Consumer Attitudes to Feed Sustainability

Scottish Aquaculture Research Forum

Final Report

February 2008

Thistle Environmental Partnership

Acknowledgements

This project was commissioned by the Scottish Aquaculture Research Forum (SARF), and funded by:

- SARF;
- Scottish Salmon Producers Organisation (SSPO);
- Biomar Ltd;
- EWOS Ltd; and,
- Skretting UK and Ireland.

The generous financial support of the above organisations is acknowledged.

The project steering group included representatives of the above organisations as well as Scottish Environment Link and the Federation of Scottish Aquaculture Producers. The steering group performed a valuable and supportive role and their participation is much appreciated.

Consultations and discussions were undertaken with a range of organisations and individuals throughout the supply chain including feed companies, fish farmers, processors and supermarkets as well as wider stakeholders such as non-governmental organisations (NGOs) and academics. They all engaged with interest and their contributions were essential to the successful conclusion of this project.

Valuable assistance was provided by Dr Carrie Ruxton of Nutrition Communications in respect of Chapter Six.

It should be noted that while some comments made by the steering group were adopted, this is an independent report which is presented in good faith and represents the views of the authors.

Executive Summary

1. This study aimed to identify possible barriers to the increased use of plant materials as a partial substitute to fishmeal and fish oil in feed for Scottish farmed salmon. The study included a literature review, consultations and a consumer survey. Key findings are summarised below.

2. There is a ceiling on the world supply of fishmeal and fish oil that have traditionally formed the main ingredients of farmed salmon feed. Aquaculture already utilises the majority of global fish oil and half the supply of fishmeal. Demand from China and other developing economies for these raw materials is forecast to grow. Together with natural fluctuations in production, constraints on the supply of fishmeal and, in particular, fish oil are expected, which could be exacerbated by an El Niño event. Recent times have seen increasing volatility and uncertainty in the costs of fishmeal and fish oil which are causing considerable concern to many elements of the industry.

3. To maintain current production and anticipated worldwide expansion in salmonid aquaculture in a more stable price environment, many consider that there is a need to use alternatives to fishmeal and fish oil.

4. Salmon from Scotland, Norway and elsewhere fed on diets in which fishmeal has been substituted with varying proportions of plant meal are already supplied to the market and sold by most major supermarkets. Although a significant proportion of the salmon on sale in the UK is supplied by Norway from salmon fed on diets substituted with both plant meal *and* plant oil, there is resistance within the supply chain to the production of Scottish salmon fed on plant oil substitutes in particular. Recently, one Scottish fish farmer has started using feed with substituted plant oil in commercial production, while another has commenced trials.

5. This report examines the nature and scope of this resistance, defines key barriers to the use of plant substitution and makes recommendations with regard to overcoming salient constraints.

6. The consumer attitudes study found that consumer attitudes are not a barrier to feed substitution with plant materials providing that the clear health benefits from eating salmon and product quality are unaffected. The Ipsos MORI consumer survey conducted as part of this study indicates that the majority (79%) of salmon consumers are neutral or positive regarding substitution, while 21% are against. The survey suggests substitution would not significantly affect purchasing decisions; for the 3% who would buy less salmon, there were 4% who would buy more.

7. The survey also demonstrates that health benefits and taste were, by far, the two most important reasons for consumers to purchase salmon. The overwhelming majority of consumers did not consider the type of feed or environmental and animal welfare standards as being of prime importance in their purchasing decisions.

8. One of the five supermarkets consulted is receptive towards increased substitution and two more are not necessarily against, while the remaining two do not intend to sell Scottish salmon grown on feed with increased substitution. Since the supermarkets determine, to a greater or lesser extent, the types of feed used, this represents a key barrier to increased substitution. Some fish farmers, particularly those supplying niche markets, are also against increased substitution, while some others, including larger companies and multinationals remain to be convinced or are very much in favour. While the processors raised some concerns, most were positive and they are not considered to represent a major barrier to increased substitution.

9. Since some supermarkets already sell imported salmon grown on substitute oils, and two Scottish fish farmers have recently started to consider such substitute oils, a differential market has resulted, with salmon fed a marine based diet considered, rightly or wrongly, as a premium product. While some consultees suggested that the Scottish industry should maintain a marine based diet (in terms of oil) as a means of differentiation from imported

salmon, the fact that there is a move towards substituting oils suggests that a national approach in this regard will not happen.

10. Those in the supply chain that are not opposed to increased substitution do so on the basis that the human health benefits associated with consuming salmon, along with other quality parameters, fish health and performance are not compromised.

11. The key reason cited by those supermarkets and fish farmers consulted[1] who are against increased substitution is that they consider the use of marine ingredients to be closer to what salmon would eat in the wild and hence the use of fishmeal and fish oil is more natural than plant substitutes. Some also consider that increased substitution would not help make feed fisheries more sustainable since any reduction in fishmeal and fish oil would be taken up by demand from elsewhere and therefore they question the validity of the sustainability argument for increasing substitution.

12. In respect of the supermarkets and fish farmers who are not necessarily against substitution, their key concern is whether the human health benefits of eating salmon will be maintained. Most, if not all, of those consulted, had not seen sufficient information on the levels of highly unsaturated fatty acids (HUFAs)[2] being obtained in *commercial* salmon production to evaluate whether increased substitution, in particular of oils, would be acceptable in this regard.

13. There was no information made available during the study regarding the omega 3 content of farmed salmon fed on diets with substitute oil in Scotland and while data from Norwegian production is available, accompanying information on the diets is not available. Therefore, this data cannot be used to *definitively* demonstrate the omega 3 content of farmed salmon grown on substitute diets in commercial production.

14. All the feed manufacturers confirm that they can produce feed that allows Scottish farmed salmon to meet omega 3 health claims. Extensive commercial salmon production in Norway and limited production in Scotland using plant substituted diets supports these claims.

15. To facilitate the wider acceptance of substituted diets, it is recommended that the feed industry presents data on the levels of HUFAs achieved in farmed salmon in commercial production and confirms that these meet relevant health claims. Data should be clear, transparent, independently verified and easily understood by non-specialists. Consideration should be given to a supply chain forum to present data and discuss the concerns of individual companies.

16. Increased plant substitution will, in general, reduce levels of contaminants associated with some raw materials used in fish feed derived from marine sources. This could be beneficial for vulnerable groups such as pregnant women and young children where the Food Standards Agency (FSA) recommends upper limits on the amount of fish that should be consumed and should be discussed with the FSA.

17. The need for some producers to conform to production standards that limit the use of plant substitutes represents a further barrier to the increased use of substitutes in Scotland. Smaller and medium sized companies do not have sufficient flexibility to grow to different standards and tend to produce to the 'higher' specification only – even when only a proportion of their production is destined to be sold under this standard. It is recommended that these standards are amended. Consideration should be given to emphasising the omega 3 levels of the harvested salmon rather than the content of the feed.

[1] Consultations were held with five supermarkets (Asda Stores Ltd, J. Sainsbury PLC, Marks and Spencer Group PLC, Tesco Stores Limited and Waitrose Limited) and ten fish farming companies (Highland Salmon Ltd, Hjaltland Sea Farms Ltd, Lakeland Group, Loch Duart Ltd, Marine Harvest Scotland, Migdale Smolt Ltd, Pan Fish UK Ltd, Scottish Sea Farms, Wester Ross Fisheries Ltd and West Minch Salmon Ltd).
[2] HUFAs are essentially provided from fish oil in the diet of farmed salmon and give salmon it's highly regarded properties in relation to human health.

18. Although substitution with plant oil may help conserve the use of use of fish oil, it will not in itself ensure the sustainability of feed fisheries. Available fish oils will probably be consumed by other users and strict management coupled to responsible sourcing will be required to ensure the sustainability of supply. It would be helpful to initiate a well informed debate within the supply chain as a whole in order to seek a consensus on the best way to manage substitution, while optimising sustainability and satisfying consumer demand.
19. The environmental sustainability of using plant derived meals and oils is examined in this report. Feed manufacturers have taken positive steps to address sustainability issues regarding the sourcing of plant substitutes; two of the three manufacturers source some or a majority of soya products from ProTerra certified producers, and one has engaged with the soya Roundtable.
20. It is recommended that an industry-wide approach to the sourcing of soya and, if appropriate, palm products from certified sources only is adopted, together with continued engagement with the relevant Roundtables. The industry should also ensure that all raw materials are obtained from sources certified as sustainable. The industry should also engage with ProTerra to see whether information about compliance with individual clauses of the ProTerra standard could be made publicly available to increase transparency.
21. While there are unlikely to be significant impacts on the marine environment from the use of plant substitutes, research was not identified in this area and it is recommend this be considered in the future.
22. This project did not include the use of animal by-products, discards and increased use of trimmings as alternative sources of raw materials, nor did it address the socio-economic issues concerned with both marine raw materials and plant substitutes. A wider debate should consider these issues.
23. It is recommended that the reasons for substitution with plant based materials be clearly and accurately communicated in order to provide transparency to stakeholders.
24. Research suggests, and current commercial practice in using plant substituted diets for salmon demonstrates, that flesh quality (taste, odour, colour etc.) together with fish health, welfare and performance are not compromised. Nevertheless, concerns over product quality and fish health remain an issue for some fish farmers and supermarkets and it is recommended that information in this regard be presented to the supply chain and that a mechanism to disseminate research in a form accessible to non-specialists is implemented by the industry.
25. Overall, the evidence presented in this report and the associated consumer survey suggests that the most significant barrier to the partial substitution of Scottish salmon diets with plant materials is concern in regard to the potential impact on the HUFA content of salmon amongst some downstream elements of the supply chain. This may be addressed by initiating dialogue and sharing information. While acknowledging that there is a 'premium' market which will continue to demand product fed on marine-only diets, this represents a relatively small proportion of the total volume of production. There are no significant reasons why the majority of Scottish salmon should not be produced on diets partially substituted with plant derived meal and oil.

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1.0 Introduction

1.1 Introduction to the Project

Thistle Environmental was commissioned by the Scottish Aquaculture Research Forum (SARF) in January 2007 to investigate UK consumer attitudes to aquaculture feed substitution[3]. The project brief stated that the aim was to "reduce the Scottish industry's use of wild fish stocks."

The objectives of the project were to:

1. Provide a review of relevant literature.
2. Engage key players in the supply chain (feed manufacturers, fish farmers, processors and retailers) to gain an understanding of their opinions and the practical constraints on using substituted diets.
3. Provide a comprehensive, independent assessment of UK consumer attitudes towards the use of non-marine, plant based feed substitutes.
4. Based on the results of objectives 1-3 above, identify the barriers to the use of non-marine feed substitutes.
5. Make recommendations in respect of overcoming the constraints to the use of non-marine based feed substitutes.

The project was split into the following two phases, both of which are addressed in this report:

1. Literature review and consultations; and,
2. Consumer attitudes survey.

The project is concerned with the Scottish salmon industry and plant based feed substitutes. It excludes non-plant based substitutes such as feather and blood meal, the use of fish trimmings and discards, and species other than salmon. The project includes environmental issues relating to the sustainability of substitutes, including sourcing and use, but excludes consideration of genetically modified crop substitutes.

1.2 Rationale for the Project

Farmed salmon in Scotland are fed on commercial fish feed manufactured by several companies. The two main elements of the diet are protein and lipid. The former has typically been provided by fishmeal and the latter by fish oil. Both fishmeal and fish oil can be replaced or substituted in salmon feed to a greater or lesser extent with plant based materials. Substitution might be undertaken for a variety of reasons as listed below.

- Supply (price and availability of raw materials for use in aquaculture feed production);
- Production (the need to blend different raw materials to obtain the desired feed product);
- Food safety (plant based materials typically have lower levels of contaminants than those of marine origin);
- Environmental sustainability (certain marine raw materials may be associated with over-fishing); and
- Social sustainability (social and equity issues have been raised with respect to the Peruvian anchovy fishery (Hatziolos *et al*, 2006; Deligiannis, 2000).

[3] Additional assistance was provided by Nutrition Communications in respect of Chapter Six.

For the Scottish salmon industry, supply and production issues are arguably the most relevant, although food safety is a continual priority.

Most Scottish salmon is grown on feed where a proportion of the fishmeal has been substituted with plant meal. Conversely, for fish oil, just two Scottish farmers are using substitutes (one as a trial). Overseas, salmon feed typically uses a higher proportion of meal substitution and usually substitute oil. However, while imported salmon grown are sold in UK supermarkets, there is general resistance from the supermarkets to procuring Scottish salmon fed on similar diets.

The Scottish Executive's 2003 document 'A Strategic Framework for Scottish Aquaculture' set out "the way forward for the industry." This strategic document was a product of the Ministerial Working Group on Aquaculture; it established a shared vision for the industry central to which is sustainability. On the issue of feed sources, the Framework states that the industry should use feed from sustainable sources and give consideration to non-marine ingredients.

Many within the Scottish industry consider that substituted diets could be used to a greater extent, although there is a divergence of opinion as to where the barriers to greater substitution lie within the supply chain. This was emphasised at a Scottish Executive workshop in 2006 where it was considered there was a need to investigate these barriers.

1.3 Report Structure

Section One provides the introduction and approach taken to the project. Section Two presents the results of the consumer attitudes survey. Section Three addresses the findings of the literature review with individual chapters focusing on particular issues, starting with data on feed substitution to provide a background to the report. Section Four presents the findings from the consultations (although some material is also included in Section Three where appropriate). Finally, in Section Five, key themes emerging from the report are discussed in Chapter Thirteen, followed by the conclusions and recommendations in Chapter Fourteen.

References

Deligiannis, 2000. Peru's Ingenuity Gap. Constraints on the Management of Natural Resources and the Crash of the Peruvian Anchovy Fishery. University of Toronto.

Hatziolos, M. and Haan, C. Increasing the Benefits form the Fisheries Sector through Policy Reform, 2006.

2.0 Approach

2.1 Literature Review

The literature review included published and 'grey' sources and considered:

- Fish health, welfare and production characteristics when fed on substituted diets;
- Environmental impacts of substituted diets in terms of sourcing and feeding;
- Product quality for consumers when using substitute diets/'finishing'[4] protocols;
- Use and sourcing of substitute diets in other producer countries; and,
- Presence in the UK market place of imported products.

There is a wide range of literature relevant to this subject and, due to time constraints, it was necessary to limit research to key papers and documents. Initial discussions on salient references with the Steering Group were followed up with an internet search, research through the University of Stirling's Institute of Aquaculture and sources identified by consultees.

2.2 Consultations

A key element of the project was to consult significant players in the supply chain of the Scottish industry. The consultation process was informal and by invitation. Organisations were approached across a wide spectrum of stakeholder interests; most responded positively, although several declined to participate. The consultees (listed in Appendix A), included representatives from the feed industry, fish farmers and their associations, fish processors, retailers, representatives of major producer schemes and NGOs.

The majority of consultations were face to face meetings, with the remainder by telephone. A structured approach was taken based on discussion sheets developed early in the project and refined on the basis of the literature review and initial consultations. The topics addressed are included as Appendix B.

Consultations were confidential unless otherwise agreed. Confidentiality has been maintained in the report either by the aggregation of comments or reference to companies by terms such as the 'first' or 'second' company. It should be noted that the use of such descriptors bear no resemblance to the order in which consultees' views are presented.

The purpose of the consultation process was to ascertain each consultee's factual understanding, knowledge and beliefs related to plant substitution in salmon diets. The views and opinions expressed in the consultation sections of this report may not reflect the actual state of knowledge of a given subject area, nor do they necessarily reflect the policy or approach of the consultee's organisation. The information presented serves to summarise the nature and diversity of opinion but should not necessarily be interpreted as factually accurate or representative.

A number of consultees discussed product schemes such as the Tartan Quality Mark (TQM) or Label Rouge; summary information of relevant schemes is included in Appendix C.

[4] A diet used in the latter stages of salmon production to restore levels of omega 3s (see Chapter 6).

3.0 Consumer Attitudes Survey

3.1 Introduction and Approach

A survey to assess the views of consumers towards the use of substituted feed in farmed salmon was undertaken by Ipsos MORI. Prior to the survey a brief literature search was undertaken, although no references with direct relevance to this project were identified.

The survey questions were developed in conjunction with MORI with input and approval from the Steering Group. MORI's report is presented below. MORI also provided technical details on the survey (including fieldwork, sample design, weighting and data processing, statistical reliability and definition of social grades) as well as the topline[5] results; these are presented in Appendices D and E respectively.

3.2 Objectives

The main objectives of the study were:

- to investigate salmon consumers' awareness of the diet used in salmon farming;
- to establish whether salmon consumers think farmed salmon should be fed predominantly fish or plant diets;
- to discover whether a change in the diet of farmed salmon could lead to any changes in consumption.

3.3 Methodology

The questions were tested in a pilot of 20 interviews, using paper questionnaires. This was conducted by Ipsos MORI over the weekend of 16th-17th June in Manchester.

The nationally representative main survey involved 1987 interviews with adults aged 15+ spread across Great Britain. It was conducted by Computer Assisted Personal Interviewing (CAPI) as part of Ipsos MORI's regular CAPIBUS survey. Results for the main survey only are presented in this report. The questionnaire was not changed in light of the pilot.

Data have been weighted to reflect the national population profile. For further details of the sampling procedure, quotas and weights applied please see the Technical Details Appendix.

3.4 Interpretation of Data

When interpreting the data, it is important to note that:

- overall survey findings for samples of around 1,000 carry a margin of error of around plus or minus three percentage points (see Technical Details Appendix).
- percentages for certain questions (i.e. 1a, 2, 3 and 4) can add up to more than 100% since respondents could choose more than one answer.
- percentages are rounded to the nearest whole number. This means that the percentages for some questions may add up to more than 100%.

[5] "Topline" means the initial results from the survey prior to any secondary analysis, such as by gender or social grade. Appendix E also includes the full survey questions.

3.5 Publication of Data

Our standard terms and conditions apply to this report. No press release or publication of the findings of the survey shall be made without the advance approval of Ipsos MORI. Such approval will only be refused on the grounds of inaccuracy or misrepresentation.

3.6 Summary of Main Findings

Frequency of Consumption (Question 1)

Three fifths (60%) of people eat salmon or salmon based products. The remaining two fifths (40%) either never eat salmon or say they do not know or that it varies. 41% of people eat salmon at least once a month, including 15% who eat salmon about once a week and 6% who eat it more than once a week.

Women eat salmon more frequently than men. 24% of women eat it at least weekly compared to 17% of men. 43% of women eat it monthly or more versus 37% of men.

People from more affluent social classes are more likely to eat it than those from less affluent ones: three quarters of ABs (73%) eat it compared to only half (49%) of DEs. More affluent social classes also eat it more frequently: 30% of ABs eat it at least weekly but only 14% of DEs do. The biggest differences in frequency of consumption are between ABs and all of the other social classes (C1, C2, D and E).

In terms of readership groups, three quarters (77%) of broadsheet readers eat salmon, compared to two thirds (67%) of mid-market readers and half (51%) of tabloid readers.

The highest concentrations of weekly consumers are to be found in the South East (26%), South West (29%) and West Midlands (28%). Weekly consumers are least concentrated in the North West (17%), Scotland (18%) and Yorkshire & the Humber (17%). Three quarters of people in the South West (75%) consume salmon compared to only half in Scotland (50%) and the North West (49%).

All subsequent questions were directed to the 1,155 people who responded to Question 1 that they ate salmon. The exception was the final question which was asked to a smaller group of 477 persons.

Places Bought (Question 1a)

83% of consumers who purchase salmon obtain it from supermarkets, most usually Tesco (29% of consumers), Sainsbury's (22%), Asda (17%) and Morrisons (12%). Within these supermarkets, salmon is most frequently bought by these social classes: Tesco – C1s (33% of that supermarket's salmon purchasers), Sainsbury's – ABs (26%), Asda – DEs (21%), Morrisons - C2s (18%).

In contrast to supermarkets, fishmongers (9%) and markets (5%) are used by only a small minority of salmon purchasers. A larger proportion of ABs (13%) obtains salmon from a fishmonger than DEs (3%). The use of markets is not significantly different across different social classes.

The major supermarkets are used by similar proportions of frequent and infrequent salmon consumers. In contrast to this, more frequent consumers are more likely to use fishmongers than less frequent consumers. Only 8% of consumers who eat salmon less than once a week obtain it mostly from a fishmonger. This rises to 13% of weekly consumers and 15% of consumers who eat salmon more than once a week.

Where Salmon Comes From (Question 2)

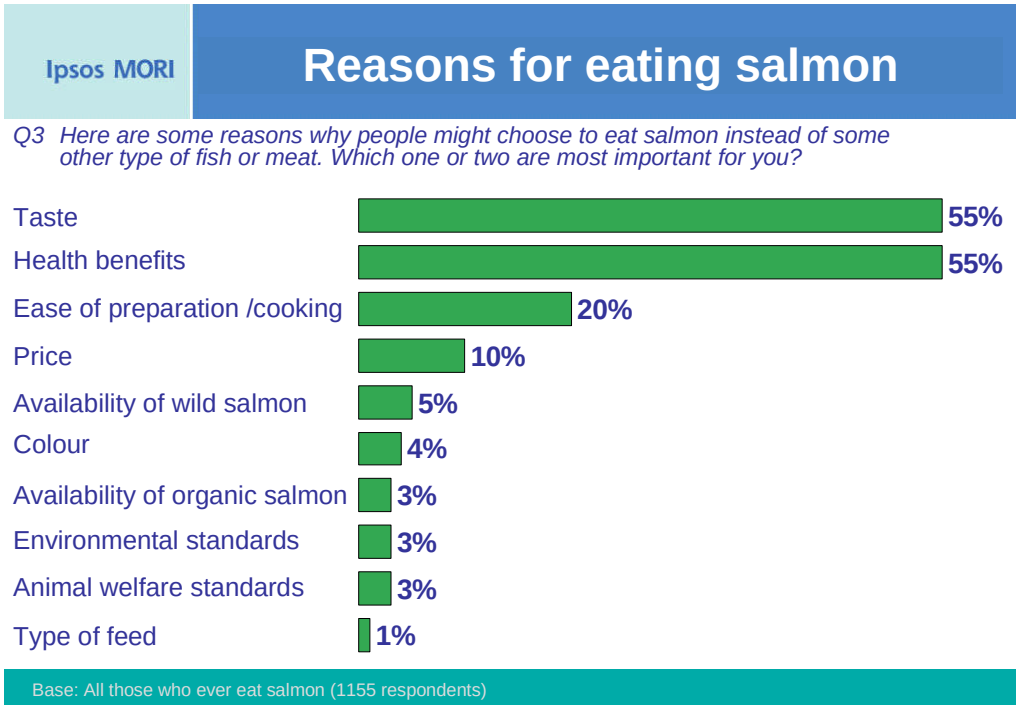
Only 14% say they do not know the origin of the salmon they eat. Almost half of consumers (46%) think that most of the salmon they eat is reared in farms. Organic farmed salmon was mentioned by only 7% of consumers, compared to 42% who name non-organic farmed salmon as one of the most common sources of the salmon they eat. More affluent social classes are more likely to think that their salmon is reared. Just over half (51%) of ABs think their salmon is reared, compared to only a third (33%) of DEs.

A third of salmon consumers (33%) think their salmon mostly comes from Scotland. Other geographical sources such as Alaska (12%), Canada (12%), Norway (5%) and Chile (less than 1%) are much less frequently mentioned. Scottish consumers are the most likely to think their salmon comes predominantly from Scotland. Almost half of them (47%) think this, compared to 33% of consumers across the whole country.

Most Important Reasons for Eating Salmon (Question 3)

Respondents were then informed that a lot of the salmon sold in Britain comes from fish farms. They were then given a list of reasons for choosing salmon and asked which was important for them.

