EX- POST BENEFIT-COST ANALYSIS OF THE FISHMEAL REPLACEMENT SUB-PROGRAM

Sub Program 93/120

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Non-technical Summary

In this study, all seven projects in the Fishmeal Replacement Sub-Program were evaluated using the techniques of benefit/cost analysis. Projects under this Sub-Program covered the period 1993 to 1996/97. There were two types of project within the Sub-Program. Five of the projects were species-based, investigating fishmeal replacement in the diets of prawns, silver perch, barramundi (two projects) and Atlantic salmon. The remaining two projects, examining aspects of feed processing and the use of diet supplements, supported the species-based projects.

This Executive Summary provides a brief description of the Sub-Program and the results of the analysis on each of the species-based projects. It is assumed that any benefits of the support projects will be realised through the commercial results of the species-based projects. For the purpose of this analysis, the costs of the support projects are, therefore, spread across the species-based projects. Estimates of the costs and benefits for each of the species–based projects and for the Sub-Program as a whole are provided in Table 1 in the "Concluding remarks" section of this Executive Summary.

<u>Objectives of Benefit-cost Analysis</u>

For a research-funding agency, knowing that a project has met its objectives is not sufficient, it is also important to know if projects being funded are producing net economic benefits. The ultimate purpose is not merely to determine whether it is technically possible to replace fishmeal with low-cost alternatives, but to invest in research that will be used by industry to generate increased wealth. Although technical feasibility is obviously very important, economic viability (the perspective of benefit-cost analysis) is normally the aim of applied research.

The objective of benefit-cost analysis is to measure the net economic benefits that flow from a specific project, such as a research project or a development. To carry out benefit-cost analysis, estimates of the net economic benefits of a project have to be made. Net economic benefits occur when the sum of the benefits is great enough to more than offset the costs, irrespective of whether or not those benefits are used to compensate those who bear the costs. Costs of a project are usually incurred early whilst the benefits are spread out over the life of the project. Comparison is achieved by discounting future benefits and costs to their present value.

Almost every research program, particularly strategic research, also has benefits that are intangible. These may be as important as the quantifiable benefits. Such intangible benefits may include improved research capacity, better communication between scientists and industry and upgraded research facilities. Even though these benefits can be identified, valuation is usually impossible. Nevertheless, these benefits have to be taken into account when evaluating the overall benefits of any research program.

In this analysis, the net quantifiable benefits of the research projects conducted under the Sub-Program are evaluated. An assessment of any intangible net benefits attributable to the Sub-Program as a whole is also presented.

Context of the Sub-Program

Clearly, reductions in the cost of aquaculture feed will increase the profitability of aquaculture, provided production rates are not affected. One approach to achieving this objective is to replace the fishmeal content of feeds with a cheaper, but equally effective alternative. Another way is to increase the efficiency of the feed, so that less food is needed to grow a certain quantity of fish. The third way is to develop feeds which increase growth rates so that the same weight of fish can be grown over a shorter period of time, thus allowing farmers to shorten their production cycle. Yet another approach is to improve the management of the farm, so that the fish are cultured in a way that optimises fish growth, including feeding. This would include consideration of issues such as frequency of feeding and stocking densities.

The Sub-Program focused on the first approach by investigating ways to reduce feed costs through replacement of fishmeal with alternative ingredients available in Australia.

There appear to have been four reasons for choosing this path rather than alternative approaches. First, at the time that the projects were proposed, fishmeal prices were rising, making the potential use of alternative meals increasingly attractive. Second, aquaculture production, particularly in China and South-east Asia, was growing rapidly (and continues to do so) with the implication that there would be increasing pressure on global fishmeal supplies. Third, it was thought that the world supply of fishmeal was limited and that catches of species used in fishmeal, would in the longer term, be directed toward human consumption and no longer be available for aquaculture feeds. Fourth, Australian grain and meat meals were cheap and easily available.

The rationale for reducing feed costs by replacing fishmeal with cheaper alternatives is usually based on the fact that fishmeal normally accounts for about 35-50% of feed production costs[1] in aquaculture feeds and feed costs account for 30-50% of direct operating costs. On the face of it, it would therefore seem reasonable to conclude that replacement of fishmeal with cheaper ingredients would have a significant impact on the direct operating costs of farmers. However, a closer look shows that replacing 50% of fishmeal in aquaculture feeds with an ingredient that costs half the price of fishmeal, results in a reduction in direct operating costs of between 2.6%[2] and 6.25%[3]. If 90% of fishmeal is replaced with another ingredient that is half the price of fishmeal, then direct operating costs will be reduced by between 4.73%[4] and 11.25%[5]. These calculations illustrate the potential net benefit to the farmer of fishmeal replacement in terms of reduced direct operating costs[6].

Although research on alternatives to fishmeal had been carried out in other countries, none of the research had looked at ingredients that were easily and cheaply available in Australia. The Sub-program considered that potential existed to develop new diets for domestic species using these ingredients and, as a result, to increase the export opportunities for these products.

To address these issues, research was carried out to identify ingredients with the greatest potential to replace fishmeal; to determine ways to make the potential ingredients as nutritionally effective as fishmeal (using processing and supplements) and to test the effect of these new diets on fish growth, flavour and smell.

The Sub-Program selected four species (prawns, silver perch, barramundi and Atlantic salmon) with different dietary requirements. As levels of knowledge on nutrition of the four species differed, the projects in the Sub-Program focused on slightly different aspects when investigating the potential for fishmeal replacement with Australian ingredients.

Project 93/120- 02 Fishmeal Replacement in Aquaculture Feeds for Prawns

The research was carried out by the CSIRO Division of Marine Research in Queensland. Laboratory trials with juvenile prawns showed that up to 66% of fishmeal could be replaced with meat meal without affecting growth rates. Plant meals could replace fishmeal, but at much lower levels. No commercial trials were undertaken.

There is only one prawn feed manufacturer in Australia. It has not adopted the findings of the research. This is because the company is focused on producing high performance, high quality diets, rather than attempting to reduce costs through the use of cheaper ingredients. It was suggested that Australian manufacturers cannot compete with south-east Asian manufacturers that enjoy both substantial economies of scale and cheap labour costs, so producing higher quality diets is the most effective market strategy for Australian manufacturers.

The company also mentioned that although sourcing meat meals was straightforward, there are problems in consistency and quality of supplies. With regard to plant meals, the high costs

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1 This assumes fishmeal accounts for 50%-70% of ingredient costs and that ingredient costs are 70% of total feed production costs.

2 If fishmeal accounts for 50% of feed production costs and feed costs account for 35% of direct operating costs.

3 If fishmeal accounts for 70% and feed costs account for 50% of direct operating costs.

4 If fishmeal accounts for 50% of feed production costs and feed costs account for 35% of direct operating costs.

5 If fishmeal accounts for 70% and feed costs account for 50% of direct operating costs.

6 For details of the calculations, see Table 2 in Section 3.2 of the main report.

of transport and processing of some products, such as lupins, makes their use financially unattractive. In discussions with a prawn feed importer and with prawn farmers, it was stated that achieving reductions in feed costs was not a high priority for the industry; lack of wild broodstock and availability of post-larvae were considered to be more pressing issues. They also expressed little confidence in a diet that had not been tested commercially.

As there has been no adoption of the research findings by feed manufacturers, there are no apparent quantifiable benefits from the research. Some benefits may arise in the future, as there is interest in carrying out commercial trials with meat meal based diets on a commercial prawn farm in Indonesia, in collaboration with the Meat and Livestock Corporation. This may create an export opportunity for Australian meat meals. For this reason, Table 1 concludes that future net benefits of this project are considered "possible", meaning that any future benefits are conditional on the commercial adoption of the results of further research.

Project 93/120-03 Fishmeal Replacement in Aquaculture Feeds for Silver Perch

The research was carried out by NSW Fisheries. Research results identified meat meal, poultry meal, dehulled lupins and dehulled field peas as the most promising ingredients with which to replace fish meal. On-station trials showed that meat meal could replace 95% of fishmeal in silver perch diets without any affect on flavour, texture or smell of the fish.

A feed manufacturer developed the diet and carried out commercial trials. The trials were successful and the new diet was marketed in 1998. Discussions with farmers and the feed manufacturer suggest that the diet is now being used commercially and is producing higher food conversion ratios than previous diets. Farmers attribute this to diet formulation and the quality of the pellet. Using the diet reduces farmer's costs by between $150 and $350 per tonne of feed, depending on the type of feed previously purchased. The diet produced by this feed manufacturer now dominates the market in silver perch feeds.

There are both current and potential benefits of this research. Current benefits are in the form of savings to farmers from using lower cost feeds. Lower production costs are likely to lead to increased production of silver perch, and the resulting profits to farmers and feed manufacturers are attributable to the research results. It is possible that consumers may also benefit if the price of silver perch falls because of higher supplies, but in the absence of information on the likely price response this possibility is ignored[7].

Projections of the likely discounted net benefits of the research were carried out, based on the following key assumptions:

- 100% adoption by farmers of the new diet;

[7] A decrease in silver perch prices would, in any case, result in a reduction in profits to farmers. The net effect in terms of overall benefits would depend on the elasticities of supply and demand.

- a 20% annual rate of growth of silver perch production, attributed entirely to lower feed costs until 2003, when a new diet is introduced; and
- the new diet has increased average profit margins of existing farmers by $235 per tonne.

Using these relatively optimistic assumptions, the net benefit of the project is estimated to be marginally positive.

Although the project has been successful in developing a commercially accepted, cost reducing diet, the current small scale of the industry limits the scale of commercial benefits from its adoption. Even allowing for a relatively high rate of industry growth, spurred by lower production costs, the high costs of the research are just balanced by the discounted commercial benefits of the new diet. Apart from these anticipated benefits, Table 1 shows that other future net benefits of this project are considered "possible", meaning that any future benefits are conditional on the commercial adoption of the results of further research. These "possible" benefits are in addition to the projected future benefits of the project.

Project 93/12-04 Fishmeal Replacement in Aquaculture Feeds for Barramundi and Project 95/069 Replacement of Fishmeal in Aquaculture feeds: Improving Nutritive Value of Alternative Feedstuffs using Crystalline Amino Acids

This research was carried out by the CSIRO Division of Marine Research and QDPI. Two projects on barramundi were carried out – the second one, a direct follow-up to the first.

Results of on-station and commercial trials showed that meat meal could replace fishmeal, provided the protein content of the diet was maintained above 50%. Following the success of the commercial trials, the main manufacturer of barramundi diets developed and marketed a meat meal based diet soon after the research was completed. This diet was a failure. Growth rates were poor and one farmer claimed that an outbreak of pancreatic disease in his fish was due to the new diet. Although the reasons for poor growth have not been investigated fully, researchers and feed manufacturers think that the absence of anti-oxidants in the meat meal, exacerbated by poor storage of feeds by some farmers, might have been the cause of the problem.

According to feed manufacturers, the effect of this initial failure of meat meal based diets was to develop an industry resistance to the use of meat meal. Although a feed manufacturer adopted the diet, the commercial failure of the diet means there are no current economic benefits from the research.

