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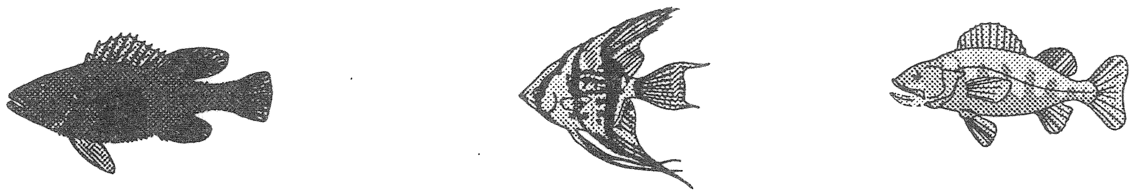
PROJECT NO 8



"FISH MEAL PRODUCTION USING BY-PRODUCTS OF COMMERCIAL FISHERIES (PILOT STUDY)"

FINAL REPORT

Prepared for

Fisheries Research and Development Corporation

By

Dr Elena Tsvetnenko
Associate Professor Louis H Evans
Associate Professor Stanley Kailis
Curtin University of Technology
Mr Phillip Walsh
Food Factotum

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1.0 EXECUTIVE SUMMARY

1.1 INTRODUCTION

Fish meal is used extensively as a source of protein in aquaculture feed which represents the major cost constituent in aquaculture production. Commercial fish meals used to manufacture aquaculture feeds in Australia are currently imported from Denmark, Peru, Chile and other countries. These feeds are expensive (approx. $1,000/tonne) and , in the case of prawn head meals, are a possible source of disease introduction. Fish meals produced from locally sourced fisheries wastes could offer an alternative supply, possibly at a lower cost than is presently available.

1.2 AIM OF STUDY

The overall aim of this project was to determine the range, seasonal variation and annual production of seafood waste products in Western Australia and to assess their suitability as aquaculture feed ingredients.

The specific aims of the study were to identify sources of fisheries waste materials, determine annual production and seasonal variability of the wastes in question and perform proximate analyses and fatty acid analyses on selected materials with the view of assessing their suitability for inclusion in aquaculture feeds.

1.3. SURVEY OF THE MAJOR SOURCES OF FISHERIES WASTES

1.3.1 Survey Results

The annual production and seasonal variability of waste materials were analysed for the following fisheries: western rock lobster, scallop, prawn, abalone, herring, pilchard, salmon and white fish. The availability of waste materials resulting from aquaculture such as yabby and trout farming was also determined.

The by-product of rock lobster (*Panulirus cygnus)* industry, which is represented by lobster heads, was shown to be unreliable source for aquaculture feed production due to the recent drop in catch and also to the increasing amount of heads being exported at high prices.

The waste materials in the form of prawn heads which are generated as a by-product of processing of a banana prawn and western king prawn were shown to be the most abundant waste products. Over 1,800 tonnes of prawn heads were estimated to be available this year.

Herring, pilchards and salmon fisheries were considered together in the survey because they are caught in similar locations and all are used as lobster bait. More than 200 tonnes of salmon gut are available each year from February to May when salmon are caught. Research into their suitability as the ingredients of aquaculture feed is recommended.

By-products of other fisheries are generated less regularly and in lesser quantities which may limit their potential as aquaculture feed ingredients.

1.3.2 Annual production of the fisheries by-products

As a result of the survey the following by-products have been identified as potential components of aquaculture feed:

By-product	Annual tonnage
Prawn heads	1800
Salmon wastes (heads & gut)	450-600
Scallop gut	700
White fish heads, frames & offal	300-500
Scallop lesions	20-200
Abalone offal	10
Trout offal	data not available

1.4 CHEMICAL ANALYSES STUDIES

1.4.1 Criteria for choice of test materials

The selection of by-products to be analysed for nutritional value was based on the data obtained in the survey discussed above.

Prawn heads were selected as the most abundant waste material in Western Australia. The frozen heads of banana prawn (*Penaeus merguensis*) and western king prawn (*Penaeus latisulcatus)* were obtained from Nor-West Seafood Pty Ltd in June 1994.

The amount of scallop lesions which comprise slices of muscle tissue containing a small nematode parasite is estimated to range from 20 to 200 tonnes per year depending on the age of scallops when caught. This waste material has been already trialled as a fish meal substitution and selection of this by-product was based on the promising results of the preliminary studies. The frozen scallop lesions were obtained from Nor-West Seafoods Pty Ltd in March 1994.

Although the abalone fishery in Western Australia is relatively small producing at present not more than 10 tonnes of by-product in the form of offal, the local processors of abalone expect much higher volumes of offal in the future. Considering an additional Victorian and Tasmanian product, the use of abalone waste materials for reduction to fish meal may become viable. The frozen offal from three different species of abalone (*Haliotis roei, H.laevigata and H.ruber*) was obtained for this study from Lonimar Australia in February-June 1994.

The trout waste materials were used for chemical analysis to enable the comparison between by-products obtained from wild and aquaculture species. Trout wastes were represented by offal and bones with flesh remaining after filleting the farmed trout.

1.4.2 Proximate analysis results

The waste material from trout processing containing flesh and bones had the highest percentage of dry matter (42.0%), twice as much as scallop waste , which had the lowest amount (20.7%). Scallop lesions had an extremely high protein content (80.6% of dry matter), while protein content in other by-products ranged from 42.9% (trout flesh and bones) to 63.5%(abalone offal). Lipid levels were highest in the trout offal (26.2% of dry matter) and trout flesh and bones (24.5% of dry matter) and lowest in scallop lesions (7.9% of dry matter). The abalone offal also contained high levels of lipid (12.6-14.3% of dry matter). Ash was very high in prawn heads (29.8% of dry matter) but similar in other by-products (9.6-14.9% of dry matter).

1.4.3 Fatty acid analysis

The main emphasis of the present research was on fatty acid composition of lipids from the waste materials. Although there are many other alternative protein sources of non-seafood origin for aquaculture feeds, these sources rarely provide the full spectrum of essential fatty acids present in aquatic organisms.

The highest variety of fatty acids was observed in trout wastes, which contained minor fatty acids absent in abalone, prawn heads or scallop lesions (C19:0, C19:1, C22:0, C22:1).

Trout wastes were characterised by a very high level of monounsaturated fatty acids (mainly oleic), which accounted for about a half of all fatty acids present. The lowest percentage of monounsaturated fatty acids was observed in scallop waste.

Trout waste had the lowest percentages of polyunsaturated (PUFA) and highly unsaturated (HUFA) fatty acids. Scallop waste had significantly higher percentages of total PUFA, as well as HUFA, in its fatty acid profile compared to other products.

The highest n-3/n-6 ratio was observed for lipids from scallop waste (3.89), followed by prawn heads (2.18). The lowest ratio was obtained with trout waste (0.75), which may reflect the fact that these wastes were obtained from cultured fish which probably were fed diets containing low levels of n-3 fatty acid sources.

For the purposes of diet formulations, the absolute quantity of fatty acids, especially EPA and DHA, in the fish meal, rather than the fatty acid profile of its lipids, is the indicative parameter. The analysis of absolute amounts of fatty acids shows the following:

a) The amount of total saturated fatty acids in trout waste was about twice as high as in other waste materials.

b) There were significant differences in total monounsaturated fatty acids, with the highest level being observed in trout wastes and the lowest in scallop waste.

c) The absolute amount of total PUFA was the highest in trout waste materials. The amount of HUFA was similar in all waste materials, only in trout flesh and bones and in batches 1 & 3 of abalone offal it was less than in the scallop lesions.

1.5 POTENTIAL OF VARIOUS BY-PRODUCTS FOR USE IN AQUACULTURE FEEDS

All wastes studied have potential use in aquaculture feeds both as a protein source and as a source of HUFA. The limiting factors to this application will be the percentage recovery after drying (and hence the financial return to fish processors), the annual production volume and the seasonal variation. and the annual production volume.

In terms of total annual production the products with most potential are prawn heads, salmon wastes and scallop gut. However, seasonal variations in annual production may limit salmon wastes application in aquaculture feed production.

In terms of the chemical composition of the wastes analysed scallop waste was found to be superior to other waste products as it had the highest protein content and the highest n-3/n-6 ratio.

In terms of recovery after drying trout offal offers the best return, containing 42% dry matter compared to 20.7-31.6% in other wastes. The total PUFA was higher in trout wastes than in other wastes and high levels of DHA were also present. However, the low volumes of production of this waste suggest it would not be economical to manufacture aquaculture feeds using these products, unless the wastes were incorporated into practical feeds on-farm. Such an application could be developed with commercial marron farms located in the South West of Western Australia where the trout offal is also produced. Care would have to be taken in formulating the practical feeds to ensure that overall levels of lipid are not excessive.

Three waste sources identified in the annual production survey with potential application in aquaculture feeds, salmon wastes, scallop gut and white fish wastes, were not analysed as part of this study due to limited time frame of the project. Future dtudies on these wastes are recommended. Fatty acid analysis of these three wastes should be carried out to assess the levels of HUFAs present in these wastes and to determine other important compositional criteria (% dry matter, protein, lipid and ash components). However, investigation into use of scallop gut in fish meal production should involve an evaluation of heavy metals accumulation in addition to other chemical analyses.

Our recommendations include further investigations into salmon wastes utilisation which may involve the use of solar drying technology developed in the Argyle catfish

NSC project and the incorporation of the dried materials into an artificial salmon feed to be tested in nutrition trials. Also, we recommend further investigation into the use of abalone wastes which could be sourced in considerably higher volumes than is indicated in the accompanying survey.

Both salmon and abalone wastes may be used in production of specialized feed such as broodstock maturation diets or feed additives in finishing diets to boost the levels of HUFA in the marketed aquaculture products.

An analysis of the Western Australian Fishing and Seafood Processing Industry to determine the major sources and tonnages of by-catch and by-product waste.

This analysis forms part of the National Seafood Centre Project No. 8 - "Fish Meal production using by-products of commercial fisheries (pilot study)"

Prepared for: Associate Professor Louis H. Evans
Associate Professor Stanley Kailis
Curtin University of Technology

Prepared by: Phillip Walsh
Food Factotum
55 Pandora Drive
City Beach 6015

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1
Summary of Findings

The primary purpose of the analysis was to determine the range, seasonal variability and annual production of seafood waste products in Western Australia and to identify those that might be used as components of fish meal production of aquaculture feed.

