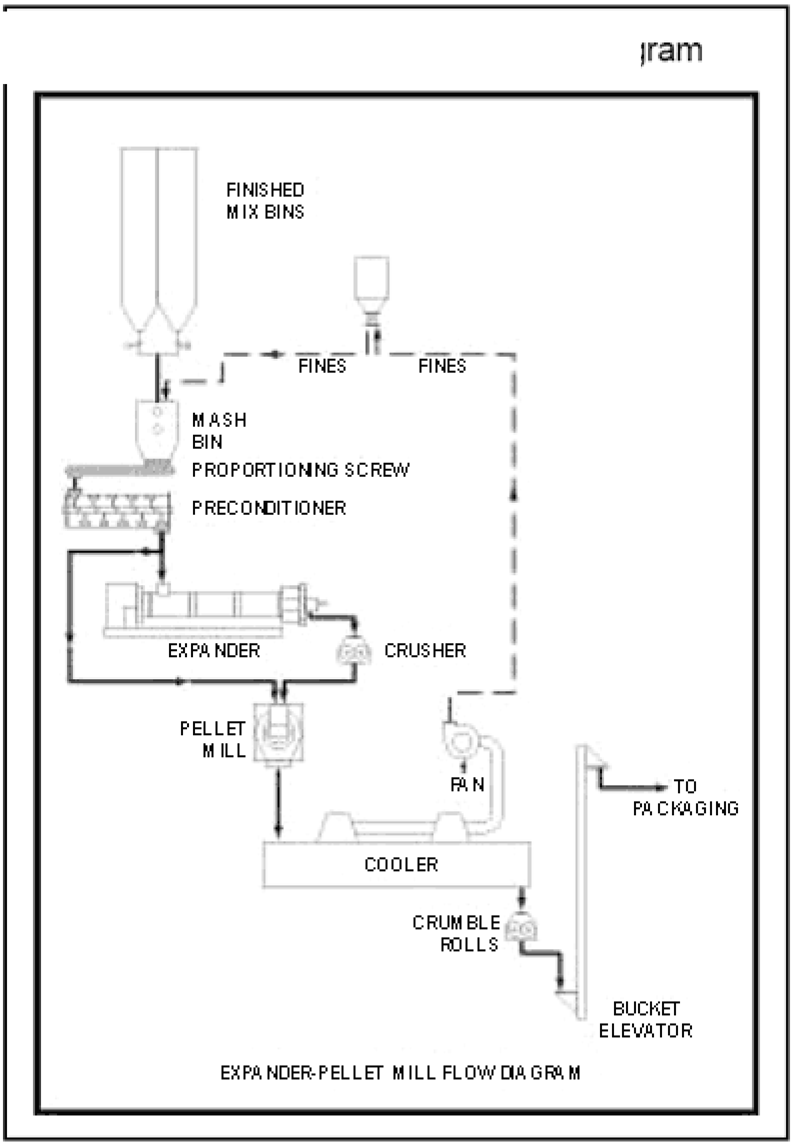


Figure 16: Expander-pellet mill flow diagram.

Equipment required:

- Loading and unloading machinery
- Intake elevators
- Storage holding bins (concrete bays)
- Dryer
- Dry material storage
- Grinder
- Storage of ground material
- Weigh machines
- Batching to achieve nutritional requirements (adding grains, vitamins, minerals)
- Ribbon mixer
- Boilers for steam
- Steamer
- Pellet press
- Cooling

- External coating (if applicable)
- Sieving
- Storage for bulk outloading
- Bagging equipment
- Warehouse storage bulk bins or stacker bins

Sensitivities

- Potatoes contain toxic alkaloids and can kill monogastric livestock.
- Pellet size will vary depending on the livestock species.
- Temperature and moisture levels must be strictly maintained to prevent fungal activity which can generate mycotoxins.
- Each type of vegetable waste must be considered by the animal nutritionist.
- Pelleting equipment must achieve the mean particle size and formulation specified for high quality pellets. Particle size is important for animal performance and also for pelleting. Coarse grinds create voids and fractures in pellets, making them prone to breakage.
- Large particle size or foreign matter can plug or partially block the die opening and change the appearance of the pellets. When the desired pellet diameter is 4 mm or less, the suggested maximum particle size should be one-third the diameter of the opening.
- Starch, proteins, and fibres act as natural binders, but will function differently with each product, and all recipes will need testing.