Taste (55%) and health benefits (55%) are the main reasons people buy salmon. Ease of preparation/cooking (20%) and price (10%) are notable, but much smaller influences. Broader considerations about how the fish are produced are much less important. Only 8% of purchasers are influenced by availability issues. Environmental and animal welfare issues are important for only 5% of purchasers. The feed that the salmon receive is currently not seen as important.



For salmon eaters as a whole, taste and health benefits are important for the same proportion of consumers (55%). Looking at the same two factors split by gender reveals that taste is important for more men (58%) than health benefits (48%). The reverse is true for women, of whom 61% are motivated by health benefits against 53% who are driven by taste. The relative importance of taste, health benefits and other reasons for eating salmon does not vary between more and less affluent social classes or between the readers of different types of newspaper.

The relative importance of taste and health varies according to how frequently consumers eat salmon. Reading across the table from the left reveals these variations.

Reasons for eating salmon

	Eat salmon more than once a week	**Eat salmon about once a week**	**Eat salmon less than once a week but more than once a month**	**Eat salmon less than once a month**
Base: All who ever eat salmon	*(114) %*	*(300) %*	*(390) %*	*(382) %*
Taste	63	44	61	59
Health benefits	59	69	55	44

Source: Ipsos MORI

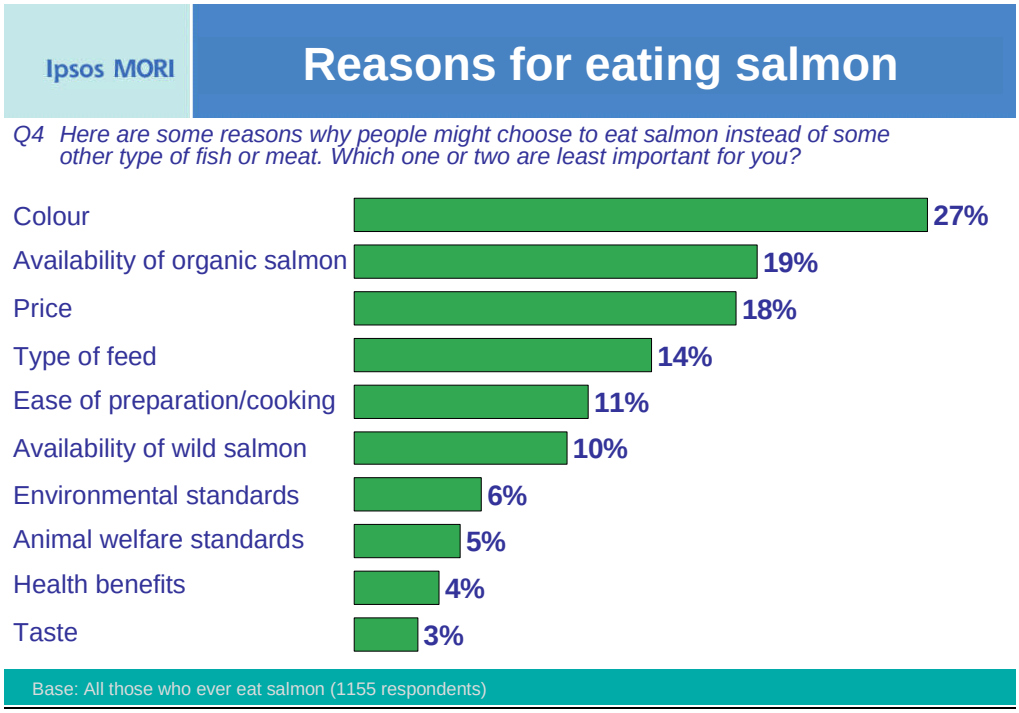
The first column shows that the most frequent consumers are motivated by taste and health benefits in similar proportions. For weekly consumers, health benefits are much more likely to be a factor. The final two columns show that less frequent consumers are focussed more on taste than health, with the least frequent consumers the least likely to mention health benefits.

Waitrose and M&S provide more detailed animal welfare and environmental impact information on their packaging than many of their supermarket competitors. Despite this, environmental and animal welfare standards are no more likely to be the main reason to buy salmon for their customers than they are for consumers as a whole. Similarly, there is not a significant difference between their opinions and those of customers of other supermarkets.

Consumers in the regions who consume salmon most often (South East, South West and West Midlands) are more likely to be influenced by taste than by health considerations.

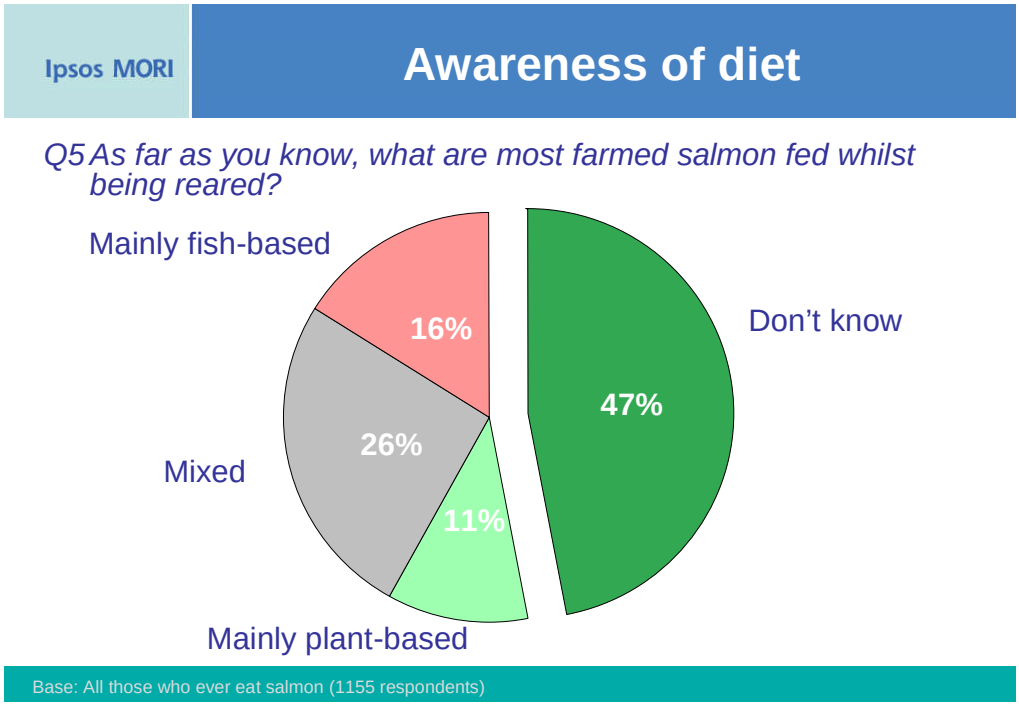
Least Important Reasons for Eating Salmon (Question 4)

Factors that are less important to consumers include colour (27%), availability of organic salmon (19%), price (18%) and the type of feed that the salmon are fed (14%).



Awareness of Salmon Diet (Question 5)

Question 5 asked about awareness of salmon diets. There are essentially two correct answers, either that salmon are fed on a mainly fish based diet, or a mixed fish and plant diet. 42% of consumers selected one or the other of these categories which is higher than may have been expected and suggests either that consumers have greater knowledge, or that some may have guessed.

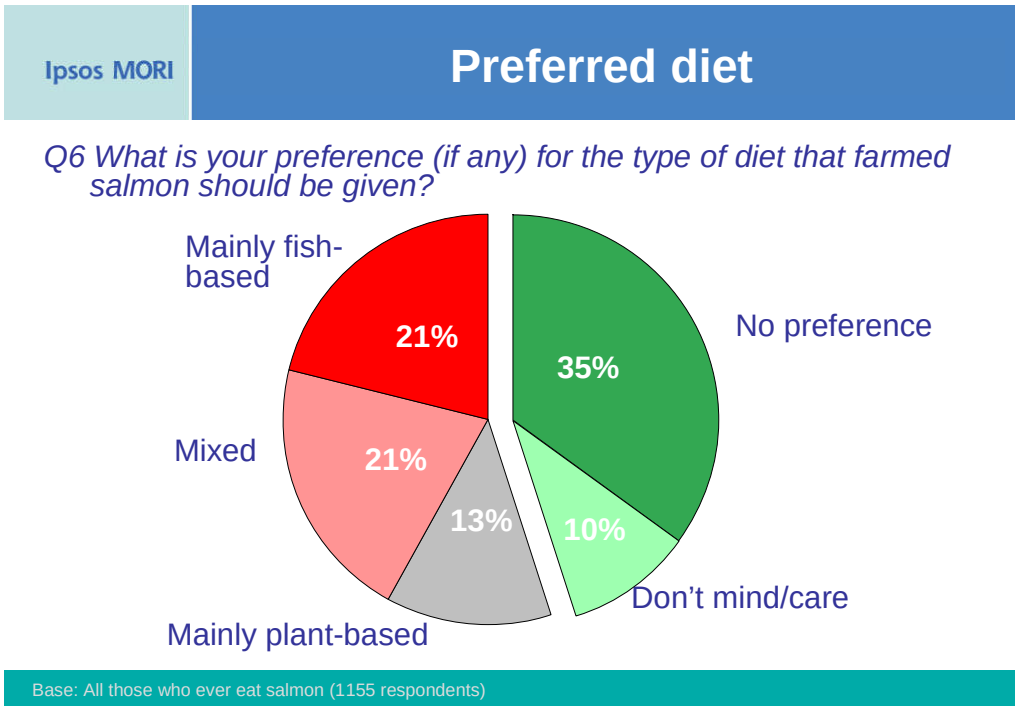


47% of salmon consumers say that they do not know what the fish are fed. More women (53%) say that they don't know than men (42%). Newspaper readership makes less difference to awareness of the issue than might be expected. Broadsheet readers (45%) are less likely to say they don't know what salmon are fed than mid-market (51%) or tabloid readers (49%). Frequency of eating salmon makes little difference to awareness of the issue.

Preferred Salmon Diet (Question 6)

Question 6 began by giving participants some background information about the types of diets that salmon can be fed: "a fish based diet is closer to what salmon would eat in the wild, while a more plant-based diet can help to ensure that stocks of fish used to feed salmon are conserved for the future."

The findings suggest that consumers do not have a clear single preference, with 21% choosing both mainly fish-based or mixed diets and 13% a mainly plant-based diet. Preferences for the different diets do not vary noticeably between different groups of consumers.



Only just over half of consumers (55%) have any preference about what the fish are fed. 45% either have no preference or do not mind or care what the salmon are reared on. This lack of preference does not vary greatly between different groups of consumers. More frequent consumers are no more likely than less frequent consumers to have a preference.

At face value, this suggests that just 13% of consumers might be in favour of substitution. However, if we look on this the other way, there are 35% who have no preference and a further 10% who don't mind or care. These 45%, along with the aforementioned 13% who are in favour of a mainly plant-based diet, mean that almost six out of ten, (58%) either do not mind or are in favour of substitution.

Change in Salmon Diet and Purchasing (Question 7)

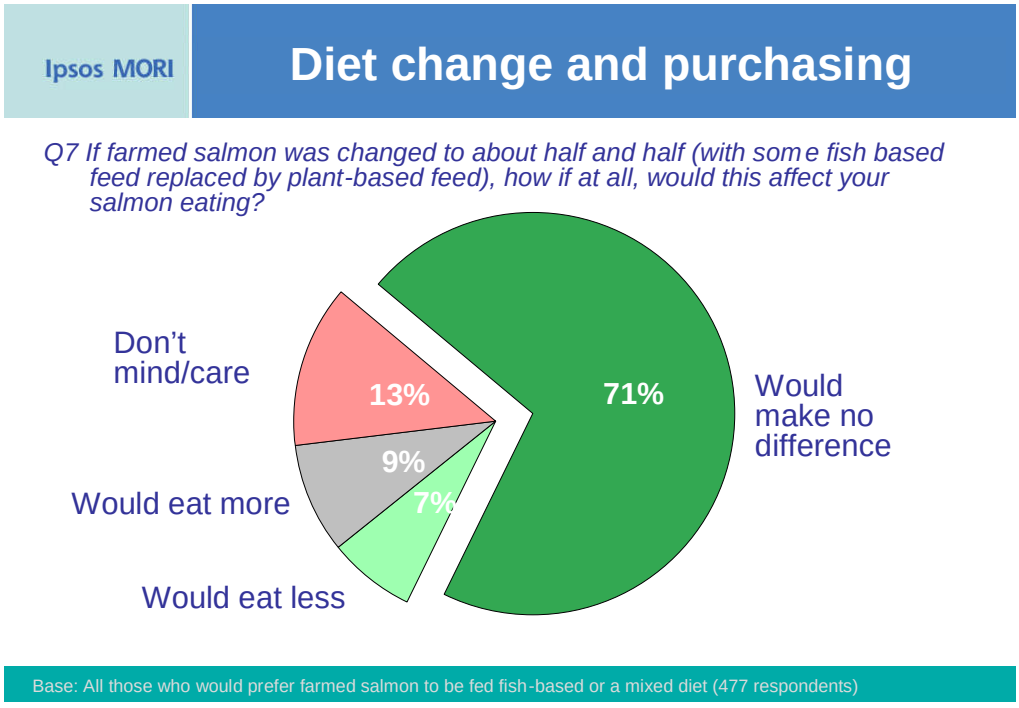
Question 7 was designed to explore whether people's preferences towards substitution might affect their purchasing behaviour. It was asked of those 477 respondents who answered in

Question 6 that they preferred a mainly fish-based diet or that they preferred a mixed fish-based and plant-based diet.

Question 7 first of all informs respondents that most farmed salmon in British supermarkets is actually fed a diet that is about three quarters fish-based and one quarter plant-based. It then asks respondents to say how, if at all, a change to a diet which is about half fish-based and half plant-based would affect their salmon eating.

A total of 84% say that such a change – i.e. an increase in substitution – would not affect their decision to eat salmon (71% said that it would make no difference, and 13% said they do not mind/care). Of the 16% who it would affect, a slightly larger proportion (9%) would eat more than would eat less (7%).

With reference to Question 7, it is important to remember that the percentages do not represent the whole population, rather they are a sub-group of those 42% of salmon consumers who would prefer a fish based or mixed diet (from Question 6.) In a sense therefore, it is actually 7% of 42% (3% of salmon consumers) who would eat less and 9% of 42% (i.e. 4% of salmon consumers) who say they would eat more salmon products. [6]



There is no discernable pattern related to the frequency of consumption.

[6] This assumes that consumers with no preference about salmon diet (45% of salmon consumers) would not decrease their purchasing as a result of the diet change. Similarly, it assumes that customers who favour mainly plant-based diets would not decrease their consumption if the diet became more plant-based.

3.7 Summary

Salmon consumers are generally not aware of the diet of farmed salmon. Almost half (47%) do not know what salmon are fed and only 16% believe it is a mainly fish-based diet.
When asked to consider their preferred diet for farmed salmon, almost half (45%) either have no preference or do not mind or care what farmed salmon are fed. Fish-based and mixed diets are both favoured by around one in five consumers (21%), while plant-based diets are favoured by just over one in ten (13%).

Most consumers say they would not change their consumption if farmed salmon were switched to mostly plant-based diets. Of those who favour fish-based or mixed diets for salmon, almost three quarters (71%) say that a switch to a plant-based diet would make no difference to the amount they currently eat. Only 7% say that they would eat less.

These findings can be combined to produce an estimate of the possible effect on consumption of increasing the plant component of the diet given to farmed salmon. Consumers who said they would consume less as a result of a change to a more plant based diet account for only 3% of all salmon consumers[7] which is essentially balanced by 4% that would eat more. Caution does need to be exercised in the use of this estimate. It is based on the assumption that consumers with no preference about salmon diet (45% of salmon consumers) would not decrease their purchasing as a result of the diet change. Similarly, the estimate assumes that customers who favour mainly plant-based diets would not decrease their consumption if the diet became more plant-based.

Taste and health benefits are the most important reasons why consumers select salmon in preference to other types of fish or meat. Both are important to over half (55%) of salmon consumers. Only 1% currently view the salmon's feed as an important contributor to their decision to eat salmon.

[7] This is based on the assumption that the respondents who were not asked Q7 gave answers at Q6 which suggested they would not have reduced their consumption as a result of the proposed diet change.

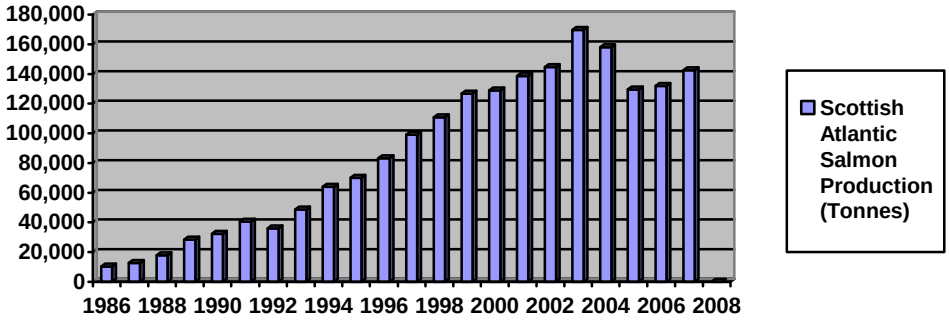
4.0 Data on Use of Substituted Materials in Salmon Feed

4.1 Introduction

This discusses general trends in aquaculture production, the demand for key fish feed ingredients and data on the substitution of fishmeal and fish oil in salmon feed.

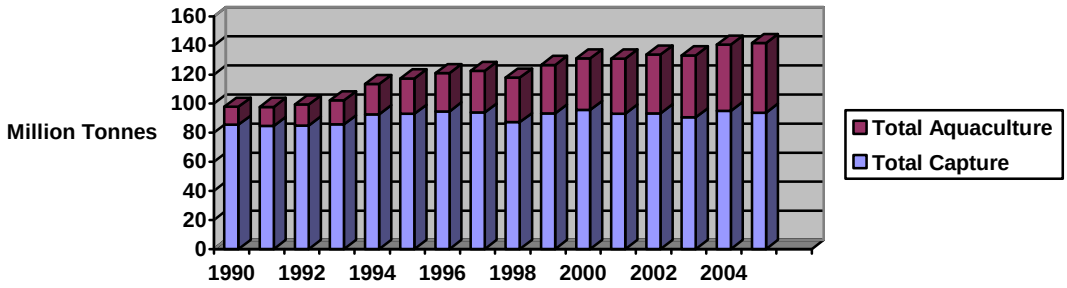
4.2 Trends in Aquaculture Production

The production of Scottish Salmon has increased enormously over the past two decades, as shown below. Production peaked in 2003 at just under 170k (170,000) tonnes, with a downturn in the next two years to just under 130k tonnes in 2005 and just short of 132k tonnes in 2006. The figure for 2007 is forecast to be 143k tonnes which although a significant increase, remains considerably short of the 2003 figure.



Source: Fisheries Research Services (FRS), 2006 (note: the 2007 figure is an estimate based on stocks at the time of the survey).

Until the 2004/5 downturn caused by over supply and low prices, Scottish Atlantic salmon production mirrored a worldwide trend of increased and sustained growth across all aquaculture species. Indeed, while output from capture fisheries has remained relatively stable over recent years, aquaculture has grown steadily and now contributes about one third of total worldwide food fish as illustrated below.



Sources: Food and Aquaculture Organization of the United Nations (FAO), 1996; FAO 1998; FAO 2002; FAO 2006 (note the 2005 figure is an estimate).

Global aquaculture growth has been more rapid than all other food producing sectors and has considerably outpaced population growth with per-capita production increasing from 0.7 kg in 1970 to 7.1 kg in 2004 (FAO, 2006).

China is by far the most productive country in terms of aquaculture across all species, accounting for nearly 70% of global output, with the rest of Asia at just over 20% (FAO 2006). Of the remainder, the largest producers are Western Europe (3.5%), Latin America and the Caribbean

(2.3%) and North America (1.3%). Aquaculture production from developing countries has far outstripped that from developed countries over recent years, with the average annual growth rate for the former being 10.2% since 1970 compared with 3.9% for the latter.

There are a wide and increasing range of aquaculture species, with salmon/trout representing only 4% worldwide (see table below). While global salmon production continues to increase, the growth rate (between 2002 and 2004) was below that of some other species.

Species Groups in Worldwide Aquaculture 2004

Species Group	Production: Million Tonnes	% of Total Production	Average Annual Growth Rate (APR) 2002-2004 (%)
Carps & other cyprinids	18	39.6	4.8
Oysters	4.6	10.1	3.1
Clams, cockles, arkshells	4.1	9.0	9.1
Miscellaneous freshwater fishes	3.7	8.1	-0.3
Shrimps, prawns	2.5	5.5	28.7
Salmonids	**2.0**	**4.4**	**5.1**
Of which, Scottish Atlantic salmon	***0.16***	***0.3***	**-**
Mussels	1.9	4.2	4.6
Tilapias and other cichlids	1.8	4.0	10.9
Scallops, pectens	1.2	2.6	-2.6
Miscellaneous marine molluscs	1.1	2.4	-12.4
Other	4.6	10.1	-
Total production (all species)	**45.5**	**100**	**-**

Source: FAO 2006.

Although Atlantic salmon production is extremely important for Scotland[8], when viewed in the global context it represents a relatively small proportion of total output (at 8% of global salmon/ trout production and a third of one per cent of global aquaculture in 2004). Besides Scotland, the other large producers of farmed salmon are Norway, Chile and North America.

4.3 Future Scottish Salmon Production

It is important to consider not only the current industry position, but also future trends. Within Scotland, the local government planning authorities and the Scottish Environment Protection Agency (SEPA) are the principal bodies regulating salmon aquaculture. These control the location and level of production, based on an assessment of environmental impact including the carrying capacity of the receiving environment.

Since production of Scottish salmon has fallen since 2003, it might be expected that there will at some point be a return to 2003 levels, although this is not considered likely by the industry in the short term. The opportunity for expansion is partially reflected in the number of licensed sea sites that were not producing in 2005; of the total 278 licensed sites, only 166 were in use with 112 not producing (FRS, 2006). However, many unused sites are small and uneconomic, and some may also be left out of production for other reasons. In order to optimise production costs the trend is toward bigger tonnages at fewer sites.

[8] Atlantic salmon production is Scotland's largest food exporting sector producing 50% by value of total food exports (Scottish Executive, 2003)

SEPA considers that there is the scope to develop new sites in coastal waters and that although limited, this should be sufficient to meet the expected demand in the near future (D. Sinclair, SEPA, 2007, *pers. comm.*). However, many fish farmers do not consider that there are significant new and economically viable sites available. While there is speculation regarding the potential for offshore salmon farms, there are significant financial, technical, biological and potentially legal constraints (James and Slaski, 2006) and thus little commercial appetite for such development at the present time in Scotland.

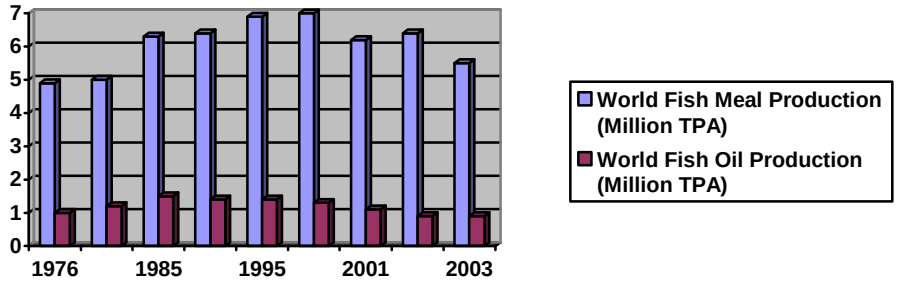
4.4 Demand for Marine Based Fish Feed Ingredients

Fish feed for salmon has developed over several decades to be a highly specialised blend of ingredients designed to meet nutritional and production requirements at optimal cost. The basic feed requirements are proteins, lipids, carbohydrates, vitamins and minerals.