Detailed information by species is provided in the following pages with the list below identified as potential components of the meal :-

- scallop gut
- scallop lesions
- prawn heads/shell
- abalone gut
- Australian salmon gut
- white fish heads, frames, and offal
- trout gut

An additional purpose was to identify significant tonnages of by-catch waste, by-product or under utilised species which might be the subject of further investigation of value adding opportunities.

The major tonnage of discarded by-catch derives from both the Western Australian and Commonwealth prawn fisheries. Data would need to be collected by a team approach between fishermen, researchers and processors to accurately measure the total by-catch and it's constituents before any usage strategy could be developed.

There is no large volume by-catch waste from any other WA fishery.

Australian herring and to a lesser extent Australian salmon are under utilised as food fish and could be included in studies for improving the quality and acceptability of under utilised species in general. Note in the case of herring it's improved value would need to exceed it's worth as lobster bait.

Prawn heads are available in sufficient quantity to justify experimentation in the extraction of flavourings and the growing yabby industry has the potential to support R & D into value adding of the 35% by weight unsaleable as live product.

Western Rock Lobster (Panulirus Cygnus)

The Western Rock Lobster, with an annual catch typically 10,000 tonnes and a value close to $300 million, is economically the most important fishery to Western Australia.

It also provides a very interesting example of the difficulties inherent in developing products to utilise by-product. The by-product of rock lobster is the lobster head removed when lobster tails are packed for sale.

The following statistics are relevant.

Rock Lobster Tail Exports	85/86	86/87	87/88	88/89	89/90	90/91	91/92	92/93	93/94*
Tonnes Tails	2273	2287	2983	1940	1746	1063	1277	1370	400
% of Total Export	56	41	42	23	25	15	14	15	6

* Estimate based on year to date figures

As the head comprises 60% of the weight, eight years ago 2,000-3,000 tonnes of lobster heads annually were being dumped at sea or in land-fill with very few used for soups, stocks or exported as whole heads.

A number of projects were developed to utilise the head, including preparing a rock lobster paste, extracting the red colour, astaxanthin, for fish feed and a fully costed plant for extracting chitin and subsequently chitosan from the shell. One flavour company still has an interest in extracting lobster flavour and, as lobster prices increased, it became cost effective to cook the heads and remove horn and leg meat for secondary sale.

As the statistics show, the tonnages and percentage of catch have dropped dramatically, to the point where this year to the end of January only 208 tonnes of tails had been produced. In addition, in 1986 and 1987 less than 10% of heads were exported, but by 1991 and 1992 the figure was 40% and this year export prices for heads have been as high as US$3-4 per kg.

Although the major cause of the decline is the relative sell price for whole cooked and live compared with tails, now that land-fill is difficult and expensive processors are more prepared to pack and freeze heads, even during the heavy catches in December and January.

The rock lobster season is November 15 - June 30th.

Conclusion

Small tonnages (less than 100t) of heads will always be available, but with erratic supply. Future predictions are for smaller tonnage catch through pot reductions, better handling and, thus, less need for tailing. Where tails are prepared it is likely that the value of the head as a saleable item will be included in the costing.

It would be an unreliable source for aquaculture feed, but could still be used for stocks and flavours where the equipment is used for other products as well. A dedicated lobster facility would be a high risk.

There is very little by-catch from the rock lobster fishery.

Southern Rock Lobster (Jasus edwardsii)

A relative small fishery for W.A. of less than 50 tonnes annually. Live exports are growing with processors introducing recirculating tank systems.

King crabs (pseudocarcinus gigas) are also targeted by the fishermen.

4
Scallops (Amusium balloti)

The bulk of the scallops trawled in Western Australia are concentrated in the Shark Bay area. A smaller south west trawl if of interest because this was the subject of a W.A. fisheries research report (No. 100) covering by-catch, which is detailed in the Appendix.

Scallop catches have varied considerably in recent years, with 6,000 tonnes recorded for 1990/91; 20,000 tonnes for 91/92; and 10,000 tonnes for 92/93. The scallop season runs from April to October.

In Western Australia shucking is carried out on board, with only the meat retained for further processing. Apart from the above report, there is little by-catch information and by-catch is not significant according to the processors.

Of greater interest are the by-products, of which there are three- shell, gut and 'lesions'. The lesion is the piece of scallop meat removed during processing to remove the nematode worm which infests scallops from the second year of age onwards.

If we assume a 10,000 tonne average catch, then the breakdown will be :-

Shell	7,000 tonnes
Gut	700 tonnes
Meat	2,000 tonnes
Lesion	20-200 tonnes

The shell may become a valuable by-product if the Queensland calcium carbonate extraction plant comes on stream.

Gut is a considerable tonnage and worth investigating further. One cautionary note was the suggestion that the gut may concentrate heavy metals, particularly cadmium. The literature search revealed only one reference to pecten species from Port Phillip Bay, but this did show a mean level of 7.7mg/kg and a range of 3.7 - 15.1. I contacted Heloise Mariath at BRS, who is currently testing other seafood products for cadmium, and she indicted a willingness to include a few tests on scallop gut if the samples are supplied.

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The tonnage of lesion material is dependent on the age of scallops when caught. The large tonnage 2 years ago, with a 10% loss of meat as lesions, caused a flurry of activity to find uses for the material, including "dried scallop meat". High returns will be sought as this meat represents a loss to the processor.

Conclusion

When gut from scallops in Victoria and Queensland is included there is a considerable tonnage available on a consistent basis for further utilisation.

In the context of this project it's nutritional adequacy and feed potential should be investigated, with some cautionary tests for heavy metals. For W.A. the gut value would need to cover collection, freezing, landing and transport costs.

The lesion material has been previously tried as a prawn feed supplement with some success and work on this option should be completed. It's continued availability is likely to be limited by volume and value.

6
Prawns

Western Australian processors are involved with the Commonwealth Northern Prawn Fishery and the State fishery concentrated in Exmouth and Shark Bay.

A crude average of 8,000 tonnes Northern Prawn and 2,000 tonnes for the State fishery gives an indication of the relative volumes.

By-Catch

The nature of the trawl (perhaps with the exception of banana prawns) and the size of the net has inevitably resulted in large tonnages of by-catch. Nick Ruello's report for the NSC. details much of the known information and a number of the papers referred to are compiled in the CSIRO publication, The Effects of Fishing, Edited by W. Craik, J. Glaister and I. Poiner.

Additional comments below come from discussions with fisheries researchers and processors and relate mostly to the State fishery.

There is a wide diversity of opinion regarding the merits or otherwise of attempting to utilise by-catch, limit by-catch, or obtain ongoing statistics relating to retained and discarded fish. Opinions are diverse and strongly held. At one extreme I am told to ignore by-catch, it is not an issue, many of the fish are poisonous, sorting operations would be too costly, the fish discarded are returned nutrients, juveniles would be collected, large catches of by-catch would be targeted in addition to prawns, etc. On the other hand, some are keen to pursue utilisation of by-catch, understand the impacts by careful study of volumes, weights and sizes and ensure that by-catch is a managed fishery alongside the target species.

Statistics are limited. Catch and effort statistics only relate to retained by-catch and consist primarily of squid, some fin-fish, tuna and blue swimmer crabs. Much of the fish is caught by line from the boat when not trawling.

Anecdotal evidence has the discarded by-catch consisting of small fish, such as grinner, small whiting and goat fish. There is a belief that this is generally small fish rather than juveniles. The W.A. Fisheries Research Report No. 100 also covered the impact of trawling for western king prawns recording discarded catch, but the area concerned is not the major fishery (See Appendix 1)

By Product

The by-product of prawn processing is prawn heads, removed when packing headless prawns and the remaining shell plus tail, removed when prawn meat is packed.

Tonnage of heads, as in the case of rock lobster, is dependent upon market demand for the different pack styles and will, therefore, vary considerably. However, some prawns, e.g. kings, are usually sold headless. I was advised that this year probably 70% of the banana prawn catch will go to Japan headless. Based on a 4,000 tonne catch and a 34% head weight, this alone equates to over 1,300 tonnes. Estimates from processors of heads available from the W.A. fishery totalled 400t p.a. with a further 100t of waste from peeling.

Conclusion

By-Catch: a detailed analysis of the opportunities is beyond the scope of this report. I understand a Northern Territory Fish Co-op is looking to prepare fish paste for human consumption using by-catch and is willing to pay up to $1.50/kg. for the raw material. Another W.A. company is investigating the viability of fish ball manufacture for the Asian market. In the first instance more facts and less hearsay are required.

By-Product: prawn heads and total shell should be included in the pilot study on fish meal production.

Small quantities of heads are being exported and there is further potential for their utilisation in the preparation of stocks and flavours.

8
Abalone

The abalone fishery in Western Australia is small compared with other States, totalling some 300 tonnes per year whole weight. Apart from greenlip and brownlip abalone, the small roe's abalone (haliotis roei) is also collected to a total of about 120 tonnes per year.

Much of the greenlip, brownlip and some roe's abalone collected off the south coast is shucked on board with only the meat retained. Catch quota is based on meat weight.

Most of the roe's abalone from the west coast is transferred as whole weight and then canned.

By-product is the shell and gut. A percentage of the shell is sold and some of the gut has been made into fish sauce, but the bulk is discarded.

Conclusion

Better utilisation of shell and gut are the only opportunities. With probably less than 10 tonnes of gut available in W.A. each year, any project would depend upon additional Victorian and Tasmanian product.

9
Herring/Pilchards/Australian Salmon

These three fish are considered together because they are caught in similar locations and have a common usage - lobster bait.

Using as a guide that 1kg. lobster caught requires 1kg. bait, there is a demand in Western Australia for at least 10,000 tonnes of lobster bait. Since much of this has to be imported, packaging, freezing and freight charges ensure than lobster bait will sell to the fishermen for about $1 per kg. This provides the incentive for large tonnage fishing purely for bait.