However, subsequent FRDC-funded research under the Aquaculture Diet Development Sub-Program has built on the main findings of the fishmeal replacement project. A diet has been developed in response to the needs of farmers who have said they did not want a cheaper diet, but a better performing one. They argued that this would lead to a reduction in production costs anyway, as less feed would be used. Feed manufacturers have adopted the new diet formulation, and their new "high energy" diets appear to be yielding positive results. Although their diet formulations are confidential, some meat meal is being used, probably in the range of 10-20%.

A share of the potential benefits flowing from the adoption of the "high energy" diets is probably attributable to the Fishmeal Replacement Sub-Program as research under this program appears to have contributed to the development of the new diet. For this reason, future net benefits of this project are considered "probable". Apart from these anticipated benefits, Table 1 shows that other future net benefits of this project are considered "probable". This means that future net benefits are conditional on results from further research which have already shown positive results and have been taken up by feed manufacturers.

Project 93/120-05 Fishmeal Replacement in Aquaculture Feeds for Atlantic Salmon

This project was undertaken by the School of Aquaculture, University of Tasmania.

Laboratory trials with juvenile salmon showed that soybean and pea protein concentrates can be added to feeds to replace at least 33% of fishmeal protein without having a significant effect on salmon growth. The research also found that phytase (an enzyme), which breaks down phytate (a carbohydrate) in plants, has the potential to be used in salmon feeds which contain significant amounts of plant meal. Using phytase enables phosphorous to be used by the fish, rather than excreted, which could also have a positive impact on the environment.

One feed manufacturer completely dominates the market for salmon feeds in Australia. This company indicated that none of the research results had been used. As with the other species-based projects, the development of more efficient diets was the priority of industry; not the development of a cheaper diet. Moreover, it was pointed out that fishmeal prices were falling and, as a result, there was no cost pressure to replace this ingredient. However the feed manufacturer did recognise the strategic benefits of knowing that fishmeal can be replaced with alternative ingredients.

As feed manufacturers have not adopted the research results, there are no commercial benefits from the project.

However, if fishmeal prices rise substantially there may be incentive for manufacturers to reconsider the plant meal based diet. Industry noted that stricter environmental standards may also result in the research on phytase contributing to the development of diets that limit the amount of phosphorus released in the water, thus reducing potential environmental compliance costs. Industry representatives considered the project to be valuable strategic research, whose benefits would be realised in the longer term. Apart from these anticipated benefits, Table 1 concludes that other future net benefits of this project are considered "possible", meaning that any future benefits are conditional on the commercial adoption of the results of further research.

Non-Quantifiable Benefits of the Sub-Program

Apart from the costs and benefits ascribed to each of the species-based Sub-Program projects, there are certain non-quantifiable benefits that can be ascribed to the Sub-Program itself.

There is considerable concern about the long-term sustainability of fisheries supporting the production of fishmeal. Consequently, research that contributes to reducing the dependence of aquaculture on fishmeal, will have long term benefits. All species-based projects under the Sub-Program were able to show that fishmeal replacement with Australian ingredients is technically feasible. If economic conditions change, feed manufacturers of prawn, barramundi and salmon feeds, have this information to develop commmercial diets with smaller quantities of fishmeal. Furthermore, research being carried out under the FRDC Aquaculture Diet Development Sub-Program may take the fishmeal replacement research closer to commercial relevance.

There are other pressures relating to food safety and environmental degradation that could also encourage fishmeal replacement. For example, the European Commission recently issued a directive proposing to ban the use of animal products (including fishmeal and fishoil) which contain high dioxin levels. The International Fishmeal and Fishoil Manufacturers Association (IFOMA) has stated that analysis to date indicates current fishmeal and fishoil levels exceed this limit. If the EU directive is enacted, IFOMA believes it would have devastating consequences for the fishmeal and fishoil manufacturing industries and, because of their reliance on fishmeal and fishoil, effectively close down most fish farming (jncluding salmon, trout, seabass and seabream) in Europe. Research that can find ways to reduce the environmental impact of aquaculture, such as the work on phytase be of longer term benefit to industry.

Within the Sub-Program there were sixteen collaborating institutions[8]. Collaboration occurred not only at project level on a day-to-day basis but also at Sub-Program level when all collaborators met at the annual scientific meetings. From discussions with researchers, this collaborative approach to research has greatly improved communication and cooperation between research institutions and has led to a greater sharing of information.

The participation of industry representatives at scientific committee meetings and in the on-going research has led to an improved understanding of the research by industry and increased understanding by scientists of the concerns and priorities of industry.

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[8] NSW Fisheries, Port Stephens; Bribie Island Aquaculture Research Centre. QDPI; International Food Institute of Queensland, QDPI; CSIRO Marine Research; CSIRO Division of Food Science and Technology; Queensland University of Technology; Key Centre for Teaching and Research in Aquaculture, UTAS; SALTAS; NSW Agriculture; Dept. of Farm Animal Medicine and Production, Queensland University.

The Sub-Program has also contributed to the development of expertise in fish nutrition in Australia. This is best demonstrated by the increase in the number of commercial contracts awarded to institutions participating in the Sub-Program. Another indicator is the publication of research findings in peer-reviewed journals and the presentation of papers at international and national workshops and conferences. Papers have been presented to at least seven international symposia and two national workshops.

The skills developed under the Sub-Program have also contributed to the quality of the research being carried out under the new FRDC Sub-Program Aquaculture Diet Development.

Concluding remarks

As shown in Table 1, FRDC's overall investment in the Fish Meal Replacement Sub-Program has not yielded net economic benefits, after accounting for research costs. One project on silver perch diet is estimated to approximately breakeven, based on projections of resulting industry growth and profitability. For the other three species-based projects, results have shown that fishmeal replacement is technically feasible. However, feed manufacturers have not adopted the diets for various commercial reasons.

Table 1: Summary of research costs and benefits for projects in the Fishmeal Replacement Sub-Program

Project	Total cost[1]	FRDC cost[1]	Total benefits	FRDC benefit/cost ratio	Future benefits
1. Prawns	$2,144,137	$ 843,737	$0	Less than 1	Possible
2. Silver Perch	$1,486,218	$ 558,260	$2,044,478	1:1	Possible
3. Barramundi	$1,719,607	$ 346,955	$0	Less than 1	Probable
4. Atlantic Salmon	$ 534,061	$250,527	$0	Less than 1	Possible
Sub-Program	$ 5,884,023	$1,999,479	$2,044,478	Less than 1	Probable

1 Each of the four species projects includes pro rata costs of the two "support" projects (feed processing and technology audit).

The lack of positive returns on FRDC's investment in this Sub-Program is, in some ways, not surprising. Potential benefits of fishmeal replacement are primarily in the form of cost savings from the use of lower cost ingredients. It is, therefore, important to put the potential cost savings of fishmeal replacement in perspective. A simple example illustrates the potential scale of cost savings. If fishmeal typically accounts for 10.5% - 25% of a farm's direct operating costs, and 50% of fishmeal is replaced with an ingredient that is 50% cheaper, then total production costs will be reduced by between 2.6% and 6.3%.

Clearly, the scale of the potential savings is not large given the high costs of the nutrition research and the small size of most aquaculture industries in Australia. These factors weigh heavily against the likely commercial success of the research. A requirement by FRDC for researchers to include a basic quantitative analysis of likely costs and benefits of their research might well have revealed, in these cases, a low probability of net economic benefits being achieved.

In general, researchers, feed manufacturers and farmers who were interviewed[9] acknowledged that the research was strategic in nature and that they did not necessarily expect to see immediate benefits. However, industry representatives emphasised that their needs were for high performance diets that would lead to faster fish growth and shorter

[9] See Annex 1 for list of persons consulted.

production cycles. This approach is now being pursued under the Aquaculture Diet Development Sub-Program.

1 INTRODUCTION

This report is an economic evaluation of projects funded by the FRDC Fishmeal Replacement Sub-Program over the three year period 1993/4 – 1995/6. Initially, six separate collaborative projects were funded under the programme. Four projects focussed on a different cultured species (jumbo tiger prawn, silver perch, barramundi and salmon). The two remaining projects were relevant to all four species. One focussed on feed processing and the other carried out a technology audit of aquaculture feeds. In 1995, a subsequent project on barramundi nutrition was funded by the FRDC under the Sub-Program, and is also included in this evaluation.

Two other projects on nutrition[10], also funded by FRDC, were brought under the umbrella of the Fishmeal Replacement Sub-Program. Although these projects are not strictly part of the Sub-Program as they were funded before the Sub-Program commenced, some of the results are included in this analysis. The projects themselves are, however, not included in this benefit/cost analysis.

2 OBJECTIVES OF BENEFIT-COST ANALYSIS

The objective of benefit-cost analysis is to measure the net economic benefits that flow from a specific project, such as a research project or a development project (e.g., building a dam). A benefit-cost exercise usually proceeds in three stages. First, current and future costs and benefits are identified and valued (in monetary terms). Second, benefits in the future are discounted and added to benefits in the current year to produce discounted gross benefits; the same exercise is applied to current and future costs to produce discounted gross costs. Third, discounted gross costs are subtracted from discounted gross benefits to produce net economic benefits (which is also referred to as the discounted net present value of a project).

There are two major components of net economic benefit - producer's surplus and consumer's surplus. Producer's surplus is a measure of net economic benefits created in the harvesting and processing sector from a specific research project. Although somewhat of a simplified explanation, producer's surplus can be thought of as additional profits generated by a research project. If research findings result in the employment of previously unemployed labour, then the associated wages would also be included as a benefit in producer's surplus.

Consumer's surplus is a measure of net economic benefits to consumers. For example, if a research project induces an increase in production, and that in turn results in a decline in prices on the domestic market, then domestic consumers would be better off. Consumer surplus is simply a measure of this improvement in consumer well being.

In an effort to keep technical jargon to a minimum, economic benefits related to each of the seven projects will be discussed in terms of increased profits, increased wages and other familiar concepts.

Almost every research program, particularly strategic research, also has benefits that are intangible. This may include improved research capacity, better communication between scientists and industry and upgraded research facilities. Even though these benefits can be identified, valuation is usually impossible. Nevertheless these benefits have to be identified and taken into account when evaluating the overall benefits of any research program.

The analysis carried out here therefore looks at the net quantifiable benefits of the research carried out under each project under the Sub-Program, and assesses any intangible net benefits attributable to the Sub-Program as a whole.

In carrying out benefit-cost analysis for the Sub-Program, it became apparent that there was confusion over the difference between attaining the objectives of a research proposal and the results of benefit-cost analysis. For example, if a research proposal has the stated objective of finding low-cost feed substitutes for fishmeal, and if low cost substitutes are found, is the project not a success? Under such circumstances, what is the meaning of benefit-cost results that show zero net economic benefits? Arguably, this is the situation for some of the projects in the Sub-Program, and it is not surprising that researchers find the situation somewhat perplexing.