Typically, salmon feed contains a proportion of fishmeal and fish oil. The former is primarily for protein and the latter primarily for energy. Some of the fishmeal can be substituted by plant protein and some of the fish oil by plant oil. Such substitution of fishmeal is established in salmon producing countries, including Scotland. However, substitution of fish oil is now routine in major producing countries except Scotland.

The type and composition of fish feed varies between companies, with different fish farmers preferring different types of diets to meet their own commercial requirements and the preferences of their customers. Diet composition is also driven by industry specific product standards such as TQM or Label Rouge, generic standards such as EurepGap, or customer related specifications such as a supermarket's own standard. Many of the standards contain specific requirements regarding the type and proportion of protein and oil in fish feed and can be significant in defining the nature and proportion of protein and oils used in practice. An overview of the requirements of the key product standards is given in Appendix C.

As shown below, global production of fishmeal and fish oil has remained relatively static over recent years, with meal generally between 6 million (6m) and 7m tonnes per year and oil fluctuating between 1m and 1.5m tonnes, and likely to be nearer to 0.8m tonnes today (D. Low, EWOS, 2007, *pers. comm.*). However, fishmeal production in South America can be adversely impacted by the El Niño effect which resulted, for example, to a fall in fishmeal production to just over 5m tonnes in 1998.



Note: based on Tacon *et al*, 2006. TPA: tonnes per annum.

The main fishmeal and fish oil producing countries are Peru, Chile, USA, Denmark, Iceland, Norway, Japan, China and Spain (Tacon *et al*, 2006). The United Kingdom produces just under 1% of global fishmeal and just over 1% of fish oil (2003 figures) (Tacon *et al*, 2006)). Conversely, the UK is the world's fifth largest importer of fishmeal (5.0% of world production) and fish oil (6.9% of world production in 2003) (Tacon *et al*, 2006).

There is an apparent ceiling on fishmeal and fish oil supply, due to many stocks being fully or over exploited, and this has led to a consensus that the aquaculture industry cannot rely on the

finite availability of marine feed raw materials in order to continue to expand (Ng *et al*, 2007, Tacon *et al*; 2006, Shepherd *et al*, 2005; Cremer, 2004; Tuominen *et al*, 2003).

In 2003, aquaculture worldwide used 46% of global fishmeal and 81% of global fish oil – these percentages were notably lower in 1988 when aquaculture used 10% of global fishmeal and 16% of global fish oil (Tacon *et a*l 2006). Salmon aquaculture worldwide was responsible for 10% of global fishmeal use and 45% of global fish oil used in 2003. Fishmeal and/or oil are also used in terrestrial animal feeds, human consumption and some varnishes and greases (Tacon *et al*, 2006).

Most observers forecast that the use of fishmeal and fish oil within aquaculture will increase. For example, the International Fishmeal and Fish Oil Organisation (IFFO) estimate that aquaculture will take 50% of the world's supply of meal and 88% of oil by 2012 (Tacon *et al*, 2006)[9], while the Royal Society of Edinburgh predicts 56% of meal and 97% of oil by 2010 (Royal Society of Edinburgh).

However, Tacon's opinion is that the industry's use of meal and oil will decrease by 4.4% and 12.3% respectively by 2012 due to economic, environmental and social factors, including increasing global meal and oil prices and concerns over the sustainability of fisheries. Tacon acknowledges that China could significantly affect these estimates and that any repercussions are unknown. This is because China is the world's largest importer of fishmeal (22.5% of global imports) and soya beans (a plant substitute), the world's largest producer of carnivorous finfish, the largest global user of low value fish for aquaculture, and its economy is growing at an average rate of 9.5% per year (Tacon *et al*, 2006).

The UK feed producers estimate that without substitution 100% of globally available fish oil will be used by the aquaculture industry by early 2008 and that demand will reach in excess of 120% by 2012 (Feed Producers Annual Review, 2006). They forecast that demand for fishmeal would reach just under 80% by 2012. With increased substitution, they estimate that demand for fish oil would be between 85% to 90% and meal around 60%.

The prices of fishmeal and fish oil have fluctuated considerably over the years. In 1998 the average for both meal and oil was just over $600 per tonne. This was followed by significant drops the following year to *circa* $350 for meal and $222 for oil. Fishmeal prices climbed to around $750 per tonne in 2005. Oil prices meanwhile rose to about $450 in 2002/3, and then dropping off to just under $400 by 2005. (Tacon, 2006; Feed Producers Annual Review, 2006). During 2006 both fishmeal and fish oil prices increased significantly to unprecedented highs. Oil rose sharply to $800 per tonne and meal to just under $900 (Tacon, 2006; Feed Producers Annual Review, 2006). Some types of meal prices broke the $1,000 a tonne barrier, e.g. super prime fishmeal at $1,325 (Millar, 2006a). During the latter half of 2006, prices started to stabilise and fall a little. Nevertheless, during 2006 the industry commentator Gavin Millar wrote about record prices and how this was forcing users to look even harder for alternative sources of raw materials (Millar, 2006b). He considered that the industry was at a "crossroads" and an "interesting new dawn" (Millar, 2006c).

Millar suggests that while it is difficult to forecast prices in the short term due to fluctuations in demand and supply, the future trend for fishmeal and fish oil would be upwards due to continued industry expansion and the finite supply of these commodities (Millar, *pers. comm*., 2007). He notes that marine and plant raw material prices are linked and that the price of substitutes is also rising due to increases in demand principally from the biofuels sector.

[9] Our calculations using Tacon's figures (Tacon *et a*l 2006) suggest that these levels may have already been reached.

4.5 Global Consumption of Salmon Feed

Worldwide, 1.9 million tonnes of feed were consumed by salmon production in 2006 as shown below. This is projected to rise to between 2.3-2.8m tonnes by 2010, an increase of 0.4-0.9m tonnes or 21-47% (Feed Producers Annual Review, 2006). Norway is by far the highest consumer followed by Chile and then Scotland, at just under a quarter of Norway's consumption or 10% of global use.

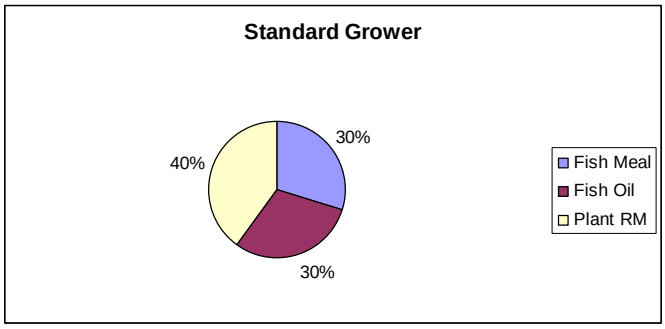
Annual Salmon Feed Consumption 2006 to 2010

Country	2006 (tonnes)
Norway	814k
Chile	642k
Scotland	195k
North America	194k
Faeroes	20k
Ireland	15k
Total	**1.9m**

Source: Feed Producers Annual Review, 2006.

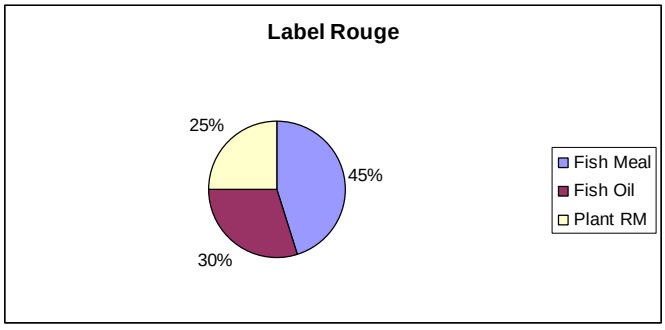
4.6 Substitution of Fishmeal and Fish Oil in Salmon Feed

In the UK and abroad fishmeal has been partially substituted in many feeds, with the actual proportion dependent upon the commodity markets, feed production requirements, farmer preferences, product schemes (or standards) and customer specifications. However, fish oil is only just starting to be substituted in the UK. An indication of the typical origin of key raw materials for two different types of salmon feed in the UK in 2006 is illustrated below.



Source: Feed Producers Annual Review, 2006.

Note: RM: raw material.



Source: Feed Producers Annual Review, 2006.

Note: RM: raw material.

It can be seen that fishmeal may constitute between 30 and 45% of UK salmon feed and plant materials between 25 and 40%. In both of the above diets, fish oil is 30%. Hence, the marine content is typically around 60% for Standard grower and 75% for Label Rouge.

The feed industry confirmed that in 2006 about 5% of Scottish salmon feed was produced using plant oil substitution. This would have required about 750 tonnes of plant oil (D. Low, EWOS, *pers. comm*., 2007).

Different materials are used worldwide for fishmeal and oil substitutes in commercial salmon feed as highlighted below.

Canada: substitutes up to 70% of protein and 50% of oil including the possible use of canola[10] meal, pea meal, soybean meal, canola (rapeseed) oil, maize gluten meal and soybean protein concentrate.
Chile: substitutes up to 60% of protein and 20% of oil including the possible use of canola meal, soybean meal, rapeseed oil, maize gluten meal and lupin.
Norway: substitutes up to 55% of protein and 50% of oil including the possible use of soybean protein concentrate, soybean meal, maize gluten, wheat gluten and rapeseed.
UK: substitutes up to 45% of protein with only a limited replacement of fish oil (up to 5-10%) possible use of maize gluten, soya products (mostly extracted), wheat gluten and rapeseed oil.
Additional substitutes (not country specific) palm oil, maize oil, coconut oil, sunflower oil and linseed oil.

Source: Tacon *et al* 2005; Tacon *et al* (2006).

Since UK consumers purchase imported farmed salmon from Norway, Canada and Chile, it can be seen from the above table that they are already consuming salmon fed on a range of different diets and substitutes. For example, in 2006 the UK imported some 65k tonnes of salmon in 2007 (Seafish Industry Authority, 2007) which, in 2006, included 37.5k tonnes from Norway (Statistics Norway, 2007, *pers. comm*.).

4.7 Summary of Key Findings

There is a ceiling on the worldwide supply of the fishmeal and fish oil that have traditionally formed the main ingredients of farmed salmon feed. Aquaculture already utilises the vast majority of global fish oil and half of global fishmeal.

The future availability of marine raw materials (oils in particular) to the Scottish feed industry is threatened by increasing demand from China and other developing economies, and the potential risk of fisheries collapse from an El Niño event. While the Scottish salmon industry is of great national importance, it accounts for just a fraction of total global aquaculture production and a relatively small proportion of global salmon production. Many consider that alternatives to fishmeal and fish oil are required to give the Scottish salmon industry stability and potential for expansion.

Fishmeal is partially substituted by plant meal in most Scottish salmon feeds. Fish oil, however, is not typically substituted, although this has recently commenced on a relatively small scale. It is estimated that in 2006 oil substitution represented about 5% of total Scottish fish feed and around 750 tonnes of plant oils were used.

[10] Canola (also known as LEAR) is the trade name for a genetically modified (GM) rapeseed variant grown extensively across North America (Wikipedia (a)). GM crops are outside the scope of this report.

In contrast, both fishmeal and fish oil are typically substituted in Norway and other major salmon producing countries. Since the UK imports salmon from abroad, many UK consumers are eating salmon reared on feed containing substituted meal and oil ingredients.

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5.0 Fish Health, Welfare and Performance

5.1 Introduction

Diet formulation can affect fish health and welfare, which can in turn affect performance. This chapter discusses these aspects of salmon farming in relation to the literature review. Reference should also be made to Section Four for the views of consultees.

Welfare is an ethical concern of producers, retailers and consumers. 'Ethics and regard for animal welfare' are part of the principle of stewardship enshrined in the Strategic Framework for Scottish Aquaculture (Scottish Executive, 2003).

The Welfare Subgroup of the Aquaculture Health Joint Working Group (AHJWG) – a Government and industry group – published a Welfare Code for Finfish Aquaculture in 2004. This was subsequently incorporated into the Code of Good Practice for Scottish Finfish Aquaculture (CoGP). The practices recommended in both documents are based on the principles of the 'Five Freedoms' which also form the basis of the RSPCA 'Freedom Foods' standard held by several Scottish salmon farming companies. These are:

- Freedom from hunger and malnutrition;
- Freedom from discomfort;
- Freedom from pain, injury or disease;
- Freedom to express normal behaviour; and,
- Freedom from fear and distress.

The diet is one important element with regard to all five freedoms and is a key determinant of fish health and welfare. Farmed salmon diets must supply all the nutritional requirements of the fish – proteins, fats, carbohydrates, minerals and vitamins – in the right quantities and qualities to suit the particular life stage of the salmon. Knowledge of the formulation of manufactured salmon feeds is constantly evolving and in recent years considerable attention has been directed towards the use of non-marine sources of proteins and oils.

5.2 Research Cited

A number of trials have assessed various aspects of fish oil substitution in freshwater and sea water diets from the late 1980s to the present. Tocher *et al* (2004) gives a brief summary of such papers up to 2004. Most of these trials tended to be of relatively short duration and hence unrepresentative of commercial production cycles.

Two major research programmes have taken place since 2000 to assess the effects of fish oil substitution on a wide range of parameters; Fish Oil Substitution in Salmonids (FOSIS) and Researching Alternatives to Fish Oil in Aquaculture (RAFOA). FOSIS considered salmonids and RAFOA focused on several species used in European aquaculture, including Atlantic salmon. Both studies are well regarded because they were designed to replicate some elements of commercial production, including timescales and approach to feed formulation, while following an experimental approach in terms of fish oil substitution. Therefore, the findings of these studies are considered in detail in this chapter and elsewhere in this report, and background information on each is provided below.

FOSIS

The FOSIS study investigated the effects of complete substitution of fish oil with a blend of rapeseed and linseed oils. It was funded by the LINK Aquaculture programme and carried out by the Institute of Aquaculture, University of Stirling. This study, which commenced in 2000

and finished in 2003, covered the whole life cycle of the fish from fry to harvested salmon at 2kg. Four different diets were used, two at relatively low levels of added oil[11] and two at higher levels, as summarised below.

1. Low fish oil: 14% added fish oil with no substitution.
2. High fish oil: total of 25% added fish oil with no substitution.
3. Low plant oil: 14% added rapeseed and linseed oils on a 1:1 blend with no fish oil.
4. High plant oil: 25% added rapeseed and linseed oils on a 1:1 blend with no fish oil.

The above diets were fed throughout the FOSIS study, except that the proportion of oil was increased to 17% in the low oil diets and 30% in the high oil diets in the sea water phase. Diets were formulated according to current practices by the feed companies. For the final 24 weeks all fish were switched to the high fish oil as a finishing diet.

RAFOA

The RAFOA project conducted extensive trials looking at substitute diets for salmon. These were full life cycle trials, starting in freshwater then following through in sea water over a period of between 27 and 31 months. Trials were undertaken more or less simultaneously in both Scotland and Norway and compared fish oil with individual plant oils followed, in a second round of trials, with blended plant oils. The two trials are summarised below.

RAFOA I consisted of two studies in each of Scotland and Norway from juvenile salmon to market size. The Scottish trial used 3,000 post-smolt salmon grown in sea water in Scotland for a total period of 64 weeks, starting in June 2001. Five diets were fed to investigate the effects of different levels of substitution – i.e. 25%, 50%, 75% and 100% of fish oil being replaced with linseed oil while the control group was fed a 100% fish oil (capelin) diet. All fish were switched to the 100% fish oil diet for the final 24 weeks of the trial as a finishing diet.

The Norwegian trial was similar except that it was based on fewer fish (600 post-smolt salmon), lasted a little longer (37 weeks) and used a slightly longer finishing diet (25 weeks). Fish oil was substituted in four groups at 25%, 50%, 75% and 100% by rapeseed oil with an additional group using 50% olive oil. A control group was fed a 100% fish oil diet.

RAFOA II again consisted of two studies in Scotland and Norway. This time the studies were over a complete two year production cycle of salmon from fry in the freshwater phase of growth to harvested salmon in sea water. Both studies used 3,000 Atlantic salmon and investigated the effects of replacing fish oil with a blend of rapeseed, linseed and palm oils.

The plant oils trialled in RAFOA II were agreed after the completion of RAFOA I. The blend used was designed to replicate commercial fish oil's saturated, monounsaturated and polyunsaturated fatty acids, but with none of the highly unsaturated fatty acids found in the fish oil which in this case was capelin. The normal amount of fishmeal was used in each diet. The composition of oils used in the diets is indicated below.

[11] The dietary oil total provided by discrete oils is termed 'added oil' in order to differentiate from the relatively small proportion of oils contained within the meal content.

Location	Diet	% Oil in the RAFOA II Trial Diets				
			Substitute Plant Oil Blend			
		Fish oil	Rapeseed	Linseed	Palm	Total Substitute
Scotland	A	100	0	0	0	0
	B	25	41.25	11.25	22.5	75
Norway	A	100	0	0	0	0
	C	0	55	15	30	100

Source: RAFOA, 2005.

In the Scottish freshwater phase the control salmon were fed 100% fish oil and the trial fish a 75% plant oil substitute diet which constituted 20% of added oil. These fish were transferred to sea in April 2003 into 5m x 5m x 5m pens at 700 fish/cage. The salmon were fed the same diets but with an increasing proportion of added oil to 32%, following normal commercial practice. Trial time including the freshwater phase was 25 months. All were fed a 100% fish oil finishing diet for the final 6 months. In Norway the trial was duplicated, but using a 100% plant oil diet. Trial time including freshwater was 22 months with a 5 month 100% fish oil finishing diet. Fish were sampled periodically throughout the trials.

5.3 Research Approach

For experimental purposes, both the FOSIS and RAFOA studies used higher inclusion rates of plant oils than are used in current commercial applications. The high levels of substitution allowed researchers to hypothesise that if an effect was not evident at a higher substitution level it would be unlikely to be present at a lower [commercial] level. Our consultations with the industry (see later in this chapter as well as Section Four) suggested that these high levels of substitution would not be used in production diets in the foreseeable future.

Although FOSIS included 24,000 fish and each RAFOA study included 3,000 fish, the studies used relatively small cages in the sea water phase which is not representative of industry conditions. It is also difficult for research trials to fully replicate the wide range of other husbandry and technological variables found in commercial practice. Some of these issues may have a limited bearing on optimising the use of diets and might be usefully addressed through further research, or by the release of existing unpublished work in this area.

A limiting factor to consider in respect of the available research is time. The life cycle of a farmed salmon is 1–2 years in freshwater followed by 1–1.5 years in sea water. In the wild a salmon can spend up to four years in freshwater and may be at sea for 1–4 years before returning to freshwater for the first time (Mills, 1971). (Some wild salmon spend their whole lives in freshwater.) Some of the research followed groups of fish over their whole life-cycle (albeit short in comparison to wild salmon) while other research involved shorter time periods. Thus it is possible that any long term, chronic or inter-generational health impacts related to diet may escape analysis in the short to medium term.

Even full life-cycle trials, covering fish from first feeding in freshwater to harvest in the sea, are unable to identify problems which may occur after several generations of fish have been raised on plant substitutes. An example of a long-term industry health problem is malformations (skeletal, backbone and gill), which occur in all farmed finfish species. One causative agent could be nutrition – whether or not substitutes are included in diets. We did not identify any completed research on diet and malformations, although this is currently being researched as part

of the EU funded FineFish project[12]. Atlantic salmon is one of the species being researched and it is recommended that the results be reviewed when available to assess whether there are implications for diet formulation.

The oils used in FOSIS and RAFOA II were those of most interest to the industry at the time. The industry may now also wish to see research assessing the potential effect of individual oils or of different types and blends to those previously researched. It is noted that research is ongoing in this regard, with a recent paper reviewing major studies undertaken on palm oil (Ng, *et al*, 2007).

The published work on substitution has the general aim of determining whether or not substitutes can be used as efficaciously as fishmeal and oils, including comparative analysis of health and welfare parameters, as this knowledge is also required by industry for ethical, economic and marketing purposes. Although research thus far has not generally focused on the sustainability, including the environmental impact, of using some substituted diets, this is clearly a growing concern which needs to be addressed explicitly to ensure that use of substitutes is defendable scientifically, commercially and ethically.

It should also be noted that the feed manufacturers have conducted a considerable amount of in-house research and development with regard to feed substitution, much of which remains unpublished for reasons of commercial confidentiality. While commercial sensitivities are understandable, this may have contributed to a general lack of awareness of important advances in this field (for example, Chapter Twelve suggests that some supermarkets may be unaware of the current status of research on substitution) It would be helpful for the industry and wider stakeholders to have access to a scientific evaluation of commercial substitute diets in a wholly commercial environment with normal production levels, and it is recommended that the industry implements a mechanism for disseminating in-house findings from the UK and overseas.

5.4 Fish Health and Welfare

Farmed salmon obtain fats from the oils and meal-fat residues in fish feed. These fats are sources of energy, essential fatty acids, phospholipids[13] and eicosanoids[14]. Changes in dietary oil composition have the potential to impact on the salmon's physiology, and consequently its health and welfare.

Atlantic salmon cannot synthesise the essential omega 3 and omega 6 polyunsaturated fatty acids (PUFA) and so these must be provided in the diet by fish and/or plant oils. The fatty acid profile in salmon, which largely mirrors that of the diet, can be manipulated through diet composition (Morris, 2005). Salmon have to adapt to different life stages. A major life change is when salmon parr become smolts and go from freshwater to sea water. As poikilotherms[15], their body temperatures have to adjust and follow different water temperatures. Being able to alter the fatty acid profile in the salmon may assist these processes (Morris, 2005). In the wild, the fatty acid profile of the salmon diet more closely resembles those of plant rather than fish oils during the freshwater phase because they feed on non-marine matter.

Fish and plant oils contain PUFAs, with fish oils being high in omega 3s and plant oils rich in omega 6. While some plant oils may contain omega 3s they do not contain the essential highly

[12] See http://www.aquamedia.org for further information about this project.
[13] Phospholipids are major components of cell membranes and responsible for many cell properties (Penguin, 2001).
[14] Eicosanoids are signalling molecules derived from omega 3 or omega 6 fatty acids. They exert complex control over many bodily systems, especially in inflammation, immunity and as messengers in the central nervous system (derived from Gunstone *et al* 2002 and Wikipedia).
[15] Poikilotherms are animals whose body temperature fluctuates with that of its environment.

unsaturated fatty acids (HUFA) eicosapentaenoic acid (EPA) or docosahexaenoic acid (DHA) found in fish oils. Variations in the fatty acid content of different oils are shown below.

Fatty acid composition of oils (g/100g fatty acid)			
Oil Type	**Total omega 3s**	**Total omega 6s**	**Omega 6:omega 3**
Fish Oils			
Menhaden	23.9	3.9	0.16
Herring	16.8	3.3	0.2
Capelin	17.9	2.5	0.1
Plant Oils			
Soya	7.1	54.4	7.67
Maize	0.9	50.4	56
Linseed	56	14.5	0.26
Rapeseed	10	29.5	2.95
Sunflower	0.1	65	650

Note: compiled from various sources by the authors.

The above table also shows how different oils/fats have different omega 3 and omega 6 content, and substituting fish oil with single plant oils will result in an imbalance in the omega 6:3 ratio. Health is promoted in diet formulation by ensuring that the oil or blend of oils used provides the essential omega 3s and an appropriate omega 6:3 ratio (Webster *et al*, 2002).

The key findings from the RAFOA project from a fish health and welfare perspective are summarised in the following table and discussed below. It should be noted that some of this research employed substitution levels very much greater than that used in commercial production.