Herring or Tommy Ruff (Arripis georgianus)

This is 99% utilised as bait. Tonnage catch varies from 400 - 2,000 tonnes, typically 1,500 tonnes, with a value of 0.70 to $1/kg as bait. Herring is generally preferred by lobster fishermen over salmon heads, the only problem being that the herring season peaks towards the end of the lobster season, thus incurring storage costs and quality deterioration prior to use in the next season.

Since it is a trap fishery there must be some by-catch, but the tonnages and types of fish discarded were not recorded. The fish are frozen whole, so there is no by-product.
Little work has been done recently on human food/higher value uses. The Hunts cannery at Albany packed herring fillets at one time in a similar way to mackerel, but there was little interest in the product.

10
Pilchards or Sardines (sardinops neopilchardus)

These are purse-seined off the south coast in King George Sound, Albany and Bremer Bay, with a smaller fishery off the west coast centred on Fremantle. Typical total catch is 7,500 tonnes per year with a peak in the early winter months.

Pilchard is sold for a number of uses with a range of prices :-

IQF bait	130c/kg
Block pilchard	100c/kg
Tuna feed	70c/kg
Petfood	55c/kg
Lobster bait	50c/kg

Prices vary with quality and demand, but are indicative of the relative values. Thus recreational fishermen's bait as IQF or block provides the best return but petfood, tuna feed and lobster bait take up the tonnage. The tonnage catch is regulated by quota with very little by-catch and no by-product as the product is sold whole. (Bait pilchards are often referred to as 'mulies'.

Mendolia's Fremantle Sardine Company are the largest suppliers of pilchards to the human food market where they are sold as sardines.

The sardines are prepared whole, headed and gutted, filleted and crumbed for wholesalers, restaurants and retail stores. Some are prepared in the tradition of anchovies and sold as 'Auschovies". Human food sales of sardines total less than 10% of the total catch.

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Australian Salmon (*Arripis trutta esper*)

Australian salmon is known as Kahawai in the E. States and New Zealand, where the catch is a related smaller species. Quantities of New Zealand Kahawai are bought as lobster bait in the whole form, whereas only the salmon head and flaps are used for bait from the WA catch.

Australian Salmon are caught by Beach seine along the south and lower west coasts from February to May with a total catch typically 1,500 - 2,000 tonnes.

A guide to components usage and value is given below :-

Component	Usage	%	Value
Heads	Bait	20	100c/kg
Gut	Petfood/Silage /Dump	10	15c/kg to -7c/kg
Flaps	Bait	6	70c/kg
Backfin/tail	Petfood	3	35c/kg
Scale	Dump	2	-7c/kg
Body	Canning	59	90c/kg

The beach price for salmon is typically $400 - 450 per tonne. Each quota holder has a maximum tonnage which can be used purely for bait (30t), the rest must be caught for human consumption. Most is canned as cutlets in brine, with a small amount precooked, as tuna, and canned with sauce using only the flesh. A significant tonnage is used for fish paste by Peck's, whilst a small tonnage is also smoked. The canned product has a limited market and low value. Thus the heads are worth more than the body and cut correspondingly large.

Because of the low returns from canning some effort has gone into by-product utilisation. With the exception of the scales, only the gut has a very low or negative return. The petfood value includes freezing and packaging and only has a value by avoiding dumping costs. One company ensiles salmon gut, removing the oil and using the resulting product in a fish emulsion fertiliser.

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Scaly Mackerel (Sardinella lemuru)

Scaly mackerel is included in this section as there has been renewed interest in fishing for this species off the mid west coast, primarily as lobster bait, but it has also been shipped to Indonesia as a food fish. Upwards of 500 tonnes per annum could be caught.

Conclusions

Salmon gut should be included in the pilot study. Up to 200 tonnes a year are available, most of which is dumped. Silage and petfood use simply prevent dumping costs.

Herring, salmon and pilchards are all under utilised species from a human food perspective. Salmon handling on the beach is poor, but the pricing does not encourage improvements. If a higher return human food use could be found handling might be improved to match. Any study should include herring.

13
Snapper/Other white fish

Snapper fishing is concentrated around Shark Bay (hand line) and the Pilbara (trap and line) with a total catch of 500 - 1,000 tonnes per year. Estimates are that over 95% of the catch is either the target fish or a valuable and thus retained by-catch.

The bulk of white fish catch is returned to Perth for processing by one of four major seafood processors, with the rest spread across various retailers.

By-product available is, therefore, estimated at 300 - 500 tonnes of total offal, comprising head, guts, skin and frames. Some heads are used for bait and some are sold for preparation of fish stock, but this probably amounts to no more than 10% of the total. Rendering in meat plants and silage production (as for salmon) are the only other uses for the waste. There is no fish-meal production.

A separate white fish catch continues to be operational off the south coast in the Commonwealth Great Australian Bight fishery. Tonnage catches of orange roughy, dory and some gemfish have been inconsistent, but up to 500 tonnes of roughy and dory heads were quoted as available. Some has been used as lobster bait.

Estuarine fisheries along the coastline contribute a further 1,000 tonnes to the total WA catch, but this is spread over a large number of boats and locations and could not be considered as "available" by-product.

Conclusion

Setting up a fish meal plant with the ability to extract oil (particularly orange roughy) is the obvious option for the available by-product. It's viability is questionable and would depend upon guaranteeing supply from the major processors and from the Bight fishery.

If discarded by-catch from other fisheries was retained this could provide another source of raw material, but at what cost?

Shark

Shark is the only other major fishery in Western Australia with a total catch of about 1,500 tonnes. Again, this is split between a southern fishery of 1,000 tonnes, using gillnets and long-lines and west coast gillnets catching the remainder.

The total fishery is managed by effort restrictions and targets, but no quotas. The figures relating to by-catch suggest 15% discarded and 15% retained. This will vary with the area fished. On the west coast boats are generally only out for one day and thus have capacity to return the by-catch. On the south coast (Esperance) the boats can be out for a week or ten days relying on brine storage. If the tanks can be filled with target shark, then excess scale fish will be discarded.

Heads and guts are discarded, skin occasionally used for leather, fins retained and trunks kept for fillets where mercury levels allow. Only the Port Jackson sharks is discarded in total apart from the fins. The spur dog shark from deep water is targeted for it's liver oil.

Conclusion

If other shark utilisation projects across the Country become viable they may find application in WA.

Southern Bluefin Tuna

The local fishery is now small in size with few quota license holders. Whole sashimi for Japan is the target market. One processor prepares smoked tuna for domestic and export sale.

15
Aquaculture/Inland Fisheries

Aquaculture in WA consists principally of pearl oyster, yabbies, marron, trout and mussels.

Yabbies are currently of most interest for this particular project, since the potential supply from traps in farm dams is very high. It has developed from a cottage industry to a significant export of live product exceeding 150 tonnes per year (including interstate).

Yabbies grow slowly during the cold winter months, but otherwise it is an all year industry. The bulk of the product goes to Europe with northern hemisphere summer demand providing the peak when stocks are lowest.

One collector and packer handles two thirds of the total catch. He currently sells all the product into Europe, as a "manufacturing product", where it is sorted and 'culled' with the unsaleable yabbies converted into meat, lobster stock and sauces. The cull is 30 - 35% of the total; mainly yabbies with marked shells, missing claws or too small for the restaurants. There is an opportunity to cull in Australia and value add the culled by-product.

Trout farming is relevant to the fish meal project since the trout has a high oil content and particularly high levels of the 20:5 and 22:6 unsaturated fatty acids. Anecdotal evidence has it that aquaculture snapper "go mad for trout". Mike Hoxey, an aquaculture feed consultant, is determining tonnages available in WA. Although these will be small in WA nationally there will be significant tonnages of gut available.

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Lake Argyle/Cobbler/Barramundi

Lake Argyle supports a wild catfish (Argyle cobbler) fishery of about 100 tonnes fresh weight per year, plus an additional 60 tonnes of by-catch. Filleting is carried out at Lake Argyle resulting in 130 tonnes of by-catch and by-product. Some of this by-product is used to supplement feed for a barramundi aquaculture project which co-exists in the lake. Funds are currently being sought for a project which will convert all of the by-product to a dry feed using low cost technology.

Conclusions

The use of by-product into aquaculture feeds is well advanced in the above examples.

Culled yabbies may have a higher value potential than will be realised from fish meal. Reformed products, flavourings and soups have been suggested as possible end products.

Appendix 1 - WA Fisheries Report No 100 1993

"The impact of trawling for saucer scallops and western king prawns on the benthic communities in coastal waters off south-western Australia"

L.J.B. Laurenson, P. Unsworth, J.W. Penn, R.C.J. Lenanton.

Whilst this two year study did not cover the fishing grounds in which the bulk of scallops and prawns are caught in Western Australia, it does provide data on the tonnages of total by-catch (retained and discarded) relative to the target species.

Quoting from the abstract "During a year of intensive commercial catch sampling (1990/91) an estimated 354 tonnes of marine fauna were taken by the trawlers, comprising 109 tonnes of the target species, 21 tonnes of retained by-catch and 224 tonnes of discards of which approximately 67 percent were unlikely to survive.....Comparisons of fish communities present in surveys of commercially trawled and untrawled grounds indicated that commercial trawling had no significant impact on the benthic communities of existing commercial trawl grounds."

Typical species of by-catch were whiting, rays, angel sharks, sand trevally and blue manna crabs.