However, it is important to note that there is a difference between meeting research objectives and evaluating the net economic benefits that flow from research findings. An analogy might help highlight the difference, and illustrate why it is appropriate to employ benefit-cost analysis to examine the latter (as opposed to undertaking an evaluation of the former).

Suppose it was decided to undertake research aimed at producing genetically-modified bananas that would grow in cold-climate northern Canada. Clearly the implicit aim of the project is to create economic opportunities in this region of the country. If researchers succeeded in creating bananas that could be produced cost effectively in cold climates, is the project a success? From a *researcher perspective*, the answer is certainly yes. However, due to transportation, skill shortage or other problems, what if banana production never took off, should the project be considered a success from a *research-funding agency perspective*?

For a research-funding agency, knowing that a project met its objectives is not sufficient, it is also important to know if projects being funded are producing net economic benefits. In the above example, the end game is not merely to determine whether it is technically possible to produce cold-climate bananas, the ultimate purpose is to invest in research that will enable the creation of net economic benefits. Technical feasibility is important, however economic

[10] Project 92/63 "Dietary requirements and optimal feeding practices for barramundi" and Project 93/16

viability (the perspective of benefit-cost analysis) is often the ultimate objective of applied research.

3 THE FISHMEAL REPLACMENT SUB-PROGRAM IN CONTEXT

The nutrition research carried out under the Sub-Program is highly technical in nature. The results have been summarised as simply as possible but it is helpful to explain briefly some core themes running through the Sub-Program. Understanding these themes places the research in the context of the broader issues concerning fishmeal replacement in aquaculture and assists readers who are not fish nutritionists in understanding some of the fundamentals of this type of research.

3.1 Feed Costs in Aquaculture

There are four main ways in which feed costs can be reduced. One way is to use cheaper ingredients that achieve the same growth rates. Another way is to improve the efficiency of the feed so that less food is needed to grow a certain quantity of fish. This can be achieved by using ingredients which have a high nutrient value, can be digested by the fish and give better food conversion ratios (kilos of feed:kilos of growth) and/or better growth rates. The third way is to increase growth rates so that the same weight of fish can be grown over a shorter period of time thus allowing farmers to shorten their production cycle. The final way is to improve the management of the farm, so that the fish are cultured in a way that optimises fish growth, including feeding. This would include consideration of issues such as frequency of feeding and stocking densities.

"Development of more cost-effective feeds for the Tasmanian Atlantic Salmon industry".

Table 2
Effects of 50% and 90% fishmeal replacement on direct operating costs of a fish farm

Fishmeal as a % of feed production costs **Feed costs as a % of direct operating costs**	**50%** **50%**	**35%** **30%**
BASE CASE:	**$**	**$**
NO FISHMEAL REPLACEMENT		
Direct Operating Costs	1000	1000
Feed costs	500	300
Fishmeal costs	250	105
Fishmeal as a % of direct operating costs	25%	10.5%
CASE 1:	**$**	**$**
50% FISHMEAL REPLACEMENT WITH INGREDIENTS WHICH ARE HALF THE COST		
Direct Operating Costs	1000	1000
Fishmeal cost	125.00	52.50
Fishmeal replacement ingredient cost	62.50	26.25
Total feed costs	187.50	78.75
Savings made as a % of direct operating costs	6.25%	2.63%
CASE 2:		
90% FISHMEAL REPLACEMENT WITH INGREDIENTS WHICH ARE HALF THE COST	**$**	**$**
Direct Operating Costs	1000	1000
Fishmeal contribution to direct op.costs	25.00	10.50
Fishmeal replacement ingredient contribution to direct op.costs	112.50	47.25
Total feed costs	137.50	57.75
Savings made as a % of direct operating costs	11.25%	4.73%

The rationale for reducing feed costs by replacing fishmeal with cheaper alternatives is usually based on the fact that fishmeal normally accounts for 35 –50% of the total costs of aquaculture feed [11] and aquaculture feed accounts for 30-50% of direct operating costs. On the face of it, it would therefore seem reasonable to conclude that replacement of fishmeal with cheaper ingredients would have a significant impact on the direct operating costs of farmers. However, as the example in Table 2 shows, replacing 50% of fishmeal in aquaculture feeds with an ingredient which costs half the price of fishmeal results in a reduction in direct operating costs of between 2.63%[12] and 6.25%[13]. If 90% of fishmeal is replaced with another ingredient which is half the price of fishmeal, then direct operating costs will be reduced by between 4.73%[14] and 11.25%[15]. These calculations illustrate that the potential net benefit of fishmeal replacement in terms of a reducing direct operating costs.

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11 This assumes fishmeal accounts for about 50-70% of ingredient costs.

12 If fishmeal accounts for 50% of feed production costs and feed costs account for 35% of direct operating costs.

13 If fishmeal accounts for 70% and feed costs account for 50% of direct operating costs.

14 If fishmeal accounts for 50% of feed production costs and feed costs account for 35% of direct operating costs.

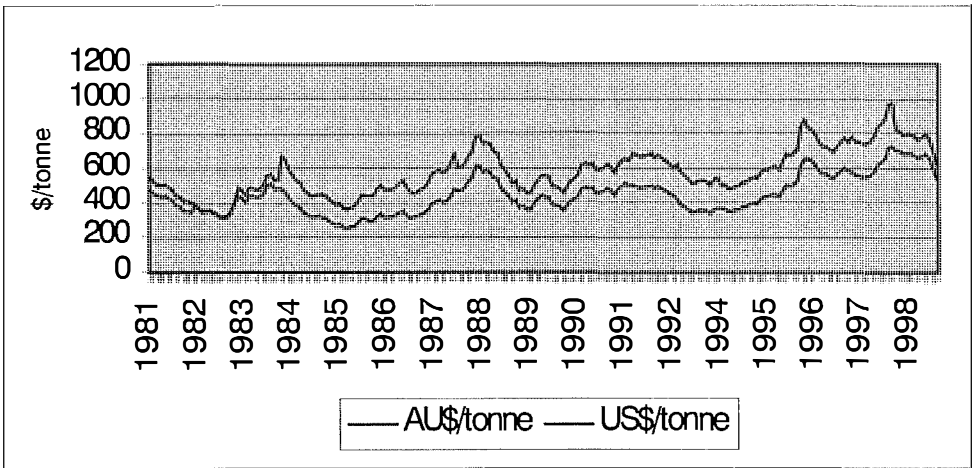
15 If fishmeal accounts for 70% and feed costs account for 50% of direct operating costs.

3.2 Fishmeal in aquaculture

Presently, fishmeal is the major component (50-70% of weight) of aquaculture feeds. Aquaculture feed manufacturers and commercial fish farmers prefer fishmeal because it is considered to be a "natural" dietary component, has high protein levels and because it is highly palatable to the cultured fish species. Quantities of the fishmeal utilised in aquaculture

Figure 1. International market prices for fishmeal (monthly averages), 64/65% protein, any origin, wholesale, CIF Hamburg, Jan 1981-Dec. 1998.

Source: OIL WORLD/GLOBEFISH;ABARE



feeds in Australia have been estimated to be around 12,000 tonnes[16] some of which is produced in Tasmania.

As shown in Figure 1, during the 1990s standard grade (64-65% protein) fishmeal have fluctuated between $500/t to nearly $1,000/t. Aquaculture grade fishmeal (67% protein) commands much higher prices, although time series data was not available. In Australia, due to the small quantities of aquaculture grade fishmeal which is required, the price has reached AU$1500/tonne in the last five years and is currently around AU$1100/tonne. At the time the Sub-Program was designed, fishmeal prices were increasing due to lower anchovy catches in Peru, resulting from the El Nino effect on fish stocks. However, by the time the some of the results from the Sub-Program had been tested under commercial conditions, average fishmeal prices (standard and aquaculture grade) were falling, although the price of aquaculture grade fishmeal was falling more slowly. In the short term, relatively low fishmeal prices means that feed manufacturers do not have an incentive to replace fishmeal unless the price of alternative ingredients is lower than that of fishmeal. In the longer term, feed manufacturers might have

16 Evans, T. Final Report, Fishmeal Replacement Sub-Program Project 93/120-06

an incentive to reduce fishmeal content of their feeds if they see that catches of some of the species used for fishmeal become increasingly directed toward human consumption or that prices of fishmeal are likely to continue to rise, and/or of they see a positive financial advantage to replace fishmeal.

3.3 Alternatives to fishmeal

Compared with fishmeal, most potential replacement ingredients are inferior in terms of total protein, amino acid and carbohydrate content. They also contain anti-nutrients. As plant materials contain significant amounts of carbohydrate, they are better used in diets of herbivorous or omnivorous fish because these species already have the capacity to digest plant material and utilise the starch for energy.

Carnivorous fish, on the other hand, have a limited ability to utilise starch and no capacity to digest non-starch polysaccharides. Efficient alternatives to fishmeal for farmed carnivorous fish are therefore more likely to be found in animal meals.

There are two main problems with meat meals: ash content and saturated fat content. The ash, which comes from bones, has no nutritional value. More importantly, higher ash contents have a negative impact on the environment by increasing the amount of phosphorous deposited in the water. Saturated fats usually have no negative effect on fish, but fish fed diets with high concentrations of saturated fats tend to have a body composition lower in unsaturated fatty acids, which may be a marketing disadvantage.

Some of the deficiencies of plant and animal protein alternatives can be overcome through grinding, cooking and removal of less digestible components as well as by removing carbohydrates (for plant meal) and ash (for meat meal). The addition of enzymes and feed supplements after processing may also help to increase the nutrient availability of animal and plant feeds. Processing technologies such as extrusion can maintain protein quality and produce a product with the desired physical characteristics. Identification of alternative ingredients to effectively replace fishmeal, requires analysis of their " apparent digestibility".

4 Project No: 93/120-06 Replacement of Fishmeal in Aquaculture feeds: Feed Processing Project

Research Agency: CSIRO Division of Food Science And Technology

4.1 Objectives

- To provide protein enriched fractions from grain legumes for nutritional evaluation.
- To evaluate plant polysaccharide materials for their nutritional utilisation and role in aquaculture feeds.
- To produce by extrusion processing a range of commercially acceptable feed pellets with nutritional and physical attributes optimised for selected target species.
- To evaluate the use of encapsulated processes and materials for the incorporation of additives into extruded feeds.

4.2 Background

This project provided support to the four species-based projects on fishmeal replacement. Any new feed formulation, that reduces fishmeal content, requires special processing conditions to produce stable feed pellets. Also, to minimise environmental pollution and optimise efficient production, feeds must be utilised efficiently by the cultured fish. This requires that the pelleting/extrusion process be optimised for each feed formulation.

Most alternatives to fishmeal have less protein and amino acids. This means that there is a need to supplement these feeds with enzymes. Most alternative ingredients to fishmeal contain unwanted carbohydrate or ash. To substitute fishmeal these problems have to be overcome through processing. In order for all the four species based products to formulate feeds which optimised efficiency, the FRDC funded this project as a support project to the four species based projects.