RAFOA: Fish health related findings (RAFOA, 2005)

- Fatty acid composition in the fish is closely related to fatty acid composition in the diet.
- There was evidence of reduced prostaglandin[16] production, although this was reduced when feeding a plant oil blend (rapeseed, linseed and palm) compared to single oils.
- Cataract incidences in salmon fed 75% and 100% plant oil blend were four and five times higher, respectively, compared to fish fed 100% fish oil.
- When using a single plant oil substitute a number of immune parameters were altered in salmon. With a plant oil blend immune functions were not affected up to 75% substitution.
- A blend of plant oils provided greater optimisation of fish performance, biochemistry and health and imposed less stress on fish physiology than use of a single plant oil.
- Vaccination efficacy (for protection against the bacterial pathogens Vibriosis and Furunculosis) in salmon was not affected by the dietary plant oil.
- Post-smolt salmon challenged with Vibrio anguillarum did not show significant differences in mortality when fish oil was replaced by a plant oil blend.
- No clear effect from plant oil diets on disease resistance was found.

[16] Prostaglandins are a type of eicosanoid. An absolute or relative deficiency of prostaglandins has been found in many disease and clinical conditions. Excess can cause inflammation. (Derived from Gunstone *et al*, 2000 and Wikepedia.)

Cataracts

Cataracts are considered to be a multi-factorial production-related disease, potentially associated with a range of factors including rapid growth, temperature and salinity variation, exposure to ultra violet light, genetic susceptibility, medication effects and nutrition (Bjerkás, *et al*, 2006). Salmon may be particularly vulnerable during the time around parr to smolt transformation and during the first summer following transfer to sea water. The negative effect of cataracts on growth rate has been demonstrated and, with regard to nutrition, an increased incidence in the late 1990s was associated with the removal of bloodmeal, rich in the amino acid histamine, from fish diets (Bjerka *et al*, 2006). Research in this area is ongoing (R. Waagbo, 2007, *pers. comm*.).

An increased incidence of cataracts occurred in both the Norwegian and Scottish RAFOA II trials although this did not appear to compromise fish growth and performance[17]. This may have been associated with the freshwater stages because cataract incidence was not above background levels in sea water only trials. Researchers also noted that the increased incidence was during the particularly warm, and light, summer of 2003 in Norway and Scotland. No further evidence of this was found in trials with other fish species in the RAFOA project.

The incidence of cataracts in relation to nutrition is discussed by Bjerkás, *et al*, (2006) who consider that there is the potential for cataracts to arise from an increased use of plant substitutes and call for further studies in this regard.

Cataracts were discussed at length with the feed manufacturers. All three companies were adamant that cataracts were not an issue with regard to feed substitution with, for example, EWOS stating that "millions of tons of salmon have been grown on plant oil substituted diets with no incidence of related cataracts" (D. Low, EWOS, 2007, *pers. comm.*) and "my understanding is that with commercial diets this [i.e. cataracts] is not seen" (D. Robb, EWOS, 2007, *pers. comm.*).

Industry vets consulted considered that causes of cataracts in salmon were multifactoral and, while care must be taken in feed formulations using plant oils in order to ensure all essential amino acids remain present in the diet, there was no evidence of increased incidence of cataracts caused by substitution (Fish Vet Group, *pers. comm*, 2007). Consultations with a Scottish farmer using substitute diets with up to 60% plant oil (of total added oil) backed this up by confirming that there was no evidence of problems related to cataracts.

We also note a comment from Kjell Maroni, the Director of Research and Development at FHL, the SSPO's counterparts in Norway, who stated that "my impression is that cataract[s] [are] not a problem today. We had a higher level of incidence some years ago in the industry, probably caused by the elimination of blood meal from the diets causing histidine deficiencies until this was alleviated by adding histidine." (forwarded by M. James, SARF, *pers. comm*. 2007).

Immune Parameters and Disease Resistance

With regard to the salmon's immune parameters and prostaglandin production, the effects of single plant oil substitutes were largely dissipated by using the plant oil blend which copied the saturated, monounsaturated and polyunsaturated fatty acids (but with no HUFA) found in capelin (the fish oil used in the control group). Nevertheless, the RAFOA research suggests that relative to fish oil diets, the use of plant oil blends did affect immune parameters, with some blood parameters suggesting increased stress levels.

With regard to disease resistance, RAFOA found no clear effect from plant oils when salmon were challenged with Vibrio and found no decreased vaccination efficacy between fish fed fish oil or plant oil blend. As part of the FOSIS project, fish were challenged with Furunculosis. Results showed that plant oils (a linseed and rapeseed oil blend) did not impair the ability of the

[17] G. Bell, *pers. comm*. 2007.

fish to respond to the challenge although, in this project also, there was some evidence of immune system depression (Institute of Aquaculture, 2002-2003).

RAFOA pointed out that when researching the immune function of fish, numerous factors other than diet are important and hence immune system depression could be due to life-stage, dissolved oxygen, water temperature and rearing conditions as well as diet. Isolating the effects of diet on the immune system is a complex and advanced science. Consequently, this is an area which is likely to continue to be researched in order to gain an understanding of the effects on immune function of both individual and blended plant oils in fish diets. As these effects occurred at higher substitution levels than used in commercial diets, further research may be helpful to assess potential immune effects at commercial levels of substitution, although it should be noted that at present there is no evidence from commercial production using current levels of substitution that there are any significant or attributable immune system effects.

Smoltification

As discussed above, adaptation to different life stages, and in particular to smoltification, could in theory be beneficially assisted by altering dietary omega 3s and omega 6s. During their lives in freshwater, marine sources of fatty acids are unavailable to wild salmon and the fatty acid profile of their natural food sources more closely resembles plant oils than marine fish oils. The beneficial effect from plant oil diets with regard to assisting sea water tolerance, indicated by lower levels of chloride in the plasma of salmon, has been demonstrated on two occasions. (Tocher *et al,* 1999; Bell *et al*, 1997).

A Norwegian study in 2003, supported by industry and the Norwegian Research Council, looked at the effects of changes in dietary fatty acids between the freshwater and sea water rearing stages of salmon and did not observe improved preparedness for sea water transfer in salmon fed a substitute plant oil diet (Bendiksen. E.A. *et al*, 2003). This trial was experimental, using small numbers of fish. They were fed low and high proportions of plant oil (rapeseed and linseed blend) or low and high fish oil (sand eel) in the freshwater stage and then these diets were exchanged post smolt transfer to sea water. There was the normal weight loss, irrespective of diet, in the initial post transfer period, and neither freshwater nor sea water diets affected the smoltification indicators (plasma chloride or plasma osmolality) measured. Thereafter, however, growth was significantly improved amongst smolts that had been fed a low plant oil feed in freshwater and then fed a high fish oil diet in sea water. The importance of low and high proportions of oils in the diet is discussed in the section on performance below. It is recommended that further research – preferably undertaken with greater numbers of fish – would assist in determining optimised pre- and post smoltification diet formulations.

Adaptation to Low Temperatures

Plant oils may be a better dietary option to fish oils in assisting salmon to adapt to cold-water conditions. Salmon do require oil with a low melting point because saturated fats, which are mostly higher in fish oils than in plant oils, are poorly digested (Webster *et al*, 2002). Digestibility is a critical variable in the diet, affecting the efficiency of the diet in terms of conversion of food to flesh as measured by the food conversion ratio (FCR). Our review has not, however, found clear evidence to support or negate the hypothesis that plant oils may be a better dietary option to fish oils in assisting salmon to adapt to cold-water conditions and further research would elucidate this.

5.5 Performance

By performance, we mean the growth characteristics of farmed fish which are usually measured by growth over time, specific growth rate, FCR, and survival. Growth is dependent to a certain extent on the pre-determined genetic make up of the species. Thereafter, nutrition (ration and energy content) and temperature are key variables. Other determinants include daylight length, stress, disease, reproductive status, water quality and husbandry methods. Our focus is on nutrition and specifically diet formulation.

The use of plant oil as a partial substitute for fish oils is no longer considered novel in many quarters. It has evolved over the last decade and commercial use outside the UK has not presented any performance obstacles.

Several studies have shown that replacing fish oil with plant oil does not have a negative effect on fish growth or performance (Torstensen *et al*, 2000, Grisdale-Hellan *et al* (2002) Bell *et al* 2003b). For example, in 2001 Nutreco ARC reported that groups fed with 75% of fish oil substituted by rapeseed or soybean or linseed oil resulted in no growth or feed utilisation differences, except where soya was mixed with low omega 3 fish oil (Rosenlund, 2001).

Final fish weights in the FOSIS project reflected the level of oil in the diet rather than the type with significantly lower weights in the low oil diets – for both low plant oil and low fish oil. FCR values were lowest in the group fed a high fish oil diet and highest in the salmon fed a low fish oil diet (Institute of Aquaculture, 2002-2003).

RAFOA also looked at performance. In the Norwegian trials (Torstenson *et al*, 2000) where a blend of 55% rapeseed, 30% palm and 15% linseed oils were used at both 75% and 100% substitution levels the only significant effect on growth and mortality was that growth increased in salmon fed 100% plant oil compared with 100% fish oil during the sea water winter period which may be attributable to the increased digestibility of plant oils relative to fish oils at cold temperatures discussed above (Torstensen, 2005). At the time the 100% plant oil trial ended these salmon were larger than either the 75% plant oil or the 100% fish oil salmon. In the corresponding Scottish trial there were no significant growth differences between the 75% plant oil and 100% fish oil salmon. Thus RAFOA demonstrated that substitution of fish oil by plant oil in salmon diets does not have a negative effect, and may have a positive effect on growth (Bell *et al*, 2002; Menoyo *et al*, 2005; Young *et al*, 2005).

The most significant differences identified in studies using different proportions of oils, as well as different types, were between the proportions rather than the type of oil. Feeds containing 35-40% crude fat are used routinely in salmon aquaculture in order to maximise protein retention (i.e. muscle tissue) and minimise FCR (Morris *et al*, 2005). Generally, performance has improved over time as diet formulations, genetic selection, husbandry practices, feed management and other variables affecting performance have been improved and refined.

While fishmeal continues to be the predominant protein source in salmon, plant meals – mostly soybean and wheat and maize gluten – have also been a major ingredient in salmon diets for many years. These have a lower nutrient density than fishmeal, therefore feed manufacturers have to put more into the feed pellet to obtain the same proportion of protein and so plant meals take up more volume in the pellet than fishmeal. Increasing the proportion of plant meals in salmon diet formulation has been found to reduce performance due to decreased digestibility (Morris *et al*, 2005) which is not compensated for by increased food intake and which might in any case increase feed costs for the farmer (Mundheim *et al*, 2004). Further processing of plant meals can increase digestibility but this adds to the raw material cost. While plant meals are currently substituted for fishmeal in significant quantities, the content of fishmeal in salmon diets, which has fallen over the last two years from around 30-35% to 25-30% is unlikely to fall below 20% of the feed content in the near future without performance penalties (Morris *et al*, 2005).

5.6 Summary of Key Findings

A number of trials have assessed various aspects of fish oil substitution in salmon diets from the late 1980s to the present day, particularly two major research programmes; FOSIS and RAFOA which sought to mimic some important elements of commercial production, particularly timescale. Both used levels of substitution which were higher than those used in, or proposed for, commercial diets. While this approach may allow effects to be more easily identified, some stakeholders (particularly fish farmers, processors and supermarkets) may also like to see the results of trials using commercial substitute diets (which have lower levels of substitute oils).

Using substitute diets does not appear to compromise fish survival, growth or other performance indicators (FCR for example). This is evident from research and from commercial use.

Although plant oils have been used extensively in the Norwegian industry for a number of years without documented health problems, it cannot be confirmed from our literature review that there are no inter-generational issues since the research is focused on single cycle trials. It is noted that the effects of nutrition on malformations are an area of current study by FineFish and it is recommended that the results of this work be considered.

An increased incidence of cataracts was found in the RAFOA II freshwater and sea water trials in Norway and Scotland, although not in sea water only trials or other RAFOA studies. The researchers suggested this may have been linked to the particularly warm and light summer of 2003. Consultations with feed manufacturers, industry vets and farmers using substitute diets confirmed that cataracts are not an issue with regard to substitution. Nutrition is one variable associated with the production-related incidence of cataracts which is continuing to be researched.

RAFOA also identified evidence of some negative effects on stress and the immune function in salmon fed a single plant oil. This is avoided in the commercial environment through the use of blended plant oils or the use of single oils at lower inclusion levels.

No effects of substitute diets on disease resistance or vaccination efficacy were found in the literature reviewed.

Plant oils do appear to benefit the smoltification life change, though further work in this area is recommended in order to optimise pre and post smolt diets. With regard to digestibility, there was some evidence that salmon perform better on high levels of plant oils in cold water temperatures.

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6.0 Human Health

6.1 Introduction

Eating salmon provides a range of health benefits. It is a good source of protein, minerals, vitamins and very long-chain omega 3 fatty acids – often termed highly unsaturated fatty acids (HUFA) which are particularly associated with heart disease prevention.

In the marine environment HUFAs are synthesised by marine algae and transferred up the food chain into oily fish and, to some extent, shellfish. They are, however, scarce or absent in plants and animals. While humans can convert alpha-linolenic acid (ALA), a shorter chain omega 3 found in plant foods, into HUFAs, this process is inefficient (Ruxton *et al*, 2005) and so oily fish are highly valued due to their HUFA content. Salmon is a very important source of HUFA in the UK.

Omega 3s are provided in farmed salmon by fish oil contained in the feed. There is a positive correlation between the amount of fish oil in the feed and the amount of omega 3s in the flesh of farmed salmon (Bell *et al* 1998) and so there concerns have been raised that oil substitution may lead to a reduction in omega 3s, particularly HUFA.

This chapter focuses on omega 3s and also considers issues surrounding contaminants since these also are of interest from a substitution perspective.

6.2 Highly Unsaturated Fatty Acids (HUFA)

Health Benefits of HUFA

The most common fatty acids in salmon are eicosa-pentaenoic acid (EPA) and docosa-hexaenoic acid (DHA). The majority of research (but not all) considers that the consumption of oily fish such as salmon reduces the risk of coronary death and is beneficial for early neurological development (Mozaffarian *et al* 2006) due to its DHA and EPA content.

As described in a review by Ruxton *et al* (2005) clinical trials of HUFA have tended to focus on the secondary prevention of cardiovascular disease in heart attack survivors, finding that increased intake of HUFA reduces risk of mortality. For example, the GISSI Prevenzione (1999) study, with over 11,000 subjects, found that HUFA supplementation (equivalent to 850mg of EPA and DHA per day) reduced the relative risk of death from heart attack by 17% over 3.5 years. Similarly positive results were found by the DART study (Burr *et al*, 1989), which included over 2000 patients. Men advised to eat two oily fish meals per week experienced a 29% reduction in total mortality over 2 years, which was ascribed to a reduction in heart disease mortality. A meta-analysis of 11 randomised controlled trials (Bucher *et al,* 2002) concluded that HUFA can reduce heart-related mortality, while another review (Hooper *et al* 2003) reported a strong beneficial effect of HUFA in groups at risk from heart disease. Mozaffarian *et al* (2005) undertook a long-term study of congestive heart failure. The baseline diets of 4,738 adults aged over 65 years were analysed in 1989-90, after which time they were followed for 12 years. It was concluded that regular fish consumption, and high intakes of HUFA, were associated with a lower risk of congestive heart failure. In contrast, fried fish consumption was positively linked to congestive heart failure.

A few studies have not found heart health benefits associated with HUFA consumption. For example, Cundiff *et al* (2007) examined secondary data to demonstrate that the apparent relationship between oily fish or DHA/EPA supplements and heart health may in fact be confounded by other dietary and lifestyle factors. In 2006, the controversial systematic review by Hooper *et al* concluded that long-chain and shorter-chain omega 3s did not have a clear impact on total mortality, combined cardiovascular events, or cancer. The review was based on primary data from 48 randomised controlled trials up to February 2002. The Hooper paper has been

criticised by a number of authors because of the weight given to a study by Burr *et al* (2003) whose methodology has been questioned by the Independent Scientific Advisory Committee on Nutrition (SACN). When the Burr data were included in Hooper's analysis, the risk of death increased as the length of the trial increased. However, an examination of Hooper's findings by the FSA (Food Standards Agency, 2006) found that this association was lost when the Burr trial was removed. The FSA concluded that no change to the SACN recommendations of two portions of oily fish per week was warranted as a result of Hooper's findings.

While the cardiovascular benefits of HUFA have received the most attention, a growing body of evidence is now focusing on other health aspects including mental health, inflammation and cognitive function (Ruxton *et al*, 2003; Calder, 2006). However, some of these studies are criticised for being scientifically flawed and the resulting publicity misleading (Purvis, 2007). Related health claims are currently unproven and cannot be officially used.

As well as total HUFA consumption, benefits are attributed to the ratio between omega 3 and omega 6 polyunsaturated fatty acids (PUFAs). This ratio has increased in Western diets over recent decades, but remains low in Japan and other traditional fish-eating communities which have lower rates of cardiovascular mortality and mental illness. Scientists believe that a high omega 6 intake, from margarines and plant oils, combined with a low omega 3 intake is detrimental to human health. In the UK, the daily intake of omega 6 is about 10g while omega 3s are between 1-2g (Mason, 2004), giving a high omega 6 to omega 3 ratio. Warnings have been made of the future epidemiological consequences of increased cardiovascular disease and mental illness resulting from low omega 3 diets (Crawford, 2004).

Health Claims in Respect of Salmon

In 2004 the International Society for the Study of Fatty Acids (ISSFAL) recommended a HUFA intake of 650mg/day, equating to 4.6g/week. This would be expected to significantly reduce the risk of death from coronary heart disease in healthy adults, including pregnant and lactating women. While this does not constitute government guidance or official ISSFAL policy, these views would be expected to influence public health policy.

SACN and the Committee on Toxicity (COT) reviewed key research on the risks and benefits of eating oily fish (SACN 2004). SACN concluded that the UK population eats insufficient fish and recommended a weekly intake for most adults of 1 to 4 portions a week (defined as 140g per portion), one of which should be oily. The SACN recommendations can be translated into a HUFA intake of 450-900mg/day. This is considerably higher than an earlier official recommendation of 200mg/day (Department of Health, 1994).

It is thought that SACN have been careful not to couch their recommendations as levels of DHA or EPA because (a) most of the research has been carried out on oily fish or fish oils which contain both DHA and EPA and (b) where evidence exists for single fatty acid supplementation, it is not clear whether EPA or DHA is the primary health driver, or whether they work in tandem. SACN's recommendation is lower than ISSFAL's; this might be because the former only considered health benefits while SACN also included the risks posed by possible contaminants (see below).

In the UK, the FSA endorsed the findings of SACN and COT and recommended that the public should "eat at least two portions of fish a week, one of which should be oily fish"[18]. The recommendations were adapted for children and pregnant women to 1-2 portions to lower potential exposure to contaminants. However, a recent FSA survey found that almost half of UK residents rarely or never eat oily fish (FSA, 2007). (Note that the findings of the consumer attitude survey undertaken as part of this project, presented in Chapter 3, found that 60% of adults eat salmon, 15% on a weekly basis.)

[18] http://www.eatwell.gov.uk/healthydiet/nutritionessentials/fishandshellfish/

The only official health claim that can be included on UK food labels is that "*eating long chain omega 3 polyunsaturated fatty acids, as part of a healthy lifestyle, has been shown to help maintain heart health*" (Baldwin *et al*, 2004). This was accepted by the Joint Health Claims Initiative (JHCI) in 2005 who restated it as: "*eating 3g weekly, or 0.45g daily, long chain omega 3 polyunsaturated fatty acids*, *as part of a healthy lifestyle, helps maintain heart health*."

Claims based on the above statement can, under certain conditions, be included on labels, as long as a further statement is made that: "*The Government advises that at least two servings of fish, one of which should be oily, containing approximately 3g LC omega 3s PUFA, is consumed each week*."[19] The JHCI ceased to operate as of March 2007 and its functions will be transferred to the FSA pending full implementation of the new EU Nutrition and Health Claims regulation in 2010. It is not yet clear how the oily fish claim will be adapted in response to these regulations, although it is not expected to be dropped. Regardless of the wording of any future claim, levels of DHA and EPA in salmon flesh will remain critical to any health claims used on salmon products.

The health claims discussed above are summarised below. Of these, only the third one is official UK Government guidance, while the last is relevant to claims made on food and beverage products until 2010.

Organisation	**Health Claim in respect of Salmon Consumption**	**Official UK Government Guidance**
ISSFAL, 2004	• For cardiovascular health, a minimum intake of EPA and DHA combined of 500mg/day.	No
SACN, 2004	• Eat at least two 140g portions of fish a week, one of which should be oily. • This should be up to 4 portions of oily fish a week for males and females not intending to become pregnant.	No
FSA, 2004	• Eat at least two portions of fish a week, one of which should be oily.	Yes
JHCI, 2005	• Intake of long chain omega 3 PUFA should be 3g per week or 0.45g daily. • A stand alone serving must contain no less than 0.2g PUFA.	No

HUFA Levels in Farmed Salmon fed Fish Oil Diets

Salmon are unable to synthesise omega 3 or omega 6 fatty acids and instead gain these directly from their diet from the fishmeal and, principally, fish oil in the feed (Webster *et al*, 2002). A farmed salmon feed with 30% fish oil may provide about 5g EPA and 10g DHA per kg (Bell, 2001; Bell, *et al*, 1998). This greatly exceeds the relevant health claim for a single serving and easily provides the recommended daily intake of EPA and DHA to help maintain cardiovascular health (see the JHCI and ISSFAL health claims in the section above).

Recent figures on the omega 3 composition of Scottish farmed salmon were provided by the Scottish Salmon Producers Association (SSPO) and Food Certification (Scotland) Ltd (FCS) (FCS *pers. comm*., 2007). Based on 25 random samples taken by FCS inspectors over the last 2 years, EPA and DHA averaged 1.13g and 1.99g respectively per 100g of flesh, meaning a 140g

[19] http://www.jhci.org.uk/approv/omega.htm The claim relates only to very long chain PUFA (polyunsaturated fatty acids of chain length 20 carbons or above) including EPA, DPA and DHA which are elsewhere referred to as HUFA.

portion would provide 4.37g EPA+DHA. While these results should be treated with caution due to the small sample size, they suggest that Scottish farmed salmon in commercial production comfortably exceed all the previously discussed health claims with one 140g portion. While most of the salmon tested are expected to have been grown on fish oil based diets (because there is currently little use of substitute oil in Scotland), the feed formulation(s) used for the sampled fish could not be confirmed.

Effects of Substitution on HUFA

The well regarded RAFOA II research project (see Chapter 5 for further details) investigated the use of plant oil substitution at a range of concentrations[20]. These included diets very much higher in plant oil concentration than those in commercial use, both currently and in the foreseeable future, which were chosen in order to identify any effects at higher levels.

RAFOA II findings confirmed that salmon fed on diets with high levels of plant oil substitution resulted in reduced HUFA content, i.e. 0.76g and 0.47g per 100g for substitution at 75% and 100% respectively (RAFOA, 2005). This is significantly lower than the control group of 1.75g per 100g representing 43% of the original HUFA content at 75% substitution and 27% at 100%.

The study also showed that the use of a finishing diet could considerably boost HUFA content in harvested salmon fed a substitute oil diet (RAFOA, 2005). This gave 1.35g per 100g for 75% substitution and 1.21g for 100%, i.e. 77% and 69% respectively of the fish oil control group. The FOSIS study (see Chapter 5 for further details) similarly found that the use of finishing diets restored HUFA to 80% of those fed fish oil using salmon grown on 100% substitute feed (Bell *et al*, 2005).

The RAFOA final report concluded that the "judicious" use of finishing diets could restore HUFA levels to those seen in salmon fed entirely on a fish oil diet (RAFOA, 2005). Torstensen *et al* (2005), in a paper presented as part of the RAFOA project was slightly more cautious, saying that while a finishing diet can "restore" levels of HUFAs, they will be lower than those in a salmon grown on a fish oil diet and "might" benefit human health nutritional requirements.