Appendices

APPENDIX 2 - PROFILE OF FISHERIES AND AQUACULTURE

Nature of fishery	Area	Species	Fishing method	No. of fishing units	No. of fishers	Est. total value of licences	Est. total value of boats	Average annual catch	Annual value	Markets	Fishing season	Management approach
Western rock lobster	North West Cape to Cape Leeuwin	Western rock lobster	Pots	676 boats & 69300 pots	2000	$600m	$150m	10000t	$250m	USA Japan & Taiwan	15 Nov - 30 June	Input pot nos
Augusta-Windy Harbour rock lobster	Augusta to Windy Harbour	Western rock lobster	Pots	13 boats & 1058 pots	26	$1m	$1m	30t	$0.2m	USA Taiwan	15 Nov - 30 June	Input pot nos
Esperance rock lobster	Hopetoun to Israelite Bay	Southern rock lobster	Pots	10 boats & 514 pots	16	$0.5m	$0.8m	20t	0.4m	Australia	15 Nov - 30 June	Input pot nos
Tropical rock lobster	East of North West Cape	Tropical rock lobster	Diving	9 boats	13	Not transferable	N/A	2t	N/A	Australia	Winter	Input Diver nos
Deep water crab	West and south coasts	Deep water crabs	Traps	N/A	N/A	Not transferable	N/A	N/A	N/A	Japan	N/A	Input boat nos
Abalone Zone 1	SA border to Shoal Cape (near Esperance)	Greenlip brownlip & Roe's abalone	Diving	6	12	$7.5m	$0.3m	36t meat	$1.5m	SE Asia	All year	Output Individual meat quota
Abalone Zone 2	Shoal Cape to Busselton	Greenlip brownlip & Roe's abalone	Diving	8	16	$7.5m	$0.4m	40t meat	$1.6m	SE Asia	All year	Output Individual meat quota
Abalone Zone 3	Cape Leeuwin to NT border	Roe's abalone only	Diving	12	24	$4.6m	$0.6m	108t whole	$1.3m	SE Asia & USA	All year	Output individual Whole & zone quotas
Shark Bay prawn	Shark Bay	King tiger & endeavour prawns & scallops	Trawling	27	162	$32m	$11m	1500t prawns & 800t scallops	Prawns $17m Scallops $18m	Japan Australia & SE Asia	March to October	Input boat nos & gear
Exmouth prawn	Exmouth Gulf	King tiger & endeavour prawns	Trawling	16	64	$18m	$6m	1000t	$10m	Japan & Australia	April to November	Input boat nos & gear
Onslow prawn	Ashburton R. mouth to Dampier Archipelago	King tiger endeavour & banana	Trawling	Area 1-3: 4 Area 2-3:11 Area 2: 16 Area 3 :14	120	Area 1: N/A Area 2: Not transferable	$11m	40t	$0.5m	Japan & Australia	April to November	Input boat nos & gear
Nickol Bay prawn	Dampier Archipelago to 120oE longitude	King & banana prawns	Trawling	14	50	$3.5m	$40m	150-200t	$3.5m	Japan	All year (mainly April to November)	Input boat nos & gear
Kimberley prawn	Kimberley coast	Prawns	Trawling	172	N/A	N/A Restricted transferability	N/A	N/A	N/A	Japan	Winter	Input boat nos
Shark Bay scallop	Shark Bay	Scallops	Trawling	14	182	$16.8m	$5.6m	4200t	$50m	SE Asia & USA	April to October	Input boat nos gear & crew nos
Abrolhos Is & Mid West trawl	Abrolhos Is & Port Gregory	Scallops & prawns	Trawling	17	60	$1.2m	$2.7m	10t to 200t	$0.2m to $4.0m	Scallops to SE Asia & prawns WA	April to Nov	Input boat nos & gear
Pilbara trawl	North West Cape to 120E long.	Snapper emperor cod	Trawling	9	N/A	Not transferable	N/A	N/A	N/A	Australia	All year	Input boat nos
South West trawl	Cape Leeuwin to Burns Beach	Scallops & finfish	Trawling	16	60	$3.0m	$1.5m	20-50t	$0.4m-$1m	WA	All year	Input boat nos
Southern trawl	East of Cape Leeuwin	Fin fish	Trawling	4	12	Not transferable	N/A	N/A	N/A	Australia	All year	Input boat nos
South coast surface trawl	East of Hopetoun	Garfish	Surface trawling	4	N/A	Not transferable	N/A	N/A	N/A	South Australia	Winter	Input boat nos
West coast purse seine	Lancelin to Cape Bouvard (near Mandurah)	Pilchards scaly mackerel Perth herring & anchovy	Purse seine	17 (8 full & supp)	45	Full $1.6m but supp not transferable	$1.0m	1000t	$0.5m	Australia	All year	Input boat nos
King George Sound purse seine	King George Sound	Pilchards	Purse seine	25	75	$5.0m	$2.5m	5500t	$2.5m	Australia New Zealand	All year	Output Indiv quota
Bremer Bay purse seine	Bremer Bay	Pilchards	Purse seine	9	27	$1.0m	$1.0m	1800t	$0.9m	Australia New Zealand	All year	Output Indiv quota
Development purse seine	WA outside West Coast KGS & Bremer Bay fishery	Pilchards	Purse seine	Not finalised	N/A	$0.4m	N/A	300t	$0.2m	Australia	All year	Input boat nos &

Appendices

Nature of fishery	Area	Species	Fishing method	No. of fishing units	No. of fishers	Est. total value of licences	Est. total value of boats	Average annual catch	Annual value	Markets	Fishing season	Management approach
Estuary fisheries	Perth to Esperance	Mullet whiting black bream & cobbler	Gillnet & seine net	South Coast Estuaries: 66 Hardy Inlet: 4 Leschenault Inlet: 11 Peel-Harvey: 30 Swan Canning: 11	200	Generally not transferable	$1.2m	1000t	$2.5m	WA	All year	Input boat nos plus season closures
Cockburn Sound fisheries	Cockburn Sound	Baitfish finfish crabs & mussels	Beach seine gillnet diving	66	100	Not transferable	$1.0m	Crabs 150t Mussels 200t & Fish 150t	$1.6m	WA	All year	Input boat nos
Shark Bay beach seine & mesh net	Shark Bay South of Cape Levillain	Whiting & mullet	Beach seine & mesh net	14	28	Not transferable	$1.7m	320t	$1.0m	Australia	All year	Input boat nos
Exmouth Gulf beach seine	Exmouth Gulf	Whiting & mullet	Beach seine & mesh net	12	24	Not transferable	$0.6m	75t	$0.1m	WA	All year	Input boat nos
Metropolitan beach seine	Burns Beach to Tim's Thicket	Scale fish	Beach seine	N/A	N/A	N/A	N/A	N/A	N/A	Australia	All year	Early planning
South west beach seine	Tim's Thicket to Cape Leeuwin	Scale fish	Beach seine	N/A	N/A	N/A	N/A	N/A	N/A	Australia	All year	Early planning
Salmon (south)	Cape Beaufort to Shoal Cape	Australian salmon	Beach seine	21	60	N/A	N/A	1700t	$0.5m	Australia	February to April	Output total allowable catch
Salmon (west)	Cape Beaufort north	Australian salmon	Beach seine	13	25	N/A	N/A	600t	$0.2m	Australia	March & Apr	Output total allowable catch
Herring trap	Cape Beaufort to Shoal Cape	Australian herring	G trap	18	40	N/A	N/A	1000t	$0.4m	Australia	January to May	Input fisher numbers
Snapper	Shark Bay	Snapper	Line	22	50	$2.5m	$2.0m	520t	$1.6m	Japan Australia & Italy	Winter peak season summer off season	Output indiv quota input boat nos
Pilbara trap	North West Cape to 120oE longitude	Snapper emperor & cod	Trap	Approx 20	N/A	Not transferable	N/A	N/A	N/A	WA	All year	Input boat nos & gear
Southern demersal gillnet and demersal longline	Cape Bouvard to SA border	Shark and scale fish	Demersal gillnet and demersal longline	46 full &43 supp	200	$4.5m	$4m	1000t	$3m	Australia	All year	Input boat nos & gear
West coast gillnet	Cape Bouvard to NT border	Shark and scale fish	Demersal gillnet	42	80	Not transferable	$4.0m	550t	$1.6m	WA	All year	Input boat nos
Barramundi & gillnet	19oS latitude to NT border (ie Kimberley coast)	Barramundi threadfin salmon bluenose salmon	Gillnet	14	25	Not transferable	$0.7m	55t	$0.2m	WA	All year	Input boat nos & gear
Catfish	Gillnet	6	10	N/A	N/A	90t	$0.2m	WA	All year	Input boat nos & gear		
Aquaculture												
Pearl oyster	Exmouth Gulf to NT border	Pinctada maxima	Diving then culture	13 licensees 23 boats	450 employees	$1-2m /10 000 shells	$15m	500 000 shell	Pearl $120m & shell $7.5m	Japan USA & Europe	Winter months	Output shell quota
Pearl oyster (non P. maxima)	Shark Bay to Pilbara	Pinctada albina magarifera Pteria Penguin	Spat collection hatchery prod culture	7	N/A	N/A	N/A	N/A	N/A	Australia	N/A	Sources of juvenile seed stock
Yabbies & Koonacs	Geraldton to Esperance	Yabbies & koonacs	Traps in farm dams	50	N/A	N/A	N/A	127t	$1.14m	Australia Asia Europe	All year	
Marron	Mostly south west	Marron	N/A	27	35	N/A	N/A	15.7t	$0.43m	Australia	All year	Construction of culture facilities
Trout aquaculture	Mostly SW	Rainbow trout	N/A	7	12	N/A	N/A	48t	$0.36m	WA	All year	Industry liaison
Aquarium fish	Perth	Aquarium fish	N/A	8	12	N/A	N/A	N/A	N/A	WA	All year	Industry liaison
Mussel aquaculture	Cockburn Sound Warnbro Sound Geographe Bay	Blue mussel	N/A	9	9	N/A	N/A	249t	$0.68m	WA	All year	Industry liaison

8 Western Australian fisheries production

	1990-91		1991-92		1992-93 ps	
	t	$'000 s	t	$'000 s	t	$'000
Crustaceans						
Lobster	9 262	194 722	12 202	252 150	12 036	216 492
Prawns	3 152	25 719	3 085	25 158	1 718	13 329
Crabs	315	1 738	270	1 191	167	751
Other	8	47	8	49	5	28
Total	12 738	222 225	15 565	278 547	13 925	230 599
Molluscs						
Abalone	302	7 359	309	8 199	192	4 811
Scallops	6 264	17 164	20 539	57 510	10 000	28 000
Mussels	158	304	124	263	19	40
Squid	73	261	62	240	33	126
Other	9	10	11	18	16	26
Total	6 807	25 099	21 046	66 229	10 260	33 003
Fish						
Tuna	262	410	168	244	36	57
Shark	1 923	4 433	2 136	4 998	1 321	2 973
Australian salmon	2 119	774	1 306	483	2 000	900
Snapper	1 284	3 815	1 192	3 848	567	1 752
Cobbler	187	499	207	945	134	610
West Australian jewfish	219	1 493	183	1 174	103	664
Spanish mackerel	265	1 040	389	1 422	220	804
Sea mullet	427	515	492	716	362	526
Yelloweye mullet	–	–	229	229	121	97
Pilchards	9 106	4 185	7 327	3 945	7 500	4 500
Australian herring	1 518	608	1 298	519	530	239
Whiting	207	630	196	750	113	431
Other	2 662	5 759	3 049	9 862	2 819	8 160
Total	20 179	24 158	18 774	29 088	15 825	21 713
Aquaculture						
Pearls a	–	126 187	–	79 000	–	79 000
Other	210	1 149	401	2 157	401	2 157
Total	210	127 336	401	81 157	401	81 157
Total production	39 934	398 818	55 786	455 021	40 411	366 472

a Includes an estimate of pearl production in Western Australia and the Northern Territory. p Preliminary. s ABARE estimates.
Sources: Western Australian Fisheries Department ; ABARE.