4.3 Research Findings

There were three main components to this research:

(1) A benchmarking study on aquaculture feeds.

(2) Optimisation of diets using extrusion.

(3) The production of protein rich fractions from grain legumes.

4.3.1 Benchmarking Study

An industry survey and benchmark study was carried out to determine the most important physical characteristics of aquaculture feeds for each target species and the methods determined on how these characteristics can be measured. Visits were made to aquaculture feed manufacturers in Europe (salmon feeds) and the USA (catfish feeds) and a survey was undertaken of feed manufacturers in Australia. This information was then used to generate quality benchmarks. It was found that the physical characteristics of Australian prawn and salmon feeds were comparable to leading international salmon and prawn feed producers but the Australian industry had not adopted quality control standards for maintaining the physical characteristics of barramundi and silver perch feeds.

4.3.2 Optimisation of diets using extrusion

Extrusion optimisation trials were carried out for soybean meal, canola meal, cotton seed meal and peanut meal and for complete feeds for silver perch and salmon. In trials with complete feeds, the extrusion process was optimised for feeds in which there was partial replacement of fishmeal by soymeal and lupin and pea-protein rich fractions. After the trials, test diets for the species-based projects were produced. Pea protein fraction behaved most like soybean meal during processing and produced feeds which met target specifications. Lupin protein fraction was satisfactory for inclusion in silver perch diets, but in salmon feeds pellets of only marginal standard could only be produced.

4.3.3 Production of protein-rich fractions

Grain legumes such as field peas, faba beans and lupins have a protein content within the range of 20% - 35%, higher than most cereals. To produce protein rich fractions (i.e. protein concentrates), dry milling and separation technologies can be used. The highest protein concentrations achieved were lupin (51%), pea (50%), faba bean and vetch (47%). Lupin and field peas were selected for further evaluation in the species – based projects.

4.4 Research Recommendations

Specifications should be developed for the physical characteristics for diets of silver perch and barramundi to encourage the production of more uniform and better quality feeds.

4.5 Benefit-cost Analysis

As the research under this project provided support to the four species-related projects, the potential benefits and actual costs have been divided equally between them. In simple terms, the project costs are treated as a fixed cost for the four species-related projects. Any economic benefits realised under these species-based projects are assumed to be partially attributable to this feed processing project.

5 Project No: 93/120-07 Fishmeal Replacement in Aquaculture Feeds: Amino Acid Supplementation of Feeds – A Technology Audit

Research Agency: International Food Institute of Queensland, QDPI

5.1 Objectives

- Carry out a technology audit of current and potential amino acid products for use as nutritional additives.
- Prepare a review article on the results of the technology audit for publication.
- Report the results of the technology audit, including recommendations on how to proceed, to the FRDC.

5.2 Background

The amino acid balance in fishmeal is superior to alternative protein sources. To overcome this, synthetic amino acids are added to fish feeds, but there have been problems with leaching and poor assimilation. A technology audit to determine methods to overcome these problems was considered an important platform for fishmeal replacement research. In response, the FRDC agreed to fund such an audit under the Sub-Program, in support of the four species-based projects.

5.3 Research Findings

A technology audit was carried out of current and potential amino acid products for use as nutritional additives in animal feeds. The research confirmed that the major amino acid forms used in the supplementation of animal diets are produced by fermentation, enzymatic and chemical synthesis technologies. No encapsulated or coated commercially available amino acid products are used in aquaculture feeds.

In the short term, crystalline amino acids will be the major form used for the supplementation of aquaculture feeds based on cheap protein sources. In the long term, there may be potential for peptidic supplements.

5.4 Benefit-cost Analysis

As the research under this project provided support to the four species-related projects, the potential benefits and actual costs have been divided equally between them. The project costs are treated as a fixed cost for the four species-related projects. As in the previous feed processing project, any economic benefit would be realised under these projects.

6 Project No: 93/120-02 Fishmeal Replacement In Aquaculture Feeds For Prawns

Research Agency: CSIRO Division of Marine Research

6.1 Objectives

- To determine, for prawns, the digestibility of alternative protein sources and the assimilation of the nutrients in them.
- To investigate methods of enhancing the digestibility of feeds and feed ingredients.
- To develop methods to enhance the nutrient balance, attractiveness and palatability of diets formulated using alternative protein sources.
- To determine the prawn's protein requirements in relation to different amounts of digestible energy available in the feed.
- To use this information in the continued testing of potentially commercial diets using selected alternative protein sources to replace or partially replace fishmeal.

6.2 Background

Prawn farming in Australia involves intensive culture in earthen saltwater ponds. In 1996/97, Australia produced just over 1500 tonnes of prawns (jumbo tiger and kuruma) with an estimated value of $34 million (Allen, 1999). The contribution of prawn aquaculture to the total value of Australian aquaculture production is just under 8%.

Whilst most tiger prawns are targeted for the domestic market, kuruma prawn production is targeted at the live market in Japan. There is also a growing export market for jumbo tiger prawns. The greatest constraint on expansion of production in Australia is availability of suitable land, wild broodstock and post larvae.

Production and growth rates are amongst the highest in the world, attributed to well-managed ponds using the latest technologies.

Prawns are fed formulated pelleted diets, produced by one domestic aquaculture feed company or imported from feed manufacturers in south-east Asia. Until fairly recently, many prawn farmers considered the quality of the locally produced pellet to be inferior such that the feed market was dominated by imported product.

Typically, feed costs account for 30-40% of total operating costs and are the single largest component of operating costs. In response to the perceived need to reduce the costs of prawn feeds, FRDC funding was made available for prawn nutrition research under the Fishmeal Replacement Sub-Program.

6.3 Research Findings

There were four main components to the research:

(1) Estimation of the digestibility and nutritional values of plant and meat proteins available in Australia.

(2) Calculation of protein energy ratios.

(3) Investigation of methods to enhance their digestibility, palatability and attractiveness of alternative protein sources.

(4) Testing potentially commercial diets using the results from the other components.

6.3.1 Digestibility of plant and animal proteins

A shortlist of potential ingredients (5 plant ingredients, 3 meat meals) was prepared based on criteria that included price, availability and crude protein content. Following trials to test different in vivo methods, a protocol was developed to measure apparent digestibility based on the use of inert markers in the diet and the recovery of those markers in the faeces. This enabled apparent digestibility of the potential ingredients to be estimated. With the exception of canola meal, apparent digestibility of plant proteins was around 90% and for meat meals varied between 74 – 83%. The digestibility of lupins improved if they were dehulled.

Once the method was validated, tank based trials using juvenile prawns were carried out using the selected ingredients. For diets with a total digestible crude protein content of 32%, it was found that growth was not affected if up to 300g/kg of fishmeal and squid meal was replaced by 400g/kg of high ash meat meal. Without taking into account processing and transport costs, it was calculated that, at the time of the experiment, replacement of fishmeal with meat meal represented a saving of AU$122/tonne. At inclusions of 200g/kg or less, the research found that meat meal was interchangeable with soybean meal, with no adverse effects on growth.

Tank based trials with juvenile prawns were also carried out using selected plant proteins. The maximum inclusion levels for wheat gluten was 30%, canola, lupin, dehulled lupins and lupin protein concentrate was 20% and cotton seed meal was 10%.

No effective in vitro method was determined.

6.3.2 Protein Energy Ratios

Following a literature review, experiments were carried out to determine the optimum level of protein and energy to use in commercial feeds for jumbo tiger prawns. The results of the experiments were inconclusive.

6.3.3 Attractants and Palatability

The purpose of feed attractants is to stimulate animals to feed so as to maximise feed intake and growth rates. In existing prawn diets, fishmeal and other ingredients of marine origin are sufficient attractants. If terrestrial ingredients replace fishmeal, then they are unlikely to have the same level of attractant so attractants have to be added.

Experiments with juvenile prawns in tanks were carried out using a variety of commercial attractants. The variability of the results meant that it was not possible to rank all the attractants tested. It was only possible to identify that the most effective attractant was cooked shrimp powder. However it did not give a substantial improvement in feed preference or feed intake when included in diets containing low levels of marine ingredients. Shrimp powder is already highly regarded as a raw ingredient for prawn diets.

6.3.4 Estimate of protein requirements

Research findings did not enable definition of optimal inclusion levels, that would give maximum growth rate with minimum protein content.

6.4 Research Recommendations

- 66% of fishmeal and other marine products can be replaced by meat meal.
- The maximum inclusion levels for wheat gluten was 30%, canola, lupin, dehulled lupins and lupin protein concentrate was 20% and cotton seed meal was 10%.
- Further research needs to be carried out on optimum inclusion levels of protein.
- Further research is required on the cost-effectiveness of using attractants compared to low inclusions of high quality, marine protein meal.

6.5 Benefit-cost Analysis

In simple terms, in order to undertake a benefit-cost analysis, any economic benefits that flow from the research findings need to be estimated and compared to the financial cost of the research, plus any economic costs which are required to capture the benefits.

6.5.1 Potential Benefits

There are three potential benefits in replacing fishmeal in prawn diets with locally available meat and plant proteins:

(1) A reduction in costs of prawn feeds. This could benefit feed manufacturers (by lowering their production costs) and/or prawn farmers if prices of prawn feeds were reduced.

(2) An increase in net employment if decreased production costs led to an expansion of production in existing prawn farms or an increase in the number of prawn farmers. Net employment might also increase in the meat and plant meal industry and the feed manufacturing industry.

(3) An increase in profits made by feed manufacturers and prawn farmers as a consequence of the production expansion described in (2).

(4) A reduction in the price of jumbo tiger prawns paid by domestic consumers.

(5) An increase in export sales and profits of Australian plant and meat meal suppliers to prawn feed manufacturers in other countries.

6.5.2 Realisation of Benefits

Benefits will only arise if, as a result of the research, the feed manufacturers begin to replace fishmeal with meat or plant meals in prawn diets.

Currently there is a dominant manufacturer of prawn feeds in Australia. Discussions were held with the manufacturer concerning the replacement of fishmeal in prawn diets. The main problem facing this company at the time when the research was undertaken was the ability to produce a prawn feed which could successfully compete, in terms of quality, with imported prawn feeds from Thailand and Taiwan. It was not the cost of fishmeal.

Whilst the company recognises that there may be potential long term benefits of having the knowledge that meat meal and plant meal can be used to partially replace a proportion of fishmeal in prawn diets, fishmeal replacement in prawn feeds is not a current priority. In the company's view, current prices of fishmeal, coupled with the demand for good quality prawn feeds, does not justify the replacement of fishmeal with other, terrestrial based ingredients available in Australia.

Sourcing meat meals of consistent quality and supply was mentioned as another disincentive to use meat meals. A disincentive to use plant meals was transport cost for lupins (most lupins are grown in Western Australia) and the high cost of field pea and lupin protein concentrates. The cost of lupin and field pea concentrates is high because two thirds of the product has no current value. Discussions with the feed miller who provided these concentrates confirmed this. Whilst the raw material is relatively cheap, the production of a concentrate of 40-50% protein, means that two thirds of the raw material becomes a by-product (starch) which currently has no ready market. Therefore the real price of the legume concentrate to be used in aquaculture feeds would be at least three times more than the cost of the raw material.