Although we calculate that neither of the RAFOA substitute diets would meet all the previously discussed health claims with one 140g portion, this comparison is of academic interest only since oil was substituted at levels considerably above commercial practice. These studies did, nevertheless, demonstrate that finishing diets could partially restore HUFA.

We were unable to identify any publicly available data on the HUFA content of commercial substitute diets in either Scotland or Norway and no appropriate data was available from the Scottish industry[21].

Data on commercial salmon production in Norway was, however, obtained from the Norwegian sampling programme through the National Institute of Nutrition and Seafood Research (NIFES). This showed HUFA content in commercially farmed salmon to be 2.79g per 100g which comfortably meets all the previously discussed health claims with a single 140g portion. From our consultations, it would be expected that this data is representative of salmon grown on diets with perhaps 40% of plant oil substitution. However, NIFES could not provide information on the nature or composition of the actual diets, and so this could not be confirmed.

Random sampling of Scottish farmed salmon should be undertaken in order to determine average levels of omega 3s. This could be undertaken by the Fish Health Inspectorate as part of their existing sampling regime.

[20] Note that while RAFOA I researched substitution at a wider range of concentrations than RAFOA II, this chapter refers to the latter which used blended oils designed to replicate fish oil.
[21] While limited data was made available by one company, insufficient supporting information was provided to allow interpretation and presentation in this report.

Industry Consultations

The aforementioned Norwegian data suggests there is not a problem in meeting omega 3 levels with one 140g portion. The two Scottish fish farmers using substitute diets were confident that they would also be able to obtain similar levels and meet the customer specifications in this regard.

This matter was discussed at some length with senior representatives of the major Scottish salmon feed companies. All three companies were adamant that they could and, for the two currently producing feed using substitute oils, did provide feed that allowed fish grown on substitute plant oils to meet the omega 3 health claims. Further written consultations confirmed that:

- "If [the] correct blend of South American fish oil and vegetable oil is given, it is possible to achieve the same n-3 [omega 3] content in the salmon flesh as would be the case if northern hemisphere fish oils had been fed" (G. Mace, Biomar, D. Low, EWOS, P. Morris, Skretting UK and Ireland, 2007, *pers comm*.).
- "Feed companies have the ability to control the level of EPA and DHA in salmon flesh as required by the farmer" (D. Low, EWOS, 2007, *pers comm*.).

We also consulted with the two Scottish fish farming companies currently using substitute oil diets, one in commercial production and the other as a large-scale trial. In both cases the farmers were entirely confident that the final salmon product would meet customers' omega 3 requirements.

Farmers and the supply chain as a whole are very aware of the importance of health claims to the consumer and to the successful marketing of Scottish farmed salmon and would not risk losing market share through reduced omega 3 levels. Indeed it is interesting to note that at least one major supermarket is now providing information on omega 3 content on their packaging of some salmon products.

It is recommended that independently verified data on the levels of omega 3s in commercially produced farmed salmon grown using substitute diets be provided by the industry. This would assure the supermarkets in particular, as well as farmers, processors, consumers and wider stakeholders that salmon product health claims can be sustained. This could be controlled by the Fish Health Inspectorate, which already undertakes sampling for disease monitoring purposes.

6.3 Contaminants

There are a number of potential dioxin and dioxin-like contaminants which can be present in farmed salmon as well as in other marine foods. These include:

- polychlorinated biphenyls (PCB)
- polychlorinated dibenzofurans (PCDF)
- polychlorinated dibenzodioxins (PCDD)
- polybrominated diphenyl ether (PBDE)

These dioxins or dioxin-like contaminants (often referred to as persistent organic pollutants or POPs) may originate from terrestrial pollution sources, volcanoes and forest fires. They are present in the marine environment and can be present in farmed salmon through accumulation in the food chain and hence into the ingredients of fish feed, particularly fish oil (Jacobs *et al*, 2002). Arsenic, cadmium, fluorine and mercury are naturally occurring contaminants in the marine environment and therefore can also potentially accumulate in marine fish feed ingredients. The

most significant of the above contaminants in terms of farmed salmon and human health are the POPs and methylmercury (Hites *et al*, 2004).

Mercury concentrations in UK farmed salmon and trout were found to be relatively low in an FSA study in 2002. Organic forms of mercury (e.g. methylmercury) are more toxic following ingestion but total mercury was measured because of the difficulties in reliably determining methylmercury in food. The maximum concentration found in 46 samples of fresh/frozen or smoked trout and salmon was 0.1mg/kg, which is below the EC regulatory limit of 0.5mg/kg fish (FSA, 2003).

Research has indicated that the level of contaminants in Scottish farmed salmon is low and acceptable. With regard to dioxins, the FSA sampled 48 species of farmed and wild fish (including farmed salmon) and shellfish consumed in the UK in 2006. The results were considered to be of low concern for health and did not affect the Agency's advice on fish consumption (discussed earlier in this section) (FSA, 2006). In another study, evidence reviewed both for and against the increased consumption of omega 3 rich fish oil concluded that dioxin levels were low, and potential carcinogenic and other effects were outweighed by the benefits of consuming fish (Mozaffarian *et al*, 2006).

There are a number of ways in which the presence of contaminants in salmon can be reduced further including:

- sourcing fishmeal and oils from a supply with low levels of dioxins;
- processing out some or all contaminants; and,
- increasing the proportion of plant meals and oils in the diet.

There is wide variation in the levels of contaminants in marine based raw materials for salmon diets which primarily depends on the geographic origin of fishmeals and oils. In general, Northern European sources are higher in dioxins than the South Pacific (Morris, 2005). Although the technology for processing out contaminants is developing, it presents major investment implications for feed manufacturers which would be transferred to the salmon production cost (FAO, 2006) and instead the manufacturers minimise the risk of contamination through sourcing and quality inspection procedures.

Plant derived raw materials may also contain contaminants, but these have been found to be lower in POPs than marine raw materials. The POPs level in plant-based feeding stuffs is approximately 15% of that in fishmeals and 4% in plant oils compared to fish oils (Morris, 2005). The RAFOA study also demonstrated that the substantial replacement of fish oils by plant oils leads to a marked reduction of dioxins that are largely derived from marine fish oils (Bell *et al*, 2005; RAFOA, 2005). Consequently the available evidence suggests that the inclusion of substitutes in salmon diets reduces contaminant levels from dioxins and dioxin like materials in salmon flesh.

A contamination risk in plant based raw materials is pesticide residues. For imports, this can include materials which might not be approved in the UK but which are permitted in the country of origin. No relevant literature was identified and we are not aware of concerns in this regard.

Other contaminants in plant raw materials are possible. For example, the potentially toxic substance melamine was recently identified in fish feed in the USA from wheat gluten imported from China and manufactured in Canada (Fish Update, 2007), although we are not aware of any other similar instances.

The presence of genetically modified organisms (GMOs) is another possible 'contaminant' of plant raw materials, although GMOs are not currently used in UK salmon feeds. While GMOs are outside the scope of this project, this issue is likely to be of interest to certain stakeholders.

6.4 Summary of Key Findings

Eating salmon provides a range of human health benefits of which the most prominent is that it helps prevent heart disease due to the presence of omega 3 highly unsaturated fatty acids (HUFA) and their ratio to omega 6 fatty acids. Although omega 3s are present in other oily fish, they are scarce or absent in most other foods and hence salmon is particularly valued from a human health perspective.

The UK Government's official guidance is that consumers should eat at least two portions of fish per week, one of which should be oily. Several other health claims have been made by expert bodies, including the former UK Joint Health Claims Initiative (JHCI) which recommends a weekly intake of long chain omega 3 poly-unsaturated fatty acid (PUFA) of 3g per week, and at least 0.2g PUFA per serving.

The omega 3s in farmed salmon originate from fish oils in the feed. Research demonstrates that diets using substitute plant oils at high concentrations (higher than in current or foreseeable future commercial production) reduce omega 3 content and that these can be largely restored by the use of a finishing diet.

Data provided by the Norwegian sampling programme confirms that Norwegian salmon comfortably exceeds UK health claims. No equivalent data was available in Scotland. Since Norwegian salmon is typically grown on diets using 40% substitute plant oil, this strongly indicates that commercial salmon production using substitute oil diets is entirely satisfactory from a human health claim perspective. However, information on the sampling regime and feed formulation were unavailable and so this cannot be unequivocally confirmed.

Nevertheless, the three major Scottish feed manufacturers were adamant that they could and do provide diets that allow salmon farmers to meet the omega 3 health claims. Consultations with the two Scottish fish farmers using substituted oil diets confirmed that they were meeting omega 3 specifications.

It is recommended that independently verified data on the levels of omega 3s in commercially produced farmed salmon grown using substitute diets be provided by the industry. This would assure the supermarkets in particular, as well as fish farmers, processors, consumers and wider stakeholders that salmon product health claims can be sustained. This could be controlled by the Fish Health Inspectorate which already undertakes sampling for disease monitoring purposes.

Scottish farmed salmon may contain contaminants that have accumulated further up the food chain. These are monitored to ensure that they remain well below the relevant EC regulatory limits. The use of plant substitutes has been found to further reduce the level of contaminants in farmed salmon.

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7.0 Product Quality

7.1 Introduction

Product quality is a critical consideration in diet formulation since it affects the whole supply chain. This chapter describes some of the results from a multitude of research – academic and industry based – on the quality of salmon fed on substitute diets. Methods used in research differ and, due to the nature of some of the trials, academic rigour is not always a requirement.

A common methodology is to evaluate a quality variable by giving it a score. Factors evaluated depend on the purpose of the trial. For example, it is more relevant to evaluate "Degree of Unami"[22] for the Japanese market. They also depend on the type of product being evaluated; e.g. quality factors for smoked salmon would differ from those for cooked salmon fillets. Panels undertaking the evaluation may be expert, trained taste panels or consumers drawn randomly. Quality tests or assessments are described as objective and/or subjective, depending on the method used to determine any given parameter.

The main characteristics of quality examined later in this chapter are freshness, colour, texture, and organoleptic/sensory variables.

7.2 Research Cited

The main sources for this chapter are the projects and research establishments described in the table below.

RAFOA The RAFOA project (described in Chapter 5) included objective and subjective quality and sensory trials. In Scotland, fresh cooked fillets were analysed by a trained taste panel at the Food Industry Forum at Queen Margaret College, Edinburgh. Similar analysis was undertaken in Norway.
ALISA The ALISA project was sponsored by Nutreco and designed to "document and verify to the value chain" the use of fish and plant oil blends. These quality tests looked at semi-commercial quantities of fish grown by Nutreco using the "Alisa" blend of oil in the diet. Six hundred tonnes of salmon were produced using this diet containing 40% plant oil (or 100% fish oil). Consumer tests were undertaken at Campden Chorleywood Food Research Association. (The results are summarised in Trouw Outlook 17 2002 and Skretting Outlook, April 2004.)
ARC Quality tests are carried out at Skretting's Aquaculture Research Centre (ARC) in Norway. ARC has fish farming facilities for undertaking in-house or collaborative fish research – usually about nutrition – and has undertaken trials on substitute diets for several years. In addition to standard quality testing (e.g. colour retention) expert taste panels and "regular consumers" are used for sensory and hedonic characteristic testing. (As well as published papers in journals, results have been reported in summary in Skretting Outlook, April 2004 and Trouw Outlook 15 2001.)
Akvaforsk and EWOS In this study by Akvaforsk (Institute of Aquaculture Research, Norway and EWOS), fish were grown from 700g to market size using a diet containing either 100% fish oil or 100% soya oil (Bencze Rora *et al*, 2005). Fresh, frozen and smoked salmon were analysed for colour, texture, and liquid holding capacity. A consumer panel was also used for sensory evaluation.

[22] *Unami* is the Japanese term for a fifth taste in addition to sweet, sour, salty and bitter.

7.3 Freshness

Freshness can be scored using the Quality Index Method (QIM) – a method intended as a normalised standard throughout the EU fish community[23]. Trained QIM inspectors allocate a score of between 0 and 3 for the "key" variables (skin, eyes, gills and abdomen) which are then totalled and applied against a species index to determine shelf-life. The best salmon QIM score is 0 and the worst 24.

Although storage time on ice does affect freshness, and correlates significantly with the QIM value, the type of oil used in the diet (including whether of a fish or plant origin) was not found in the RAFOA study to affect freshness measured in this way (RAFOA, 2005).

7.4 Colour

Wild salmonids have coloured flesh imparted by the consumption of naturally occurring carotenoid pigments in their diets. In farmed salmonids, carotenoids are added to commercial diets to mimic the flesh colouration of wild fish, enhance the appearance of the flesh and provide nutritional properties important to fish physiology.

Colour is generally measured, both in research and the commercial environment using the Roche SalmoFan (a colour card guide), or electronically with a Minolta Chroma meter.

Some differences have been found in colour when using particular oils. There appears to be some correlation between the use of substituted oils and reduced colour intensity, although this does not appear to be significant and is somewhat dependent upon the level of substitution. Some examples from the literature are highlighted below:

- Smoked fish fed using anchovy oil had a better colour tone than those fed from a soya/capelin mix. Those from a capelin oil only diet were not different to the soya/capelin mix group, only to the anchovy oil only group which emerged with the best colour tone (Skretting Outlook, 2004).
- Muscle pigment concentration and colour of fresh, frozen and smoked salmon were significantly different (lower colour) for salmon fed 100% soya oil compared with a fish oil diet (visual and instrumental) (Bencze Rora *et al*, 2005).
- Higher inclusion levels of rapeseed oil or a plant oil blend led to a significant decrease in colour (SalmoFan) (RAFOA, 2005).
- Rapeseed oil only diets showed deceasing redness and yellowness, whereas linseed oil increased redness (instrumental) (RAFOA, 2005).
- In smoked salmon, the plant oil or linseed oil diets had no or only minor effects (instrumental) (RAFOA, 2005 and Skretting Outlook, 2004).
- SalmoFan scores decreased (i.e. became paler) with increasing storage time on ice – except where linseed oil had replaced fish oil (RAFOA, 2005; Skretting Outlook, 2004).
- All instrumental colour parameters increased (i.e. lightness, redness and yellowness) with ice storage time (RAFOA, 2005; Skretting Outlook, 2004).

The interaction between carotenoid (pigment) uptake, deposition and dietary oil composition will doubtless continue to be investigated and significant differences will continue to be identified. In general, colour differences appear to be more evident from single plant oil diets than from plant

[23] http://www.qim-eurofish.com/index_start.htm

oil blends when compared with fish oil diets or from plant oil followed by finisher diets. Other factors, such as storage time, appear to be more significant than diet type in affecting colour, with longer storage times reducing colouration. Flesh colour is mediated by a range of factors, including genetics, but for practical purposes it is primarily a function of both the pigment level included in the diet (rather than the diet type) and the status of muscle development in the fish (see Johnston *et al*., 2000).

7.5 Texture, Liquid Holding and Oxidation

Storage time results in liquid loss and increasing softness but variation in the dietary oil does not appear to affect texture or liquid holding (except with increasing inclusion rates of rapeseed oil where liquid loss and fat loss decreased (RAFOA, 2005)). Plant oil diets do however result in lower lipid oxidation (chemical change that can result in unpleasant odours and taste in the fat) than do fish oil diets.

Evidence that smoking yield (the amount of smoked product obtained from the fresh fillet) is affected by diet and that it decreases, has been found but this was from a 100% added soya oil diet and other research has indicated that smoking yield is unaffected (Bencze Rora *et al*, 2005).

7.6 Organoleptic Testing

Organoleptic testing, which typically includes taste, colour, odour and texture, has been carried out to assess any differences on salmon from the use of substituted feed. These studies have included experienced taste panels, experienced salmon consumers or the general public. The findings have shown there to be few discernable differences between the controls (usually fed a 100% fish oil diet) and samples containing different levels of plant oils with the latter often being preferred (Skretting Outlook, 2004; RAFOA, 2005).

For example, in one consumer test 224 regular salmon consumers preferred the taste of fish grown using a diet containing up to 75% rapeseed oil to that grown using 100% fish oil. The same fish were subject to appraisal by a specialist taste panel who found no discernable difference between the two types of salmon, or preference with regard to smell, colour, appearance, texture or taste (Williamson, 2002). In the Bencze Rora *et al* tests the consumer panel were unable to detect any significant differences between the dietary groups and only 22 out of 100 consumers were able to identify the correct sample (Bencze Rora *et al*, 2005).

The RAFOA taste panel found that in a ranking test, flesh from salmon grown on a 100% plant oil diet was preferred over the other groups grown on combinations of fish and plant oils or 100% fish oil diets. Where fish were grown on either 100% plant oil or 100% fish oil the flavour of the plant oil scored significantly higher than the fish oil (Torstensen *et al*, 2005).

7.7 Summary of Key Findings

Diet type (with regard to the use of substitutes) does appear to affect the quality parameters assessed but other factors such as storage time on ice, level of pigment in the diet, feeding regime and starvation period are also important variables influencing product quality.

Organoleptic testing of substitute diet fed salmon appears to have had positive results in that the either plant oil fed salmon are sometimes preferred to salmon fed purely on fish oil or that the differences are not significantly discernable.

Virtually no effects of dietary type on freshness, texture and liquid holding were identified.

Colour variations resultant from diet type can be identified, more so at high levels of substitution or where one oil is compared instrumentally with another. Other factors, such as storage time, appear to be more significant than diet type.

In general, it appears that product quality is not a barrier to increased substitution. It would be useful for quality testing of salmon produced from commercial substitute diets to be undertaken on an ongoing basis using independently verifiable analysis to continue to build the knowledge base in this regard.

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8.0 Environmental Issues

8.1 Introduction

Salmon feed is of interest from a sustainability perspective with regard to two main issues:

1. The sustainability of reduction fisheries[24]; and,
2. The sustainability of plant substitutes used to partially replace fishmeal and oil.

The sustainability of reduction fisheries is outside the scope of this project. It is appropriate, however, to highlight that considerable concerns have been raised in this regard (e.g. Marine Conservation Society, 2007; Porritt *et al*, 2005; Poseidon Aquatic Resource Management Ltd, 2004; Scottish Executive, 2002; Tacon, 2005) and these issues should be considered in the debate on feed substitutes.

Although this chapter is concerned with environmental issues, there has also been considerable concern over socio-economic issues in relation to the production of plant proteins and oils (and reduction fisheries) (e.g. Corporate Watch, undated; Deligiannis, 2000; Hatziolos *et al*, 2006). These concerns do not necessarily relate to proteins and oils used specifically for aquaculture. While these topics are outside the scope of this report, they should be included in the debate on substitutes.

Chapter 4 highlighted the crops that can be used within aquaculture as a substitute for fishmeal and fish oil and suggested key raw materials for the UK were soya, rapeseed, maize and wheat. Chapter 9 gives consultees' views on the most important crops used as substitutes in fish feed, and cites rapeseed, linseed and soya. Palm oil is not currently used because other plant oils have preferred qualities and it has been subject to recent price increases. However, palm oil has been considered in this chapter as it is possible that it could be considered as a raw material for aquaculture feeds in the future should it become significantly cheaper than other oils.

There is an increasing amount of literature concerned with the environmental impacts of large scale production of soya and certain other such crops. No direct references were identified that focused on the impacts specifically from sourcing protein and oil substitutes for aquaculture. However, many of the general issues identified in the literature are relevant for aquaculture and so these are highlighted where relevant.

8.2 Consultations

Consultations were held on sourcing plant substitutes with key NGOs known to be active in aquaculture: the Marine Conservation Society (MCS), Scottish Environment Link (LINK) and WWF[25] US. All are in favour of increased use of substitutes to reduce pressure on wild fisheries providing they are from sustainable sources and that consideration is also given to the sustainability of feed fisheries.

The MCS has recently released a set of principles and criteria for sustainable fish farming. Feed is one of the six principles and the MCS states that it "should be manufactured from a combination of environmentally sustainable marine and non-marine raw materials from independently certified sources, and from fish processing trimmings" (MCS, 2007).

LINK was concerned that in its view many, but not all, farmers demonstrated poor awareness of feed sources and had little interest in feed sustainability. Both LINK and MCS were critical of

[24] The term "reduction fisheries" is used along with others such as "industrial fisheries" and "feed fisheries" to describe fisheries used to source fishmeal and fish oil.
[25] Formerly known as Worldwide Fund for Nature and now called WWF.

the Scottish industry's Code of Good Practice regarding feed since they felt it failed to ensure that feed was produced from sustainable sources.

8.3 Approaches to the Sustainable Sourcing of Plant Substitutes

With regard to soya, one of the three feed companies procures the overwhelming majority of its soya from sources certified to the ProTerra standard (discussed below) with the remainder from organic sources. The second company sources some soya certified to the ProTerra standard and is currently "pressing" to increase this to 100%. The third company does not source soya from ProTerra certified companies, although its parent company is a signatory to the Round Table on Sustainable Soya and one of its suppliers has signed up to the Abieove Moritorium. There is also use of assurance schemes with regard to non-genetically modified (GM) organisms, which are not discussed further as this is outside the scope of this report. It is understood that crops other than soya are not sourced under any assurance schemes.

ProTerra

The ProTerra standard was published in April 2006. It addresses environmental sustainability (as well as ethics, social responsibility and traceability) regarding the production, processing, storage and transport of agricultural commodities. It is applicable to any crop world-wide, and used in Scottish aquaculture in relation to soya. The standard is certified by the company Cert ID who, assuming compliance, issue an annual site specific certificate.

Certain ProTerra requirements are termed "basic requirements" and are required to be met throughout the certification period. Other requirements are known as "progressive requirements" and have to be met "in time" in accordance with a plan developed by the company. Many of the requirements of this scheme are not attributed to either category which, it is understood, means these are also "progressive." This will be clarified in the forthcoming revision of ProTerra.

From an environmental perspective ProTerra contains two basic requirements: that "areas of primary vegetation, namely forests, wetlands, swamps and floodplains, and areas of high preservation shall not be converted into farming or agricultural areas" and that GM seeds shall not be used (Cert ID, 2006).

There are also three progressive environmental requirements: "agriculture and/or farming activities shall not be established in areas cleared of native vegetation, including rainforests, after 1994" and that the use of pesticides, fungicides and herbicides be minimised and that environmental risks shall be regularly monitored (Cert ID, 2006). In terms of processing there are also two relevant progressive requirements, reducing "greenhouse" gas emissions and the elimination of products which impact on the ozone layer. There are also numerous other clauses addressing a wide range of other environmental issues including compliance with legislation, clearing areas by burning, study of environmental impacts, and that the quality and quantity of natural water resources shall be preserved.

ProTerra's emphasis on the protection of primary vegetation addresses a major concern of environmentalists regarding soya production (as discussed further below). With regard to most other clauses, including legislative compliance, these can be addressed through ProTerra over time rather than prior to certification, with an auditor monitoring progress. This reflects the reality that an organisation might not be able to comply with certain clauses immediately. Therefore, while ProTerra does not guarantee that compliant companies guarantee environmental protection, it sets a base line against some issues and ensures that a process of improvement is implemented and maintained with regard to others.

It is recommended that the industry sources all materials from sources independently acknowledged as sustainable, and consideration should be given to adopting ProTerra as an industry standard.

It is difficult to identify the extent to which the supply chain complies with individual ProTerra clauses as this information is not available due to commercial confidentiality. It is recommended that the industry engages with Cert ID in order to identify ways in which this information could be published or identify other ways, such as an independent audit and/or environmental reporting.

Roundtable on Sustainable Soya

The Global Roundtable on Responsible Soy Association (RTRS) has been recently initiated by the WWF, who considered that a multi-stakeholder approach was required to address the environmental (and socio-economic) impacts associated with soya (and also palm) across the world (Harrison, WWF, 2007, *pers. comm.*). The soya Roundtable is currently working on a strategy to aid responsible soya production which will be based on the Basel Criteria (developed to aid responsible soya production on behalf of the Co-op in Switzerland, ProForest, 2004). To our knowledge, a date has not been set for the strategy to be published or implemented.