12 Commonwealth fisheries production *(continued)*

	1990-91 s		1991-92 s		1992-93 ps	
	t	$'000	t	$'000	t	$'000
Great Australian Bight						
Orange roughy	959	1 199	627	1 762	458	1 017
King flathead	365	514	621	785	508	642
Gemfish	172	162	274	468	132	226
Bight redfish	40	62	131	172	44	58
Jackass morwong	53	103	81	96	68	80
King dory	12	21	63	90	27	39
Blue grenadier	32	63	50	83	45	74
Spiky oreo	23	45	46	58	21	24
Ling	28	23	33	30	17	15
Squid	27	61	32	69	5	11
Other	433	661	178	317	173	256
Total	2 144	2 914	2 136	3 929	1 499	2 442
Southern shark						
School and gummy	2 361	12 988	2 134	13 529	2 003	11 876
Other shark	368	1 105	613	1 236	583	1 245
Other	638	2 550	638	2 617	664	2 791
Total	2 801	16 643	3 385	17 383	3 250	15 912
East coast tuna						
Yellowfin	569	4 500	628	4 998	626	4 977
Southern bluefin	8	300	–	–	–	–
Albacore	86	200	177	407	174	399
Bigeye	14	150	26	247	26	248
Billfish	36	150	62	312	60	300
Skipjack	–	–	208	125	212	128
Other fish	283	1 464	143	768	149	1 000
Total	997	6 764	1 244	6 857	1 246	7 052
East coast purse seine						
Yellowfin	40	150	–	–	–	–
Skipjack	6 000	3 600	6 633	3 980	6 630	3 978
Albacore	–	–	1	3	1	3
Bigeye	–	–	–	–	–	–
Total	6 040	3 750	6 634	3 983	6 631	3 981
Southern bluefin tuna						
Domestic	3 059	14 100	2 142	11 049	1 741	9 962
Joint venture	941	30 110	2 073	37 936	2 450	66 934
Other	344	11 344	800	14 640	650	17 758
Total	4 343	55 554	5 015	63 625	4 841	94 654
Total production	82 285	294 484	66 283	277 769	59 009	309 297

a Includes north west slope and Kimberly coast prawn fisheries. na Not available. p Preliminary. s ABARE estimates.
Sources: Department of Primary Industries and Energy; Australian Fisheries Management Authority; ABARE.

A REPORT ON A CHEMICAL ANALYSIS STUDY OF SELECTED FISHERIES BY-PRODUCTS

This study forms part of the National Seafood Centre Project No 8 - "Fish meal production using by-products of commercial fisheries (pilot study)"

Prepared by: Dr Elena Tsvetnenko
Associate Professor Louis H Evans
Associate Professor Stanley Kailis

Curtin University of Technology

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1.0 EXECUTIVE SUMMARY

1.1 INTRODUCTION

By-products of Australian fish processing plants are an underutilised resource. A significant proportion of this resource is currently disposed of via land fill or by effluent disposal into coastal waters. The former represents an on-going cost to fish processors and the latter can lead to environmental pollution. An alternative means of utilisation is in aquaculture feeds, either as a source of protein or as a feed additive. The aim of this project was to investigate the suitability or various fish waste components produced in Western Australia as aquaculture feed ingredients by studying their chemical composition, the annual production and seasonal variations.

The annual production and seasonal variation of fish processing waste in Western Australia are described in a separate report which was previously submitted to the National Seafood Centre (Walsh, 1994). This report presents the findings on the chemical analysis study.

1.2 AIM OF STUDY

The aim of the study was to perform proximate analyses and fatty acid analyses on selected fisheries by-products with the view on assessing their suitability for inclusion in aquaculture feeds.

1.3 BY PRODUCT ANALYSED

The by-products analysed included abalone offal, scallop lesions, prawn heads, trout offal and trout flesh and bones remaining after filleting. The by-products were provided by North West Seafoods Pty Ltd, Lonimar Australia Pty Ltd and Clover Cottage Trout Farm.

1.4 PROXIMATE ANALYSIS RESULTS

Scallop lesions contained a higher protein content than any other by-product (range 42.9% (trout flesh and bone) to 80.6% dry matter (scallop lesions)). Lipid levels were highest in the trout offal (26.2% dry matter) and trout flesh and bone (24.5% dry matter) and lowest in scallop lesions (7.9% dry matter). The abalone offal also contained high levels of lipid (12.6-14.3% dry matter). Ash was very high in prawn heads (29.8% dry matter) but similar in other by-products (9.6-14.9% dry matter). The % dry matter of fish by-products was similar for abalone offal (23.6-29.6%), scallop lesions (20.7%) and prawn heads (27.1%) but was higher in trout offal (31.6%) and trout flesh and bone (42.0%).

1.5 FATTY ACID RESULTS

While there were few significant differences in percentages of total saturated fatty acids between waste materials (27.1%-33.7% total fatty acids) there were marked differences in the total amount of saturated fats found in the fisheries wastes (range: 2.07g/100g (scallop lesions) - 7.18g/100g (trout offal)).

There were significant differences in total monounsaturated fatty acids with the highest levels being observed in trout waste (10.43-10.72g/100g), and the lowest levels in scallop lesions (0.83g/100g).

The total quantity of polyunsaturated fatty acids (PUFA) was highest in trout waste (3.25 and 3.94g/100g) and lowest in prawn heads (1.92g/100g) but the total amount of n-3 HUFA's was similar in all by-products studied. The most abundant fatty acid in all waste materials, except for trout waste, was palmitic acid C16:0 (14.3-21.4% total fatty acids). In lipids from trout offal and trout flesh and bones oleic acid, C18:1, was the most abundant, representing up to 30% of total fatty acids.

1.6 POTENTIAL FOR USE IN AQUACULTURE FEEDS

All wastes studied have potential use in aquaculture feeds both as a protein source and as a source of HUFA's. The limiting factor to this application will be the percentage recovery after drying (and hence the financial return to fish processors) and the annual production volume.

Scallop waste was found to be superior to other waste products as they had the highest protein content and the highest n3/n6 lipid ration. However, the market seasonal variation in this product (Walsh, 1994) and its present use as a rock lobster bait probably precludes its application in aquaculture feed manufacture.

In terms of recovery after drying trout offal offers the best return, containing 42.0% dry matter compared to 20.7-31.6% in other wastes. The total PUFA was higher in trout wastes than other wastes and high levels of DHA were also present. However, the low volumes of production of this waste (Walsh, 1994) suggests it would not be economical to manufacture aquaculture feeds using these products, unless the wastes were incorporated into practical feeds on-farm. Such an application could be developed with commercial marron farms located in the South West of W.A. where the trout offal is also produced.

Two waste sources identified in the annual production survey with potential application in aquaculture feeds, salmon wastes and fish heads and frames, were not analysed as part of this study. Fatty acid analysis of these wastes should be carried out to assess the levels of HUFAs present in these wastes and to determine other important compositional criteria (% dry matter, protein, lipid and ash components).

2.0 CHEMICAL ANALYSIS OF SELECTED FISHERIES WASTES

2.1 INTRODUCTION

By-products of Australian fish processing plants are an underutilised resource. A significant proportion of the resource is currently disposed of via land fill or by effluent disposal into coastal waters. The former represents an on-going cost to fish processors and the latter can lead to environmental pollution. An alternative approach to land or water disposal is to convert this processing waste into a saleable product. One such product is a fishmeal preparation for use in aquaculture feeds.

Aquaculture accounted for 12-14% of world's fisheries production in 1987 and this figure is expected to rise to 20% by the year 2000. In fact, there are predictions that the amount of fish harvested from aquaculture could some day surpass the yield from wild fish (Bimbo & Growther, 1992). Feed represents the major cost constituent in aquaculture production. For example, in shrimp aquaculture the cost of feed has been estimated to represent up to 60% of total production costs (Akiyama et. al. 1992; Sarac et. al., 1993).

Fishmeal is used extensively in aquaculture feed as a source of protein and, to a lesser extent, fatty acids. A total of 873,000 metric tonnes of fishmeal were used in world aquaculture feeds in 1990 (Bimbo & Growther, 1992) and demand is expected to increase as aquaculture grows. Commercial fish meals used to manufacture aquaculture feeds in Australia are imported from Denmark, Peru, Chile and other countries. These feeds are expensive (approx $1,000/tonne) and, in the case of prawn head meals, are a possible source of disease introduction. Fish meals produced from locally sourced fisheries wastes could offer an alternative supply, possibly at a lower cost than is presently available.

The use of fishmeals in aquaculture feeds also provides benefits in terms of the quality of the farmed fish products. Epidemiological, clinical and biochemical studies performed during the last ten to fifteen years have suggested that consumption of seafood is beneficial in reducing the risk of cardiovascular disease (Dyerberg, 1986;

Fernandes and Venkatraman, 1993). This beneficial effect is considered to be primarily due to the lipid in marine animals which is rich in polyunsaturated fatty acids (PUFA) of the n-3 family, such as eicosapentaenoic acid (EPA, 20:5 n-3), docosapentaenoic acid (22:5 n-3) and docosahexaenoic acid (22:6 n-3) (Ackman, 1982).