At the start of the project, the interest of the feed company was to improve its product. This has been now been achieved partly with the assistance of a private contract with CSIRO. Today, the priority of the feed company, is to produce high performance diets for the top end of the market (predominantly for kuruma prawn). This would require using the best ingredients in feeds rather trying to compete with South-east Asian producers in the volume prawn feed market, where they have the benefit of economies of scale and lower labour costs.

As the research results from the Sub-Program are in the public domain, international prawn feed manufacturers may also have taken up replacing fishmeal with meat and plant proteins. Following discussions with a prawn feed importer and the President of the Australian Prawn Farmers Association, there is no evidence that fishmeal replacement has taken place other than by using soybean meal which was a replacement to fishmeal before the start of this project. Although prawn feed prices have fluctuated over the last three years, this has been attributed to changes in fishmeal prices and exchange rates, rather than fishmeal replacement.

In discussions with two prawn farmers, the benefit of the research to them was considered negative and not considered a high priority for them. The absence of full commercial trials on the meat meal and plant meal diets did not induce confidence in farmers that such diets would work under commercial conditions. However, the potential long-term benefit for fishmeal replacement was recognised, particularly from an environmentally sustainable perspective.

All those interviewed in the emphasized that using cheaper ingredients to reduce the cost of the prawn feeds was not a high priority of farmers. In terms of prawn nutrition, more important was the development of feeds that produced faster growth rates and higher food conversion ratios with no effect on taste and minimum effect on water quality. This would decrease operating costs as less feed would be used to produce more prawns. Provided the price of the feed was lower than the benefits gained, farmers would be willing to pay a higher price for such feeds.

In discussions with Meat and Livestock Australia, which partially funded some of the meat meal research, the findings have engendered an interest in developing markets for meat meal in the aquaculture feed industry in south-east Asia. Apart from a trial shipment, no meat meal has been exported for sale although there are plans for a large-scale commercial trial in Indonesia.

6.5.3 Costs

The total research cost of the project was $1,945,910 of which FRDC contributed $645,510. Costs of the sub-project 93/120-06 " Replacement of fishmeal in aquaculture feeds- feed processing" and the project 93/120-07 " Replacement of fishmeal in aquaculture feeds - Amino Acid Supplementation of Aquaculture Feeds – A Technology Audit which was applicable to all species related projects should also be added. These costs divided equally between these four projects. For each project, this works out to be $ 198,227, of which the pro rata FRDC contribution is $ 57,741 Thus, the total project cost was $2,144,137 and the FRDC contribution was $843,737.

Other potential costs would be the expenditures of feed manufacturers by adopting the project recommendations.

6.5.4 Net Benefits

The net benefits of this project are assessed to be negative. This is because feed manufacturers have not adopted the research findings. This outcome can be mainly attributed to four factors:

(1) Current relatively low prices and high availability of fishmeal.

(2) Poor reliability and quality of supply of plant and animal proteins available in Australia.

(3) Absence of commercial trials of feeds using meat meal and plant meals.

(4) Demand from prawn farmers for high performance diets rather than cheaper diets.

However, the research may have some long- term strategic benefits by demonstrating that fishmeal replacement is possible in prawn feeds without a negative effect on growth. If fishmeal prices rise dramatically, feed companies may benefit from this information and initiate trials based on the results of this research.

Furthermore, the methodologies developed by the project to measure apparent digestibility are available to feed manufacturers should they wish to investigate other ingredients.

Finally, the development of Australian research capacity in prawn nutrition may have long term potential benefits for the prawn aquaculture industry.

7 Project No: 93/120-03 Fishmeal Replacement in Aquaculture Feeds for Silver Perch

Research Agency: NSW Fisheries, Port Stephens Research Centre

7.1 Objectives

- To identify potential feed ingredients to replace fishmeal in aquaculture feeds for silver perch.
- To evaluate promising ingredients in terms of their *in vitro* and *in vivo* digestibility and assimilation.
- To develop and evaluate methods of improving the usefulness of ingredients through processing (eg. extrusion and cooking) and the use of enzymes and supplements.
- Identify areas where inadequate knowledge of nutritional requirements may restrict fishmeal substitution and determine these requirements for silver perch.
- To formulate and evaluate diets with reduced contents of fishmeal for silver perch.

7.2 Background

Silver perch is an omnivorous native Australian freshwater fish cultured in earthen ponds. The fish is a temperate warm-water species that reaches 500 grammes after an average growing season of 15 – 18 months. Most farms are small, low capital-intensive operations, located in areas where temperatures are most suitable for growth (the Murray River to northern Queensland). Fish are farmed under intensive, semi-intensive or extensive conditions. The industry has grown from 2.6 tonnes in 1992/3 to an estimated to 135 tonnes valued at AU$ 1.5m in 1996/97[17]. Silver perch production contributed 0.3% to the value of Australian aquaculture in 1996/97. Some silver perch farmers are "backyard" farmers whose farm gate sales go unreported. The 1998 unofficial estimate of production is, therefore, around 200 tonnes. Currently, the main market for silver perch is the domestic live fish trade, although potential is thought to exist in the restaurant and catering sectors and the domestic market for fresh or frozen fillets.

Under intensive and semi-intensive conditions, silver perch readily accept pelleted diets. The small size of the industry has meant that little work has been carried out on silver perch diets and silver perch-specific diets were not available to farmers when the project was proposed. As silver perch was an omnivorous freshwater fish having some aquaculture potential, it was included in the FRDC Fishmeal Replacement Sub-Program

17 Allan,G. Aquaculture in Australia:Now and in the Future, World Aquaculture Magazine March 1999

7.3 Research Findings

The research comprised three main components:

(1) identification and evaluation of potential ingredients to replace fishmeal;

(2) methods to measure apparent digestibility

(3) formulation of silver perch diets with less fishmeal content.

7.3.1 Identification and evaluation of potential ingredients

After carrying out a literature review, database search and discussions with animal and plant meal suppliers, a comprehensive list of ingredients was compiled. From this list, the most promising alternative ingredients to fishmeal were identified which included meat meal, poultry meal, dehulled lupins and dehulled field peas. Composition, availability and price were criteria taken into account when selecting these ingredients.

As most potential ingredients are inferior to fishmeal in terms of nutritional composition, processes that would improve digestibility and nutrient utilisation were evaluated. Dehulling and removal of starch and non-starch polysaccharides increased protein content of plant ingredients. Removing bone (ash) from meat meal increased its nutritional value. Steam conditioning and extruding diets improve utilisation of starch. Production of protein concentrates from lupins, field peas and faba beans also improved dry matter and energy digestibility.

There was no conclusive evidence that silver perch responded to the most common dietary supplements.

7.3.2 Methods to Measure Digestibility

Three experiments were carried out to determine the most appropriate measure of in vivo digestibility. The most suitable method for juvenile silver perch was collection of faeces by settlement over 18 hours. The digestibility co-efficients calculated from this method were then used to determine the maximum amount of a particular ingredient that could be used.

In vitro methods were useful for ranking but not for determining digestibility co-efficients for use in diet formulation.

7.3.3 Diet Formulations

Two experimental diets were formulated with minimal fishmeal content (5% and 10%) on a least cost (ingredient cost only) basis. These least cost diets had a mix of ingredients (meat and plant meal) which contained all the required nutrients. The least cost diets were steam conditioned. These were tested with a commercially available non-steam conditioned diet (27% fishmeal) under commercial conditions. Fish grew most rapidly with the experimental diet that contained 5% fishmeal and most of the protein supplied by lamb meal (37%). Compared to the commercially available feed, food conversion ratios were higher in both the experimental diets. This means that a lower quantity of food is required to achieve a certain weight of fish. On the basis of ingredient cost only, it was estimated that the least cost formulation using 5% fishmeal was 25% cheaper than the reference diet that was fishmeal based. From the sensory tests that tested smell, flavour and texture, there were no significant differences between all three diets with the exception that fish fed the diet with the most meat meal, had whiter flesh.

7.4 Research Recommendations

- Australian agricultural ingredients can be successfully used to replace all but 5% of fishmeal in diets for silver perch.
- The most promising alternative ingredients to fishmeal include meat meal, poultry meal, dehulled lupins and dehulled field peas.
- Diets do need to be cooked using steam conditioning or extrusion in order to optimise nutritional value.
- A digestible lysine (protein) content of 1.5% was sufficient for optimum growth.
- On going development in ingredient evaluation, determination of limiting nutrient requirements, diet validation, and determination of optimum feeding strategies is required.

7.5 Benefit-cost Analysis

7.5.1 Potential Benefits

The potential benefits in replacing fishmeal with locally available meat and plant proteins in silver perch diets are as follows:

(1) A reduction in costs of silver perch feeds. This could benefit feed manufacturers (by lowering their production costs) and/or silver perch farmers if prices of silver perch feeds are reduced.

(2) An increase in net employment if decreased production costs led to an expansion of production in existing silver perch farms or an increase in the number of silver perch farmers. Expansion of silver perch farming might also increase net employment in the meat and plant meal and feed manufacturing industries.

(3) An increase in profits made by feed manufacturers and silver perch farmers as a consequence of the production expansion described in (2).

(4) A reduction in the price of silver perch paid by domestic consumers.

7.5.2 Realisation of benefits

Benefits can only arise if the feed manufacturers for silver perch adopt the new ingredients and the cost of the new formulation reduces the production cost of feeds.

Currently, one producer of silver perch feeds in Australia dominates the market. A few other feed manufacturers make small quantities of silver perch diets. Given the small size of the silver perch industry, feed quantities required are very low (an estimated 400 tonnes assuming some underreporting of official production figures) such that feed production is not so attractive for the larger feed companies as they are unable to achieve economies of scale.

Discussions were held with the largest producer of silver perch feed. Respecting commercial confidentiality, the company says it has adopted a diet based on the formulation developed by the project. Their product came on the market in 1998 following on-farm commercial trials. Other feed manufacturers also tried to formulate a diet based on the research findings but seem to have had less success. Farmers mostly attributed this to the poor quality of the pellet, rather than the feed formulation.

In discussions with two silver perch farmers who use the new formulation[18], feed costs for farmers have fallen from between AU$150/tonne to AU$325/tonne, depending on the price of the previous feed they bought. Production rates with the new feed have also improved but there is uncertainty as to whether this has to do with the feed itself, improved pond management or improved pellet quality. One farmer calculated that his direct costs have fallen by 22% when using the new feed, attributing a significant part of that to the development of a silver perch specific diet as well as improvement in pellet quality.

7.5.3 Costs

The total research cost of the project was $1,287,991 of which FRDC contributed $500,519. Costs of the sub-project 93/120-06 " Replacement of fishmeal in aquaculture feeds- feed processing" and the project 93/120-07 " Replacement of fishmeal in aquaculture feeds - Amino Acid Supplementation of Aquaculture Feeds – A Technology Audit which was applicable to all species related projects should also be added. These costs divided equally between these four projects. For each project, this works out to be $ 198,227, of which the pro rata FRDC contribution is $ 57,741. Thus, total project costs are $ 1,486,218 with and FRDC contribution of $558,260.Other potential costs are the expenditures of farmers and feed manufacturers in adopting the project recommendations.

