Fish silage:
Can it be used in aquaculture?

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Contents

Summary

1 A study has been carried out to ascertain the quantities and type of fish waste in Victoria, South Australia and Tasmania with a view to adding to its current value.

2 In the absence of statistics gathered by State instrumentalities, the present survey consulted directly with processors and wholesalers in each State.
Major centres where waste fish was generated were Hobart (5000-6000t/annum), Port Lincoln (2500t), Melbourne Wholesale Fish Market (1100t), Adelaide (1100t).
Smaller quantities were generated at Lakes' Entrance (400-500t), Geelong (150t) and the area surrounding Lake Eildon (100t).

3 In Hobart, waste were primarily converted to a composted fertiliser though, with little demand, large supplies have been accumulated with some environmental impact on surrounding habitation.

4 In Melbourne, fish waste is accumulated by the City of Melbourne for collection for freezing by an external operator who supplies petfood manufacturers.

5 In Port Lincoln, prawn wastes are buried at municipal tips.

6 In Victoria, scallop wastes are buried at municipal tips at significant cost (10-20% of the processing profit).

7 In other provincial localities, wastes are generally buried at cost to the processor.

8 The present study centred on the possibility of converting fish wastes to fractions which could be incorporated into aquaculture diets and livestock diets.

9 Technologies for converting fish wastes into liquid fish protein (LFP), flesh colourants (astaxanthin and canthaxanthin), feed attractants and fish oils were investigated.

10 The economics of LFP production were incorporated into a model for a stand-alone ensiling plant based in Melbourne or Hobart. Key determinants for economic viability were world price for competing feed proteins, cost of ensiling agent (acidulant) and transport from plant to customer.

11 Sensitivity analysis indicated that a stand-alone LFP plant became viable when a throughput of 1000t/annum was reached or exceeded and when product could be sold at more than $1000t of protein. The internal rate of return (IIR) rose sharply if the volume manufactured increased to 1500-2000t/annum.

12 Cost of acidulant accounted for around 40% of the production costs. While formic acid was the most effective and convenient acidulant, it was also the most expensive.
Acidification was much cheaper when the fermentation was driven by bacteria and a carbohydrate source such as molasses, but this technique requires ambient temperature greater than 25°C for acceptable liquifaction times.
Inorganic acids, such as sulphuric acid, are also cheap but are dangerous to use and require neutralising prior to feeding to stock.

13 Transport costs were a significant proportion of production costs and can be ameliorated only when silage was produced at large volumes, over 2,000t/annum, or if a cheaper means of acidification were used.

14 The use of LFP as part of a fish sausage for feeding to tuna being held in pens in South Australia was investigated.
Currently, oily fish such as pilchards and sardines are used for tuna feed. Due to local shortages, this product is often sourced from South America, Russia, Japan and Korea and has reported feed conversion ratio as low as 16:1.
There are advantages in using LFP as part of a semi-moist feed, both in terms of feed conversion ratio and in preventing the weight loss which currently obtains when tuna are subjected to a change in diet.

15 In Tasmania, while there is a favourable congruence of fish waste and salmon-based aquaculture, the local feedmilling industry is reluctant to depart from dry pellet formulations based on imported fishmeal as nitrogen source.
While continuity of supply and the requirement for new pelletising technology were seen as impediments, the threat of disease transmission from offal was paramount in the rejection of LFP for incorporation into salmonid diets.
However, the long-term use of LFP in salmonid diets in Norwegian farms coupled with prospects for new aquaculture ventures in Tasmania based on flounder and trumpeter, should prompt a review of current wisdom which precludes this product.

16 The City of Melbourne is reviewing its current policy of disposing fish waste gratis to a contractor and is considering LFP production geared with a major pig-raising operation in southern NSW.

17 In east Gippsland, large feed milling operations are favourably disposed to incorporating LFP in diets for rearing of replacement dairy heifers.
Similar outlets exist near Eildon.

18 The present survey investigated a number of ancillary areas:

- Methods for separating edible portion from scallop shell.
- Current status of carotenoid extraction from crustacean wastes and its utility as a flesh colourant for trout and salmon.

- Sensitivity analyses for LFP transport from Hobart to tuna farms in Port Lincoln and from Melbourne to piggeries in southern NSW.
- Sensitivity analysis of various acidulants (organic acid, inorganic acid and microbial acidification).
- Likelihood of fish waste playing a role as a vector in the transmission of unspecified viral and bacterial diseases to salmonids.

19 The present survey prompted the following recommendations for further research and development:

- Pilot trials in South Australia on prawn waste and in Tasmania on finfish and scallop/abalone waste, to provide data on carotenoid, protein and amino acid levels, with special reference to salmonid, flounder and trumpeter diets.

- Trials on processing steps in LFP manufacture which are lethal for viral and bacterial pathogens for salmonids. The results of these trials could form a basis for a formal risk analysis on using LFP for salmonids.

- Pilot trials on acidulants in combination to minimise this major production cost.

- Trials on methods of separating edible portion from shell of scallops. This would generate LFP and shell free of contamination.

- Drying of LFP.

- Characterisation of amino acid and fatty acid profiles of LFP.

1 Identification of fish processing wastes in Tasmania, Victoria and South Australia

1.1 South Australia

The fisheries of South Australia are dispersed from the Australian Bight trawl fishery located west of Port Lincoln, to the Victorian border. Resources are presented in Table 1.1.

Table 1.1: Fisheries resources of South Australia

		1990-91	1991-92	1992-93
CRUSTACEA				
Prawns		2086	2155	2155
Rock Lobster		2666	3162	2900
Other		583	527	583
	Total	5335	5844	5638
MOLLUSCS				
Abalone		863	885	885
Pipi		293	441	441
Squid		279	329	329
Other		387	504	385
	Total	1822	2159	2040
FINFISH				
Australian salmon		508	601	601
Mullet		152	128	128
Tommy ruff		308	363	363
Snapper		457	437	437
King George Whiting		692	750	750
Garfish		454	514	514
Ocean jackets		949	1008	1008
Other		545	667	546
	Total	4065	4468	4347
AQUACULTURE		1993	1994	1995
Tuna		170	750	2100

Since no data are available for the level of processing or location of sale and/or processing a qualitative estimate was conducted based on the two main ports /processing centres in South Australia, Port Lincoln and Adelaide.

1.1.1 Port Lincoln

Port Lincoln is the major fishing centre west of Adelaide and is of particular interest in the present context as it is a significant source of fish wastes and a location for aquaculture. There is a rapidly developing oyster farming industry with potential for further development of other shellfish industries such as abalone and mussels. Tuna fishing and farming industries are located there, serviced by a tuna cannery with associated facilities for meat and fish rendering at Lincoln Bacon Pty Ltd. Port Lincoln is a regional prawn processing centre based on Australian Bight Fisheries Pty Ltd and is the location of the Australian Bight trawl fishery.

There are intensive piggeries and dairy farms in the region and their isolation of Port Lincoln from other sources of protein and energy feed sources adds to their costs.

1.1.2 Fish wastes generated in Port Lincoln

Fish wastes generated by the major processors in Port Lincoln are estimated in Table 1.2.

Table 1.2: Fish waste (t/annum) generated by the Port Lincoln fish processing industry

	Tuna frames/viscera
Cannery	1500
Tuna farms	900
Other wholesalers/processors	300
Subtotal	2700
	Prawn wastes
Prawn processors	400
Total	3100

A total of eight processors was surveyed, associated with tuna farming and fishing, tuna canning, prawn processing and trawl inshore fishing industries in the region. Two waste sources predominated, tuna (2500t) and prawn wastes (400t).

Port Lincoln Tuna Canners Pty Ltd produces 1400-1600 t/annum of cooked waste comprising frames and viscera of both locally-caught and of imported species. This waste is collected and rendered by Lincoln Bacon Pty Ltd into meal.

Australian Bight Fishermen Pty Ltd processes locally-caught prawns into a range of products from whole, green prawn to prawn cutlets and prawn meat, the latter resulting in considerable volumes of prawn shell wastes comprised of carapace and viscera. Prawn wastes are discarded at the local Shire tip at a fee to the company of $200/t. The same company also produces 100 t/annum of fish frames.

Tuna landed at Port Lincoln from both farms and wild stocks are exported gutted, which generates 700-1000t/annum of viscera. Regional inshore fishing for whiting, mullet etc is processed primarily by Craig Rough Pty Ltd in Port Lincoln. Around 24 t/annum of trawl waste is collected free of charge by Lincoln Bacon Pty Ltd, together with around 50 t/annum of shark waste processed by Agiros Pty Ltd and converted either to fish meal or liquid fertilizer. The protein content of the local fish meal produced by Lincoln Bacon approximates 50% and costs $520/tonne (equivalent to $1083/t protein).

Fish meal and other fish offal are sold to local dairy and pig producers. None is currently used in local aquaculture diets, although Lincoln Bacon, in conjunction with the Tuna Boat Owners Association and SARDI, is involved in developing a range of "fish sausages" as an alternative to the frozen pilchards which is used for tuna fattening. Liquid fertiliser is sold in bulk to horticultural distributors for repacking to the retail horticulture market.

Tuna farming is based on the fattening of tuna caught under existing management quotas. Larger size tuna bring higher prices, not only because of their greater mass but because of their higher oil content and deeper flesh colour. This is a relatively new development, and is expanding rapidly. (production figures and projections in here?)

Tuna prefer either a fresh fish or a moist/semi-moist feed to a dry feed and are fed primarily on frozen pilchards or similar species. Tuna farms consume 12,000 t/annum of mostly frozen, imported pilchards fed either thawed or as frozen blocks. Frozen pilchards are by no means an ideal food source, differences in protein and fat content Table 1.3) affecting both nutrition, flesh colour and palatability.

Table 1.3: Proximate analysis of pilchards used for tuna farming (% wet weight)

	Fat	Protein	Ash	Moisture
Average	7.8	19.1	2.9	70.5
Minimum	4.8	16.6	2.1	63.5
Maximum	18.2	20.8	3.5	75.2

The feeding process is wasteful and inefficient in terms of feed consumption, conversion and handling and is likely to present a number of problems for the environment. In particular, it represents a threat because of:

- The use of unprocessed frozen fish from other countries raises the probability of introducing to the Port Lincoln waters a number of potentially harmful exotic organisms, including in particular, algae, amoebae protozoans and viruses to which both shellfish and tuna may be susceptible.
- Excessive bio-deposition in the proximity of the tuna farms resulting from inefficient methods of feeding frozen pilchards puts at risk the developing bivalve aquaculture in the area by creating nutrient levels which sustain algal blooms harmful to shellfish.

Pilchards cost $0.7-0.9/kg, with an apparent feed conversion ratio of 20:1. Artificial feeds made using fish meal, meat meal and plant protein are bound with water in a sausage skin with water added to raise moisture 33-50%.

On first appearance, it should be possible to replace some or all of the mix with fish silage based on local fin-fish and prawn wastes, offering a number of advantages:

- Silage has much the same nutritional value as pilchards (Table 1.4).
- Silage has a semi-liquid consistency with good binding characteristics and palatability.
- Silage imparts attractant properties to the feed.
- Silage has flesh colourant properties, particularly if prawn wastes are included.

Current practice, involving conversion of fish into a low-moisture meal, followed by rehydration to a semi-moist product adds considerable expense to prepared tuna feeds. Given the economies of silage production versus rendering, it should be possible to prepare silage-based feeds more economically than at present. This would not penalise other end-users of protein in the area since adequate quantities of meat meal will remain - only the manner in which raw materials are distributed and processed will be altered.