Polyunsaturated fatty acids of aquatic foods are formed in uni- and polycellular plants such as phytoplankton and algae that grow in marine and freshwater environments (Dyerberg, 1986). These fatty acids eventually move up the food chain and are incorporated into fish lipid. The n-3 PUFAs found in marine animal fats are almost exclusively 20- and 22- carbon highly unsaturated fatty acids (HUFAs).

Terrestrial food chains also contain n-3 PUFAs, but the majority of fatty acids in terrestrial derived foods belong to the n-6 PUFA family. The PUFA found in edible plant oils and animal muscle fat is primarily linoleic acid (18:2 n-6). Only a small amount of linolenic acid (18:3 n-3) is present. Human beings do not efficiently elongate and desaturate linolenic acid to 20- carbon fatty acids, even when taken in high doses (Renand and Nordoy, 1983; Herald and Kinsella, 1986; Dyerberg, 1986). In contrast, rainbow trout readily convert C18:3 n-3 to C20 and C22 HUFAs, and other fish and shellfish species elongate and desaturate L-linolenate with varying degrees of efficiency (Pigott and Ticker, 1990). Thus, farmed fish and shellfish could be significant source of n-3 HUFAs in food consumed by humans.

The fatty acid profile found in farmed fish and shellfish is affected by the PUFA content of formulated diets fed to the cultured stock.

A direct comparison of the n-3 fatty acid content of cultured versus wild fish and crayfish has revealed distinctly lower levels of n-3 fatty acids in cultured species unless they were fed diets enriched with oils high in n-3 fatty acids (Suzuki et. al. 1986). Thus, if cultivated fish are fed diets containing primary vegetable based oils n-6 PUFAs are likely to predominate. The components of the aquaculture diets are controlled mainly by cost and are often based on soybean meal in which n-6 fatty acids predominate. The level of n-3 fatty acids can be increased by dietary manipulations (Chanmugam et. al., 1986; Pigott and Ticker, 1990). The waste products from fish processing industries as well as being economical protein source for aquaculture diets could be source of highly unsaturated fatty acids thereby ensuring the availability of HUFAs in aquaculture products.

As consumers has become more nutrition-conscious, their demand for more information on nutritional value of fish will increase. The levels of n-3 HUFAs in products of commercial aquaculture may be an important marketing parameter which influences market demand and, hence, industry growth. Further research on the occurrence of n-3 PUFA in aquaculture feed ingredients and on the influence of their inclusion in diets on the fatty acid content of farmed product is clearly warranted.

The aim of the present research was to perform proximate analyses and fatty acid analyses on selected fisheries by-products with the view of assessing their suitability for inclusion in aquaculture feeds..

The by-products analysed included abalone offal, scallop lesions, prawn heads, trout offal and trout bones with flesh remaining after filleting.

2.2 MATERIALS AND METHODS

2.2.1 Source of Fish Processing Wastes

The abalone by-products were obtained from Lonimar Australia and comprised frozen abalone offal. The first two batches of abalone waste were obtained in March 1994. The first batch contained offal from the Roe's abalone *Haliotis roei* caught in January - February 1994. The second batch contained offal from the greenlip abalone *Haliotis laevigata* caught in March 1994. The third batch was obtained in June 1994 and contained offal from the brownlip abalone *Haliotis ruber* caught in June 1994.

The waste material from scallop *Amusium balloti* was obtained from Nor-West Seafoods Pty Ltd. It comprised frozen slices of muscle tissue containing a small nematode parasite which is cut from the main body of the scallop prior to marketing. Only one batch of scallop lesions was available in the span of this project. It was obtained in March 1994.

The waste products in the form of prawn heads are generated as a by-product of processing of banana prawn *Penaeus merguiensis* and western king prawn *Penaeus latisulcatus*. The frozen prawn heads were obtained from Nor-West Seafoods in June 1994.

Trout wastes were represented by offal and bones with flesh remaining after filleting the farmed trout. They were obtained from Clover Cottage Trout Farm in March 1994.

2.2.2 Preparation of Fish Meals

The by-products were defrosted and dry matter of wet material was analysed (AOAC, 1975). Defrosted by-products were then dried at 50°C for 5 hours using a domestic dehydrator (Harvest Maid Dehydrator - High Speed Model FD-1000), finely ground in an electric grinder and stored in glass jars in a refrigerator until analysed.

The resulting powders were used for proximate analyses.

2.2.3 Proximate Analysis

For moisture determination, approximately 7g of powder were dried at 105°C for 24 hours. The completely dried sample was then ashed in a muffle furnace for 6 hours at 600°C for ash determination (AOAC, 1975). Protein analysis was performed by macro-Kjeldahl method using Kjeltec Auto System with a Kjeltec Auto 1030 Analyzer. Total lipids were extracted from 1g samples by the Folch et. al. (1957) method. Fatty acid composition of total lipids was analysed by gas chromatography-mass spectrometry analysis (Christie, 1989).

2.2.4 Fatty Acid Analysis

Fatty acids in the lipid fraction, dissolved in toluene, were converted to their methyl ester derivatives by adding 2 volumes of 1% v/v sulphuric acid in methanol and allowing to stand for 12 h at 50°C. Five ml of 5% aqueous sodium chloride solution was added to each sample, followed by 10ml of hexane. The supernatant from each mixture was removed and stored and the residue re-extracted with an additional 10ml volume of hexane. Supernatants for each sample were pooled and washed with 4ml of 2% aqueous $KHCO_3$ solution. After phase separation, the supernatants of each sample were dried by passing through a small column of anhydrous sodium sulphate. These methylated lipid fractions in hexane, which contained the methylated fatty acids (FAMES), were analysed using a Hewlett Packard GC-MS Model 5971. Chromatography was performed on a DB 23 column (ID 0.32mm and film thickness 0.25mm) using helium as the carrier gas. The initial column temperature was 50°C for 5 min, followed by an increasing gradient of 5°C/min to a temperature of 240°C, with the latter temperature being held for at least another 20 min. Run times were approximately one hour. Individual fatty acids were identified using known retention times, standards and mass spectra and quantified by introducing an internal standard (nonadecanoic acid) of known weight before methylation. The added nonadecanoic acid provided a known ratio of area integration to weight of standard concentration allowing the weight of the other fatty acids to be calculated from their area integrations. The results were expressed as percentage of total fatty acids and as grams per 100 grams of sample.

2.2.5 Statistical Analysis

Analysis of variance (ANOVA) was used to determine significant differences among means for the individual and total fatty acids for each waste material. Differences between means were determined to be significant at $P<0.05$.

2.3 RESULTS

Data on chemical composition of fisheries by-products are listed in Table 1.

TABLE 1

PROXIMATE ANALYSES OF SELECTED FISHERIES BY-PRODUCTS

By-product	Dry Matter % Fresh material	Dry Matter % Prepared powder	Protein (% of Dry Matter)	Lipids (% of Dry Matter)	Ash (% of Dry Matter)
1	29.58	96.07	63.52	12.56	14.94
Abalone Offal 2	23.61	98.40	60.17	14.30	12.53
3	25.64	94.39	61.90	13.84	11.33
Scallop lesions	20.74	88.82	80.55	7.86	14.35
Prawn heads	27.70	96.69	53.76	9.51	29.80
Trout flesh and bones	41.96	99.46	42.93	24.47	16.25
Trout offal	31.62	98.78	63.62	26.17	9.58

* 1. *Haliotis roei*
2. *H. Laevigata*
3. *H. Ruber*

The waste material from trout processing containing flesh and bones had the highest percentage of dry matter, twice as much as scallop waste. The scallop by-product meal, compared to other by-products, had higher protein and lower lipid contents, which is in agreement with our previous findings (Sudaryono et. al., 1994). The trout waste meals were found to have the highest lipid contents, while trout flesh and bones had the lowest protein level and trout offal the lowest ash contents. Prawn head meal had twice to three times as much ash as other waste materials.

Table 2 shows the relative percentages of fatty acids in the lipids of fisheries by-products investigated. Significant differences among individual fatty acid percentages were detected.

The most abundant fatty acid in all waste materials, except for trout waste, was palmitic acid C16:0. In the lipids from trout flesh and bones and trout offal oleic acid 18:1 was the most abundant, representing up to 30% of total fatty acids. Trout waste materials also differed in the percentage of linoleic acid (C18:2 n-6) which was 4-5 times as much as in other materials. The percentage of linolenic acid (C18:3 n-3) in trout waste was lower than in abalone, but higher compared to prawn heads.

Extremely low amounts of arachidonic acid (20:4 n-6) and eicosapentaenoic acid (EPA, 20:5 n-3) were observed in the lipids from trout waste, compared to other wastes. The levels of these fatty acids were similar in all other waste meals, with the exception of arachidonic acid being slightly higher in the batch 2 of abalone offal and EPA being lower in the batch 3 of abalone offal.

Some fatty acids such as C19:0, C19:1, C22:0 and C22:1 were not detected in most materials. In those products where they were found, they were present in small amounts (less than 1%), except for C22:1 in trout wastes.