7.5.4 Net benefits

Commercial confidentiality of feed formulations prevents accurate estimation of the cost price of the new feed. Although the project itself estimated the cost of the new diet, these estimates are not accurate as they exclude the cost of transport of ingredients and processing costs.

However, some broad estimates can be made regarding the benefits to farmers and feed manufacturers as a result of using the new feed. Current benefits are the cost saving and, hence, increased profits of farmers as a result of using the new feeds. Future benefits are the profits made by farmers on increases in production that are directly attributable to the introduction of the new diet, and the profits made by feed manufacturers from additional sales of feeds. To provide a long-term perspective on the value of the project, the stream of

[18] one of whom was the President of the Silver Perch Farmers Association

expected annual net benefits is discounted over the estimated life of the new feed, up to 2003. It is then assumed that a new feed will be developed. The expected annual net benefits are detailed in Table 3.

In making these calculations, the following assumptions are made:

(1) Production of silver perch increases by 20% p.a. as a direct result of the new feed.

(2) The price of silver perch is constant.

(3) Average profit margins for feed manufacturers are 10%, assuming a price of AU$900/tonne delivered to the farm.

(4) Average profit margins for farmers as are result of the new diet are $3,160/tonne. All farmers switch to the new diet. Profit margins are just over 8% i.e. $235/tonne.

(5) The savings are realised until the year 2003. After this date it is assumed that new diets would have been developed.

(6) The discount rate is 10%.

(7) Total research costs are used.

As can be seen in Table 3, the project breaks even. Benefits could be greater if any new diet was developed, as a direct result of this research. The results of a sensitivity analysis, show that the project is most sensitive to increases in production.

With regard to increase in net employment in either the ingredient suppliers or feed manufacturing industry, clearly, the dominant supplier of pelleted silver perch feeds is increasing their production. But given the small quantities produced and the fact that the company is involved in the production of other feeds, it is unlikely that there has been an increase in net employment.

With regard to increases in net employment in silver perch farming, lower production costs of silver perch feeds might lead to an expansion of the silver perch industry. How much of the production increases will occur on existing farms using current labour and how much will occur from new entrants is not possible to estimate. However, given the small size of the industry and the character of most of the farms (family-run), net employment is likely to be marginal.

Consumers may benefit from the new feed, if prices of silver perch fall. Given the small size of the market and the lack of information on price elasticity, any estimate of consumer surplus would be very unreliable. At this stage, it is sufficient, to say there may be some benefit.

TABLE 3: ESTIMATED ECONOMIC BENEFITS OF FISHMEAL REPLACEMENT RESEARCH ON SILVER PERCH DIETS

AUS $

Year		1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Annual Production	mt	5	17	29	80	200	240	288.0	345.6	414.7	497.7
Profits of farmers	$					47,000	173,400	325,080	507,096	725,515	987,618
Profits of feed manufacturers	$	-	-	-	-	-	3,600	7,920	13,104	19,325	26,790
Total profits	**$**	**-**	**-**	**-**		**47,000**	**177,000**	**333,000**	**520,200**	**744,840**	**1,014,408**
Research Costs	$	439,459	493,183	552,451	-						
Net economic gains	$	- 439,459	- 493,183	- 552,451	-	47,000	177,000	333,000	520,200	744,840	1,014,408
Net Present Value (NPV)	**$**	27,475									

Sensitivity Analysis	NPV
10% increase in annual production to 22% p.a.	170,393
10% Increase in Profits of Farmers	148,336
Increase in Proft Margin of Farmers from 8% to 10%	81,320

Finally, there may be some non-quantifiable net benefits concerning the development of silver perch diets. The research has encouraged feed manufacturers to develop specific diets for silver perch, which were previously not available elsewhere. This in itself might encourage growth in the industry.

8 Project No: 93/120-04: Fishmeal Replacement in Aquaculture Feeds for Barramundi

Research Agency: CSIRO Division of Marine Research

Project No: 95/069 : Replacement Of Fishmeal In Aquaculture feeds: Improving Nutritive Value Of Alternative Feedstuffs Using Crystalline Amino Acids

Research Agency: Queensland Department of Primary Industries

8.1 Objectives (93/120-04)

- To determine the digestibility of alternative protein (and energy) sources to fishmeal for barramundi using *in vitro* and *in vivo* (faecal and ileal) procedures.
- To assess the animal's assimilation of nutrients from identified feedstuffs using comparative slaughter procedures.
- To determine the effects on diet acceptability (physical characteristics and palatability to barramundi) and growth performance of barramundi when alternative feedstuffs are used as substitutes for fishmeal.
- To compare and validate information gathered on the nutritive value of alternative feedstuffs using growth assay procedures.
- To improve feed formulations and strategies to reduce wastage of feeds and to increase the utilisation of nutrients.

8.2 Objectives (95/069)

- Establish the efficacy of crystalline amino acids in sparing dietary protein for juvenile barramundi.
- Improve the nutritional quality of fishmeal alternatives through the use of crystalline amino acids.
- Improve the nutritional quality of fishmeal alternatives using complementary intact protein sources.

8.3 Background

Commercial barramundi farming started in 1986. Fish are farmed in freshwater ponds, cages in ponds or estuaries, tanks and intensive recirculation systems. Most fish are grown to "plate size", between 350 – 500 grammes which are sold whole in domestic markets.

Most barramundi are farmed in northern Queensland where water temperatures are ideal. In 1996/97 production was estimated to be 496 tonnes valued at AU$5,208 million (Allan,G, 1999). This is 1% to the total value of Australian aquaculture in that year.

Barramundi are carnivorous fish, easily weaned onto pelleted feeds. When farming first started, salmon, trout and imported feeds were used. Feed manufacturers then started to produce specific barramundi diets made from imported fishmeal. Feed costs contribute around 30% of total operating costs (Treadwell et al, 1991).

One of the factors limiting the expansion of barramundi farming was considered to be the unavailability of cost-effective nutritionally adequate diets, specific for barramundi farming. In response to this, the FRDC provided funding for fishmeal replacement research to be carried out under the Fishmeal Replacement Sub-Program.

The first project was aimed at evaluating the suitability of locally available ingredients as alternatives to fishmeal. However, a year before this project was funded, another FRDC-funded project (not under the Sub-Program), was investigating feeding strategies and nutrient requirements for optimising barramundi production. To bring both these projects into alignment, a one year linking project was funded in (95/069). This looked at both the nutritive value of crystalline amino acids and carried out on-farm commercial trials on meat meal based barramundi diets. The on-farm trials were also partially funded by the Meat Research Corporation.

8.4 Research Findings

There were four main components of the research:

(1) Development of methods to determine apparent digestibility of alternative ingredients.

(2) Assessment of the nutritive value and acceptability of fishmeal replacement.

(3) On farm trials of meat meal based diets.

(4) Determination of the nutritive value of crystalline amino acids.

8.4.1 Procedures to measure digestibility

Alternative methods were assessed. It was found that manual stripping of large barramundi produced more reliable digestibility estimates than anal suction collection. Intestinal dissection, which gave reliable digestibility estimates was too costly in terms of labour time and fish. The digestibility marker, ytterbium was preferred over chromium and titanium because of its solubility, precise analytical measurement and absence of toxicity.

In vitro measurement of protein digestibility had a descriptive value in ingredient assessment rather than a quantitative value. Results were variable and did not agree with tests carried out in vivo in fish. A possible pathological accumulation of glycogen and fat in the livers of barramundi was identified but the causes were not.

8.4.2 Fishmeal replacement

Trials were carried out on juvenile barramundi in tanks. The apparent digestibility of two fishmeals, three terrestrial abattoir meals and six plant protein meals were determined. Animal feeds were slightly better digested than plant feeds other than wheat gluten which was completely digestible. Fishmeal was more digestible than meat meal. This was attributed to the high ash content of the meat meal.

When plant protein meals were used to replace fishmeal, the barramundi refused the diet. When meat meal or poultry meal was used to replace fishmeal, the food was accepted by the barramundi and utilised as efficiently as diets based on Tasmanian fishmeal. Experiments with juvenile barramundi showed that they will readily accept diets containing high levels of blood meal and that blood meal may be a useful attractant to improve the unpalatability of other diet components such as casein and plant protein meals.

From these findings it was concluded that meat meal could be used to replace most, if not all, fishmeal. Plant meals were capable of being digested and utilised at an energetic efficiency apparently lower than that for animal protein feeds.

8.4.3 Commercial trials

Two on-farm trials were carried out on a commercial farm. The aim of the trials was to compare growth performance and taste characteristics of juvenile barramundi fed a commercial barramundi diet or experimental diets containing various proportions of meat meal and fishmeal. The result of the trials showed that the meat meal based experimental diets were equal or better than a commercial barramundi diet in terms of growth and efficiency. There was a strong cost advantage to using high ash meat meal as opposed to low ash meat meal, although it was concluded that there may be potential environmental benefits from using low ash meat meal. Using conventional high-ash meat meal as a partial or full replacement of fishmeal in diets resulted in a reduction of ingredient costs (excluding processing and transport) of 16% - 27% of food per unit of weight increase in the fish.

A taste panel liked as much or better fish fed on diets with a high proportion of meat meal with fish oil as a supplement compared to fish fed on a diet with a high fishmeal content.

8.4.4 Effect of Crystalline amino acids

A major difference between animal proteins and fishmeal protein sources is that they have a very different amino acid make-up. Three key amino acids are often deficient which can greatly reduce the nutritive value of the diet. This has been found in pig and poultry diets. In these animals, the use of crystalline amino acids are a proven and cost-effective way to restore the nutritive value of the ingredients.

Three experiments were carried out. The first one looked at how effective crystalline amino acids were in restoring the amino acid balance of a low protein, high meat meal containing diet.

The remaining two experiments compared the effectiveness of crystalline amino acids and protein bound amino acids in a low protein and high protein meat-meal diet. Two types of amino acids were tested: crystalline amino acids and protein bound amino acids. Where there was a critical shortage of an essential amino acid, barramundi conserve it and gain the greatest benefit from amino acid enrichment of the diet. Where the deficiency is not so critical, as in the case of high protein diets, the response to amino acid enrichment was small. In this situation, protein bound amino acids were a more effective supplement.

The deficiency in amino acids by substituting fishmeal with meat meal was found not to affect fish productivity provided the protein content of the diet is maintained above 50% and the fish are fed liberally.

8.5 Research Recommendations

The recommendations are implied from the research findings and are as follows:

Manual stripping is advocated as the best procedure for faecal recovery in barramundi.

Meat protein sources can be used to replace most, if not all, fishmeal.

Provided the protein content of the diet is maintained above 50% and the fish are fed liberally, fishmeal replacement with meat meal is unlikely to affect fish productivity.