Table 1.4: Comparison proximate analysis of pilchards and fish silage

	Fat	Protein	Ash	Moisture
Pilchards	7.8	19.1	2.9	70.5
Acid silage	5.0	16.4	5.3	70.8
Molasses silage	6.4	14.4	6.7	66.4

1.1.3Fish wastes generated in Adelaide

Adelaide is a regional centre for the fishing industry in South Australia and is home to the bulk of that State's processors. Visits were made to all major seafood processors in Adelaide from which the following comparisons can be made with neighbouring States:

- In contrast to both Melbourne and Sydney, the Adelaide Central Fish Market is not a centre for fish processing and consequently is not a source of fish wastes.
- Much of the fish landed in Adelaide are transshipped to markets in Melbourne and Sydney.
- No statistics are available for fish wastes and these are estimated, following discussion with all major processors (Table 1.5).

Table 1.5: Estimated fish wastes in Adelaide (t/annum)

Company	Average	Range
Adelaide Retail Market	50	50-70
Company A	100	100-150
Company B	400	300-500
Company C	150	100-400
Company D (finfish waste)	150	100-200
Comapny D (prawn waste)	300	200-400
Company E	300	100-400
Others	60	60
Total	1510	

Most of the wastes listed in Table 1.5 are collected and processed into fertiliser except for Company E's prawn waste which currently is discarded at a fee around $200-220/t. The company is investigating higher-value end use shrimp fronts, including a range of products for human consumption, such as flavouring for prawn crackers, pastes etc. Other fish wastes comprises fish frames and viscera of mixed species, totalling 1310 t.

Fish wastes in the Adelaide region are collected by companies Master Butchers Pty Ltd, for incorporation into protein meal, Jomoco Pty Ltd for ensiling into a soil conditioner (which is actually a fish silage) and Hortico Ltd for incorporation into blood and bone meal. The first two companies cite difficulty in obtaining sufficient supply to meet demand. Each of the three companies has similar market share. Each collects wastes on a daily basis free of charge, providing clean containers for waste.

1.2 Victoria

Major fishing ports and/or sources of fish wastes in Victoria are located at Portland, Geelong, Melbourne, Port Welshpool and Lakes' Entrance (Table 1.5).

Table 1.5: Fish waste in Victoria (1992-93)

Location	Estimated waste (t/annum)	
	Finfish	Scallop viscera
Portland	-	-
Geelong	155	300
Melbourne	5520	615
Corner Inlet	25	135
Lakes' Entrance	500	320
Totals	6200	1370

According to Victorian Govt Fisheries statistics, in 1993 approximately 9080 t of scallops were processed, giving an estimated waste volume of combined shell/viscera of 7990t and an edible waste of 1370t. At present, scallop wastes have no commercial use and, with the exception of Port Welshpool, is dumped at local tips. The cost of disposal of scallop wastes is considerable. One large scallop producer had accurate costs both for in-plant and tipping costs which totalled $35.50/t. For smaller processors, lacking economy of scale, disposal costs were $45-$55/t.

Based on the foregoing, industry-wide disposal costs in 1993 were of the order of $283,645 for 1397t of scallop meat processed, equivalent to $203/t of scallop meat and $0.20/kg of unshucked scallops. While this cost represents only 2 % of the sale price of scallops, it represents at least 20 % of the processor's profit of $1.20/kg of meat.

1.2.1Waste generated at the Melbourne Wholesale Fish Market

The Footscray Fish Market has an annual throughput in excess of 10,000t, much of which is purchased by retailers. A significant proportion, however, is processed on site, the resulting fillets being packed for inter- and intra-state consumption. Since filleting operations typically yield edible product in the 30-50% range, market processing operations generate significant volumes of filleting waste. At present, fish waste is collected by contractors and frozen for petfood manufacture.

During the period 1977-1991 the volume of finfish passing through the market increased (Fig 1.1) from around 5,400t in 1977 to 15,940 in 1991 before a subsequent decline to 13,506t for the year ending December 31, 1994.

Important in the volume trend illustrated in Fig 1.1 has been the landings of orange roughy (*Hoplostethus atlanticus*) which rose during the 1980s before falling during the 1990s. Blue and silver warehou (*Seriolella* spp) and sharks have also suffered broad declines during the same period (Fig 1.2).

Thus, the "industrial" species which form the basis of the processing trade, while not being landed in the same volumes as previously, still comprise a significant base for further processing.

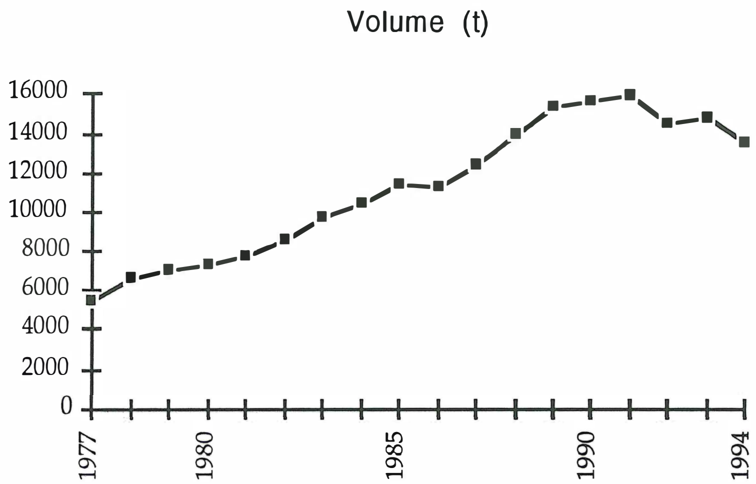


Fig 1.1: Throughput of finfish via Footscray Wholesale Market 1977-1994

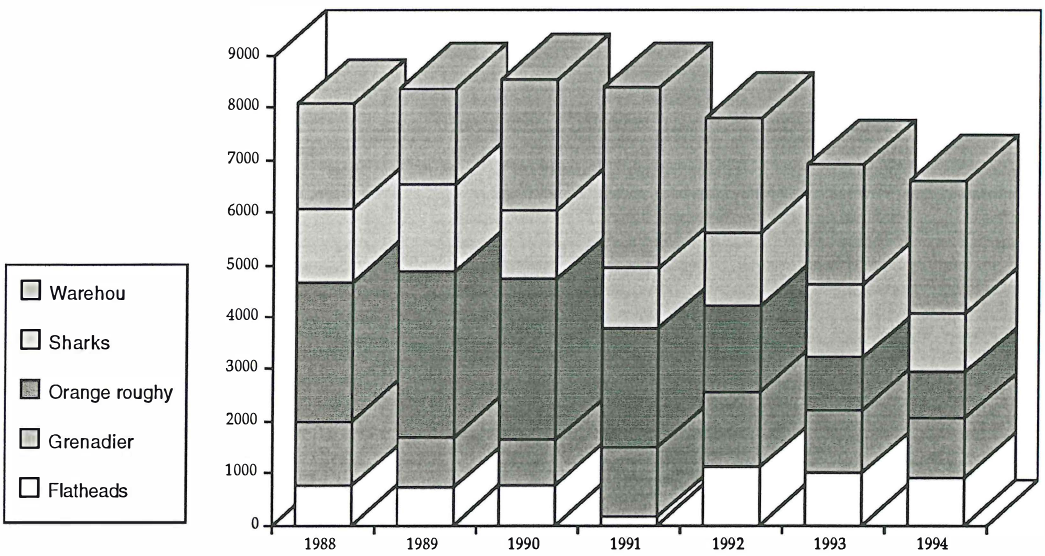


Fig 1.2: Volumes (t) of the five main species (1988-94)

1.2.1.1 Quantitative estimate of fish waste available for further processing

Wastes potentially available for further processing fall into the following categories:

(i) Filleting waste generated by market operations
(ii) Filleting waste generated by operations in the immediate vicinity of the market.
(iii) Scallop waste.
(iv) Filleting waste returned by retailers.

(i) Filleting waste at the Melbourne Wholesale Market

Filleting waste is generated by four processing establishments located in the providoring section of the market, NAK Seafood Processors, Jim Jury, Ash Brothers and Tim & Terry with the two former operations generating rather more waste.

At each establishment, waste generated by each member of the filleting team is dropped into tote boxes capable of holding around 30kg. The contents of each tote box are, in turn, deposited into a bin of around 1 tonne capacity located at the rear of each premises. A City employee transports each bin to a holding area where the contents are picked up by a contractor and removed off-site for further processing.

Because no establishment keeps a record of waste generated or of fish purchased it is not possible to make an accurate qualitative or quantitative estimate of waste generated at the market. Each establishment has a general idea of the number of bins filled each day with NAK and Jury each estimating 1-2.5t waste/d and Ash Brother and Tim & Terry estimating 1-1.5t/d, depending on the volume of fish available at the market.

Anecdotally, therefore it is believed that the four major providores generate 4-8t/day, or 20-40t/week.

(ii) Off-site filleting waste

Filleting waste is generated by two processing establishments located within a 5km radius of the market, such as McLaughlin-Lefkas in Footscray and J. Racovolis Pty Ltd located at the rear of the wholesale market.

No records are kept of raw materials purchased or of waste generated and an estimate is possible only on anecdotal evidence. McLaughlin estimates around 1t/d (5t/week) while Racovolis estimates 5-12t/d (25-60t/week).

(iii) Scallop waste

Within and near the market there are several scallop-shucking operations which generate shell attached to the "beard" (intestine and gill), both of which are potentially useful as raw materials. At present shell and beard are transported to a tip for prescribed wastes in Geelong at a cost to the processors.

(iv) Filleting waste returned by retailers

Within a 10km radius of the market there are large number of retailers, most of whom operate from the Queen Victoria, Preston, Footscray, Prahran and South Melbourne markets. Current arrangements for disposing of waste (estimated to toatl around 10t/w) from these markets involves removal by an external contractor (e.g. Pridhams remove waste from the Queen Victoria Market) or liquidising waste and discharging into the sewer (e.g. Prahran Market).

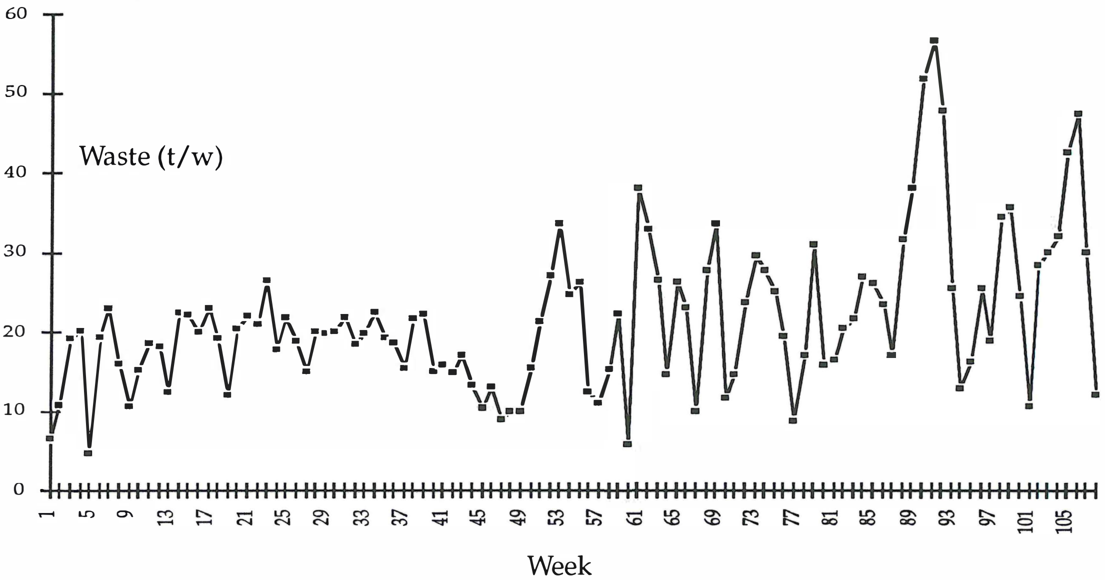
In general, retailers pay their local council for removal of waste. A number of retailers interviewed all believed it would be advantageous if they were able to return waste to the market. Logistically, however, it seems unlikely that retailers will be prepared to return filleting waste to the market.