Impact on current processes

The current processes must be examined and changed to allow for the separation of dirty and clean vegetable wastes and to ensure the maintenance of hygiene standards through waste removal. However, these process changes will probably have a positive affect on the overall business.

3.6.3 Outputs and likely Volume

The annual volume of an input mixture of mixed vegetables and potato waste from the Devonport and Ulverstone plants is about 44 000 tonnes. Drying will reduce this by 85% to about 6660 tonnes.

3.6.4 Market information

Market size

The stockfeed market is growing. Australia uses over 10 million tonnes of livestock feed annually. This volume excludes pasture grazing, hay, and silage, and does not account for spikes in feed used in times of drought. The breakdown of feed use by livestock sector is presented in Figure 17. The biggest markets are currently dairy, beef, poultry and pigs (Figure 18).

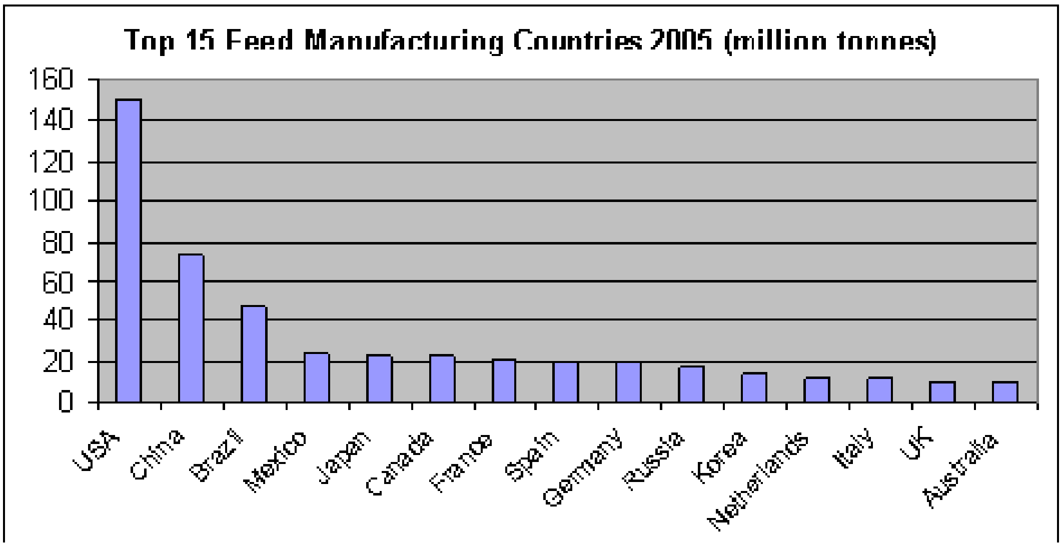


Figure 17: Feed manufacturing countries in the world and their use of feed in million of tonnes per annum.

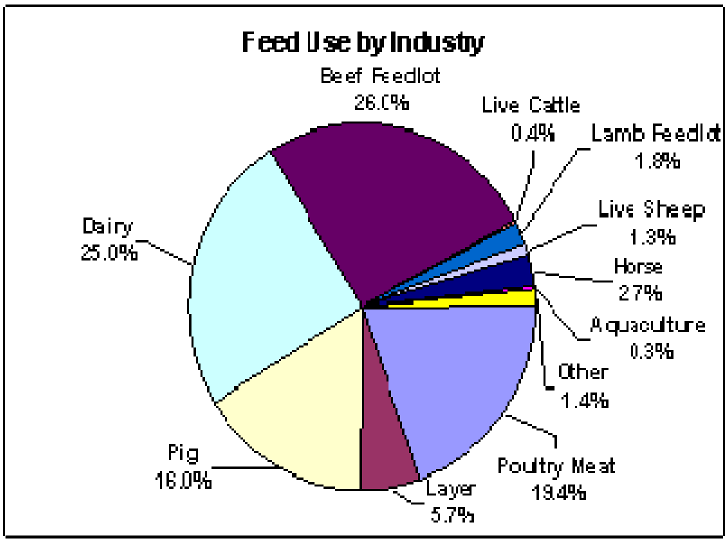


Figure 18: Percentage of feed used by different industries in Australia.