8.6 Benefit-cost Analysis

8.6.1 Potential Benefits

The potential benefits in replacing fishmeal with locally available meat and plant proteins in barramundi diets are as follows:

(1) A reduction in costs of barramundi feeds. This could benefit feed manufacturers (by lowering their production costs) and/or barramundi farmers if prices of barramundi feed were reduced.

(2) An increase in net employment if decreased production costs led to an expansion of production in existing barramundi farms or an increase in the number of barramundi farmers. Expansion of barramundi farming might also increase net employment in the meat meal industry and the feed manufacturing industry.

(3) An increase in profits made by feed manufacturers and barramundi farmers as a consequence of the production expansion described in (2).

(4) A reduction in the price of barramundi paid by domestic consumers.

8.6.2 Realisation of Benefits

The two largest feed manufacturers in Australia were producing barramundi diets at the time of the research. At that time, only one of these companies dominated the market. On the basis of the positive results of the commercial trials, this company introduced a new meat meal based diet in last quarter of 1996, only a couple of months after the end of the research project.

The feed was 15% cheaper than other diets but was not successful as it led to very poor growth rates and on one farmer claimed that the fish contracted a pancreatic disease from using the new diet. As a result, farmers stopped buying this feed. Although, the reasons for its failure have not been investigated fully, researchers and feed manufacturers suspect that the problem was caused by the absence of anti-oxidants in the meat meal, exacerbated by poor storage of feeds by some farmers. Farmers, on the other hand, suspect that it was the meat meal itself that was the problem.

According to the two main feed manufacturers and barramundi farmers in northern Queensland, the effect of this was to create an industry resistance to meat meal. Consequently the short term benefits of the project are negative as the diet failed and for the farmers who used the feed, increased their production costs as growth rates were so low.

However, subsequent FRDC funded research under a different Sub-Program (the Aquaculture Diet Development Sub-Program) has built on the research findings of this project. A diet has been developed in response to the demands of barramundi farmers who did not want a cheaper diet *per se*, but a high protein high energy diet which produced faster growth rates and thus led to cheaper production costs. The result of the subsequent FRDC funded project has led to the development of a high performance diet that the feed manufacturers have adopted (although their exact formulations are confidential). Results have so far been very positive with good growth rates being achieved. These new diets, produced by the two largest feed manufacturers do contain some meat meal, but the quantities used are confidential due to the sensitivity of the barramundi industry to meat meal. The range is likely to be between 10 and 20%.

How much of the benefit gained from the high energy diet can be attributed to the project under review is difficult to estimate. These are non-quantifiable benefits. The expertise developed by researchers during the course of the research is acknowledged by farmers and feed manufacturers alike.

8.6.3 Costs

The total research cost of the first project (93/120-04) was $1,031,450 of which FRDC contributed $194,150. The costs of the second project were $489,930 of which the FRDC contributed $95,064. Costs of the sub-project 93/120-06 " Replacement of fishmeal in aquaculture feeds- feed processing" and the project 93/120-07 " Replacement of fishmeal in aquaculture feeds - Amino Acid Supplementation of Aquaculture Feeds – A Technology Audit which was applicable to all species related projects should also be added. These costs divided equally between these four projects. For each project, this works out to be $ 198,227, of which the pro rata FRDC contribution is $ 57,741. This has been added to the total cost of the first project giving a total project cost of $1,229,727. Total costs for both projects were $1,719,607 of which the total FRDC contribution was $346,955. Other potential costs are the expenditures of farmers and feed manufacturers by implementing the project recommendations.

8.6.4 Net Benefits

The net benefits of this project are assessed to be negative. Although one of the main feed manufacturers did produce a diet based on the research results, the poor growth rates and disease problems attributed to the diet led to it being taken off the market within a year. Therefore, there was no reduction in production costs.

However, the research experience and the results obtained during the project have been of benefit to the subsequent research programme on barramundi diet development under the FRDC-funded Aquaculture Diet Development Sub-Program.

9 Project No: 93/120-05 Fishmeal Replacement in Aquaculture Feeds for Atlantic Salmon

Research Agency: School of Aquaculture, University Of Tasmania

9.1 Background

The culture of Atlantic salmon began in Tasmania in the mid-1980s and has grown from a production level of 50 tonnes in 1987 to just over 7000 tonnes in 1996/97. In 1996/97, the estimated value of the Australian salmon industry was AU $63.6 million, contributing around 15% to the total value of aquaculture in 1996/97.

Atlantic salmon is a carnivorous species that spawns in freshwater and can undergo growth and maturation in fresh and seawater. The greatest quantity of feed is required during the nursery and grow-out stage where fish are grown from 70g to 1.5. kg and then to market size (3-4kg). This period takes about 21-24 months. During this time, salmon are fed a pelleted feed which is high in protein (at least 50%) and high in fat. On average, feed costs comprise about 50% of a salmon farm's operating costs.

Compared to many other cultured species, international research in salmon nutrition is highly advanced. Meat meal is not considered suitable because of its high lipid content. Whilst considerable work has been carried out using soybean meals as a replacement for fishmeal, there has been more limited research on other high protein plant meals. In the Australian context, as soybeans are also imported, it was felt important that the potential for plant meals produced in Australia to replace fishmeal in Atlantic salmon feeds should be investigated. In response, Atlantic salmon was included as one of the species under the Fishmeal Replacement Sub-Program. The project was designed to build on earlier FRDC-funded research on methods to measure digestibility of plant proteins in Atlantic salmon diets (93/126).

9.2 Objectives

- To obtain a range of enzyme and feed supplements for use in Atlantic salmon feeds.
- To establish an effective experimental protocol for measuring the food consumption and growth and calculating growth efficiency of Atlantic salmon.
- To establish an effective *in vivo* digestibility method.
- To determine the effectiveness of enzyme supplements and feed components in improving the growth and efficiency of Atlantic salmon:
  - (i) proteases and/or phytase and/or carbohydrases with different soybean meals.
  - (ii) Carbohydrases with cereals.

- To determine the effectiveness of feed supplements and feed components in improving the growth and efficiency of Atlantic salmon:
  - (i) Ferrous sulphate with cotton seed meal
  - (ii) Specialists yeasts with high fat diets
  - (iii) Biosurfactants with high fat diets
- To establish whether improvements in digestibility due to enzyme and feed supplements are translated into improvements in growth efficiency.
- To establish whether *in vitro* digestibility data can be used to screen and select food components and suitable combinations of enzyme and feed supplements for inclusion in Atlantic salmon feeds.

9.3 Research Findings

There were three main components to the research.

(1) Screening and assessment of potential enzymes and feed supplements to improve the utilisation of diets by increasing nutrient availability.

(2) Establishment of an effective method to measure apparent digestibility.

(3) Evaluation of the potential of plant meals available in Australia to replace fishmeal in salmon diets.

9.3.1 Feed additives and enzyme supplements

The original objectives of the project were to investigate the use of commercially available supplements to improve fat utilisation in high fat feeds and to investigate the use of ferrous sulphate with cotton seed meal. Cotton seed meal was later identified as an unimportant ingredient and not investigated. The objectives were changed to allow more detailed and relevant trials on soybean, pea protein concentrate and lupin protein concentrate and on the effect of adding phytase to diets containing only fishmeal protein or a plant protein replacement.

Salmon, which were fed a phytase-supplemented diet showed statistically significant higher wet weight gain. This was mainly because the diet stimulated appetite (so the fish ate more food) and improved the utilisation of phosphorous. The inclusion of other enzymes (lecithin or betaine) had no advantage in terms of growth or feed conversion efficiency of Atlantic salmon. The result of the experiments showed that phytase, which releases phosphorous, has the potential to be used in salmon feeds which contain significant amounts of plant meal.

9.3.2 Methods to measure digestibility

The most appropriate method to measure digestibility of relatively small salmonids like Atlantic salmon, is the collection of settled faecal material in Guelph-type traps. This method provided a large amount of faecal samples without imposing stress on the experimental animals.

Using in vitro methods led to the conclusion that it was difficult to predict differences in the performance of diets when there are small differences between the digestibility of nutrients in the diets.

9.3.3 *Fishmeal replacement*

As modern extruded salmon diets require a high protein content of at least 50%, the research focused on meals and protein concentrates made from soybean, lupin and pea. Experiments were carried out to test the potential for plant protein meals. These established that a pea protein concentrate and a dehulled soybean meal produced the best growth performance. When pea protein concentrate or soybean concentrate was added to replace either 25% or 33% of the fishmeal content, there was a higher weight gain and there was similar growth efficiency. With lupin meal, only 25% of fishmeal could be replaced to achieve similar growth levels. Trials under commercial conditions (parr only i.e. freshwater stage) confirmed these results and found that soybean and pea protein concentrate can be added to replace at least 33% of fishmeal protein without having a significant effect on growth. There was also some evidence that salmon adapted themselves to different diets and as they did so, used these diets more efficiently.

9.4 Research Recommendations

- Relationship between phytase inclusion levels and performance needs to be studied further.
- Further trials are needed on the FinnStimm®, a commercially produced betaine with either amino acids used by the commercial aquaculture industry which affects feed intake.
- Further development to produce high protein plant meals and increased use in salmon feeds.

9.5 Benefit-cost Analysis

9.5.1 *Potential Benefits*

There are potential benefits associated with fishmeal replacement, and benefits associated with the use of enzymes and additives. The potential benefits are:

(1) A reduction in costs of salmon feeds. This could benefit, through reduced production costs, both feed manufacturers and/or salmon farmers.

(2) An increase in net employment if decreased production costs led to an expansion of production on existing salmon farms or an increase in the number of salmon farmers. Net employment might increase in the plant protein industry and the feed manufacturing industry if salmon aquaculture expanded.

(3) An increase in profits made by feed manufacturers and salmon farmers as a consequence of the production expansion described in (2).

(4) Some benefit gained by domestic consumers through a reduction in price of salmon.

(5) An increase in sales of Australian plant meals or to salmon feed manufacturers domestically or internationally and/or an increase in export sales of salmon aquaculture feed.

(6) A decrease in research and development costs of feed companies as enzymes and additives can be screened more cost effectively.

(7) A decrease in the environmental costs of salmon farming by using feeds with additives, which break down harmful phosphorous and nitrogen.

9.5.2 Realisation of Benefits

Benefits can only be realised if the research findings are incorporated into commercial diets for salmon and if this leads to a decrease in production costs of feed manufacturers and/or salmon farmers.

Salmon feed production in Australia is dominated by one company, which supplies 95% of the market. The company produces 20,000 tonnes of salmon, trout and barramundi feeds. The company had some participation in the research project by providing feeds for testing and a representative of the company attending Sub-Program scientific committee meetings.

Discussions were held with this company to ascertain whether they have used the research. It appears that none of the research findings have been adopted, although the feed manufacturers recognise that the findings might have some strategic benefit in the longer term, should commodity prices or exchange rates alter significantly in favour of alternatives to fishmeal. This is affirmed by the fact that this feed manufacturer is co-funding with FRDC a subsequent research project on fishmeal replacement.