Summary of waste available

Anecdotal evidence from interviews with providores and processors at the wholesale market indicates that 50-100t/week of filleting waste is generated (providores 20-40/t and processors 30-60t). Since scallop waste is removed from the market, this has been eliminated as a potential raw material source for further processing.

A more definitive estimate of waste removed from the market has been made available from data provided by the contractor which removes waste in bulk bins for further processing, Tanon (Vic) Pty Ltd. These data (Fig 1.3) are available for the period December 6, 1992-December 31, 1994.

Fig 1.3: Waste fish removed from the Melbourne Fish Market (1992-1994)



Data provided by Tanon Pty Ltd indicate a level of waste generally increasing during 1994 (25.2t/w) compared with 1993 (18.3t/w). A dramatic increase in waste generation has occurred since July, 1994 with the inclusion of waste from the Safeway (Racovolis) operation. In the period Jan-July, 1994 average weekly waste was 21t, compared with 31t for the period Aug-Dec, 1994.

The increased volume during 1994 notwithstanding, on a weekly basis, there was great disparity in the volume of waste produced, from 8.8t (29/5) to 56t (4/9). This disparity has implications when considering value-adding options.

1.2.1.2 Qualitative estimate of fish waste available for further processing

An important aspect of the present study is a qualitative evaluation of waste available for further processing. Such an evaluation is made difficult because of the lack of records kept by processors. One approach to qualifying the waste generated at the market is to compare the volume of waste with volume of raw material, and this comparison is presented in Table 1.7.

Table 1.7: Volume (t/month) of raw material and waste passing through the Melbourne fish market

1993	Market throughput (t)	Waste (t)	Waste (%)
Jan	1227	63	5.1
Feb	1193	62	5.2
Mar	1467	87	5.9
April	1353	74	5.4
May	1291	109	8.4
June	1228	73	5.9
July	1329	80	6.0
Aug	1201	75	6.2
Sept	1072	89	8.3
Oct	953	62	6.5
Nov	1138	57	5.0
Dec	913	112	12.2
Total	14365	943	6.68
1994			
Jan	1059	66	6.2
Feb	1178	112	9.5
Mar	1496	87	5.8
April	1123	83	7.3
May	1063	110	10.3
June	1220	80	6.5
July	1153	119	10.3
Aug	1222	138	11.3
Sept	898	142	15.8
Oct	1069	131	12.2
Nov	908	93	10.2
Dec	852	164	19.2
Total	12389	1283	10.0

While the data substantiate the increased percentage of waste available at the market during the latter part of 1994, the actual percentage of filleting waste is only a small fraction of that potentially available. For the main industrial species, filleting waste varies from around 50% ("wing-on" flathead) to 73% (orange roughy). Thus, since around 1000t/month passes through the market, the resulting waste is of the order of 500-600t/month.

One expectation is that, in those weeks when large volumes of waste are generated, it is a reflection of the volume of industrial species passing through the market e.g. orange roughy, warehou and grenadier. To an extent, the data in Table 1.7 bear out this expectation. For example in the months July-Dec. 1994, the volume of waste comprised a large proportion of the three major industrial species (Table 1.8).

Summary of the qualitative composition of waste at the market

From Tables 1.7 and 1.8, and Fig 1.2 it is likely that the qualitative make-up of waste generated at the market will be filleting waste from the major industrial species of warehou, grenadier and orange roughy. This waste will comprise frames, heads and guts.

Table 1.8: Volumes (t) of industrial species sold and of waste generated at wholesale market

Month, 1994	Orange roughy (t)	Warehou (t)	Grenadier (t)	Total (t)	Volume waste (t)	Waste (% of warehou/ orange roughy)
July	87	240	113	440	119	27
Aug	159	336	145	645	138	21
Sept	35	323	22	380	142	37
Oct	65	214	51	330	131	39
Noc	66	125	39	230	93	40
Dec	37	164	61	262	165	63

1.3 Tasmania

During 1994 around 11,000t of finfish were landed in Tasmania, around 8,000t from Commonwealth waters, almost all of which was either Orange Roughy or Grenadier. Just under 3,000t was landed from inshore waters and comprised mixed species e.g. morwong, flathead and barracouta.

Around 2,500t of abalone were landed and processed in Tasmania and around 5,000t Atlantic salmon were harvested and processed.

1.3.1Fish waste in Tasmania

In Table 1.9 is presented an estimation of the volumes of fish processing waste generated in Tasmania.

Table 1.9: Estimated fish waste generated in Tasmania

Species	Landings 1994 (t)	Type of waste	Volume (t)
Orange Roughy	6250	Head, guts, frames	4500
Blue Grenadier	1200	Head, guts, frames	700
Other finfish	3000	Head, guts, frames	1800
Atlantic salmon	5000	Gills, guts, frames, skin	750
Abalone	2500	Viscera	750

Basis for estimations

Estimations for the volume of waste generated in Tasmania have been made:

(i) By calculating the volume of filleting or shucking waste using conservative industry estimates.
(ii) By using estimates provided by individual companies.
(iii) By using estimates provided by TasCrays of waste which enters their composting system.

Filleting and shucking waste

Filleting ratios for Orange Roughy (70:30, waste: edible fillet), Blue Grenadier (60:40) and trawl species e.g. Morwong (60:40) were used to estimate waste from these species.

Filleting waste of 15% was used for processing of Atlantic salmon, based on data supplied by the industry.
Abalone waste was calculated using a ratio of shell (30%), gut (30%) and meat (40%).

1.3.2 Location of processing waste

The vast majority (>90%) of filleting waste from wild and farmed fisheries is generated in the Hobart-Margate area in the south of Tasmania, with the remainder being processed in Devonport.

Abalone waste is generated in three areas of the state:

- In the north-west (Stanley, Smithton, Strahan).
- On the east coast (St Helens, Swansea, Triabunna).
- In the south, (Dover, Hobart, Margate).

1.3.2.1 Southern Tasmania

The vast majority of fish waste (>80%) is disposed of via TasCrays in Margate. The process is a crude composting of whole fish/finfish processing waste and abalone waste with pine bark using natural defiles to retain batches of compost. The compost heats to >70°C due to microbial action. Oil and water-soluble materials flow from the compost and are retained at a gate. Oil is skimmed from the surface and sold for heating fuel at $0.25/L. The compost is dried, bagged and marketed for home use as "OR 90". The operation currently handles around 5,000t/ annum of mixed seafood wastes.

1.3.2.2 Northern Tasmania

The majority of waste which is utilised is accumulated at the Petuna operation in Devonport. This finfish waste is removed by a farmer and composted in large dammed areas. The liquid waste is used for fertilising paddocks.

Relatively minor quantities of abalone waste is generated in various ports around the north, north-west and west coasts of Tasmania. In general, this waste is either dumped in landfill or pumped into harbours or rivers adjacent to the processing plant.

There are several current developments in Tasmania which may result in changes to the way in which wastes are utilised:

(i) Use as plant fertiliser

At present considerable quantities of waste are processed via Tascrays as OR90 or "Fish-and-chips", both products being marketed via the retail trade. It is probable that an opposing operation may be set up. Vitek have reportedly approached a number of salmon and abalone processors with a view to licensing their process for converting waste into fertiliser. Vitek have also reportedly approached the Tasmanian State government for assistance in setting up the operation. In total, some 750,000L of plant fertiliser will be manufactured from salmonid wastes.

The government has also been approached by Tascrays who wish to market their product for land rehabilitation schemes. The government has not been supportive of the Tascrays scheme which involves the purchase of specialised plant and equipment for spraying fertiliser onto land rehabilitation areas. It is stated that Tascrays current operation is jeopardised because of leaching of fish solubles into the surrounding environment which has residential housing.

(ii) Use in production of fish oils

Salmonid processors who enter a licensing agreement with Vitek are studying the feasibility of utilising the oil fraction as a source of omega-3 and omega-6 fish oils for human consumption. Around 50t of salmonid oil may be recovered from the fertiliser process which, if refined, will compete with the large import sector for essential fatty acids based on menhaden (from USA) cod and capelin (from Europe).

2 Liquid Fish Protein plant and equipment

Liquid fish protein has been used for some decades in Europe as stockfeed. In Denmark and Poland, for example, the use-rate of LFP is 60,000t and 100,000t/annum, mainly for pig feed. In Asia and Latin America, the process has been evaluated and LFP products used for a range of stockfeeds (poultry and fish feed) and human products (shrimp crackers).

In the UK, British Petroleum (BP) Nutrition market a turnkey LFP plant comprising a chopper pump mounted in an acid-resistant tank. The chopper pump blends and mixes the fish waste with formic acid which is used to drive the fermentation. BP's interest in LFP comes primarily because it is a major producer of formic acid and fermentation is seen as a means of increasing sales of this product

In Scandinavia, fermentation plants integrate with fish meal and fish oil operations. Accordingly, the oil fraction which overlays the LFP, is passed through decanters and refiners. LFP plants can be constructed in equilibrium with throughput and degree of sophistication required.

A simple, cheap plant has been trialled using Victorian fish waste.

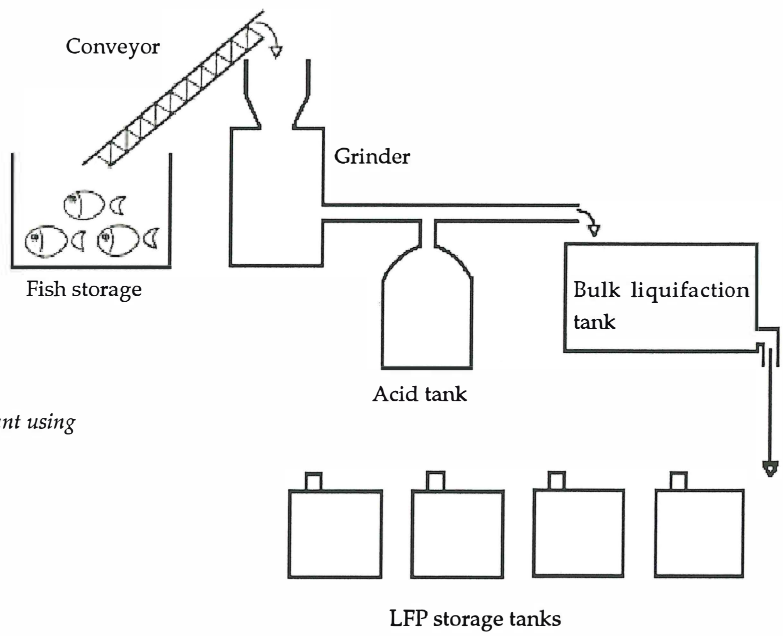


Fig 2.1: Simple LFP pilot plant using locally-available equipment

A LFP plant must be able to accommodate the ranges of fish waste which result from gluts and bad weather. In the present study, the Melbourne wholesale fish market had the largest peak requirement for waste fish utilisation. Bearing in mind the quantitative and qualitative make-up of the market waste fish, a fermentation plant has two major specifications.