TABLE 2

Fatty Acid Composition of Lipids from Fisheries By-products (% of total fatty acids) *

Fatty Acid	Abalone offal			Prawn Heads	Scallop Lesions	Trout Flesh and Bones	Trout Offal
	Batch 1	Batch 2	Batch 3				
14:0	4.46 ± 0.15[a]	4.24 ± 0.65[a]	9.45 ± 0.36[b]	2.09 ± 0.10[cd]	1.65 ± 0.22[c]	3.04 ± 0.11[d]	2.84 ± 0.07[d]
15:0	1.06 ± 0.08[ac]	1.65 ± 0.18[b]	1.24 ± 0.01[a]	1.86 ± 0.02[b]	0.82 ± 0.07[cd]	0.76 ± 0.03[d]	0.84 ± 0.02[cd]
16:0	21.30 ± 2.14[a]	18.84 ± 1.90[ab]	22.14 ± 0.26[a]	14.30 ± 0.41[b]	16.55 ± 2.19[a]	17.96 ± 0.07[a]	19.33 ± 1.08[a]
16:1	2.98 ± 0.15[a]	2.22 ± 0.25[b]	5.86 ± 0.30[c]	5.26 ± 0.17[c]	2.18 ± 0.25[b]	8.05 ± 0.11[d]	7.35 ± 0.10[e]
17:0	1.46 ± 0.08[a]	1.55 ± 0.18[ac]	1.02 ± 0.02[ad]	2.66 ± 0.02[b]	2.00 ± 0.29[c]	0.66 ± 0.03[d]	0.68 ± 0.03[d]
18:0	4.84 ± 0.10[a]	4.58 ± 0.40[a]	3.74 ± 0.01[a]	9.36 ± 0.25[b]	6.48 ± 0.85[c]	7.10 ± 0.36[c]	6.95 ± 0.24[c]
18:1	15.78 ± 1.02[a]	12.30 ± 0.72[a]	21.32 ± 0.42[b]	12.38 ± 0.265[ac]	7.65 ± 0.94[c]	31.21 ± 2.36[d]	30.57 ± 2.09[d]
18:2 n-6	1.90 ± 0.07[a]	1.31 ± 0.09[b]	0.50 ± 0.00[c]	1.40 ± 0.02[b]	7.32 ± 0.09[b]	8.01 ± 0.10[d]	7.92 ± 0.15[d]
19:0	- **	-	-	0.62 ± 0.01[a]	-	0.38 ± 0.01[b]	0.36 ± 0.01[b]
19:1	-	-	-	-	-	0.34 ± 0.02[a]	0.35 ± 0.02[a]
18:3 n-3	2.88 ± 0.11[a]	1.84 ± 0.42[b]	0.24 ± 0.08[c]	0.32 ± 0.04[c]	-	1.15 ± 0.06[d]	1.12 ± 0.02[d]
18:4 n-3	1.37 ± 0.06[a]	0.98 ± 0.04[a]	-	-	1.03 ± 0.38[a]	0.34 ± 0.03[b]	0.29 ± 0.03[b]
20:0	0.20 ± 0.04[a]	0.26 ± 0.04[a]	-	0.81 ± 0.03[b]	-	0.25 ± 0.02[a]	0.30 ± 0.02[a]
20.1	5.72 ± 0.38[a]	6.01 ± 0.41[a]	6.15 ± 0.27[a]	3.06 ± 0.04[b]	1.27 ± 0.22[c]	6.65 ± 0.26[a]	6.14 ± 0.31[a]
20:4 n-6	6.51 ± 0.17[a]	9.07 ± 0.93[b]	5.74 ± 0.22[a]	6.07 ± 0.08[a]	5.14 ± 0.75[a]	0.64 ± 0.07[c]	0.99 ± 0.11[c]
20:5 n-3	7.72 ± 0.23[a]	7.42 ± 0.98[ab]	4.90 ± 0.17[b]	8.08 ± 0.16[a]	9.07 ± 1.37[a]	0.84 ± 0.10[c]	0.81 ± 0.06[c]
22:0	-	-	-	0.46 ± 0.03	-	0.18 ± 0.02	0.18 ± 0.03
22:1	-	-	0.30 ± 0.00[a]	-	-	2.60 ± 0.14[b]	2.44 ± 0.15[b]
22:5 n-3	3.69 ± 0.06[a]	4.07 ± 1.18[a]	2.55 ± 0.09[ab]	2.20 ± 0.01[abc]	1.17 ± 0.13[bc]	0.52 ± 0.07[bc]	0.39 ± 0.05[c]
22:6 n-3	-	-	-	5.82 ± 0.05[a]	14.38 ± 2.15[b]	4.15 ± 0.42[a]	5.62 ± 0.38[a]

* Values are means ± SE of 4 replications. Mean values across rows not sharing the same superscript letter are significantly different.
** A dash (-) indicates not detected.

TABLE 3

Fatty Acid Composition of Lipids from Fisheries By-products (g/100g sample) *

Fatty Acid	Abalone offal			Prawn Heads	Scallop Lesions	Trout Flesh and Bones	Trout Offal
	Batch 1	Batch 2	Batch 3				
14:0	0.52 ± 0.02^{a}	0.54 ± 0.08^{a}	1.21 ± 0.06^{b}	0.17 ± 0.00^{c}	0.13 ± 0.02^{c}	0.65 ± 0.02^{d}	0.66 ± 0.02^{d}
15:0	0.12 ± 0.01^{a}	0.21 ± 0.02^{bd}	0.16 ± 0.00^{ab}	0.15 ± 0.00^{ad}	0.06 ± 0.00^{c}	0.16 ± 0.01^{d}	0.19 ± 0.00^{d}
16:0	2.49 ± 0.25^{a}	2.41 ± 0.26	2.83 ± 0.03^{a}	1.16 ± 0.03^{b}	1.27 ± 0.17^{b}	3.86 ± 0.17^{c}	4.49 ± 0.25^{c}
16:1	0.35 ± 0.02^{ac}	0.28 ± 0.03^{a}	0.75 ± 0.04^{b}	0.43 ± 0.01^{c}	0.17 ± 0.02^{d}	1.73 ± 0.03^{e}	1.71 ± 0.02^{e}
17:0	0.17 ± 0.01^{abc}	0.20 ± 0.02^{ac}	0.13 ± 0.00^{bc}	0.22 ± 0.00^{b}	0.15 ± 0.02^{bc}	0.14 ± 0.01^{bc}	0.16 ± 0.01^{c}
18:0	0.57 ± 0.01^{a}	0.58 ± 0.05^{ab}	0.48 ± 0.01^{a}	0.76 ± 0.02^{b}	0.50 ± 0.06^{a}	1.52 ± 0.07^{c}	1.61 ± 0.05^{c}
18:1	1.80 ± 0.09^{ab}	1.57 ± 0.08^{a}	2.72 ± 0.05^{b}	1.00 ± 0.02^{ac}	0.59 ± 0.07^{c}	6.70 ± 0.53^{d}	7.10 ± 0.48^{d}
18:2 n-6	0.22 ± 0.01^{a}	0.17 ± 0.01^{b}	0.06 ± 0.00^{c}	0.11 ± 0.00^{a}	0.10 ± 0.01^{c}	1.72 ± 0.02^{d}	1.84 ± 0.04^{e}
19:0	-	-	-	0.62 ± 0.01^{a}	-	0.08 ± 0.00^{b}	0.08 ± 0.00^{b}
19:1	-	-	-	-	-	0.07 ± 0.00^{b}	0.08 ± 0.00^{a}
18:3 n-3	0.33 ± 0.01^{a}	0.23 ± 0.05^{b}	0.03 ± 0.01^{c}	0.03 ± 0.00^{c}	-	0.25 ± 0.01^{b}	0.26 ± 0.03^{b}
18:4 n-3	0.16 ± 0.01^{a}	0.12 ± 0.01^{ab}	-	-	0.08 ± 0.03^{b}	0.07 ± 0.00^{b}	0.07 ± 0.00^{b}
20:0	0.02 ± 0.00^{a}	0.03 ± 0.00^{a}	-	0.07 ± 0.00^{b}	-	0.05 ± 0.00^{b}	0.07 ± 0.00^{b}
20.1	0.66 ± 0.05^{a}	0.77 ± 0.05^{a}	0.79 ± 0.03^{a}	0.25 ± 0.00^{b}	0.10 ± 0.02^{b}	1.41 ± 0.05^{c}	1.42 ± 0.07^{c}
20:4 n-6	0.75 ± 0.02^{a}	1.16 ± 0.12^{b}	0.73 ± 0.03^{a}	0.49 ± 0.01^{c}	0.39 ± 0.06^{c}	0.14 ± 0.01^{d}	0.23 ± 0.02^{d}
20:5 n-3	0.89 ± 0.02^{ab}	0.95 ± 0.13^{a}	0.63 ± 0.02^{b}	0.65 ± 0.01^{ab}	0.69 ± 0.11^{b}	0.18 ± 0.02^{c}	0.19 ± 0.01^{c}
22:0	-	-	-	0.04 ± 0.00^{a}	-	0.04 ± 0.00^{a}	0.04 ± 0.00^{a}
22:1	-	-	0.04 ± 0.00^{a}	-	-	0.56 ± 0.03^{b}	0.57 ± 0.03^{b}
22:5 n-3	0.42 ± 0.01^{a}	0.52 ± 0.14^{a}	0.33 ± 0.01^{abc}	0.18 ± 0.00^{bcd}	0.09 ± 0.01^{cd}	0.11 ± 0.01^{cd}	0.06 ± 0.02^{d}
22:6 n-3	-	-	-	0.47 ± 0.17^{b}	1.10 ± 0.17^{b}	0.89 ± 0.09^{a}	1.31 ± 0.09^{b}

* See Table 2 for Legend

All three batches of abalone waste showed a complete lack of docosahexaenoic acid (DHA, 22:6 n-3). The highest percentage of DHA was detected in scallop lesions and lesser percentages were seen in prawn head meal and trout wastes.

Table 3 shows the amount of individual fatty acids expressed as grams per 100 grams of sample (g/100 g sample). It can be seen that there were no significant differences in the amount of DHA between scallop lesions and trout offal, on one hand, and trout flesh and prawn heads, on the other.

The data on summary classes of fatty acids are presented in Tables 4 and 5.

There was no significant difference in percentage of total saturated fatty acids between waste materials, except for scallop waste having a significantly lower percentage of saturated fatty acids compared to batch 3 of abalone offal (Table 4) However, the amount of total saturated fatty acids in trout waste expressed as g/100 g sample was about twice as high as in other waste materials (Table 5).

There were significant differences in total monounsaturated fatty acids (monoenes), with the highest level being observed in trout wastes and the lowest in scallop waste (Table 4 & 5).

Scallop waste had significantly higher percentages of total PUFA, as well as HUFA, in its fatty acid profile compared to other products (Table 4). The absolute amount of total PUFA was the highest in trout offal while the amount of HUFA was similar in all waste materials studied (Table 5).