Table 19: Amount of feed produced in each Australian state in 2007.

Australia	**Feed Volume (tonnes) 2007**
Queensland	**874,500**
New South Wales	**1,054,000**
Victoria	**2,148,400**
South Australia	**394,400**
Western Australia	**491,400**
Total	**4,962,700**

Market need

Australia's feed industry is relatively small compared to other countries, but it is predicted to grow to 13.1 million tonnes by 2010. Demand for feed products in Australia is due in part to:

- Vulnerability to drought due to climatic variability.
- Lack of large arable areas, such as in South America.
- Inconsistent grain harvests compared to the USA or the EU.
- Fully committed and irregular grain production.
- Quarantine rules impeding imports of grain.

Market value of outputs

The current retail price for stock feed pellets ranges from $20 to $40 for a 25 kg bag. The nutritional requirements determine the actual value.

Market competition

The majority of raw material ingredients are sourced from Australian farmers and supply companies. Changes in the availability of resources and the fluctuating cost of grains are the most common issues in this market. Enormous pressure will build to import raw materials if the domestic industry cannot supply demand at world prices.

3.6.5 Financials

The financial estimates for purchasing a pellet system to process the amount of material created by Simplot are outlined in Table 19:

- Sales: $0.80−1.60 /kg of end product.
- Cost of production: $2 million to operate per annum.
- Other cost: Associated labour is estimated at $350 000 per annum.
- Net profit: A return of about $2−6million is estimated in the first two years.
- Capital costs: $1.6 million.

Table 20: Financial summary and assumptions used to calculate the revenue earned from pelleting vegetable wastes at Devonport and Ulverstone plants.

Waste inputs	
Mixed vegetable & potato waste	44,000 tonnes
Assumes tonnage is reduced by 85% after drying (?)	6,660 tonnes
Capital costs	
Pelletiser (Biopress Model 800 capacity 1.3 tonnes/h)	$350,000
Infeed conveyor system to press Outfeed conveyor from dryer to press RJS Biomass thermal oil drying system Infeed to RJS dryer Shredder unit to process potato waste prior to drying Infeed hopper/conveyor system to shred On site installation and commissioning	$1,250,000
TOTAL	*$1,600,000*
Operating costs	
Assumes 2 staff (?)	$350,000
Assumes pellet mill consumes 98% power (?); costs significantly lower if gas is available to run machines	$350,000
Drying of wet waste with moisture retention of 12% (cost ~$20−25/tonne at 44 000 tonnes)	$1,100,000
Assumes nutritional components to procure (?)	$250,000

TOTAL	*$2,050,000*
Revenue	
25kg bag retails at $20−40; Margins range from 8 to 17%	$0.80−1.60/kg
Output 6 600 000 kg pellets @ $0.80 retail price	$5,328,000
@ $0.80 with 8% margin	$4,901,000
@ $0.80 with 17% margin	$4,422,000
Output 6 600 000 kg pellets @ $1.60 retail price	$10,656,000
@ $1.60 with 8% margin	$9,803,000
@ $1.60 with 17% margin	$8,844,000
Price paid for 6600 tonnes dried raw vegetables	$1,980000
Revenue range $4.4 million to $10 million *TOTAL*	*$4,422,000*
CAPEX	*-$1.600,000*
OPEX	*-$2 050 000*
Year 1	*$772,000*
Year 2	*$2,372,000*

Assumptions:

- Excludes: shipping charges, on site lifting equipment, any government fees or charges, any site works or building construction (e.g. 20 m high, 15m x 15m), electrical installation and air or water plumbing.
- Operating costs has been set at a high level (~$250k/annum).
- Supplying only dried raw materials to a pellet manufacturer (Year 1 = $180k, Year2 = $530k).