(i) Size

The plant must be able to accommodate large variations in volume of waste - between zero and 15t/day.

(ii) Storage capacity

The plant must be capable of up to 100t in storage and to keep separate orange roughy waste from the remainder.

2.1 Component equipment required for a LFP plant

This following components are required:

- Scales
- Mincer
- Fermentation tank
- Chopper pump
- Storage
- Transportation drum

An off-the-peg plant manufactured by BP Nutrition costs around $40,000 landed in Australia and is capable of handling around 3t/day in its basic configuration, a capacity which can be extended by purchasing larger pumps and tanks, probably doubling the landed cost.

A plant similar in sophistication to the one illustrated previously could be constructed to ferment fish waste at the wholesale market for considerably less than the BP plant. The following equipment is needed:

- Mincer

This is the rate-limiting step in preparation of raw material for fermentation. It must be capable of mincing relatively large pieces of fish e.g. orange roughy frames to a relatively small particle size which can be handled by the chopper pump.

The mincer must be capable of handling 4t/h in order to cope with the largest projected volumes of waste (15-20t/d).

The Thompson 4000 mixer/grinder has a throughput of 4t/h and grinds to a 10mm diameter mince. This model costs around $16,000.

- Chopper pump

Pumps with chopping blades are used in sewage plants to pump and break-up matter which passes through the sewage system. A sewage pump which can be moved from tank to tank using a pulley system is required. This is because the pump is used to mix ferments, a process which speeds up liquifaction. Chopper pumps are manufactured by Mono Pumps Pty Ltd in Melbourne and a Model AS 16 pump costs around $4,000.

- Storage tanks

Since the liquifaction process takes between 5 days and 3 weeks, depending on the temperature of the ferment, there is the requirement for considerable storage capacity. The largest monthly total of waste generated to date is around 100t and storage should accommodate this volume.

Storage vessels must be resistant to acid which involves lining with fibreglass or plastic. A series of five vessels, each of 22,500L capacity would be required. Team Poly in Adelaide make black plastic, acid-resistant tanks at around $2,000 each.

- Ancillary equipment

A great deal of ancillary equipment is required including:

- Scales
- Hoses
- Acid-dosing pumps
- Safety equipment
- Cleaning equipment

A summary of costs for a LFP plant are presented in Table 2.1.

Table 2.1: Component costs of equipment required for a LFP plant

Component		Cost ($)
Scales		700
Sorting tables		1000
Chopper pump		4000
Grinder		16000
Filling pump		2500
Mixing vat		2000
Storage tanks (5x$2,000)		10000
Acid-dosing pump		2000
Cleaning equipment		2000
Safety equipment		2000
Miscellaneous (hoses etc)		2000
Elevator (used)		3000
Truck (used)		25000
Office equipment		4000
	Total	75200

This equipment is depreciable at a flatrate 10% per annum (zero residual) of $7520/annum.

2.2 Layout of LFP plant

It is assumed that the plant will be installed on a level site with access for delivery trucks to bring in fish waste. The LFP facility will need cover for the raw material storage, grinding and conveying areas, optimally with a fully-enclosed building at least 100m² with doors at each end which can be opened during working hours. Tanker access to storage tanks is not required because hosing and a Mono pump will satisfactorily move product into the tanker. The chopper pump can be used to mix product in the primary mixing tank and the storage tanks. For this reason an overhead gantry bearing the chopper pump will facilitate moving this piece of equipment.

An outline plan and elevation is provided in Fig 2.2.

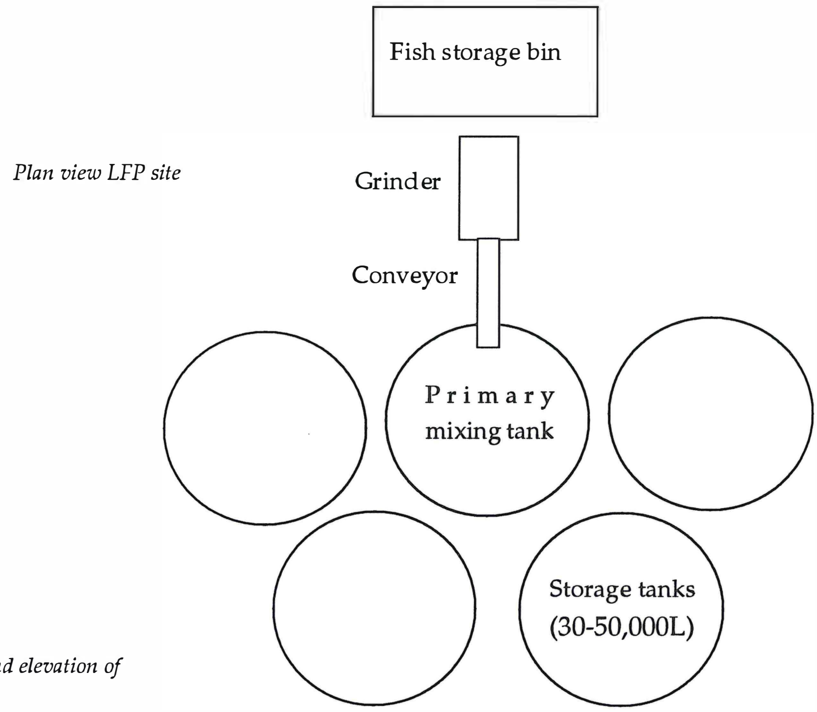
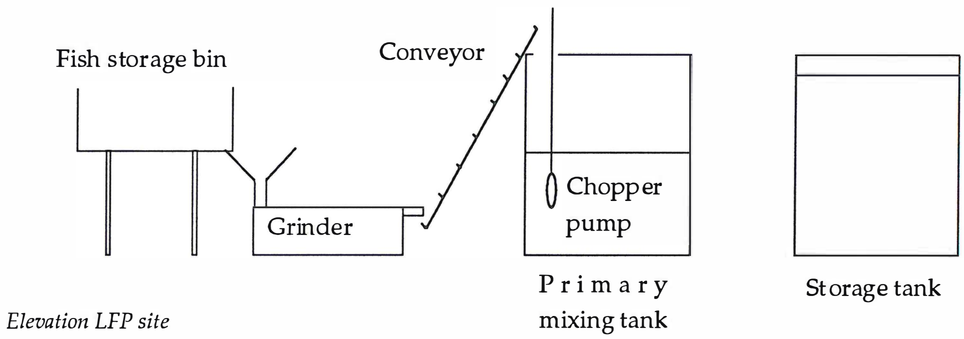


Fig 2.2: Plan and elevation of a LFP plant



3 The ensiling process and costs of production

Fish silage (or liquid fish protein) is made from fish or parts of fish, generally by the addition of acid to accelerate the enzymic breakdown of tissues. The process comprises several stages.

3.1 The ensiling process

(i) Size reduction of raw material

Ensiling is accelerated when the surface area for enzymic breakdown is increased. Typically, fish waste is ground to give a particle size no greater than 4mm in diameter, facilitating thorough mixing of acid with raw material and reducing the possibility of pockets of untreated fish which may putrefy.

(ii) Acidification

Acid is added to the ground raw material to reduce the pH to one more favourable for hydrolytic enzymes. Either organic or inorganic acids may be used. The former are more expensive but require no neutralisation and stabilise the silage at a higher pH (around 4.0).

(iii) Mixing

Acid is metered into the ground fish during a mixing process.

(iv) Liquifaction

At a pH between 2 and 4 the proteases facilitate conversion of tissue to a liquid silage. Liquifaction is accelerated by mixing of acidified mince, a process carried out by pumping the mix through a chopper pump.

(v) Storage

Liquifaction is influenced by the temperature of the mix and, in colder climates the ensiling process may take several weeks, compared with 2-3 days at temperatures between 25-35°C. Typically, acidified mix is pumped to storage tanks where it is mixed by pumping for several hours each day until liquid.

(vi) Transport

For a typical silage of 25-30% dry matter, transportation involves moving a product with 70-75% water, imposing costs disadvantages on silage compared with competing dry protein sources.

(vii) De-oiling

As a feed component for domestic mammals, especially for pigs, an oil level above 3.5% leads to tainting of final products. High-oil silages, especially from Orange Roughy, must be de-oiled, a process which can range in complexity from skimming off the oil layer, to passing the entire silage through decanters with desludgers.

3.2 Production costs

Prime determinants in calculating costs of ensiling include:

- Cost of raw material
- Volumes of raw material available for ensiling
- Labour costs
- Acidulant
- Capital investment
- Prices for competing protein sources

Typical production costs, not including labour, are listed in Table 3.1.

Table 3.1: Production costs for the ensiling process

Item	Quantity (amount/t LFP)	Cost ($/t LFP)
Operating expenses		
Energy	8kWh	2
Water		0.5
Acid	3.5% (w/w) formic	63
Labour		56
Equipment		7.4
Vehicle		26
	Operating cost/t	155
Overheads		23
	Total cost/t	178

The costing ascribes no cost to fish waste. While reflecting the current position, this is a tenuous assumption since, once a waste is no longer dumped but used as a raw material, it takes on a value. If even a minor value of $0.05/kg were ascribed to waste fish, the costs of production increase by $50/t ($250/t protein). The role of competing protein sources in influencing price of silage is important. A large-scale ensiling business would need access to consistently large volumes of raw material, a market position which may drive up its price.

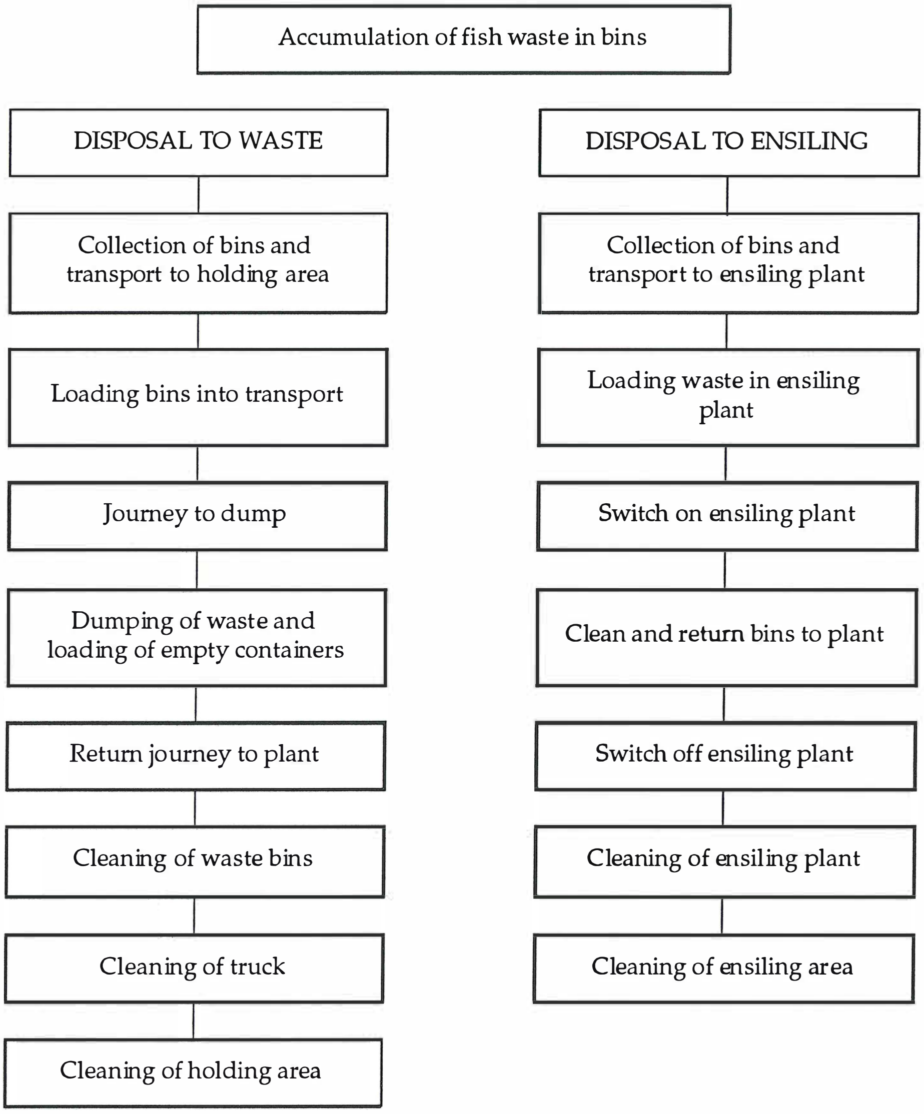
3.2.1Acidification

Acidification is by far the major contributor to production costs. At $1.80/kg, formic acid accounts for almost 40% of production costs. Inorganic acids such as sulphuric are cheaper ($0.55/kg) than formic acid but require additional cost of neutralising, after which shelf-life is only 2 days. An alternate fermentation drive is available via molasses ($0.32/kg) with lactic acid being generated by bacteria present either endogenously in the raw material, or added as starter cultures.