While the roundtable approach has many supporters, it has certain limitations including that it is not mandatory and that it is time consuming. It has also attracted criticism for taking a dialogue approach, which was felt by one stakeholder not to address the root cause of the problems (Corporate Watch, undated).

It is not known to what extent an approach using RTRS may complement or perhaps overlap or duplicate ProTerra. It is recommended that the industry proactively engages with the RTRS during the development of the strategy.

Roundtable on Sustainable Palm

The Roundtable on Sustainable Palm Oil (RSPO) was also initiated by the WWF. The RSPO has published a set of documents in relation to sourcing palm oil responsibly, which included a set of criteria in 2005 also based on the Basel Criteria (see above). Recently it has also published an approach to certification (October 2007), although this does not yet appear to have been implemented. In its infancy, the membership of RSPO focused on the production end of the supply chain and now most major supermarkets have become involved.

It is expected that some 1-1.5m tonnes of palm oil will be available in the first year (2008) which will have been grown to the RSPO criteria, although a large proportion has been acquired in advance for the biofuel industry.

The limitations associated with this Roundtable are similar to those for the RTRS discussed above. Again, it is not known to what extent an approach using RSPO may complement or perhaps overlap or duplicate ProTerra. Should palm oil be used as a future substitute, it should be sourced sustainably and, if appropriate, the industry should engage with RTRS.

Other Schemes

The Worldwatch Institute makes the point that while there are a variety of certification schemes and standards in place or being developed for agriculture and forestry, none are specific to plant oils[26] (Worldwatch Institute, 2007). It suggests that these could be a useful interim step prior to the development of schemes specifically for plant oils. The United Nations (2007) points to work being done to advance bioenergy specific certification schemes, including work by the FAO, UNEP, UNIDO, UNCTAD and the WTO. Recognition is also given to the potential applicability of existing certification schemes such as the Forest Stewardship Council.

[26] Specifically, biofuels.

While specific UK assurance schemes for rapeseed were not identified, two generic ones were noted, LEAF (Linking Environment and Farming) and the Soil Association's organic standard. There would be sufficient feedstock of LEAF certified rapeseed to meet the anticipated demands of the Scottish salmon farming industry, although it has a slight price premium (Jeremy Boxall, LEAF, 2007, *pers. comm.*). There may be other applicable standards, although time has precluded a more detailed investigation.

8.4 Environmental Impacts Related to Cultivating Soya and Palm

The ProTerra standard comprehensively addresses issues concerned with the cultivation and management of crops but not all soya used in Scottish salmon farming is sourced according to this standard. Many of the relevant clauses are progressive rather than basic requirements (see earlier in this chapter). One feed company is a signatory to the soya Roundtable, but its strategy is not yet implemented, and although palm oil is not currently used in Scottish salmon diets, it could be in the future. In light of these diverse approaches and uncertainties and given the general concerns related to the use of these raw materials, it is helpful to briefly highlight some of the potential environmental impacts associated with their cultivation and management.

The key concern in relation to soya and palm is the clearance of primary vegetation for plantations, particularly rainforests and cloud forests. This is very damaging since these ecosystems contain the greatest biodiversity of any terrestrial habitat on the planet (Worldwatch Institute, 2007; BBC, 2005; BBC, 2007[a]; ThinkQuest; FWI/GFW, 2002). The most high profile species under threat is arguably the orang-utan, which is now facing extinction in many areas of the world directly due to oil plantations, particularly palm oil (Buckland, 2005; Friends of the Earth, 2006). The typical use of burning to clear land is of great concern due to its contribution to climate change (Worldwatch Institute, 2007) – and air pollution (FWI/GFW, 2002; Wetlands International, 2006).

In addition to habitat destruction, there are a range of generic concerns which may be associated with the large scale production of these crops in certain environments. For example, fertiliser use may cause eutrophication and typically has a high energy demand in manufacture, there may be an increased demand for irrigation water and some farms may have high energy requirements (United Nations, 2007; Worldwatch Institute, 2007; Renewable Energy UK, undated). The choice of crops and husbandry techniques may help to reduce impacts.

In some cases the sensitive development of plantations can have a positive result on habitats (United Nations, 2007; Worldwatch Institute, 2007). This includes plantations in arid or semi-arid areas where biodiversity is already relatively low and where they can improve poor quality or degraded land and hence act as a means of rejuvenation.

8.5 Environmental Impacts Related to Sourcing Rapeseed

For the UK aquaculture industry, rapeseed would be largely sourced from the UK and is hence not associated with the scale and severity of impacts potentially associated with soya (and palm). Nevertheless, there are environmental issues of concern, which are briefly discussed below.

Rapeseed can have negative environmental impacts if it replaces set-aside land or other land uses with high biodiversity (Land Use Consultants, 2007). However, when compared to other cereal crops it can have a positive benefit on birds and invertebrates (Land Use Consultants, 2007; Department for Transport, 2007). The Royal Society for the Protection of Birds (RSPB) confirmed the key issue focuses on location and scale of cultivation rather than necessarily the method of production (Guy Anderson, RSPB, 2007, *pers. comm.*). The RSPB's concern is to avoid rapeseed being used in large areas of monoculture or to replace areas of greater biodiversity such as set-aside land or areas of natural habitat.

LEAF has a different perspective, suggesting that the location and scale of rapeseed are not an environmental concern because it is grown on rotation (minimum of one in three years, more usually one in five) and hence unlikely to become a monoculture system or replace land with greater biodiversity (Jeremy Boxall, LEAF, 2007, *pers. comm.*). The RSPB suggests that this is not necessarily the case, and maintains that there are concerns with rapeseed when it replaces set-aside and that monocultures can develop (Harry Huyton, RSPB, 2007, *pers. comm.*)

To our knowledge, rapeseed is not procured for the aquaculture industry from any assurance scheme. While this should be considered by the industry in the near future, priority should be given to ensuring that crops from the tropical and semi-tropical areas of the world such as soya are sourced in a responsible manner as failure to do so may be associated with greater environmental impacts.

8.6 Other Crops

We are not aware of any other plant meals or oils used for aquaculture being sourced in accordance with other assurance schemes. While this should be considered in the future, it is considered a lower priority than those discussed above.

8.7 Impacts of Processing Substitute Crops

The processing of plant materials into protein and oils has environmental impacts. This includes energy use, water use, effluent discharge and air emissions (Worldwatch Institute, 2007; Buckland, 2005). There is also the potential for nuisance from processing plants, particularly noise and odour. No examples specific to aquaculture were identified in the literature.

As previously highlighted, the ProTerra standard partially adopted by the Scottish feed industry includes processing and transport considerations.

8.8 Environmental Impacts Resulting From the Use of Substitute Feeds

Should plant substitution result in decreased digestibility this may lead to an increase or change in faecal matter which could increase the pollutant loading from tanks and cages. There is also the potential for changes in environmental impact from uneaten feed. Only one relevant reference was identified in the literature; Tuominen and Esmark (2003) cited a study in Finland by Seppala *et al* in 2001 (not accessed during our review) which showed that the nutrient load from feed with substituted materials was lower than that based on fishmeal and oil and thereby suggests that this is not an issue.

The Scottish Environment Protection Agency (SEPA) confirmed that it did not know of any research or reports on this matter noting that while any increased loading would be of concern, it was not aware of any issues in this regard and was not particularly concerned about this matter at the present time (Douglas Sinclair, 2007, *pers. comm.*).

This topic was also raised with the Environmental Manager for the County of Hordaland in Norway, which is an important fish farming area. The Manager confirmed that they "were not aware of any special issues in this regard, and was not of concern to them, since they suppose that the ordinary monitoring (which is mandatory and rather thorough) will disclose any change in the pollution picture that might take place" (Haakon Kryvi, 2007, *pers. comm.*).

We also discussed this issue with the two Scottish fish farmers currently using/trialling substitute diets. Neither company considered it to be an area of concern.

In anticipation of the more widespread use of substituted feeds, this topic may be of interest to stakeholders and consideration might usefully be given to targeted monitoring of sites where these feeds are used.

8.9 Summary of Key Findings

Two of the three feed manufacturers source some or a majority of soya from ProTerra certified producers. ProTerra addresses the key environmental concerns associated with soya production. It recognises that participating companies may not be capable of full compliance from the outset and instead requires that non-compliant elements are addressed over time. To preserve confidentiality, information on the extent of compliance by individual companies is not available.

It is recommended that the feed industry implements an industry wide approach or policy to source soya from sources certified as sustainable; this should include production, processing, transport and storage. A short timescale should be set for compliance. It is recommended that the industry engages with Cert ID to explore the potential for information about compliance to be made publicly available to increase transparency.

While there is interest from one feed manufacturer in the Roundtable on Responsible Soya (RTRS), its strategy is not yet implemented. It is recommended that the feed industry continues its involvement in this regard.

Should the industry use palm oil in the future, it should be sourced from sources certified to be sustainable. Engagement with the Roundtable on Sustainable Palm Oil is recommended.

Other plant materials are not sourced from certified sources. Since the majority of these are from the EU or UK, they are considered to be of relatively lower importance than ensuring the sustainability of materials sourced from areas with greater environmental impacts. However, consideration should also be given to the assurance of the sustainability of these sources at the earliest opportunity.

While the sustainability of reduction fisheries and consideration of the socio-economic issues of feed sources are outside the scope of this project, these issues should be considered in the debate on feed substitutes.

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9.0 Feed Manufacturers

9.1 Introduction

Consultations were held with the three main manufacturers of Scottish salmon feed, namely Biomar Ltd, Ewos Ltd, and Skretting UK and Ireland. Together, these three companies supply virtually all the salmon feed used in Scotland, including organic and customer bespoke diets. All three have manufacturing premises in Scotland and they are all subsidiary companies of international suppliers of salmon feeds and other fish and agricultural feeds:

- Biomar Ltd is a subsidiary of Biomar A/S.
- Ewos Ltd is part of the Ewos Group a subsidiary of Cermaq ASA.
- Skretting is the fish feed segment of Nutreco Holdings N.V.

Consultations were carried out face to face with two of the feed manufacturers and by telephone for the third. Follow-up phone consultations were also held with certain companies to discuss issues that had arisen as the project progressed.

Feed manufacturers operate on a "best cost solution" basis to formulate salmon diets. This balances raw material prices, food conversion ratio, fish health, growth and nutrient requirements, and customer and quality scheme specifications.

9.2 Fishmeal and Fish Oil Use

We were informed that the use of Atlantic sources of fish oil has declined. This is for a number of reasons, depending on the species in question, including the imposition of management controls such as quotas and closures, reduced landings in the case of over-exploited fisheries and higher contaminant levels. South American fish oils are increasingly preferred for use in diets where some fish oil is substituted by plant oil since these fish oils are higher in EPA and DHA. However, they are also higher in saturates and therefore less digestible in colder temperatures. While North Atlantic oils are lower in EPA and DHA, they are also lower in saturates and therefore often preferred for colder temperatures. Feed manufacturers have to consider these different factors and provide the best balance when formulating diets (with or without substitutes).

The feed manufacturers went on to say that the insistence on high levels of marine ingredients is not sustainable and a more balanced approach using feed manufacturers' knowledge of fish nutrition is needed. All felt that the use of fishmeal will not drop below 10-15% of the diet formulation for nutritional reasons (current proportions are 20-30%).

Wout Dekker of Nutreco recently commented on alternatives (rapeseed oil, soya meal, sunflower meal and corn gluten) to the use of fishmeal and fish oil in the manufacture of global aquaculture feeds. Dekker noted that in the past three years alone, while sales of feeds grew 28%, use of fishmeal and fish oil decreased by 11% and 20% respectively (Dekker, 2007).

9.3 Plant Meal and Oil Use

Plant meals are used in feeds for farmed salmon globally. Consultees stated that the sources of plant meals are soya, rapeseed, sunflower, pulses, peas, beans, lupins, wheat and maize gluten. The main ones used are soya meal, maize and wheat gluten. The non-digestible fibre content of plant meals has to be minimised since it takes up pellet space and this limits its usage.

Plant meals have been used for decades but their proportion in the diet has increased mainly due to increasing fishmeal prices. We were informed that as the percentage of fishmeal has fallen to

around 25-30%, the plant meal percentage has increased to between 20-30% of the total diet formulation. (Note that these proportions are somewhat different to those presented in Chapter 4, which is possibly due to the inclusion of wheat in some figures and/or rounding of data.)

One manufacturer stated that in accordance with the specifications of its customers, it did not use plant oil. Another manufacturer had one customer using plant oils at a commercial level. In contrast, we were informed that plant oils are being used in substitute diets by approximately 95% of the Norwegian industry.

Consultees informed us that in Norway salmon diets may be based on substituted plant oil of up to 60% of added oil, with an average of about 30%. Lower proportions are currently being used in Scotland and, while these may increase, it was thought unlikely that they would reach the higher levels used in Norwegian diets. At lower levels of inclusion single plant oils would be used while, at higher levels, a blend is more likely to reflect the fatty acid profile of fish oil. The most commonly used plant oils would be rapeseed, linseed and soya.

All feed manufacturers predicted that substitute oil diets will rapidly increase in the short to medium term in Scotland.

All said that with substitution there is a greater supply and range of raw material choice, similar to other agricultural feeds, which helps provide a more level international "playing field" Given the upward trend in raw material prices and forecasts for future scarcity, this is of great concern to the feed industry. For example, Wout Dekker (CEO Nutreco) recently stated in a webcast that by replacing fishmeal and fish oil with plant substitutes Nutreco were successfully addressing the scarcity and resultant high prices of fish raw materials without compromising quality and that "Salmon farming in 2010 will produce more fish protein than it needs today as a raw material input for salmon feed. [This] means that aquaculture can now grow to become a net producer of fish proteins." (Dekker, 2007).

9.4 Product Standards

Product standards such as Label Rouge and TQM generally specify the content of the diet to a greater or lesser degree. All manufacturers identified product standards as barriers to the use of substitute diets and specifically to the substitution of plant oils (see Appendix C for information on product standards).

Label Rouge specifies a high level of marine raw materials, higher for example than TQM. While many farmers grow to more than one standard, they often work to the more stringent one to provide greater flexibility when harvesting, which is a barrier to the more widespread uptake of feed with substituted oils.

Consideration should be given to reducing the marine content of diets in industry standards, and this might usefully be approached by emphasising the omega 3 content of the product rather than the type of raw materials. It is understood that Label Rouge members are actively considering the use of substitutes at the present time (D. Low, EWOS, 2007, *pers. comm.*).

9.5 Supermarkets and Consumers

Supermarkets generally have their own product specification and/or require farmers to conform to independent product standards such as Label Rouge, TQM etc. Directly or indirectly the supermarkets therefore specify the salmon diets to a greater or lesser extent. All feed manufacturers identified the supermarkets as a barrier to the use of substitute diets and, in particular, to the use of added plant oils. This was thought to be a somewhat contradictory position since supermarkets are also seeking product differentiation which could be at least partially achieved by greater consideration of substitutes (see Economics section below).

One feed manufacturer thought supermarkets are seeking product differentiation, tiered according to diet constituents:

1. Natural and sustainable – mostly marine raw materials and no plant oils.
2. No animal by-products (ABPs, such as bloodmeal or feathermeal) but plant oils included.
3. ABPs and substitute plant raw materials included – sold as frozen (Chilean).

"Natural and sustainable" will be the most expensive product and frozen Chilean will be the cheapest.

One feed manufacturer thought that the "upmarket" supermarkets in particular wish to be seen as ethical businesses, and do not want to be criticised for using a feed which could be perceived as unnatural to produce salmon. Echoing this thought, another said that in terms of salmon diets, "natural" (i.e. using marine based raw materials) is a bigger driver than "sustainability". Consultees stated that supermarkets view marine derived raw materials as more natural than plant ones and, despite the industry spending "millions of pounds on research and development" the message that substitute diets are benign and a more sustainable raw material than marine derived raw materials has not been accepted by the supermarkets. One consultee highlighted the need for the industry to educate the supermarkets.

Two feed producers thought that some fish farmers are still against substitution mainly because of concerns over customer reaction, restrictions of product standards and customer specifications.

9.6 Economics

All feed manufacturers said that price and limited supplies of fishmeal and fish oil are the main factors driving substitution. Two feed manufacturers were of the opinion that the use of plant oils in salmon production in Norway and Chile has marginally eased market pressure on fish derived raw materials in the UK.

One said that any savings through substitution would be passed on to the farmer. The other two considered there are no longer major savings to be made as demand for agricultural feed raw materials is increasing all the time, principally from developing economies. Substitute raw material prices "track" fishmeal and oil prices in a larger raw materials market which now includes biofuels.

All consultees considered China (and other developing economies) to be a major and continuing influence on fishmeal and oil markets. A small change in feed formulation in China has a dramatic effect on the raw material market. Two companies said that fish feed is a very important player in the fish oil market and an insignificant player in other raw material markets (e.g. soya). The general consensus of consultees was that fish oil and, to a lesser extent, fishmeal will be increasingly targeted as specialist nutrients and premium raw materials.

All consultees referred to the biofuels market, which may result in a glut of plant meals, not all of which may be suitable for fish feed. This also connects plant and fish oils to the crude oil market, introducing a different set of parameters into raw material procurement. The need for high quality and therefore expensive substitute raw materials for salmon diets was considered a constraint on reducing production costs.

Consultees recognised that demand, even with substitutes, is equal to the supply of fish oils. Two manufacturers gave the example of El Niño reducing catch biomass (e.g. 20% in 1998/99), pushing up fishmeal and fish oil prices which in turn put pressure on substitute prices and caused market instability.

Two manufacturers pointed to pressure in the form of increasing demand and lowering supplies of traditional food fish, resulting in an increasing diversion of stocks from fishmeal and fish oil production into the food market, generally through processing (e.g. herring). A knock-on result has been a shift in the feed fisheries toward less oily fish species, reducing the overall fish oil yield and further increasing its price.

9.7 Environment

All feed manufacturers cited sustainability (i.e. supply of raw materials) as the main reason for wanting increased substitutes. In theory, using plant raw materials will reduce the pressure on fisheries resulting from the increase in global aquaculture, assuming fishing pressure is effectively managed. In any event, output from capture fisheries is limited and demand is predicted to outstrip even the most optimistic predictions of sustainable supply. Utilising non-marine sources and a wider range of raw materials is therefore recognised as fundamental to sustainability in the broadest context.

With regard to environmental impact, there are positive and negative impacts from substitution in salmon diets and two manufacturers thought a wider approach should be taken by environmentalists and stakeholders which not only looked at feed fisheries depletion, deforestation and "food miles" but also included eco-efficiency. In this regard, eco-efficiency means that fish convert feed into flesh more efficiently than other protein sources such as chicken, pork and beef[27]. Substitution offers other benefits including some use of biofuels by-products and the possibility of using locally grown raw materials such as bean meals in salmon diets.

One manufacturer was concerned that the increasing pressure on the price of feed raw materials may result in the use of cheaper ingredients and, as a consequence, higher feed conversion ratios (FCRs). A higher FCR (resultant from any reduction in the quality of diets) could increase benthic impacts (i.e. impacts on organisms dwelling on the seabed) which at significant levels could present environmental legislation compliance issues, although none thought that this should be the case[28]. All consultees viewed plant meal and oil substitution as positive with respect to sustainability.

By-product fishmeal (manufactured from fish wastes from wild fish processing) is an alternative source, but also expensive. While the consensus was that supply is limited, one company mentioned that there was a considerable amount of material in principle, although storage and handling issues would need to be addressed. The consideration of meal from such sources is outside the scope of this project.

All consultees considered animal by-products (ABPs) to be a sustainable, low "food miles" feed ingredient, although it should be noted that ABPs are not used in Scotland due to concerns over market resistance. The consideration of substitutes other than those of plant origin is outside the scope of this project, but the feed manufacturers considered that the use of ABPs such as feather meal and blood meal could provide a valuable, sustainable and cost-effective raw material. Two manufacturers also pointed out that ABPs are used in other countries such as Chile and Canada, and that the resulting products can be imported in to the UK.

[27] More information is provided in this regard from the following sources: Norwegian Directorate of Fisheries (2007), Terram Foundation (2006), David Suzuki Foundation (2007), RACEnvironment Ltd (undated), Joint Marine Programme (2004), and Thistle Environment (2008).

[28] Fish farm sites are licensed by the Scottish Environment Protection Agency (SEPA). A higher FCR may result in increased deposition of faecal matter and uneaten feed on the seabed in the vicinity of fish farm cages which, if significant, could lead to a breach of licence conditions.

It was generally thought that NGOs were not fully aware of the status of feed substitution, including limitations posed by product standards and specifications. It is noted that some elements of the industry and some NGOs have worked together on some fish farming issues over recent years, including feed substitution.

9.8 Fish Health

Based on a decade of research and development, together with considerable commercial experience, particularly in Norway, none of the feed manufacturers felt that the partial substitution of meals or oils results in any fish health or welfare problems.

9.9 Human Health

All three companies stated that diets with partial meal and oil plant based substitution will meet recommended human health levels of omega 3s with less risk from contaminants. All considered it critical to keep contaminant levels well below EU limits and all are aware that there is a potential risk of pesticide residue contamination in plant raw materials.

9.10 Technological Constraints

All feed manufacturers said there were no major technological constraints on the increased use of plant meals and oils in Scottish salmon diets. Blended oils can be bought in directly (but at a higher cost to unblended) or blended on site which requires capital investment but provides more flexibility. An increase in the number of ingredients impacts on storage requirements and there are logistical and purchasing implications which may require investment.

9.11 Summary of Key Findings

In the medium term, if not the short term, feed manufacturers believed that the Scottish industry will require increased use of plant substitution, particularly in respect of oils, if it is to remain internationally competitive, supply the demands of supermarkets for product differentiation and maintain the potential for expansion. It is unlikely that there will be major savings for farmers purchasing feed containing increased plant substitutes.

Feed manufacturers confirmed that they can deliver the levels of omega 3s desired by the industry using substitute diets.

The supermarkets are viewed as a barrier to the use of substitutes for Scottish salmon, yet they are seeking product differentiation and sell imported products grown on substitute diets – which appears to be a contradictory position. The feed manufacturers envisage premium tier products being produced using high levels of fishmeal and 100% added fish oil. The rest of the salmon product range will use varying proportions of plant meals and added plant oils.

Product standards and specifications are barriers to the increased use of substituted diets. Two consultees thought that some fish farmers were hesitant to use substitute oils.

It was generally thought that NGOs were not fully aware of the status of feed substitution, including limitations posed by product standards and specifications.

No feed manufacturers would use animal by-products at the present time in the Scottish market due to reasons of market/consumer acceptance, but all believe them to be sustainable raw materials. Some believe that there is opportunity for greater use of fish trimmings, although this is expensive and has accompanying difficulties regarding handling and storage.

There were no major technological constraints on the use of plant meals and oils in salmon diets.

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10.0 Consultations – Fish Farmers

10.1 Introduction

Consultations were undertaken with a total of ten fish farming companies selected to be representative of the diversity of ownership, size, production and geography of the Scottish salmon industry. The companies that participated were as follows.

Multinationals:		
• Marine Harvest Scotland	• Pan Fish UK Ltd	• Scottish Sea Farms Ltd
Large Companies:		
• Lakeland Group	• Hjaltland Sea Farms Ltd	
Independents:		
• Loch Duart Ltd	• West Minch Salmon Ltd	• Wester Ross Fisheries Ltd
Smolt Producers:		
• Highland Salmon Ltd	• Migdale Smolt Ltd	

We have presented our findings according to size and type of company since, in general, responses varied in this regard. References in the text to the "first", "second" company etc, bear no resemblance to the order in which consultees are listed in the above table.