Note: An additional value proposition was completed in August 2008 indicating that the conversion of vegetable waste streams into vegetable pellets is not financially attractive for Simplot. The revenue calculation shown in Table 19 was based on retail prices which averaged $800-1600 per ton. Simplot does not have the capacity to sell the vegetable pellets directly through the retail market; hence products have to be sold to wholesalers. Prices given by a global ingredient company averaged between $200 and 550 per ton (free on board) depending on the product. This lowered the annual revenue significantly ($1.1 MM) which made this concept financially unfeasibly.

3.6.6 Non-financial benefits

- Recycling of waste products into animal feeds will provide green credentials, which can be a marketing tool. Partnerships with other companies may bring synergies to business.

3.6.7 Challenges and risks

Changes to the availability of resources and the fluctuating cost of international grain prices appear to dictate the market and business of livestock feeds.

Other risk factors that fall under the category of handling and stored include:

- Non-accredited feed mills putting other manufacturers and feed regulators at risk.
- Increasing controls and regulations which will increase the compliance cost.
- Bovine spongiform encephalitis bse, salmonella contamination in beef, or exotic disease outbreaks such as foot and mouth.
- Competition from other input commodities.
- Geographic isolation from end users.
- Export competition from businesses that make the livestock users a secondary market.

- The logistical challenge associated with ocean freight.
- Consistency in the specification and application of the product.

3.6.8 Recommendations

- The production of dry or pellet animal foods from waste materials shows financial and environmental benefits when capacity exists to enter the retail market. This is more cost effective than sending the raw materials to dairy farms. When products have to be sold to a wholesaler the concept becomes financially unfeasible due to the low revenue/wholesale prices and high operation costs.
- Waste must be in a semi-dry state (<10−12% moisture content) before being pelleted or sold to a manufacturer.
- Create separate dried products from raw materials that can be blended at a later date.
- Examine the opportunities for desiccating or drying a range of other materials. This may extend beyond that of dried vegetables.
- Investigate pelleting plants and engage designers with a good track record to design an operation that fits the need.
- Consider joint ventures with local feed mills.
- Identify the market products and examine them carefully. Livestock feeds formulated for the horse or companion markets seem to be more profitable than seasonal feeds produced for dairy and calf markets.
- Dry and pelletise waste to make transport more economical (Heyes et al. 1998).

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5 Technology Transfer

The industry adoption of the technology investigated in this report will depend on financial and environmental imperatives. The development of business cases was selected as the major outcome of this project to meet this reality and improve the chances of industry adoption.

The work of Phase 2 will be quickly followed by Phase 3, which will involve a broad range of vegetable and potato processing staff. The exposure to a new philosophy for waste—one that replaces 'lowest cost option' with 'value adding'—is expected to have a strong and lasting impact on the Australian vegetable and potato processing industry.

6 Recommendations

The overall aim of the vegetable processing industry has always been to reduce waste production; however waste streams will always exist. This work has shown that a critical quantitative and qualitative audit of waste streams in collaboration with waste management experts will help the industry to:

a) Further reduce the waste volume.
b) Lessen the environmental impact.
c) Increase the profitability of food processing.

The 3-stage approach (concept evaluation, technical development, and business case development) used by the project to develop technology to add value to processing waste proved to be successful. The project recommendations to industry are to:

- Engage FSA to further evaluate the business cases for 'specific protein extraction from potato waste' and 'fibre from corn core waste'.
- Engage CFR to further evaluate the business case for 'vegetable pellets from waste to feed livestock'.
- Invest in the research and development required to address the technical and commercial developmental challenges in a staged approach for one or more cases.
- Maintain a watch on financial and environmental factors affecting the viability of the case for bio-energy.
- Maintain a watch for emerging technologies with the potential to add value to vegetable and potato waste.

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