3.2.2 Labour costs

Costs of labour in silage production will vary considerably depending on the specifics of the operation. For example, in a stand-alone ensiling operation analogous to a fishmeal operation, all the costs of labour are directly attributable to the operation and costs/t of product are significant. Substantial savings arise when the ensiling operation is added to an existing process. Now, some existing operations are modified or exchanged for new operations specific to the ensiling process. The unit operations involved in handling fish processing waste are listed in Fig 3.1, both for conventional disposal and via an ensiling plant.

Fig 3.1: Unit operations involved in ensiling processing waste



As can be seen from Fig 3.1, many of the unit operations of disposal of waste to a dump or to an ensiling plant are equivalent and involve actual removal of the waste from the processing hall, together with cleaning of containers and work areas. In the case of dumping, however, there are additional time inputs required for the journey to and from the dump which probably exceed those involved in running the ensiling operation. Transport and dumping fees increase the cost of disposal of wastes to a dump.

Thus, from the outset, there are sound economic pluses for ensiling, as opposed to dumping. Certain costs may be affected by a change from dumping processing waste to ensiling it:

(i) Labour costs may be reduced by ensiling waste, rather than taking it to a dump.
(ii) Disposal fees are eliminated.
(iii) Costs of running a transport vehicle are reduced.

In some operations, therefore, substantial reductions in operational costs may be achieved.

3.2.3 Are there economies of scale in silage production?

Calculations have been made for a stand-alone ensiling plant manufacturing 1000t LFP/annum with a 19% protein content. In a 10-year model for this plant, parameters and annual costs have been established as shown in Table 3.2 (see Appendix 1 for full details).

Table 3.2: Costs ($) associated with a stand-alone LFP plant

Annual sales	199500
Operating costs	152300
Fixed costs	25500
Depreciation	7520
Price of protein	1050

Using the parameters presented in Table 3.2, a gross margin (gross sales minus operating costs) of $47200 and annual operating surplus (gross margin minus fixed costs) of $21700 are obtained. For a capital outlay of $75200 a first-year loss of $61020 is incurred, compared with an annual surplus of $21700 in subsequent years. Cumulative cash flow is presented in Table 3.3.

Table 3.3: Cumulative cash flow for stand-alone silage plant

	Year									
	1	2	3	4	5	6	7	8	9	10
Cumulative cash flow ($)	-61020	-39320	-17620	4080	25780	47480	69180	90880	112580	134280

The present study has identified a scale of waste in Melbourne, Hobart, Adelaide and Port Lincoln which could support the operation of a stand-alone ensiling plant capable of manufacturing 1000t of silage per annum. Assuming the operation is fully equipped as a stand-alone operation, prospects for profitability (indicated by an IRR of 35%) are good only if silage is sold at a price equivalent to $1050/t of protein.

Sensitivity analysis

Major variables affecting viability of LFP manufacture include:

° Revenue items	° Cost items
Protein price	Acidulant price
Volume of raw material	Labour costs

Viability of LFP manufacture has been tested (Table 3.4) in a sensitivity analysis in which the IRR was determined for a range of values for each of the major variables (above).

Table 3.4: Sensitivity analysis for LFP manufacture

Revenue factors		Protein price	
		$/t	IRR (%)
	Retail	1050	35
	Wholesale	800	(-)
		Volume of raw material	
		t/annum	IRR (%)
		1000	(-)
		1500	25
		2000	43
Cost factors		Acidulant	
		$/t	IRR (%)
	Formic acid	1800	(-)
	Molasses/sulphuric	1408	(-)
	Molasses	315	45
		Labour	
			IRR (%)
	Stand-alone*		(-)
	Integrated*		34

* 1000t/annum at $800/t

Protein price

Prices of protein vary widely, from $750/t to $1400/t, on location, depending on use and world commodity prices for competing protein sources. Towards the upper end of the protein price scale was protein for pig feed formulations, based on a high lysine content. In the present study, the IRR was calculated for protein sources at $800/t and $1050/t. At a price for LFP of $1050/t protein, the stand-alone venture was found to be viable (IRR 35%) whereas at $800/t protein the IRR was negative.

Volume of raw material

Using worst-case scenarios (LFP production 1000t/annum at $800/t protein) a stand-alone LFP plant was not viable. Profitability resulted from increased throughputs: 1500t (IRR 25%) and 2000t (IRR 43%).

Acidulant

Using worst-case scenarios (formic acid acidulant and product valued at $800/t protein), the IRR was negative and a stand-alone LFP plant was not viable. While using molasses resulted in an IRR of 45%, acidification based on a fermentation drive requires higher temperatures (>20°C, limiting the operation in season or location) and technical know-how.

Labour

The effects of labour, complicated by their relationship with other costs, are difficult to evaluate. For example, labour savings for LFP production at the Melbourne Wholesale Market also bring about savings in waste collection and motor vehicle costs. Similarly, output per unit of labour is difficult to estimate because of the lack of data. While in major centres, stand-alone LFP production is viable, other locations lack the volumes for a viable stand-alone facility. As well, other cost assumptions in the economic model are not applicable. Encouragingly, the effect of these differences often reduces operating and fixed costs e.g. labour costs and the ability to spread forklift and transport costs, thereby increasing profitability.

Thus, incorporating LFP production as an add-on to the existing operation:

- Reduces the impact of overheads.
- Allows use of existing facilities e.g. trucks, forklifts, scales.
- Allows redeployment of staff to ensiling rather than to waste disposal.
- Provides scope for discounting a managerial increment.

Exemplifying the Melbourne Wholesale Market as an add-on operation, savings of $50,000/ annum are achieved via labour and vehicle costs associated with waste collection (Table 3.5).

Table 3.5: Cost comparison stand-alone versus add-on LFP manufacture at 1000t/annum

	Stand-alone plant	Add-on plant
Sales revenue ($800/t)	152,000	152,000
Costs ($)		
Variable	152,3000	112,400
Gross margin	-300	39,600
Fixed	-25,500	15,500
Annual operating surplus	-25,800	+24,100
IRR	Negative	24%

* Formic acid used as acidulant

Although an ensiling operation of 1000t/annum can be made profitable by offsetting certain costs against other activities, the volume of profit ($24,100/annum) is insufficient to make the business attractive as a stand-alone venture i.e. despite a satisfactory IRR.

By contrast, an add-on LFP operation can be made profitable (Table 3.5). Domiciling LFP production under an existing roof incurs no additional rents, rates, insurances, collection and forklift costs and managerial increment resulting in cost savings around $50,000/annum and transforming the operation from loss to a profit after depreciation of $16580/annum.

Disposal of intractable wastes e.g. prawn waste in Port Lincoln and scallop waste in Victoria, incurs considerable cost. Ensiling these wastes would not only eliminate disposal costs but would substantially increase the volume of raw material available for LFP. As well, intrusions by EPA would be reduced which, of itself, may have appeal.

Since each location differs widely in specifics, only a generalised economic analysis is possible. However, a reading of Appendix 1 will serve to illustrate how the economics of a specific location may be analysed.

3.3 Are there economies of scale in the ensiling operation?

Substantial economies of scale exist for silage production. For a 500t/annum operation, ensiling is not viable as a stand-alone operation. However, for volumes of 1000-2000t/annum the operation was economically viable. Although the cost of many variables remained in fixed proportion with raw material throughput (e.g. acid and energy use), significant economies of scale were also achieved with increasing quantities of raw material, by the more effective spread of overheads and the more efficient use of labour (daily costs for running a pump or cleaning equipment are identical irrespective of throughput). These effects are reflected in increased IRRs with increased throughput (Table 3.4) and an attractive profit margin.

3.4 Using trash fish to increase the supply of raw material

Once an ensiling operation becomes established it is possible that additional raw materials could be sourced from trash fish currently dumped overboard during sorting. The crew already carry out almost all of the unit operations needed for sorting and storing trash fish. Additional handling will be required of the crew for trash fish landed during the last shots. Processing of trash fish imposes significant handling costs onshore. For example, 3t of trash fish will involve 100 boxes loaded with fish either stored in chilled sea water or bulk-stored in the hold.

If trash fish were valued at $0.05-0.10/kg, production costs are increased by $50-100/t. On the other hand, depreciation costs/t, while decreased by increased throughput, will not be decreased sufficiently to justify the incentive payment.

At first sight landing of trash fish for ensiling at 5-10c/kg will probably seem unattractive, given the arduous nature of current work practices of a 3-man crew (skipper and two deckhands). It is a moot point whether, over a total of 40 trips/annum and total landing of 120t of trash fish, the additional $12,000 split between owner, skipper and crew would prove sufficient incentive for the additional work. A price of $0.20-0.30/kg prevails for supply of pilchards for petfood; LFP manufacture is rendered non-viable by this cost.

4 Fish silage in aquaculture

The current survey of fish wastes in South Australia, Tasmania and Victoria indicates the existence of significant quantities and varieties of finfish and crustacean wastes in each state. An interesting corollary of increased demand for live exports of lobster and crab to Asia is reduced volumes of waste from these sources. The survey has identified two opportunities where significant volumes of wastes exist in close proximity to significant aquaculture demand for protein and other additives and/or the need to replace existing feeding practices with a range of less wasteful and more cost effective practices.

In South Australia in close proximity to the tuna aquaculture in Port Lincoln, processing wastes exist from both finfish and prawn processing. In Tasmania large volumes of wastes (5000-6000 t/annum) exist near salmon farms in the south of the State.

Both the tuna and salmon farming industries are substantial and are dependent on either high-cost feed inputs (salmon) or use low-cost, ineffficient inputs (tuna). Both industries are well aware of their exposure to these cost pressures and have R & D programs exploring options for improved costs and feed conversion ratios.

4.1 Uptake of feeds based on fish waste by the salmon and tuna industries

Fish silage represents a good, local supply of protein for both industries and may be adopted if one of the following aspects obtains:

- An economic advantage over an exisitng feed component.
- Increased feed conversion ratio.
- Some indirect benefit e.g. more environmentally acceptable effluent disposal.