10.2 Multinationals

The multinationals consulted all used feed in which a certain proportion of fishmeal had been replaced with plant protein and none identified any fish welfare, fish nutrition or product quality issues. All said they would like to increase the amount of substitution from plant sources, although different reasons were cited for not already doing so. In saying this, all stated that it was paramount that product quality had to be maintained, with salmon meeting the customer expectations in terms of health benefits, taste and product safety. The reasons for wishing to increase substitution were:

- potential limitations on the growth of the industry from the future availability of marine based ingredients, particularly fish oils; and,
- concerns over the sustainability of feed fisheries.

One company highlighted that there were two reasons the substitution of protein had not already increased to a greater extent, namely customer perception and supply. Supply was cited as being the more prominent issue. We were informed that at the present time the EU only has limited capacity to grow and supply plant proteins with high digestibility (e.g. peas, beans, sunflower seeds, maize gluten, corn gluten and certain forms of soya). The prohibitive EU import duty on these commodities is a further limit on supply.

No company had concerns about increasing the amount of substituted fishmeal providing that quality and welfare issues were met – and they saw no reason that this would not be the case.

Only one of the multinationals currently substitutes fish oil. It reported no difficulties and confirmed that it is entirely possible to produce a product with the required omega 3 levels through the use of diets high in fish oils at specific times of the growing cycle. Substitution is

required since fish oil availability limits the potential for industry growth. There was no cost benefit reported.

Of the multinationals which do not substitute oils, the second was more concerned about the substitution of fish oil than the third. The second was not necessarily against substitution, but wanted to see more evidence from commercial trials (i.e. representative of species, size and production timescale) which meant substitution was unlikely in the short term, unless there was a major impact on availability. It (and the third multinational) also cited retailer resistance as a barrier.

The third multinational considered that there was absolutely no reason not to substitute fish oils from any perspective, suggesting that consumer perception, although unfounded, might be a barrier.

All were aware of the potential environmental issues with regard to substituted products, and would aim to address these through, for example, using companies that were members of respective Roundtables, or other approaches. All were also concerned about the sustainability of feed fisheries and were keen the marine components of feed came from sustainable sources only.

All the multinationals were aware of the need to differentiate between overseas products, particularly Norwegian, to protect and enhance their markets, although there were different views on the role that substitution played in this regard. For two, substitution enhanced differentiation, although they were unsure whether this effect was real or merely perceived, while the third considered that differentiation should be possible regardless of substitution.

The multinationals considered Label Rouge a barrier towards higher levels of substitution in some cases and one company mentioned that TQM originally specified strict substitution levels which was a historical driver. However, in general, the multinationals thought that the supply chain is arguably moving away from these towards more internationally recognised or customer specified standards (note that Processors made similar comments as highlighted in Chapter Eleven).

10.3 Large Companies

Both the large companies consulted substituted fishmeal but not oil. One was interested to substitute oil in the future because of increasing feed prices and expected to see a significant reduction in cost as well as a positive impact on public relations and marketing. This company was currently running trials using substituted plant oil.

The other company did not currently substitute plant oil and would prefer to maintain this position because it considered [the use of fish oil] to be more natural. Nevertheless, it acknowledged that feed prices are likely to increase due to the limited supply of fish oil and that it would need to reconsider its position. Its perception was that the supermarkets were the main element in the supply chain that would need to be convinced to allow substitution of oils to occur.

One of the companies considered Label Rouge a barrier to substitution. Although it sold against more than one standard, it generally grew most salmon under Label Rouge to give greater flexibility when harvesting.

10.4 Independents

The first independent consulted substitutes fishmeal but not fish oil. It was relaxed about an increase in future substitution, both of oil and meal, and considered it inevitable due to potential supply constraints, assuming there is no compromise of fish health and welfare, or of omega 3s.

The company also considered Label Rouge to be a barrier. Sustainability is a much greater issue for its customers than substitution; therefore it fully anticipated its customers accepting increased substitution.

It thought this study was several years too late and noted that most companies were already substituting meal anyway. It was very concerned about public perception and the potential for media backlash, and did not think the consumer attitude study appropriate for this reason.

The second independent did not substitute fishmeal or fish oil. It had no intention of changing its position because it aimed to produce salmon in conditions that were as near to natural as possible, although there may be need to review the policy should feed prices change dramatically.

The company had concerns over fish health and welfare and particularly pointed to increased deformities in Norway, which it thought had risen with increased substitution although it was not aware of any studies indicating a causal link.

Substitution was not considered the best approach from a sustainability perspective since the worldwide expansion of aquaculture would utilise any over supply of fishmeal and oil made available through substitution. Therefore, substitution was viewed as a "temporary solution" which would not reduce the long-term pressure on fish stocks. The company was concerned that the industry and NGOs were only thinking of salmon farming, and had not considered the wider perspective of future demand on fish stocks should substitution in Scotland become the norm. Sustainability issues concerning fisheries could be addressed through careful sourcing and proactive fishery management, and environmental issues were being used – wrongly – as a justification for substitution.

The third independent also did not substitute fishmeal or fish oil. This was because it was an organic producer working to the Soil Association standard. While the standard permits substitution, organically certified materials have to be used which are prohibitively expensive and so they continue to use marine based feeds. Increased substitution across the industry may reduce supply pressure on marine ingredients which would be beneficial for the company, as well as reducing pressure on fisheries. However, should the industry fail to move towards substitution, organic production would become prohibitively expensive since the costs of sourcing marine based feed were expected to increase.

10.5 Smolt Producers

The first smolt producer was an organic producer and had noted recent increases in the price of fish feed and fishmeal. It essentially did not have a choice about its feed ingredients due to its organic status, since organic plant substitutes are prohibitively expensive. It felt that plant protein should be used for terrestrial agriculture and marine protein left for fish feed. It was concerned about the potential for chemical contamination of fishmeal and considered this a major benefit of substitution. Overall, it was concerned about the ability of the feed industry to maintain supply of marine based feed given the expected limitations on future availability.

The second smolt producer found the situation difficult to understand because the supermarkets were against Scottish salmon grown on substitute diets yet accepted Norwegian and Chilean imports with significant substitution. It considered that the supermarkets were dictating the policy and appeared to have different standards for Scottish and imported products.

The company considered Label Rouge restrictive in terms of substitution. Substitution was inevitable and should be implemented sooner rather than later. This required a culture change in the industry and a move away from Label Rouge as it currently stood.

The producer also raised an interesting point about the naturalness of freshwater diets. Freshwater feed is based on marine constituents which, it could be argued, is unnatural since in the wild such fish would not encounter freshwater prey until they entered the marine phase of their lifecycle.

Finally, it had great concern about the sustainability of fish stocks and considered that unsustainable fishing practices could not continue. Substitution might also help reduce the environmental footprint of aquaculture by reducing the transport distance of feed ingredients.

10.6 Summary of Key Findings

The practices and opinions of those fish farmers consulted during this project with regard to substitution varied across the industry, consistent, to some extent, with the size and market of the producers. A summary is provided in the table below.

	Fishmeal					Fish Oil				
Type of Company	Multi	Lge	Inds	Smolt	Totals	Multi	Lge	Inds	Smolt	Totals
Accept substitution	3	2	1	1	7	1	-	-	-	1
Open to increased substitution	-	-	-	-	0	1	1	1	1	4
May consider increased substitution	-	-	-	1	1	1	1	-	-	2
Against substitution	-	-	2	-	2	-	-	2	1	3
Totals	3	2	3	2	10	3	2	3	2	10

Note: Multi: multinationals; Lge: large companies; Inds: independents; Smolt: smolt producers.

The range of opinions of different fish farmers is not considered a major barrier to increased substitution. This is because none of the multinationals and larger companies are really against substitution and they account for the greater proportion of Scottish production. Indeed, uniformity across the industry would not necessarily assist market differentiation and could be detrimental to the continued development of niche markets.

Nevertheless, several fish farmers required evidence from commercial scale trials/production, particularly regarding oil substitution and concerns over fish health and omega 3s. While this should be viewed in the context of current large scale production in Norway using substitute oil diets, failure to provide such evidence may reduce the timescale and/or uptake of increased substitution in Scotland. It is recommended that independently verified data is made available at a commercial level which clearly identifies omega 3 levels and addresses health concerns for farmed salmon.

Only one of the three independents and one of the two smolt producers consulted was open to the substitution of fish oil.

Label Rouge was quoted as a significant barrier for many companies since it limits levels of substitution.

Responses from consultees, while broadly reflecting their scale of operation, also revealed divergent perceptions and understanding of what constitutes 'sustainability' and 'naturalness.' While some of the parameters associated with these descriptors are subjective, many can be defined objectively and quantitatively. These consultations suggest that there is a need to promulgate a common understanding of 'natural' and 'sustainability' (social, environmental and economic) throughout the supply chain.

This conundrum is embodied in the observation that freshwater salmon feed is essentially 'unnatural' since it utilises marine ingredients which, by definition, freshwater fish would not naturally encounter at this stage in their lifecycle.

11.0 Fish Processors

11.1 Introduction

Consultations were undertaken with eight processors covering the whole range of finished product from Scottish farmed salmon, including fresh and frozen fillets, steaks, fillet portions, prepared meals, smoked and added value items and organic product ranges. These processors supply the food service sector, all the major UK supermarkets and also the export market.

Processor Consultees:	
• Aquascot Ltd	• M&J Brakes
• Macrae Food Group	• Scot Trout and Salmon
• Pinneys of Scotland	• Youngs Bluecrest Seafood Ltd
• Hjaltland Sea Farms Ltd	• Seachill

11.2 Sources of Salmon and Use of Substitute Feeds

Consultees said that as well as Scottish salmon they used large volumes of Norwegian salmon and some Irish organic farmed salmon. None used Chilean farmed salmon (one had considered using Chilean fillets three years ago and rejected the option, principally on cost grounds).

All processors took Scottish salmon grown using substitute plant meal and no processor took Scottish salmon that had not been grown with some substitute meal. Not surprisingly, a minority handled Scottish product grown using substitute plant oil. Conversely, four of the eight processed Norwegian salmon grown on substituted meal and oil, the latter at proportions averaging between 30-35%.

Six out of the eight processors would be willing to accept Scottish plant oil diet salmon. Youngs Seafood Ltd provided the following statement with regard to substitution: "We endorse the use of oil substitutes. We are mindful that the supply of marine oils is finite and that for aquaculture to grow there has to be substitution" with the proviso that the quality and the health aspects of salmon are sustained (Verbal comm.). This was not a universal view however. One processor did not think it was a good idea, believing that its market required fish oil only products and two others, producing niche market premium and/or organic[29] products will continue to use fish oil salmon for these markets. Generally processors viewed substitution as necessary for the continued development of the salmon market.

11.3 Substitute Products

The processors commented that, due to Norwegian imports, many consumers are regularly purchasing salmon products grown using substitute plant oils (and have been doing so for two to three years). Therefore, the use of substitutes does not constitute a barrier *per se* and the question is more about the future direction of the Scottish industry.

All processors supplying the supermarkets spoke about the market being tiered in terms of premium and commodity food products both within and between the supermarkets. The top-

[29] Although the Soil Association farmed salmon standard allows substitute plant based products providing that they are certified as organic, we were informed by one fish farmer that these are prohibitively expensive (see Chapter 10).

end retailers demand salmon grown using fish oil only. Within store the other supermarkets have lower volume premium product ranges which will also continue the demand for fish oil only grown salmon.

They all considered that lower tier or commodity volume product will be grown in the future using plant oils. The fishmeal content of diets would decline to 20% over the next 10 years and the supermarkets will accept plant oils for these products. All considered that there would be niche/premium markets for products grown on marine based feed, but most of the industry would use substitute oil.

11.4 Economics

There was general awareness that increasing demand from developing countries and the biofuels market affects the supply of marine feed ingredients and plant substitutes. In contrast to the feed manufacturers, processors expected the increased use of substitutes in Scotland to reduce feed costs. They expected these savings to be passed on to themselves.

Substitution is generally viewed as assisting price stability and facilitating steady growth in the salmon market. There was a feeling that Scottish salmon farmers should be able to compete more readily with overseas producers.

All considered that price was the primary shopping factor for the consumer and one processor believed substitution would result in lower prices in-store. Some processors said there was a price ceiling on salmon products which had caused demand to fall in the past and would do so again if increasing feed prices are passed down the supply chain.

11.5 Consumer Knowledge

There was a range of views regarding consumer knowledge about farmed salmon. Most processors believed that consumers had limited knowledge about fish farming and are concerned about the origin of their salmon, although a minority believed consumers were unconcerned and fairly ignorant of the products they purchase with no interest in what fish are fed.

Conversely, a small proportion of processors (particularly those supplying niche markets) thought their consumers were well informed and knowledgeable, and that this influenced purchase decisions. One processor thought that the well informed consumer's purchasing decisions were, in order of priority, food safety, environmental impact, animal welfare and sustainability. Indeed, to a greater or lesser extent, all processors consulted thought that the sustainability of all food products was in vogue and was a purchase driver for consumers. Another view was that more knowledgeable consumers set the trends and were, in due course, followed by the rest of the market.

Although processors were unsure of the market reaction should consumers learn that salmon had been reared on plant diets, they considered that other feed issues (principally contaminants) would be of greater concern.

Some processors equated "marine" with "natural" and, in their view, it was unnatural for salmon to eat plant based diets. Conversely, the view was expressed that retailers were failing to capitalise on an opportunity to promote substitution in terms of being a sustainable product due to reduced pressure on the marine environment.

The media's ability to affect the market through food scares in relation to farming (bird flu, BSE, contaminants, GMOs, environmental impact etc.), whether correct or not, was emphasised by four of the processors. All consultees were aware of the potential for adverse media coverage

related to the use of plant substitute diets to affect sales, noting the impact of contaminant stories in the past.

11.6 Environment

All processors interviewed were aware of pressures on feed fisheries and the finite nature of marine raw materials for salmon diets – hence some substitution is required. They felt that marine raw materials could not supply all aquaculture and that all fishmeal and fish oil should be sourced sustainably. This was their primary concern at this time and several initiatives were being implemented in this regard (consideration of feed fisheries is outside the scope of this report).

11.7 Product Standards

The current use of product standards and certification bodies appeared to be in a state of transition. Four processors viewed TQM as no longer being of importance, yet the majority still used it as the default standard because by working to TQM processors were also able to conform to a number of other customer specifications.

Certain processors had direct links to those retailers who committed to purchase bespoke salmon products. These retailers not only specified product quality but also farming and husbandry practices. These are the "top-end" retailers who were not in favour of substitution.

One processor would like the Scottish industry to develop a standard for "Scottish superior" which companies could (within prescribed limits) amend according to their production requirements. Other processors rejected this on the grounds that the market is always seeking product differentiation.

The Code of Good Practice for Scottish Finfish Aquaculture (CoGP) is regarded as a farming standard rather than a quality standard and hence is not relevant to processors. It may be supplemented with, or substituted by, their own codes, standards and specifications, or those of their customers.

For premium and organic products, the trend is toward retailer through to farmer "partnerships" where, essentially, the retailer specifies husbandry, diet and product quality. All processors noted that for the volume market there was no generally accepted default standard at present which could be used in relation to substitute diets.

11.8 Product Quality

There was a range of views of the effects of substitute diets on salmon quality. Concerns were raised in relation to texture, carcass quality, flavour, colour and taste, but these were also raised in relation to non-substitute diet fed salmon. Two processors said that the outcomes of substitution in terms of flesh quality did not appear to be fully understood by researchers and that trials did not replicate the commercial situation. Other processors, especially those using Norwegian salmon, took the opposite view and did not believe there were quality issues related to substitute diets; one processor stated that their blind-tasting panel preferred substitute diet reared salmon and another said that he could not tell the difference between substitute and fish oil only salmon.

In summary, those processors already using salmon grown using substitutes did not consider the quality to be an issue, whereas those not using substitute salmon had concerns. In specific cases, therefore, the quality of substitute diet produced salmon is a barrier which may be lessened by providing substitute derived product to processors for their own quality evaluation.

11.9 Human Health

The health benefits of eating salmon were regarded as the most critical product asset by all processors (except for one who was supplying the food service market). Four processors expressed concerns that substitute oil diets may not deliver health benefits, noting that they may

- affect the healthy eating image of salmon;
- affect the ability to ensure adequate levels of omega 3s; and/or
- be shown to be less healthy in the longer term.

Conversely, processors using Norwegian salmon were relaxed and confident that plant oil fed salmon can maintain sufficient omega 3 levels, which are monitored, and they attribute this to the quality of oils used.

One processor highlighted that supermarkets [and some product standards] specify the marine based raw materials instead of the omega 3 profile of salmon flesh, thereby limiting options available to the feed and farming sectors.

Seven of the eight interviewed stated that the health aspects of salmon products must be ensured and maintained. The omega 3 healthy eating image of salmon was most important and use of plant oils must not jeopardize this. Most salmon products are "simple" with no great amount of processing. Therefore, the emphasis is on health. Processors knew that upper age and income groups are the biggest fish buyers who are, in the main, not looking for exotic products but do want healthy food. The six processors who already did, or would be willing to, accept plant oils in salmon said that product health claims in relation to omega 3s are essential. Some were not wholly reassured by feed manufacturers' claims regarding omega 3 levels and such concerns represent a barrier to increased substitution. It would, therefore, be useful for independently verifiable data regarding product health claims for omega 3 levels to be presented to the processors to address their concerns.

11.10 Fish Health

Generally, processors regarded fish health and welfare as issues for feed producers and farmers to address. A range of additional comments were provided in relation to plant oil substitution and fish health including that:

- trials showed there were no problems;
- a question remained over feed manufacturers' ability to provide proper nutrition;
- there might be digestibility problems; and,
- fish oil diets in freshwater followed by plant oils and then finishing diets in sea water was not a natural succession.

11.11 NGOs

Four processors reported direct consultation with NGOs, two of which were on a regular basis. The NGOs consulted included: WWF, Marine Stewardship Council (MSC), MCS, Greenpeace, Seafood Choices Alliance and Compassion in World Farming. The main topic was the sustainability of feed fisheries.

Two processors considered that some NGO thinking on salmon farming was out of date or not well developed and they tended to concentrate on issues which have already been addressed.

11.12 Other Substitutes

Processors were unanimously against the use of animal by-products, principally because it would result in a negative market response. Two expressed concern that some imported salmon contains these products. Six processors mentioned the association with BSE and three processors were concerned about maintaining "naturalness" in this respect.

The use of genetically modified (GM) crop materials was not under consideration at present although the view was expressed by two processors that eventually GM would be accepted, citing the increasing difficulty in sourcing non-GM soya. In a similar vein, an organic processor was concerned about the supply situation of organic raw materials for salmon diets (e.g. wheat).

11.13 Summary of Key Findings

Half of the processors consulted which supply major supermarkets already use imported Norwegian salmon grown on substitute diets. Therefore, the processors considered that increased substitute use was not a barrier *per se*; the question was more about the future direction of the Scottish industry.

Six out of the eight processors would be willing to accept Scottish salmon grown on diets with increased substitution, including use of plant oils if their customers agreed to their use and all consider this is inevitable.

The market is tiered. The top-end retailers and premium range products in other retailers would continue to demand salmon grown on fish oil only, while standard product would be grown in future using plant oils.

Price is considered the primary factor regarding consumer purchase, and all thought substitution would result in lower prices.

Seven of the eight interviewed stated that the health aspects of salmon products must be ensured and maintained. The omega 3 healthy eating image of salmon is most important and use of plant oils must not jeopardize this. Four had concerns that substitute diets may not deliver in this regard. However, the four processors who use Norwegian salmon were confident that sufficient omega 3 levels could be maintained. One suggested that supermarkets should specify the omega 3 profile of salmon flesh, rather than the type of feed raw material.

There was a divergence of views with regard to consumer knowledge on substitution. Concerns over the considerable power of the media to affect the market through "food scares" were emphasised by four of the eight processors.

All processors consulted thought that there was insufficient marine raw material to supply the industry at the current level in the future. There was a total consensus that all marine raw materials should be from independently verified sustainable sources in the future.

There was a divergence of opinion about the effects of substitution on quality. Some processors, especially those using Norwegian products, thought that it had no impact at all, while others were concerned. Two did not consider that researchers fully understood substitution in terms of flesh quality and that trials did not replicate commercial realities.

There was general consensus that the use of product schemes is in a state of transition. Four processors thought that TQM was no longer of importance. Some suggested a single standard for a Scottish superior product, while others rejected this idea. Several recognised the importance of schemes operated by some of the supermarkets.

No processor was aware of any fish health issues regarding the use of plant substitutes and they generally considered this to be outside their area of expertise, although one or two raised some general concerns in this regard.

12.0 Supermarkets

12.1 Introduction

Consultations were undertaken with the five supermarkets listed below. They were selected to be representative of those with high volume of salmon sales and those selling into more niche markets. In this report we use the word "supermarket" to describe the multiple retailers that we approached. While all the supermarkets were all open to the consultation process, some were unable to provide sufficient time for detailed discussions.

Consultees:	
• Asda Stores Ltd	• J Sainsbury PLC
• Marks and Spencer Group PLC	• Tesco Stores Limited
• Waitrose Limited	

12.2 Consultations

The first supermarket consulted was very much against substitution for several reasons. Primarily, its strong preference was to supply salmon produced as naturally as possible, which for it, requires feed based on marine constituents. It was also very concerned about the sustainability of the feed supply and was keen to see this addressed; hence it did not see it as an 'either/or' argument" (i.e. "naturalness" versus "sustainability"), but one where it would like to see fish grown in a natural manner with a sustainable approach.

On a related point, it did not consider that substitution would result in reduced pressure on marine materials since the fishmeal and fish oil that would otherwise have been used in feed would be absorbed by increased demand from elsewhere, including the continued expansion of salmon farming. Therefore, it viewed substitution as a "temporary solution" to the supply and demand issues surrounding marine raw materials, and did not consider it to have long term merit.

Secondly, the company was very concerned about any subsequent impacts on product quality from substitution. It considered that the general quality of farmed salmon had declined over the past fifteen or so years for a range of reasons including growing cycle and feed quality. There was concern that another change (i.e. substitution) could be difficult for processors which require a very consistent raw material; this particularly applied to smoking.

There was also concern about the potential for any impacts from substitution on the physiology of the fish, although the company did not have specific knowledge of any actual problems.

This supermarket strongly believed marine materials should be used for fish feed rather than terrestrial livestock feed, since this was a more natural diet for fish, unlike animals. It favoured a national or international debate on substitution and would like to see a global consensus, while recognising this was perhaps unlikely. It would also like to see an increased use of wasted fish from food fisheries (discards) and processing (trimmings) in fish feed.

Finally, it considered that its customers were knowledgeable on welfare and environmental issues and knew that the salmon they purchased was farmed. Substitution was not felt to be a major concern for its consumers, but was expected to become more prominent in the future.

The second supermarket did not sell salmon grown on substituted plant oil. The majority of its salmon was from Scotland and the remainder from Ireland. It had its own codes of practice and also took account of other standards.

Its preference was to maintain its current position and hence not to substitute fish oil in the future. Its main reason was a desire to maintain omega 3s at the current level which it considered would be reduced through substitution. It was the company's intention that the consumer should be able to meet the recommended daily intake of omega 3s through one portion of salmon a week. It also had concerns that substitution would upset the balance between omega 3 and omega 6.

This supermarket also preferred fish to be grown in conditions as close to the wild as possible, taking into account the current position of the industry (i.e. that there is already substitution of fishmeal), it preferred not to increase substitution. It was very much aware of sustainability concerns over feed fisheries and was promoting the Marine Stewardship Council (MSC) as a means to address this and had also funded research by the Marine Conservation Society (MCS) into the sustainability of feed fisheries.

While its current preference was to not move towards greater substitution, this position could be reconsidered in the longer term should its customers so desire.

The third supermarket currently required suppliers to work from its Farmed Fish Code of Practice which use the FCS and EurepGap standards as a baseline. Imported farmed fish was grown to equivalent standards and verified through independent auditing. Due to the farm assurance schemes in place there was some substitution of fishmeal in the UK and abroad, and also some fish oil substitution for imports.