The reason for not increasing the amount of plant meal in salmon diets was attributed to the absence of any current cost advantage in switching from fishmeal to alternative ingredients, given current prices of fishmeal.

The company felt that in the longer term it was more feasible to increase the efficiency of feeds than reduce their cost, as this was what the industry wanted. With regard to the work on additives and enzymes, they simply claimed that the research confirmed existing commercial knowledge.

In discussions with the Tasmanian Salmon Farmers industry representative on the Sub-Program scientific committee, the importance of high performance, environmental friendly diets was emphasized rather than the development of low cost diets. In this context, research on the addition of phytase in aquaculture feeds was considered important for two reasons. Firstly, as phosphorous is an essential ingredient in salmon diets, phytase can be added to feeds which are deficient in available phosphorous but contain additional phosphorous bound in phytate. Secondly, breaking down phytate into phosphorous which is utilised by the fish reduces the amount of phosphorous excreted into the water and improves water quality. Although environmental standards in the salmon industry are not as strict as standards in other salmon producing countries such as Norway, the industry anticipates that they might become stricter. Research on phytase could, in the longer term, have benefit to the industry by reducing their compliance costs to environmental standards.

9.5.3 *Costs*

The total research cost of the project was $335,784 of which FRDC contributed $192,786. Costs of the sub-project 93/120-06 " Replacement of fishmeal in aquaculture feeds- feed processing" and the project 93/120-07 " Replacement of fishmeal in aquaculture feeds - Amino Acid Supplementation of Aquaculture Feeds – A Technology Audit which was applicable to all species related projects should also be added. These costs divided equally between these four projects. For each project, this works out to be $ 198,227, of which the pro rata FRDC contribution is $ 57,741. The total project cost was therefore $534,061 of which the FRDC contribution was $ 250,527. Other potential costs are the expenditures of farmers and feed manufacturers by implementing the project recommendations.

9.5.4 *Net Benefits*

The net benefits of this project are assessed as being negative as none of the research findings have been taken up by salmon feed manufacturers. However, in the longer term, there may be some benefit to be gained from the research, provided diets are tested under commercial conditions. Salmon feed manufacturers now have the knowledge that plant meals could replace some of the fishmeal requirement in salmon diets. Should economic conditions change significantly, such that fishmeal is less available or becomes more expensive in relation to plant meals, there may be some economic benefit from the research findings on fishmeal replacement. This might be in the form of reduced production costs, increased profits of salmon farmers and feed manufacturers and a decrease in the price of salmon. However, given that international salmon feed manufacturers have carried out substantial commercial research on salmon diets, it is possible that this information already exists for other plant proteins, so the benefit of the FRDC-funded research will be limited to Australian plant proteins. This might, in the longer term, create an export market for these products.

10 Fishmeal Replacement Sub-Program: Non- quantifiable benefits

Apart from the costs and benefits ascribed to particular Sub-Program projects, there are certain benefits which can be ascribed to the Sub-Program itself but which are non-quantifiable. These are benefits gained from strategic and collaborative research and capacity building in fish nutrition research in Australia.

10.1 Long Term Benefits of Technical Feasibility of Fishmeal Replacement

One of the constraints in carrying out a benefit-cost analysis on this Sub-Program is that most of the research is strategic in nature, so that benefits may only be realised in the longer term. Many of the findings in this Sub-Program were not immediately commercially applicable given current prices of fishmeal and the size of the aquaculture industry in Australia which requires small volumes of aquaculture feed.

There is concern about the long term sustainability of fisheries used in the production of fishmeal. Consequently, research, which contributes to reducing the dependence of aquaculture on fishmeal, may have long term benefits. All species-based projects under the Sub-Program were able to show that fishmeal replacement with Australian ingredients is technically feasible.

This knowledge means that should economic conditions change, feed manufacturers of prawn, barramundi and salmon feeds, have this information to develop commercial diets with smaller quantities of fishmeal. Furthermore, research being carried out under the FRDC Aquaculture Diet Development Sub-Program may take the fishmeal replacement research closer to commercial relevance.

There are other pressures which could also encourage fishmeal replacement concerning food safety and environmental issues. For example, the European Commission recently issued a directive proposing to ban the use of animal products (including fishmeal and fishoil) which contain high dioxin levels. The International Fishmeal and Fishoil Manufacturers Association (IFOMA) has stated that analysis to date indicates current fishmeal and fishoil levels exceed this limit. If the EU directive is enacted, IFOMA believes it would have devastating consequences for the fishmeal and fishoil manufacturing industries and, because of their reliance on fishmeal and fishoil, effectively close down most fish farming (including salmon, trout, seabass and seabream) in Europe.

Also, research that can find ways to reduce the environmental impact of aquaculture, such as the work on phytase, may not be of immediate benefit, but may, in the longer term, be of benefit to the industry.

10.2 Benefits from Collaborative Research

Within the Sub-Program there were sixteen collaborating institutions[19]. Financial support was also provided by three other institutions: the Meat Research Corporation, the Grains Research Development Council and the Australian Centre for International Agriculture Research. Three feed manufacturers provided feeds: Ridleys AgriProducts, Gibsons and Janos Hoey.

Collaboration occurred not only at project level on a day-to-day basis but also at Sub-Program level when all collaborators met at the annual scientific meetings. From discussions with researchers, this collaborative approach to research has improved communication and cooperation between research institutions and consequently led to a greater sharing of information.

Industry representatives were invited and attended scientific committee meetings. There were benefits to this interaction in terms of an improved understanding of the research by industry and increased understanding by scientists of the concerns and priorities of industry.

10.3 Capacity building in nutrition research

The Sub-Program has contributed to the development of expertise in fish nutrition in Australia. This is best demonstrated by the increase in the number of commercial contracts awarded to institutions participating in the Sub-Program. The two largest feed manufacturers have contracted Walkamin Research Station to evaluate and test new feed formulations for barramundi. One feed manufacturer has contracted the CSIRO to carry out work on pellet quality. The main silver perch feed manufacturer is working with NSW Fisheries on improved diets. The main salmon feed manufacturer is involved in a collaborative project with the University of Tasmania on salmon diet development.

Another indicator is the publication of research findings in peer-reviewed journals and the presentation of papers at international and national workshops and conferences. Papers have been presented to at least seven international symposia and two national workshops.

The skills developed under the Sub-Program have also contributed to the quality of the research being carried out under the new FRDC Sub-Program Aquaculture feed Development.

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[19] NSW Fisheries, Port Stephens; Bribie Island Aquaculture Research Centre. QDPI; International Food Institute of Queensland, QDPI; CSIRO Marine Research; CSIRO Division of Food Science and Technology; Queensland University of Technology; Key Centre for Teaching and Research in Aquaculture, UTAS; SALTAS; NSW Agriculture; Dept. of Farm Animal Medicine and Production, Queensland University.

11 Concluding comments

The seven research projects evaluated in this study cover the FRDC Fishmeal Replacement Sub-Program. The main rationale of this Sub-Program was the replacement of fishmeal with Australian meat and plant meals as a way to reduce feed costs and reliance on imported fishmeal. The Sub-Program was conceived and designed at a time of rising fishmeal prices and, on that basis, there were some immediate economic benefits to be gained if the research was undertaken.

However, the cyclical trends in fishmeal supplies and prices have meant that any immediate benefits of the Sub-Program would be very sensitive to changes in the price of fishmeal. Sensitivity analysis, at the time that the research was proposed, together with a brief analysis of trends in global fishmeal production and supply, would have highlighted this. In the short term, feed manufacturers will only replace fishmeal if there is a clear cost advantage in doing so. By the time the results were available, fishmeal prices were falling. There was no longer an incentive to replace fishmeal.

It is also important to put the potential cost savings of fishmeal replacement in perspective. If fishmeal accounts for 10.5% - 25% of a farm's direct operating costs, replacing 50% of fishmeal with an ingredient, which is 50% cheaper, will reduce the contribution faquaculutre feed makes to direct operating costs by 2.6% - 6.3%. Clearly, the scale of the potential savings is not large given the high costs of the nutrition research and the small size of most aquaculture industries in Australia. These factors weigh heavily against the likely commercial success of the research. A requirement by FRDC for researchers to include a basic quantitative analysis of likely costs and benefits of their research might well have revealed, in these cases, a low probability of net economic benefits being achieved.

In general, researchers, feed manufacturers and farmers who were interviewed[20] acknowledged that the research was strategic in nature and that they did not necessarily expect to see immediate benefits. However, industry representatives emphasised that their needs were for high performance diets that would lead to faster fish growth and shorter production cycles. This approach is now being pursued under the Aquaculture Diet Development Sub-Program.

[20] See Annex 1 for list of persons consulted.

12 ANNEX 1: PERSONS CONSULTED

Geoff Allan, Principal, Aquaculture Research, NSW Fisheries, Taylors Beach, NSW

Lewis Atkinson, Manager, Processing Technology, Meat & Livestock Australia, Cannon Hill, Qld.

Robert van Barneveld, Barneveld Nutrition Pty.Ltd. (telephone)

Chris Barlow, Senior Fisheries Biologist, Walkamin Research Station, Walkamin,Qld.

Barry Butler, Blue Ribbon Barra, Mt Molloy, Qld.

Chris Carter, Deputy Head, School of Aquaculture, University of Tasmania, Launceston

Liz Evans, Executive Officer, Australian Prawn Farmers Association, Coffs Harbour, NSW

Rodney Evans, Prawn Feed Importer, Coffs Harbour, NSW

Tony Evans, Extrusion Processing & Food Components,Food Science Australia,CSIRO, North Ryde, NSW

Mark Fantin, President, Barramundi Farmers Assn., Sugarland Barramundi,Edmonton,Qld.

Craig Foster, Pivot Aquaculture(Gibsons), Cambridge, Tasmania

Helena Heasman, NSW Fisheries, Taylors Beach, NSW

Bob Johnstone, Fisheries Economist, Bribie Island Aquaculture Centre,Qld.

Pheroze Jungalwalla, Tassal P/L, Hobart, Tasmania (telephone)

Peter Lee, Technical Manager, AQUATAS Tasmania

Cris Phillips, Barramundi Waters, Mourilyan, Qld.

Greg Pointing, Food Technologist-Process, Goodman Fielder, Summer Hill,NSW

Colin Price, Manager, Sea Ranch Farms, Mossman, Qld

Bruce Rhoades, Silver perch farmer, (telephone)

Andrew Rhodes, Select Nutrition, Windsor, NSW (telephone)

Stuart Rowland, Biologist, NSW Fisheries, Grafton Research Center, Grafton, NSW

Frank Roberts, Manager,True Blu Prawn Farms, Yamba, NSW

David Smith, Nutritional Physiologist, CSIRO Marine Research,Cleveland, Qld.

Albert Tacon, Aquaculture Nutritionist,The Oceanic Institute, Hawaii

Calvin Terry, President, NSW Silver Perch Growers Association, Braunstone, NSW

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