Fish silage has potential as a protein component, flesh colourant and as a feed attractant. The extent of this potential will be evaluated for each opportunity.

4.1.1 Flesh colourant

In both salmon and tuna industries market demand inlcudes a deep red flesh colour. Failure to produce flesh of the appropriate colour results in price penalties, while optimum colour generates premium prices. Pigrnents responsible for red flesh colour are the carotenoids, astaxanthin and canthaxanthin. In the wild, carotenoids are obtained from dietary sources such as algae and crustacea (prawns and krill). It is also found other invertebrates and small fish which comprise the diet of tuna and salmonids, etc.

Neither tuna nor salmonids can synthesize carotenoids and diets for farmed fish require supplementation with an artificial source of either astaxanthin and canthaxanthin. While fish meal components of fish diets might be expected to contain some carotenoid pigments, these are substantially deactivated during the thermal process as are the carotenoid pigments in dried crustacean wastes.

Carotenoid pigments used in formulated fish diets, while included only in small concentration of the order of 50mg/kg, account for around 10 % ofthe total feed cost. Their replacement with a cheaper, locally produced alternative has obvious attractions.

A literature search was conducted to investigate the dietary carotenoid requirements of both tuna and salmonids and to establish the effect of acidification on the extraction and stability of astaxanthin and canthaxanthin in source material such as prawn wastes.

Dietary carotenoid requirements for trout are well established, (Storebakken and No, 19902 and Putnam (1991) putting requirements for trout at 40-60 mg/kg, and for salmon at 60-80 mg/kg. Dietary requirement for carotenoids in Coho salmon (*Oncorhynchus kisutch*), Smith *et al.* (1992) and crustacea (*Penaeus japonicus*), Negri-Sardagues *et al.* (1992) were of a similar order. No report in the literature was found for dietary requirements for farmed tuna.

Of the two common carotenoids (astaxanthin and canthaxanthin) the former is preferred, because of its higher absorption and retention in flesh. In crustacea, astaxanthin was found to be accumulated in the hepato-pancreas and epidermis, in contrast to canthaxanthin which was stored in neither of these locations. In trout, Storebakken and No (1992) found that free astaxanthin was more efficiently incorporated than canthaxanthin and resulted in deeper flesh colour. However canthaxanthin is more soluble and easily extracted than astaxanthin and its conversion to a stable, dry powder facilitates its incorporation in dry feed formulations.

Ensiled prawn wastes have been shown to be a source of astaxanthins. Torrissen *et al.* (1981) indicated that ensiling increased the yield of astaxanthin from shrimp waste by the acid dissolution of the shell. As well, when shrimp waste was fed to trout (*Salmo gairdneri*), utilisation of astaxanthin was higher when fed as silage than as either fresh or dried prawn waste. The levels of astaxanthin which can be extracted from shrimp waste are sufficient to satisfy dietary needs of salmon and trout formulations without further refining or concentration. Acid extraction improves the digestibility of astaxanthin from 45 to 71%, near the levels recorded for the more expensive methods of oil based extraction.

In its liquid form, fish silage is suited to incorporation into moist and dry feeds as a source of pigmentation for either salmonids or tuna. Guillou *et al.* (1995) used shrimp waste silage as a source of astaxanthin at 10 mg/kg in trout formulation. Concentration of astaxanthin in silage can be achieved by dewatering before acidification and by centrifugation of the silage. These methods are already in use in the Louisiana crawfish industry, where astaxanthin is extracted from processing wastes, and concentrated and exported to Japan for use in the diets of sea bream culture (Meyers *et al.* 1990).

The foregoing suggests that ensiling of prawn wastes may result in a flesh colourant which is more effective and cost-competitive flesh colourant than those currently available. If the astaxanthin content of ensiled prawn waste is assumed to yield 35.8 mg/kg (Guillou, 1995), the 1000t of prawn wastes in South Australia could be ensiled to satisfy the carotenoid requirement for 4000-5000 t of dry formulation. If the increased astaxanthin activity observed by Guillon, associated with milder acid extraction methods, is applicable then the mass of astaxanthin extractable from South Australian prawn wastes would be sufficient to serve as colourant for 10,000-12,500t of feed. Given the proximity of prawn wastes in South Australia to the tuna industry and the capacity to further concentrate ensiled astaxanthin, this process should be explored further.

4.1.2 Feed attractant

While the efficacy of various chemo-attractants in inciting fish to feed remains a subject of discussion and opinion, the aim is simply to increase consumption of feedstuff presented to livestock, thereby minimizing the quantity of feed ingested/wasted as a factor of weight gained. Feed attractants may also be used to increase consumption of nutritious but unpalatable or otherwise unattractive feeds which may, from time-to-time become locally available at a favourable cost.

In the context of tuna farming, there are difficulties in weaning tuna from one feed to another even where both feeds are a normal part of the tuna diet. In tuna pens at Port Lincoln, substantial weight loss has been demonstrated when diet is changed from pilchards to mackerel. The problem is exacerbated because tuna prefer soft or semi-soft diets to hard pellets which are used in the farming of other species (eg Salmon in Tasmania), inspiring current research into feed supplied as semi-soft sausages. Enclosing feed components in a casing provides better control of pigmentation, vitamin supplementation, protein levels and costs. It is possible that weight loss during weaning could be reduced if a palatable supplement with attractant properties could be added to the existing diets during the change-over period.

4.1.3 Attractant properties of silage

The silage process depends on acid autolysis of fish protein into peptides and free amino acids and the latter have been shown to be as a successful method of inciting feeding in several species, including salmon and trout (Mackie and Mitchell, 1985; Meyers, 1987; Mearns, I990; Ward, 1991), attractant properties being attributed to a small number of amino acids, glycine-betaine, inosine and inosine-mono-phosphate.

Stone *et al.* (1989), comparing the digestibility of fish silage with that of diets based on fish meal, found that the ensiling process nearly doubled the proportion of free amino acids in the ration, which is consistent with the attractant properties cited in the literature above.

While there are no data on the efficacy of silage as a fish attractant in Australia it was found to be attractive to chinook salmon in a trial in NSW. It would be relatively simple to investigate the attractant properties of silage used in conjunction with existing diets for both tuna and salmonids.

4.1.4 Reaction of the feedmillers for the salmonid industry in Tasmania

In Tasmania, feedmillers were reticent to use liquid fish protein in aquaculture diets for a wide range of reasons:

(i) **Lack of equipment for making semi-moist pellets**
Steam pelleting is currently used for manufacture of all dry feeds. Manufacturers are not set up for wet or semi-moist formulations.

(ii) **Stability of semi-moist pellets**
The keeping quality of semi-moist pellets is seen as inferior to that of dry pellets, with attendant fears of rancidity being passed on to the product.

(iii) **Phosphate levels in diets**
There is a general trend towards reducing phosphate levels in diets and the use of finfish processing waste with a high frame: flesh ratio would exacerbate phosphate levels.

(iv) Digestibility and pond waste
Current sources of flesh colourant is astaxanthin, either as the synthetic (from Roche Products) or as a yeast metabolite. Both sources cost around $3750/kg and a major feedmiller purchases around $3.5m/annum. The use of crustacean waste as a source of astaxanthin has negative features in aquaculture, according to feedmillers who consider the waste has low energy and, because it is largely undigested, results in increased pond waste.
In mitigation it should be stated that mild extraction methods reduce the percentage of undigested material.

(v) Reliability of supply
Feedmillers consider a LFP-based formulation has negatives in reliability and consistency of supply. If a consistent source of whole fish were to become available it is more likely that waste would pass via reduction operations in Hobart or Triabunna.
It is doubtful, however, that reduction of the 5-6,000t/annum of fish waste currently generated in and around Hobart would be profitable. Ensiling, by contrast, would be profitable at this volume.

(vi) Attractants
Fish meal solubles are considered satisfactory attractants.

(vii) Costs of transport
Higher transport costs for LFP compared with dry components is cited as a disincentive. While this proposition is true on a per tonne of protein basis, it discounts costs of transport of fish meal from, say, South America.
The matter of transport is considered in more detail in a later section.

(viii) Disease

As a general rule the use of salmonid wastes for salmonid feed is considered extremely undesirable because of the possibility of transfer of disease-causing microorganisms from feed to fish. This stance has achieved importance with the possibility of of Canadian salmon entering Australia.

The stance that bacterial and viral diseases may be transmitted by LFP acting as a vector must be seen in the light of the Norwegian salmon farming industry which uses LFP from fish waste and trash fish as both protein source and as feed attractant. In 1995, over 100,000t of LFP are used in Norway in semi-moist and dry salmon feeds (Strom, personal communication).

A view propounded by the Tasmanian Fish Health Unit is that pathogenic bacteria and viruses are part of the normal gut microflora of farmed salmon. These organisms become pathogenic in times of stress.

It is clear that feedmillers have no stimulus to alter their practices. However, there is a consistent supply of finfish and crustacean waste in southern Tasmania which could be converted to LFP in a manner similar to that done in Norway.

The over-riding fear of disease transmission may be obviated by further work on survival of fish pathogens in the ensiling process.

5 Regional possibilities for utilisation of fish silage

5.1 Lakes' Entrance

Lakes' Entrance is located in an agricultural/grazing district with a number of ruminant animal industries:

- Dairying based on irrigated pasture around Maffra.
  As well as milk production the industry includes contract growout of replacement females and raising of dairy beef, in which crossbred cattle are reared for beef production in conjunction with the dairy farm.
- Beef production.
  High-country areas to the north of Lakes' Entrance are an important source of weaner calves and store steers which are ongrown and fattened in Gippsland (particularly South Gippsland) for market.

Because of low rainfall and a short growing season, the immediate area of Lakes' Entrance has no significant monogastric animal industries, although some on-farm piggeries exist which serve as niche markets for the silage. There is no finfish aquaculture industry in the region.

Two feed millers in Maffra service the dairy industry. Both store, crush and process grain and grain derivatives, and are well placed to handle and market fish silage.

Two opportunities for silage exist in the region:

- As a protein supplement for contract growout of replacement heifers for the dairying.
- Supplementary feed for the fattening of steers.

Growout of replacement dairy heifers

The growout of dairy heifers as replacement of cast for age milking cows is increasingly being done by contractors. This has a number of benefits by:

(i) Removing these replacements from the farm, allowing additional productive milking cows to be run, thereby increasing the farm productivity.

(ii) Saving dairy farmers the time and trouble looking after another group of stock, which requires specialised management.

(iii) Optimising the growth rate and size of heifers at their first mating, thereby increasing fertility and their milk production over subsequent lactations.

The Victorian Dept of Agriculture estimates that this results in increased yield of 25 L of milk/ kg pre-calving body weight, over a period of three years. If pre-calving body weight increases from 200 to 280 kg, this translates into an increase in milk production of 2000-2500L over three years.

This may be achieved by approximately 80 kg of crude protein as LFP, costing $80 (assuming a cost for protein of $1000/t), resulting in a marginal return of $1200 based on an increase of 2000L at $0.60L). If the price for protein is reduced e.g. by using molasses in the ensiling process, the returns will be increased.

This practice is cost effective for dairy farmers, and is likely to expand, particularly as the cost of irrigation water increases and the availability of irrigated pasture in the area becomes increasingly limited.

Animal proteins are better suited to calf nutrition than are plant protein sources because the rumen does not operate efficiently at this age and a diet of protein that approximates to the calf protein is better utilized.