2.4 DISCUSSION

The data on chemical composition of several fisheries by-products indicate that they are rich in protein and can be used as an alternative protein source in the production of fish meal. An extremely high level of protein was observed in scallop waste, which is produced often in large quantities (see 3.0). The amount of this waste generated each year fluctuates depending on the catch but generally exceeds 10 tonnes.

TABLE 4

Summarised Fatty Acids of Lipids from Fisheries By-products (% of total fatty acids)*

Summarised Fatty Acids **	Abalone offal			Prawn Heads	Scallop Lesions	Trout Flesh and Bones	Trout Offal
	Batch 1	Batch 2	Batch 3				
Saturates	32.95 ± 1.93^{ab}	30.50 ± 3.17^{ab}	37.59 ± 0.60^{a}	32.16 ± 0.61^{ab}	27.07 ± 3.51^{b}	29.87 ± 0.44^{ab}	30.92 ± 0.44^{ab}
Monoenes	24.48 ± 0.83^{a}	20.52 ± 1.01^{b}	33.63 ± 0.36^{c}	20.68 ± 0.39^{a}	10.78 ± 0.89^{d}	48.60 ± 2.14^{e}	46.61 ± 1.54^{e}
Total PUFA	22.32 ± 1.27^{ab}	23.28 ± 2.97^{a}	13.94 ± 0.55^{b}	23.74 ± 0.44^{abc}	31.87 ± 4.47^{c}	15.14 ± 0.66^{b}	17.18 ± 0.22^{ab}
n-6 PUFA	8.40 ± 0.22^{a}	10.38 ± 0.90^{b}	6.24 ± 0.22^{c}	7.47 ± 0.07^{ac}	6.46 ± 0.78^{c}	8.654 ± 0.11^{a}	8.91 ± 0.05^{a}
n-3 PUFA	15.66 ± 0.34^{a}	12.89 ± 2.56^{ab}	7.69 ± 0.34^{bd}	16.27 ± 0.37^{a}	25.40 ± 3.69^{c}	6.48 ± 0.58^{d}	8.03 ± 0.29^{bd}
n-3 HUFA	11.41 ± 0.21^{ab}	11.49 ± 2.11^{ab}	7.45 ± 0.26^{ad}	16.11 ± 0.21^{b}	24.63 ± 3.64^{c}	5.25 ± 0.67^{d}	6.82 ± 0.48^{ad}
n-3/n-6 ratio	1.86 ± 0.02^{a}	1.24 ± 0.25^{bc}	1.23 ± 0.01^{c}	2.18 ± 0.03^{a}	3.89 ± 0.12^{d}	0.75 ± 0.06^{e}	0.90 ± 0.04^{ce}
HUFA/n-6 ratio	1.36 ± 0.01^{a}	1.11 ± 0.21^{ae}	1.19 ± 0.00^{ae}	2.16 ± 0.01^{b}	3.77 ± 0.12^{c}	0.61 ± 0.07^{d}	0.76 ± 0.06^{de}

* See Table 2 for legend

** See text for definition of PUFA, and HUFA.

TABLE 5

Summarised Fatty Acids of Lipids from Fisheries By-products (g/100 g sample)*

Summarised Fatty Acids **	Abalone offal Batch 1	Abalone offal Batch 2	Abalone offal Batch 3	Prawn Heads	Scallop Lesions	Trout Flesh and Bones	Trout Offal
Saturates	3.85 ± 0.23^{a}	3.90 ± 0.43^{ab}	4.80 ± 0.08^{b}	2.61 ± 0.05^{c}	2.07 ± 0.27^{c}	6.41 ± 0.10^{d}	7.18 ± 0.10^{d}
Monoenes	2.81 ± 0.07^{a}	2.62 ± 0.12^{a}	4.30 ± 0.05^{b}	1.68 ± 0.03^{c}	0.83 ± 0.07^{c}	10.43 ± 0.50^{d}	10.82 ± 0.36^{d}
Total PUFA	2.76 ± 0.06^{acd}	2.97 ± 0.36^{ac}	1.78 ± 0.07^{b}	1.92 ± 0.04^{b}	2.24 ± 0.34^{ab}	3.25 ± 0.13^{cd}	3.94 ± 0.06^{d}
n-6 PUFA	0.96 ± 0.02^{a}	1.33 ± 0.12^{b}	0.80 ± 0.03^{ac}	0.60 ± 0.01^{cd}	0.49 ± 0.06^{d}	1.86 ± 0.02^{e}	2.07 ± 0.01^{f}
n-3 PUFA	1.80 ± 0.04^{a}	1.64 ± 0.31^{ab}	0.98 ± 0.04^{b}	1.32 ± 0.03^{ab}	1.94 ± 0.28^{a}	1.39 ± 0.12^{ab}	1.87 ± 0.07^{a}
n-3 HUFA	1.31 ± 0.02^{a}	1.46 ± 0.26^{ab}	0.95 ± 0.03^{a}	1.30 ± 0.02^{ab}	1.88 ± 0.28^{b}	1.13 ± 0.14^{a}	1.58 ± 0.11^{ab}

* See Tables 2 and 4 for Legend

Waste products in the form of prawn heads are also generated in large quantities (see 3.0) and are presently disposed via sea, an approach which increases production costs and fails to exploit opportunities to value add. Prawn heads reduced to fish meal provide a good source of protein (54%) and minerals (30% ash).

Most of collected abalone are marketed as frozen or canned meat, producing offal as a waste material. The chemical composition of three batches of abalone waste was similar. Hepatopancreas lipids certainly contributed to the high lipid level in abalone waste, as did the liver lipids in trout offal. Trout waste resulting from filleting and containing bones with remnants of flesh also had a high lipid level. The large percentage of lipids found in trout wastes probably reflects the high energy (high fat) diets used in trout culture.

The main emphasis of the present research was on fatty acid composition of lipids from the waste materials. Although there are many other alternative protein sources of non-seafood origin for aquaculture feeds, these sources rarely provide the full spectrum of essential fatty acids present in aquatic organisms.

The results obtained in this study showed a significant variation in fatty acid profiles between waste fish meals studied. The highest variety of fatty acids was observed in trout wastes, which contained minor fatty acids absent in abalone, prawn heads or scallop lesions (C19:0, C19:1, C22:0, C22:1).

The distribution of summary classes of fatty acids in waste materials is shown in Figures 1 & 2.

There were significant differences in the percentages of some summary classes of fatty acids between three batches of abalone offal. Thus, the percentage of monounsaturated fatty acids was higher and that of PUFA - lower in batch 3. The amount of n-3 HUFA was also lower in batch 3, but the differences were not statistically significant. Whether these differences can be attributed to the different site or different season of catch, or to the fact that these batches were obtained from different species of abalone is unclear. In all batches no

DHA (22:6 n-3) was detected, but relatively high level of 22:5 n-3 compared to other products was observed.

Lipids from prawn head meal were characterised by high percentage of EPA, similar to that of batch 1 and batch 2 of abalone offal, the presence of DHA and a very low percentage of linolenic acid (C18:3 n-3). n-3 HUFA content in prawn heads was higher than that of abalone waste, but the difference was statistically significant only for batch 3.

Lipids from scallop waste had the same percentage of EPA as those from prawn heads, but the percentage of DHA was more than twice that of prawn heads. On the whole, the percentage of n-3 HUFA in scallop lesions was the highest among all wastes studied, while the percentage of monoenes was the lowest. The complete lack of linolenic acid (C18:3 n-3) in scallop tissue along with the high levels of n-3 HUFAs provides evidence for very efficient desaturation and elongation of n-3 PUFAs.

The fatty acid profiles of lipids from trout wastes differed from those of other wastes investigated. They were characterised by a very high level of monounsaturated fatty acids, which accounted for about a half of all fatty acids present.

The percentage of arachidonic acid 20:4 n-6 was very low in trout wastes but the percentage of n-6 PUFA did not differ from that of other products due to high level of linoleic acid (18:2 n-6). The distribution of arachidonic and linoleic acid in the trout fatty acid profile was the reverse of that seen in other wastes. The percentage of EPA in trout wastes was about 10 times lower than in other wastes, whereas the percentage of DHA was similar to that in abalone waste. A very low percentage of 22:5 n-3 was observed in trout wastes.

The standard approach of comparing lipids is by calculating their n-3/ n-6 ratio. The highest n-3/n-6 ratio in this study was observed for lipids from scallop waste (3.89), followed by prawn heads (2.18). The lowest ratio was obtained with trout waste (0.75).

Some land plants have linolenic acid (18:3 n-3), but the C20 and C22 n-3 HUFAs are only available from water source foods. This emphasizes mans need for seafood as a source of n-3 fatty acids since the human body does not efficiently convert linolenic acid to EPA and DHA. This fact has prompted the proposal that we should change the present method of comparing oils by calculating their n-3/n-6 ratio and consider only the C20 & C22 n-3 content (Pigott et. al. 1987).

According to our data HUFA/n-6 ratios are similar to n-3/n-6 ratios. This is due to relatively low levels of non HUFA n-3s in the lipids.

The lipids from the trout wastes contained a lower percentage of n-3 HUFA (Table 3) than other waste products. The low percentage of HUFA in trout wastes may reflect the fact that these wastes were obtained from cultured fish which probably were fed diets containing low levels of n-3 fatty acid sources.

For the purposes of diet formulations, the absolute quantity of fatty acids, especially EPA and DHA, in the fish meal, rather than the fatty acid profile of its lipids, is the indicative parameter. From this point of view trout waste is a rich source of a variety of fatty acids, due to its high lipid content and a complete fatty acid profile. The amount of total PUFA in trout wastes was the highest among waste materials studied. The amount of HUFA in trout offal was similar to that of other wastes, while in trout flesh it was 16% less than in the scallop waste.

2.5 CONCLUSIONS

Chemical analysis of fisheries by-products investigated in the present research show they are, suitable for use as components of aquaculture diets. They are rich in protein and contain lipids which could be a good source of n-3 HUFA.

Inclusion of fish meals prepared from these wastes in aquaculture feeds may enhance the marketability of aquaculture products.

Scallop by-products were found to be superior to other waste materials, as they have the highest protein content and their lipids have the highest n-3/n-6 ratio.

Trout wastes, especially trout offal, may be considered as a good source of DHA in formulating aquaculture diets.

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