In the context of ruminant nutrition, protein can be classified into Rumen Degradable Protein (RDP) and Undegradable Protein (UDP) of rumen protected protein. In heifer diets higher percentage of protected protein results in more complete digestion in the abomasum, rather than in the rumen where de-amination and microbial protein synthesis occur. Thus, meat and fish-derived meals give better growth rates than plant protein supplements, placing LFP in the more preferred protein source for calf nutrition. An additional benefit over fish meal may be expected because of the liquid consistency of LFP resulting in reduced passage time through the calf rumen and consequent reduced microbial digestion. LFP may also be used as a supplement for milk-fed calves, increasing the efficiency of protein digestion because of the operation of the calf oesophageal groove allowing liquids to bypass the rumen digestion.

Based on the foregoing, LFP could become the protein of choice for the growout of heifers.

Other uses include the production of a mash for the early growout of weaned heifer calves. This mash is comprised mainly of a mix of crushed grains and a meat meal protein supplement bound by molasses (1-2%). This mash contains 20% crude protein and retails to farmers at $15/40 kg bag ($3125/t protein). The wholesale price of protein (i.e. the price to the feedmiller) is circa $810/t bagged.

5.2 Geelong

Around 150t/annum of finfish wastes are generated in the Geelong region but are dispersed throughout the city and surrounding district. Currently, most of the wastes are discarded and, with the exception of orange roughy waste when available, these volumes are too small to interest commercial waste collection services. Edible scallop wastes around 350t/annum are generated but are currently not used because no straightforward method exists for separating them from the shell. If scallop viscera were available, the quantities of wastes would rise to around 500t, a level which would be viable and cost competitive as an add-on operation. Both finfish and scallop wastes are disposed at local tips in the Geelong region at a fee of $20/ cubic metre ($25-35/t waste).

5.2.1 Scallop wastes

Scallop waste in plants near Melbourne and Geelong present a seemingly intractable problem with 3000-5000t/annum being discarded, of which an estimated 1300t are capable of being converted to LFP. In Victoria, scallops are shucked manually. The viscera are discarded with the shell, presenting a problem in terms of mass and of putrescence, the latter with attendant odour, flies and the potential to contaminate ground water on burial. The shell, although a source of calcium carbonate, is not able to be used because of contamination with organic matter from viscera. In its present form it is not of any interest to the recycling industry. Scallop waste disposal also exists in Queensland and West Australia, where roe-off scallops are produced.

In the USA, where scallops are shucked mechanically, viscera and roe are collected and separated from the edible meat. If separation were achievable in Australia it is likely that both shell and viscera could be utilised, the former as a source of calcium carbonate and the latter for LFP. Trials in the USA indicate that scallop viscera are also readily ensiled.

Industry sources in Victoria put disposal costs at $0.20-45/kg of scallop waste, equivalent to as much as 20% of processing profit and in excess of the variable costs of producing LFP ($112-150/t). The addition of more than 1000t/annum of scallop viscera to a Victorian ensiling operation would significantly improve profitability.

5.2.2 Separation of scallop viscera from shell

Two methods have been developed:

- Hydraulic - washing shells coupled with either a mechanical agitation or stream flow.
- Hydraulic suction in which suction is applied to shell/viscera as each shell passes over a conveyor.

The effectiveness of these separation methods is not known, nor is their cost. It is of obvious commercial interest to explore separation methods for scallop viscera and shells.

5.3 Eildon

Eildon is the centre for the Victorian trout industry, which produces 700-1300 t/annum of whole trout and a local waste volume of 100 t/annum. Fish wastes represent a problem similar to that in the Geelong region, in that farms produce small quantities of wastes and are geographically dispersed. Previous inquiries by the industry to waste collection companies indicated that collection is more costly than disposal at the tip. Currently, much of the waste is buried at the trout farms. It seems likely that the only suitable means is to operate small silage systems on each farm. This could still have commercial appeal as research findings indicate that silage can be fed to trout.

The trout farms are located in a high rainfall area of cool to cold climate which slows the autolysis of fish protein, particularly if it is produced by molasses fermentation. The area is surrounded by grazing, with prominent cattle and fat lamb industries that could also find LFP attractive, particularly over summer, when pasture protein deficiencies occur.

5.4 Port Lincoln and Adelaide

The current source of feed for farmed tuna is pilchards and mackerel costing around $0.70-0.90 /kg wet weight. The protein content of pilchards is 65% (DM) and at a dry matter content of 30% translates to $3,590-4,615/t protein at the tuna farm. With a reported apparent conversion ratio of 16-20:1, a feed cost of $57-74/kg of tuna produced results.

A nutrition profile for pilchards and alternate feeds is presented in Table 5.1.

If the cost of pelletised feed can be justified, as it would be if conversion ratios were improved, there is almost certainly a place for fish silage as a component in the manufacture of semi-moist feeds for the tuna farming industry. The low cost of production coupled with the tuna's preference for a semi-moist feed, suggests that silage can be effectively incorporated in a "sausage" as a primary source of protein.

Table 5.1: Composition of fish sausage

	Percentage fresh weight		
	Acid silage	Pellet #1	Silage sausage
Dry matter	28.7	64.3	37.6
Crude protein	16.4	40.0	23.4
Fat	5.4	17.0	9.7
Ash	3.0	7.3	4.5
Water	71.3	35.7	62.4

Incorporation of silage is also appropriate because:

- The pH of silage allows pre-mixing of the sausage, despite its high moisture content and storage of pre-mixed feeds at ambient temperature without deterioration. In turn, larger, more economic production runs are possible and feed could be stored aboard the feeding vessel.

- LFP could also be used to pack the sausages thereby preserving the external moisture of the sausage and preventing dehydration and deterioration of the sausage skins. This external covering of the sausages would also act as a feed attractant, particularly if the silage has a high oil content. Alternatively, oil skimmed from the silage during acidification could be incorporated at higher concentrations in the LFP used in the external packing.

- Flesh colourants, which are acid stable, could also be added in advance rather than sprinkling them on the surface as is the current practice. Flesh colourants are a very expensive component of fish feeds and are absent from the existing diet of pilchards and mackerel, because of expense and difficulty in adding them in accurate quantities when pilchard feeding is so imprecise and their conversion efficiency is so poor.

- The LFP would also act as a binder for other ingredients.

- Additives such as flesh colourants, minerals and antibiotics and growth promotants could be accurately blended.

The composition of a silage (or LFP) based fish sausage would probably include additional fish meal, other protein concentrate, crushed lupins or other grains, fat, or fish oil, flesh colourant.

5.5 Tasmania

5.5.1 LFP in salmon diets

Tasmania is in the unique position of having large quantities of fish waste which currently have low value uses e.g. as fertiliser in close proximity to a significant aquaculture industry. At present almost all of the significant quantities of fish processing waste are composted and used as pasture and garden fertiliser. The largest operation is facing increasing environmental pressure because of the presence of habitation close to the composting site, and the fact that some materials are lost, either by leaching or by wind. It is probable, therefore, that alternate outlets will be required for disposal of Tasmanian wastes, at least in the south of the State.

The possibility of using silage made from salmonid waste as a component in feed for salmonids is rejected by the major feed millers primarily because of a fear of disease-transmission.

Less intransigent views have been expressed by regulatory bodies in Tasmania. The Department of Primary of Industry and Fisheries, while espousing the generally-held opinion that feeding processing waste to the same species is not desirable, confirmed that this practice is common in similar fisheries in other countries. Treatments are available for killing potential pathogens e.g. heat. As well, it is commonplace to use LFP-based feeds for Norwegian salmonids, a practice which must have been thoroughly researched and evaluated before implementation.

The Tasmanian Fish Health Unit underline the importance of stress as a precursor to disease from pathogenic viruses and bacteria which are present in the natural microflora of the gut of both farmed salmonids and native species. At present, frozen trash fish are used for feed for farmed yellowfin tuna, a practice which has been associated with outbreaks of disease. A major drawback in the use of trash fish for aquaculture feed is lack of control over storage, leading to high bacterial numbers in the feed.

5.5.2 LFP in diets of other species

Research into a number of species is well advanced, particularly into Stripey Trumpeter and Greenback flounder. The former is a white-fleshed pelagic with cultivation requirements compatible with those of Atlantic Salmon, with the exception of a carotene component in the diet. Greenback flounder is a demersal, better suited to intertidal water than the deeper water salmon farms. LFP may be acceptable as a component for flounder feed.

Larger plants in Norway produce an LFP concentrate with dry matter 42-45% for use specifically in manufacture of dry pellets. Inclusion rates have risen from 5% to 10%, with an expected increase to 20%. It is stated that LFP improves the handling characteristics of the feed by reducing dust. It also improves the attractant properties and has improved digestion, particularly in winter.

6 A value for silage

There are solid markets for LFP in Europe as pig feed, and in Asia, Europe and the USA as aquaculture feed. In Australia, no similar markets exist. Feed formulations typically contain nitrogen meals derived from fish, meat or from vegetables (soy). The entire feeding system is based on dry-blending and pelleting.

The effectiveness of silage in pig and poultry feed has been evaluated in a number of growth-rate trials in Australia and successful ruminant trials have also been conducted in Denmark and America. More recently silage based on fish frames and by-products have been trialled for Atlantic salmon in Norway, France and for flounder and turbot in the UK. While the process is now fully commercialised for aquaculture in these and other countries it is not yet part of finfish diets in Australian aquaculture.

6.1 Experimental work in Australia

In the mid-1980s a series of trials in Victoria established the effectiveness of LFP for pig, poultry and fish feeds. For a Master of Science degree, Brown (1985) evaluated LFP made from local mixed species:

LFP in pig formulations

In a trial carried out at the Melbourne University pig farm, Large White pigs raised from 20 to 50kg liveweight grew faster and more efficiently on LFP-based diets than on control diets including soybean meal. The cost of feeding was up to $0.08 cheaper per kg of liveweight gain on LFP-based feed than on control feeds (Brown *et al.* 1984).

LFP in poultry formulations

In a trial carried out at the Animal Research Institute, Victorian Department of Agriculture and Rural Affairs, Werribee, diets incorporating LFP were found to be equivalent to control diets incorporating soybean and/or fish meal (Johnson *et al.* 1985).

LFP in aquaculture formulations

In a trial carried out at the Snob's Creek hatchery, Chinook salmon grew similarly on LFP-based and control meals (Brown, 1985).

6.2 Current status of LFP as stockfeed

Despite the positive evaluations described above, LFP has not been incorporated into stockfeed in Australia. The most likely reason involves the geographical separation of LFP-production facilities (coastal) from feedmilling facilities (grainbelts or cities) and major intensive farming locations (grainbelts). Ideally, a LFP operation should be closely integrated with local fish processing and nearby aquaculture operations.

6.3 A value for LFP as stockfeed-comparison with other protein components

For silage to gain acceptability and use as a stockfeed, manufacture must be profitable for the manufacturer and the stockfeed must be price-competitive compared with other nitrogen and energy sources.

While comparisons between various feed supplements e.g. meatmeal, fishmeal, skim milk powder are possible on the bases of nitrogen, energy, lysine and other criteria, there are additional costs stemming from differences in feeding method, labour etc.

As a generalisation, LFP valued around $100/t is competitive with other feeding meals. Specifically, with fish meal of 66% protein at $680/t, a LFP of 17% protein would have a value of $174/t.

6.4 Oil from LFP

While most industrial species processed at the wholesale market are low in oil (<5%), Orange Roughy, can have a significant oil component. For reasons both desirable and necessary, this oil must be removed:

(i) Orange Roughy oil contains a laxative which affects both stockfeed and humans.
(ii) Oil has a value which varies according to its end-use.

Although previously a highly valued commodity for cosmetics and lubricants, Orange Roughy oil has declined in value to the extent that it is being used as diesel fuel replacer with a value around $0.30/L. It should be noted that CSIRO have undertaken considerable research into oils from orange roughy and have some optimism that their use can be increased.

Despite its low current value it is essential that Orange Roughy be processed separately from other raw materials and the oil removed. De-oiled LFP from orange roughy may then be combined with that of low-oil species.

7 Transportation of LFP

The high cost of transporting protein as LFP is often cited as a reason for not using it for Livestock and aquaculture feedstuff in Australia. Paradoxically, frozen pilchards are transported from South America, Russia and Japan to South Australian as feed for tuna farms, a conversion ratio of 16:1 notwithstanding. Transporting LFP in 200 or 1000L containers from Hobart to Port Lincoln would seem to be cost-effective alternative, given the much better utilisation and attractant properties of LFP. Significantly, limited feedmilling facilities in the Port Lincoln area implies that feeds for tuna farms will require milling elsewhere, with attendant transport costs. Critically, if LFP were manufactured as sausages and prevented weightloss when weaning tuna onto new rations, the cost of transport would become insignificant.

If rations based on vegetable or grain proteins are developed for tuna feed, the absence of fish meal and/or fish will accentuate the requirement for attractants to ensure palatability. LFPbased feeds would be ideal for this purpose and the cost of transport would need to be considered as a cost of the overall ration rather than merely as a cost of the protein component. A similar rationale already exists in justifying the cost of carotenoids in salmonid rations. In the case of LFP produced from prawn waste in South Australia, the value of carotenoids also serve to offset transport costs.

7.1 Transport costs

The following model has been developed for transport of LFP in 20t loads is summarised in Table 7.1.

Table 7.1: Cost of LFP transport

Trip length (km)	Cost ($/t km)	Cost ($/t LFP)
Up to 100	15-18	100
250	25-33	125-165
Sea (Hobart-Melbourne)		60-100

For short trips (e.g. Lakes' Entrance to Maffra) transport adds $15-18/t LFP or around $100/t of protein.

For journeys around 250km e.g. Melbourne-Riverina, costs will add $25-33/t LFP or $125-165/t protein).

The cost of liquid transport by sea from Hobart to Melbourne is of the order of $60-100/t LFP.

Only if the costs of LFP production are sufficiently low and/or prices for the product are high can the costs of transport be absorbed so that the product can still compete on the wholesale protein market.

The economic model shows that the cost of production falls substantially with increasing volumes over 2000t (Appendix 1). In Tasmania, where the volumes of fish waste are high, the opportunity exists for production savings which can accommodate transport to other centres e.g. livestock centres in Victoria and southern NSW.

By contrast, transport from Tasmania to Port Lincoln is not profitable if formic acid is the acidulant, even if the product is valued at $1400/t protein. As illustrated in Table 7.2, the product can be landed in Port Lincoln at profit if cheaper acidulants are used and a price is obtained of $1400/t protein, justifiable if seen against a current background of poor feed conversion ratios.

Table 7.2: Cost of transport from Hobart to Port Lincoln

	Formic acid	Molasses/sulphuric
Sales ($/t LFP)	286	286
Variable costs ($/t LFP)		
Labour	27.95	27.95
Vehicles etc	15.44	15.4
Rubbish dumper etc	13.1	13.1
Acidulant	63	14.08
Transport	140	140
Total variable costs	259.45	210.53
Gross margin/t	6.55	55.47
Fixed costs ($/t LFP)	16.05	16.05
Annual surplus ($/t LFP)	-9.5	39.42

In summary, while it is both technically and economically feasible to process LFP in Hobart and transport it to Port Lincoln, it is a high risk activity due to the skill base required for ensiling by fermentation. More economically viable is the use of LFP in Tasmanian livestock and aquaculture industries.

Transport to piggeries in the Riverina costs around $90/t and to Port Lincoln around $141/t LFP resulting in a positive gross margin for LFP produced both by acidification with formic acid and by fermentation (Table 7.3).

Table 7.3: Effect of acidification on profitability (annual surplus $/t*) of LFP transported from Tasmania to South Australia or southern NSW

	Formic acid	Molasses/sulphuric
Hobart-Port Lincoln	-9.50	39.42
Hobart-Riverina	40.50	89.42

* Annual surplus is the gross margin minus the annual fixed costs, excluding capital and depreciation

References

Brown, N., Sumner, J. and A. Dunkin (1984) Fish silage - can it be converted to profit, *Australian Fisheries* (Nov), 47-49.

Brown, N. P.L. (1985) Fish silage, production and utilisation. Thesis for the degree of Master of applied Science, Royal Melbourne Institute of Technology.

Guillou, A., Khalil, M. and L. Adambounou (1995) Effects of silage preservation on astaxanthin forms and fatty acid profiles of processed shrimp (*Pandalus borealis*). *Aquaculture* 130: 351-360.

Johnson, R.J., Brown, N., Eason, P. and J. Sumner (1985) The nutritional quality of two types of fish silage for broiler chickens. *Journal of the Food and Science of Agriculture* 36: 1051-1056.

Mackie, A.M. and A.I Mitchell (1985) Identification of gustatory feeding stimulants for fish - applications in aquaculture. International Symposium on feeding and nutrition in fish. Aberdeen (UK) July, 1984.

Mearns, K.J. (1989) The behavioural approach in identifying feeding stimulants for fish and its applications in aquaculture. Minisymposium on ethology in aquaculture. Trondheim Norway) Oct, 1989.

Meyers, S.P. (1987) Aquaculture feeds and chemoattractants. *INFOFISH Marketing Digest* No.. 1, 35-37.

Meyers, S.P., Chen, H.M., No, H.K. and K.S. Lee (1990) An integrated approach to recovery and utilisation of Louisiana crawfish processing wastes. International Conference on By-products. Anchorage (Alaska, USA) April, 1990.

Negre-Sardagues, G., Castillo, R., Petit, S., Gomez, R., Milicua, J.C.S. and G. Choubert (1992) Utilisation of synthetic carotenoids by the prawn *Penaeus japonicus* (Crustacea, Decapoda) reared under laboratory conditions. European Crustacean Conference, Paris (France), Sept. 1992.

Putnam, M.E. (1991) Animal health and the environment - pigments. In: Aquaculture and the environment. Ed: DePauw, N. and J. Joyce. Special publication by the European Aquaculture Society (No. 14).

Smith, B.E., Hardy, R.W. and D.J. Torrisen (1992) Synthetic astaxanthin deposition in pan-sized coho salmon (*Oncorhyncus kisutch*). *Aquaculture* 104(1-2): 105-119.

Stone, F.E., Hardy, R.W., Shearer, K.D. and T.M. Scott (1989) Utilisation of silage by rainbow trout. *Aquaculture* 76(1-2): 109-118.

Storebakken, T and H.K. No (1992) Pigmentation of rainbow trout. *Aquaculture* 100: 1-3.

Ward, N.E. (1991) Chemoattractants for trout and salmon. *Feed Management* 42(3): 6-12.

Torrisen, O., Tidman, E., Haansen, F. and J. Raa (1981) Ensiling in acid - a method to stabilise astaxanthin in shrimp processing by-products and to improve uptake of this pigment by rainbow trout (*Salmo gairdneri*). Aquaculture 6: 77-83.

APPENDIX 1: ECONOMIC ANALYSIS 1000 TONNES PER YEAR LFP STAND ALONE FACILITY (1000t/annum, 19% protein, $1050/t protein)

YEAR	1	2	3	4	5	6	7	8	9	10
Sales	199500	199500	199500	199500	199500	199500	199500	199500	199500	199500
COST OF PRODUCTION										
Labour										
Collection labour (3 hrs @ $15/hr, for 5 days a week*52 weeks)	11700	11700	11700	11700	11700	11700	11700	11700	11700	11700
Processing Labour (full time) ($500/week + 25% on-costs/per annum)	32500	32500	32500	32500	32500	32500	32500	32500	32500	32500
Part time (as for collection costs)	11700	11700	11700	11700	11700	11700	11700	11700	11700	11700
Acidulent (formic acid) $1800/tonne)	63000	63000	63000	63000	63000	63000	63000	63000	63000	63000
Protective clothing	200	200	200	200	200	200	200	200	200	200
Equipment leasing										
pallet truck ($400/month)	4800	4800	4800	4800	4800	4800	4800	4800	4800	4800
rubbish dumper ($200/month	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400
Vehicle operating expense (500 km/week @ $1.00/km)	26000	26000	26000	26000	26000	26000	26000	26000	26000	26000
OPERATING COSTS TOTAL	152300	152300	152300	152300	152300	152300	152300	152300	152300	152300
FIXED COSTS										
Manager's increment	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000
Phone/fax	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
Rates	400	400	400	400	400	400	400	400	400	400
Insurances	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
Site rent	9600	9600	9600	9600	9600	9600	9600	9600	9600	9600
water	500	500	500	500	500	500	500	500	500	500
power	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
accountancy/fees etc	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
FIXED COST TOTAL	25500	25500	25500	25500	25500	25500	25500	25500	25500	25500
DEPRECIATION	7520	7520	7520	7520	7520	7520	7520	7520	7520	7520
GROSS MARGIN (Gross Sales-Operating costs)	47200	47200	47200	47200	47200	47200	47200	47200	47200	47200
ANNUAL OPERATING SURPLUS (Gross Margin-Fixed Costs)	21700	21700	21700	21700	21700	21700	21700	21700	21700	21700
Annual Profit after Depreciation	14180	21700	21700	21700	21700	21700	21700	21700	21700	21700
CAPITAL EXPENDITURE	75200	0	0	0	0	0	0	0	0	0
TOTAL ANNUAL SURPLUS	-61020	21700	21700	21700	21700	21700	21700	21700	21700	21700
INTERNAL RATE OF RETURN ; 35%										
Cumulative Cash Flow	-61020	-39320	-17620	4080	25780	47480	69180	90880	112580	134280

IRR	PROTEIN PRICE	IRR (using 3.5% formic acid)
	$/TONNE	
RETAIL	1050	35%
WHOLESALE	800	(-)

ACIDULANT		ACIDULANT COST	IRR
	$/Tonne	$ Total	(PROTEIN PRICE OF $800/TONNE)
(1000 tonnes fish wastes)			
FORMIC ACID	1800	63000	(-)
MOLASSES/SULPHURIC	1408	49280	(-)
MOLASSES	315	11025	45%

VOLUME OF FISH	IRR
TONNES	(PROTEIN PRICE $800/TONNE)
1000	(-)
1500	25%
2000	43%

CAPITAL EQUIPMENT

	LARGE OPERATION (1000-2500 tonnes)
Platform scales (350 KG)	500
Platform scales (0-20 KG)	200
Mincer	16000
Chopper pump	4000
Mono filling pump	2500
Mixing vat	2000
Acid dosing pump	2000
Storage vat (2000 litres)	10000
Safety equipment	2000
Miscellaneous	1000
Cleaning equipment	2000
Elevators (s/hand)	3000
Truck (s/hand)	25000
Sorting tables	1000
Office equipment	3000
Phone/fax etc	1000
CAPITAL EQUIPMENT TOTAL	75200
Annual Depreciation	7520

All capital equipment is assumed to depreciate at 20% per annum, with a zero residual vaue after ten years