It commented that, in general, the Scottish industry is moving to use EurepGap as its baseline farm assurance scheme as this was EN45011 accredited and also met its overall requirements. While levels of fishmeal and fish oil were not set within the EurepGap standards, this does not mean that it could not take a decision independent of the scheme and set levels.

It would prefer not to increase the amount of substitution in the future. This was partly because it wished to provide as natural a diet as possible while focusing on the sustainability of feed fisheries. Secondly it would need to evaluate data regarding product quality and human health issues in order to understand the effects of any change. Should data be made available to its satisfaction, it might consider changing its position on certain product lines (standard rather than premium).

The fourth supermarket sold Scottish and Norwegian salmon as fresh fish and used Chilean salmon for frozen and value-added products. It worked to a combination of its own and external standards. The Norwegian products contained substituted meal and oils and the company thought it unlikely that this would be the case for Scottish products, although this was not confirmed.

It did not feel that there had been sufficient quantitative research on substitution regarding quality and animal welfare. While it was aware of research at Stirling University, it thought that this was only with regard to rapeseed and should be widened to include other types of oils and backed up with blind tasting. It also had concerns regarding the availability of soya from non-genetically modified sources in the future and the potential for a future shortage of soya.

Its preference was not to increase the amount of substitution because the consumer might consider this unnatural. Nevertheless, it accepted that it might need to do so in the future to maintain supply, assuming that sufficient research had been made available that addressed quality and health issues.

It thought feed substitution should be addressed industry wide, albeit tailored to individual supermarkets. It saw a role for a central body in this, perhaps through the Scottish Salmon Producers' Organisation (SSPO) or the British Retail Consortium (BRC).

The fifth supermarket saw substitution very much as a question of pressure on feed fisheries versus fish diet. It was positive about moving to an increased amount of substitution, including fish oils, so as to ease pressure on feed fisheries, and considered this should be at the earliest opportunity. This assumed that product quality and especially human health benefits would be maintained. It also required that any substituted products would be from sustainable sources.

12.3 Summary of Key Findings

With reference to the aims and objectives of this project, one supermarket was clearly open to increased substitution, including fish oils, providing there were no issues regarding fish health and that product quality, including human health benefits are maintained, and would like to see this occur as soon as possible. Conversely, one of the five was very much against the use of substitutes and unlikely to change its approach in the foreseeable future.

The other three were, in general, not in favour of the increased use of plant substitutes, particularly oil, in Scottish salmon feed. Nevertheless, they all, albeit perhaps to a differing degree, recognised that the use of increased plant substitutes may become a necessity due to issues over supply and demand of marine based raw materials. One of these supermarkets was less open to substitution than the other two, although they may reconsider should their customers so desire. Of the remaining two, both wished to evaluate research data and information on human health and product quality and one also mentioned animal welfare. Both were unconvinced that sufficient research has been done in this regard.

At least one of the supermarkets thought that substitution should be addressed by the fish farming industry, and that there was a role for a central body such as the SSPO or the BRC.

None of the supermarkets volunteered that they saw substitution as a potential positive in terms of marketing a more sustainable product.

One consultee thought that the industry was moving towards EurepGap as the baseline standard.

One supermarket raised concerns over impacts on product quality, and particularly smoking, from substitution. It noted that processors had already had to deal with changes in quality over the years, and that it would be difficult for them to deal with yet another change.

One supermarket would like to see a national or international debate on substitution and would like to see a global consensus on the preferential use of fishmeal and fish oil in aquaculture feeds. It would also like to see an increased use of waste fish from discards and trimmings in fish feed.

Given that the feed manufacturers and the majority of the fish farmers (in terms of tonnage) are in favour or, at the least, not against substitution, the resistance by the supermarkets represents the key barrier in respect of the adoption of increased substitution in Scottish salmon farming. Motives for not accepting product fed on substituted diets fall into two categories: the desire to maintain 'naturalness' and concerns over a reduction in product quality.

13.0 Discussion

13.1 Introduction

This study was aimed at identifying possible barriers to the increased use of plant materials as substitutes for fishmeal and fish oil in feed for farmed Scottish salmon. The main issues concern the drivers for substitution, the views of consumers, whether salmon produced on a substitute diet would be of equal quality in terms of taste and health benefits for human consumers, whether fish welfare and growth would be compromised, and the environmental impacts of sourcing plant substitutes.

This study has briefly examined the available evidence in terms of these issues. However barriers to substitution arise not only because of the actual issues, but also due to the perception and understanding of these issues and the willingness to change to substitute diets amongst various stakeholders within the value chain. These stakeholders include consumers, fish farmers, retailers, organisations operating food standards, NGOs, fish feed manufacturers and salmon processors. This discussion looks at how different stakeholders respond to the main issues.

13.2 Reasons for Substitution

The drivers for increasing substitution of plant materials in farmed Scottish salmon feed are important to bear in mind. They include environmental sustainability, raw material pricing, scarcity of supply and international competition.

Marine raw materials are under pressure for a variety of uses. For feed manufacturers, a greater choice of raw materials is likely to ease supply issues in the short to medium term and allow them to compete more easily on the international market. An El Niño event or relatively sudden change in demand from other countries, particularly China, could lead to shortages of marine raw materials. Some stakeholders also believe that dramatic crude oil price fluctuations can impact on plant oil prices affecting their availability to feed manufacturers.

While some stakeholders consider that use of plant substituted diets will lead to lower prices, most feed manufacturers and fish farmers do not think this would be the case. Indeed, the continued demand for both marine and plant meals and oils suggest that prices will continue to increase in the long-term.

13.3 Responses to Substitution

Our consultations indicate that a key barrier to the increased use of plant substitutes in Scottish salmon farming, particularly in respect of fish oil, is the supermarkets (see Chapter Twelve). In the main, their concerns were not about the impact that substitution may have on consumer purchasing decisions *per se*, but centered on the ability to maintain the human health benefits from eating salmon, as well as concerns over the 'naturalness' of diets, quality parameters and fish health. In addition, similar concerns raised by some fish farmers represent another barrier (see Chapter Eleven).

Since some of the supermarkets that were hesitant to sell Scottish salmon grown on substitute plant oils are already stocking imported salmon grown on such diets, this appears to be a contradictory position. It is possible that increased dialogue and the provision of information recommended in Section 13.4 below may help to address this situation.

A key finding from this study is our survey showing that consumers would be happy to eat salmon fed a plant substitute diet assuming health benefits, taste, quality and price are not affected. Should increased substitution go ahead, this should not affect purchasing decisions;

whilst a small percentage of consumers may buy less, this would be balanced by a slightly larger percentage buying more.

The market for farmed salmon is tiered and some players within it (two of the five supermarkets that we consulted and several fish farmers supplying niche markets) currently intend to maintain marine based diets and sell their salmon as a higher quality product, which they view as more 'natural'. Whether this quality difference is real or perceived, this means that plant based substitution is unlikely to become universal throughout the Scottish industry in the foreseeable future.

There have been calls by some within the Scottish industry to avoid increased substitution and market all Scottish salmon as a premium product, however this has not happened and parts of the industry are already moving towards substitution. Some consultees view marine based feeds as a means to differentiate Scottish salmon to attract a premium, whilst others consider that substitution may help the industry compete with [cheaper] imports.

13.4 Human Health

The clear benefits of consuming salmon on heart health have led to health claims from official and respected organisations. Of critical interest from a human health perspective are the levels of highly unsaturated fatty acids (HUFAs) (essentially provided from fish oil in the diet of farmed salmon) which give salmon this valuable property. All elements of the value chain, from feed manufacturers, through the fish farmers and processors to the supermarkets, were fully committed to the need to maintain HUFAs at a level that would continue to meet health claims for salmon. Further, consumers identified health benefits and taste as by far the most important reasons for choosing to purchase salmon.

The levels of HUFAs achieved in practice from salmon fed on substituted diets depend upon a variety of factors including the type of plant oil(s) and the proportion of substitution. It is clear that using relatively low levels of substitution and/or finishing diets can deliver levels of HUFAs which are, in general, similar to those achieved in salmon fed on fish oil diets.

Despite the clear importance attached to the health benefits of eating salmon provided by HUFAs by all stakeholders, *definitive* data on the levels of HUFAs being achieved in *commercial* salmon farming were not identified in the literature review or made available in consultations. Although the experience of Norwegian producers strongly indicates that salmon can be grown successfully in a commercial environment on substitute diets and meet the required health claims, this lack of specific information on HUFAs from commercial production rather than from trials, which have often used higher substitution rates, was highlighted by some fish farmers and supermarkets as a key reason why they were unable to consider an increase in plant substitutes, particularly in respect of oil.

Although the Scottish salmon feed manufacturers are adamant that they can and do produce feed using substitute oils that allow farmers to meet the health claims in terms of the required minimum HUFA content in salmon flesh, and also point to considerable commercial experience in Norway to back up this assertion, data on HUFA levels achieved in commercial practice appears not to have been communicated throughout the Scottish supply chain in a readily accessible form to the relevant people.

There is clearly a need to improve communication in this regard. It is recommended that the industry provide data on the HUFA content of salmon fed on different levels of substitute diets, both in Scotland and abroad, to all relevant stakeholders. This should include confirmation that salmon grown at increased levels of substitution, particularly with respect to oils, will meet the relevant health claims. In so doing, consideration should be given to the need to provide clear, transparent and independently verifiable information that is easily accessible by non-specialists.

Whilst some feed manufacturers appear reluctant to approach the supermarkets directly, since they do not wish to bypass the fish farmers, a mechanism for disseminating information would be beneficial to all concerned. Although the need to respect commercial confidentiality is recognised, making data or in-house research findings available to stakeholders, is considered important to addressing the current situation. It would be helpful to convene a supply chain forum to discuss this data and to focus on understanding and addressing the concerns of individual companies. It is recommended that the industry work with nutritional experts and engage with the relevant health authorities in this process.

Current Food Standards Agency (FSA) guidance suggests limits on fish consumption for certain vulnerable groups, such as pregnant women, because of [low levels of] contaminants. Since contaminants arise from the marine constituents of salmon feed, the use of plant substitutes could considerably reduce the level of contaminants, even with a fish oil finishing diet, thereby bringing a positive health benefit. In theory, this might enable recommended limits on eating salmon to be relaxed for vulnerable groups. It is recommended this issue be discussed further with the FSA.

13.5 Product Standards

Fish farmers work to one or more standards. Many of the standards, particularly Label Rouge and TQM, specify the minimum proportion of feed to be provided from marine materials which, in these cases, is insufficient to allow a significant increase in plant substitutes, particularly oil. Even though most farmers do not sell all their salmon under Label Rouge and/or TQM most, other than the multinationals, tend to produce to such standards across all sites because they have insufficient operational flexibility to produce to several different standards.

Standards were cited across the industry supply chain as a barrier to increased plant substitution, particularly of oils. These constraints need to be addressed and the industry should engage with the relevant certification bodies and supermarkets in this regard. Rather than specifying the nature of raw materials, consideration should be given to emphasising levels of HUFAs in the end product; all stakeholders were agreed that maintaining health benefits is essential.

13.6 Fish Health and Welfare

Research on the effects of diet on fish health is complex and evolving. There may be certain benefits associated with substituted diets such as improved winter feeding efficacy and easier transition from freshwater to seawater (smoltification). The evidence suggests that substitute diets do not have detrimental effects on the health of salmon, particularly at the levels that will be used commercially. Long term inter-generational consequences have not yet been researched. Commercial production using substitute diets is proceeding in Norway and, more recently, in Scotland without health issues emerging.

The RAFOA research found evidence of some negative effects on stress and the immune function in salmon fed a single plant oil, and an increased incidence of cataracts was observed in the RAFOA II freshwater and sea water trials in salmon fed a blend of plant oils at high levels of substitution. There is no evidence of these effects, or any other detrimental fish health effects, occurring in commercial production using plant substitute diets.

A number of fish farmers and two supermarkets had some general concerns regarding fish health centered on the feeling that it is not 'natural' to feed salmon on a plant based diet, rather than any documented health issue. Since *freshwater* salmon diets are almost universally based on *marine* based feed, a 'natural' diet has in fact already been removed with existing fish feed.

Whilst fish health is not a major constraint compared to human health, some fish farmers and supermarkets have concerns in this regard. The monitoring of fish health data from commercial

production using substitute diets is recommended to identify any nutrition related problems which may emerge over time. The current FineFish study on nutrition and malformations should also be closely monitored by the industry. In all cases, research programmes and their results should be clearly presented to the industry and stakeholders.

13.7 Environmental Issues

While, in general, there are clear threats to the sustainability of feed fisheries due to levels of demand, it is important to recognise that, should the Scottish salmon farming industry reduce fish oil and fish meal use, this will not in itself ensure the sustainability of these fisheries since other users would be expected to use available supplies. Any reduction in the use of materials sourced in an unsustainable manner is welcome, especially for fish oil which is becoming increasingly valuable as a source of HUFAs. It would be helpful to initiate a well informed debate within the supply chain as a whole to seek a consensus on the best way to manage substitution, while optimising sustainability and satisfying consumer demand.

In terms of substituted ingredients, the voluntary use of ProTerra certified plant materials by some feed manufacturers is a positive initiative to help address environmental, as well as social and ethical issues. Given the potential for significant environmental impact from the sourcing of certain plant raw materials, particularly soya (and palm oil, should this be used by the industry in the future), it is recommended that all raw materials come from sources certified as sustainable in the future.

13.8 Quality

The majority of evidence suggests that salmon produced using substitute diets can meet customer and consumer quality requirements. However, concerns over quality are an issue for two of the three supermarkets we contacted who said they might consider substitution, and evidence that quality can be maintained should be provided. Several processors are concerned that substitute plant diets may produce salmon of reduced quality, especially with regard to smoked product, but this is a minority view and many point to the fact that UK supermarkets are already successfully selling significant volumes of imported salmon grown on plant substitutes.

Whilst supermarkets will want confirmation that quality can be maintained for each product line grown on plant substitutes, particularly smoked salmon, it is not considered a major barrier to increased substitution.

14.0 Conclusions and Recommendations

This study aimed to identify possible barriers to the increased use of plant materials in fish feed for farmed Scottish salmon. Our conclusions and recommendations are presented below.

Note: C: Conclusion; B: Barrier; R: Recommendation

	Consumer Attitudes
C1	Consumer attitudes are not a barrier to plant substitution, providing that health benefits are not affected.
	Market Differentiation
B1	Substitution is unlikely to become universal throughout the Scottish salmon farming industry, but may assist and reflect product differentiation and the further development of a tiered market.
	Product Standards
B2	Product standards are considered by some fish farmers and feed manufacturers to be a barrier to increased substitution, particularly in respect of oils, for much of the industry.
R1	The industry should engage with the relevant certification bodies and supermarkets in regard to product standards. Consideration should be given to emphasising and specifying levels of highly unsaturated fatty acids (HUFAs) in the end product rather than levels of fish oil in the diet.
	Human Health
C2	Eating salmon provides human health benefits in terms of helping to maintain a healthy heart due to the presence of omega 3s which, in general, are only readily available through oily fish. These health benefits are the subject of various health claims which centre on recommendations as to the amount of salmon and oily fish that should be consumed. In farmed salmon, the omega 3 content is primarily provided through the fish oil content of the feed. All elements of the supply chain, as well as the consumer, value the health benefits of salmon and consider it essential to maintain the omega 3 content at a level that will meet the health claims.
C3	There was no information made available during the study regarding the omega 3 content of farmed salmon fed on diets with substitute oil in Scotland. Information on the omega 3 content of Norwegian salmon is available and since diets using substitute plant meals and oils are standard in Norway, it may be inferred that this information is representative of salmon grown on these substitutes. This information suggests that omega 3 content is maintained at acceptable levels using substitute plant diets. However, since information on the oil type and proportions used was not available from Norway, it is not possible to provide definitive data on the omega 3 content of salmon grown on commercial substitute diets.
B3	While one of the five supermarkets consulted is receptive, two more remained to be convinced that Scottish salmon grown on diets containing some plant oil will not have an impact on the human health benefits of eating salmon. The remaining two did not intend to sell Scottish salmon grown on using substituted oil.
B4	The product health claims were a concern to several fish farmers who, like the supermarkets, were keen to evaluate further information on the omega 3 content of farmed salmon grown on diets with partial oil substitution.
C4	The feed manufacturers were adamant that they had the knowledge and skills required in feed formulation to enable salmon products to meet the omega 3 health claims. This is supported by information from extensive commercial salmon production in Norway

	and limited production in Scotland.
R2	Communication should be improved throughout the supply chain, particularly between the feed manufacturers/fish farmers and the supermarkets.
R3	The industry should consider presenting an independently verified document or other form of communication which clearly: - states the level and ratio of HUFAs they will achieve in salmon products produced from fish fed substitute diets; - confirm these will meet the relevant health claims; The industry, working with nutritional experts and engaging with the Food Standards Agency, should also try to convene an industry forum to present this information to the whole supply chain, with particular focus on the supermarkets, where the concerns of individual companies can be resolved.
	Fish Health and Welfare
B5	Some fish farmers and supermarkets were concerned that fish health and welfare issues had not been sufficiently addressed in the research at commercial levels of production using substitute oils. The feed manufacturers were confident that there were no issues of concern and commercial production of significant volumes of salmon fed substituted diets in Norway reinforce this assertion. No evidence from commercial production was identified that suggested there are any fish health or welfare issues associated with the use of partial plant substitution at the levels used in industry.
B6	There was no research on possible inter-generational issues associated with the use of substitute diets available at the present time.
R4	There is ongoing research funded at an EU and company level with regard to fish health and nutrition. It is recommended that a mechanism to encourage timely reporting in peer reviewed journals and dissemination in a form accessible to non specialists is implemented by the industry.
	Environmental Impact
C5	Two of the three feed manufacturers sourced some or a majority of soya from ProTerra certified producers.
R5	The feed industry should implement an industry wide approach to source soya and any other significant plant (and marine) raw materials from sources certified as sustainable within the short term.
R6	The feed industry should engage with Cert ID to see whether information about compliance with individual ProTerra clauses could be made publicly available so that observers could evaluate the performance of individual companies.
R7	It is recommended that the industry continues to proactively engage with the Rountable on Responsible Soya and, if appropriate, the Roundtable on Sustainable Palm Oil.
C6	Materials other than soya were not sourced from sources certified as sustainable.
R8	In the future, it is recommended that consideration be given to the assurance of sustainability with regard to materials other than soya.
C7	It is unlikely that increased plant substitution would result in significant changes in benthic impact, although there appears to be no research in this regard.
R9	It is recommended that the potential changes in environmental impact on the marine environment be considered through a research and/or monitoring programme.
R10	The industry or individual companies should report on their environmental and sustainability credentials in a transparent and independently verified manner.

C8	Increased plant substitution will not in itself ensure the sustainability of fishmeal and fish oil because of continued demand for these resources. Nevertheless, many, but not all, view substitution as a means to conserve an increasingly scarce resource of HUFAs derived from fish oil. Given global pressures on reduction fisheries together with limits on maximum sustainable yield from such fisheries, even when managed sustainably, the use of substitutes for the majority of salmon production appears to be inevitable.
R11	It would be helpful to initiate a well informed debate within the supply chain as a whole in order to seek a consensus on the best way to manage substitution, while optimising sustainability and satisfying consumer demand.
R12	This study should not be viewed in isolation from other means of increasing the sustainability of the supply chain, particularly through the use of animal by-products and meals and increased use (if possible) of trimmings.
R13	While socio-economic issues regarding raw material sources were outside the scope of this project, they are of concern to some stakeholders and should be considered as part of an overall assessment of sustainability.
	Reasons for Substitution
C9	The drivers for increasing substitution of plant materials in farmed Scottish salmon feed are environmental sustainability, raw material pricing, scarcity of supply and international competition.
R14	The reasons for substitution given to the public, stakeholders and the supply chain should accurately reflect the current drivers.
	Quality and Performance
C10	Quality – in terms of taste, colour, odour, texture etc. – is not a significant barrier to substitution.
C11	Fish growth and performance are not barriers to substitution.
R15	It would be useful to ensure that the supply chain is informed that quality, growth and performance of fish should not be considered as barriers to substitution

Appendix A: List of Consultees

Aquascot Ltd

Asda Stores Ltd

Biomar Ltd

EWOS Ltd

Food Certification Scotland (FCS)

Gemcom Ltd

Highland Salmon Ltd

Hjaltland Sea Farms Ltd

International Fishmeal and Fish Oil Organisation (IFFO)

J Sainsbury PLC

Lakeland Marine Farms Ltd

Loch Duart Ltd

M & J Brakes

Macrae Food Group

Marine Conservation Society (MCS)

Marine Harvest (Scotland) Ltd

Marine Stewardship Council

Marks and Spencer Group PLC

Migdale Smolt Ltd

NAFC Marine Centre

Pan Fish UK Ltd

Pinneys of Scotland

Royal Society for the Protection of Birds (RSPB)

Scot Trout and Salmon

Scottish Association of Marine Science (SAMS)

Scottish Environmental Protection Agency (SEPA)

Scottish Salmon Producers Organisation (SSPO)

Scottish Sea Farms Ltd

Seachill

Seafish Industry Authority

Seed Crushers' and Processors' Association (SCOPA)

Shetland Aquaculture

Skretting UK and Ireland

Stirling Institute of Aquaculture

Tesco Stores Limited

Waitrose Ltd

West Minch Salmon Ltd

Wester Ross Fisheries Ltd

Wildlife and Countryside Link (LINK)

WWF

Youngs Bluecrest Seafood Ltd

Appendix B: Topics Included in Consultations

Feed Manufacturers, Fish Farmers and Processors

Including:

- General information
- Nature of production
- Main markets
- Location and infrastructure
- Use of substitutes
- Trends
- Technological issues
- Economic issues
- Supply issues
- Environmental issues
- Fish health and welfare issues
- Human health issues
- Product scheme issues

Supermarkets

Including:

- Position
- Environmental issues
- Consumer knowledge
- Product quality
- Fish welfare
- Human health issues
- Product scheme issues

NGOs

Including:

- Position
- Research
- Current situation and trends
- Engagement with stakeholders
- Environmental issues

All

In addition to the above:

- Any recommended references / sources
- Any recommended contacts
- Any other issues to discuss

Appendix C: Information on Product Schemes

Standard	Fishmeal / Protein	Fish Oil	Substituted Meal	Substituted Oil	Notes
FCS–TQM	Over 50% of protein should be derived from fishmeal	75% minimum of added oil	The "balance" (up to 50%	Up to 25% of added oil	Flesh must have 1.2g EPA & DHA per 100g Added oil is a maximum of 30%, of which 25% can be plant oil. Manufacturer must comply with FCS Module for the Inspection And Approval of Farmed Salmon Feed Producers as Suppliers of TQM Salmon Feed.
Label Rouge	Fishmeal minimum of 45% of the feed; vegetable protein maximum of 20% of the feed	100%	0-20%	0	i.e. some plant meal but no plant oil Added oil is a maximum of 30%. Manufacturer must comply with FCS Module for the Inspection And Approval of Farmed Salmon Feed Producers as Suppliers of Label Rouge Salmon Feed.
Code of Good Practice	No spec	No spec	No spec	No spec	Does not exclude plant meals or plant oils. Emphasises sustainable sources and quotes Strategic Framework: "consider using…non-marine feed sources."
SSQC – SQSS	No spec.	No spec	No spec	No spec	Does not exclude plant meals or plant oils. "Oils, fats and dry components" must be high quality and fully traceable. Manufacturer must be accredited to a recognised feed assurance scheme e.g. AIC UFAS
Freedom Food	No spec.	No spec	No spec	No spec	There are no specifications in regard to feed sourcing. Instead the standard asks for "a high quality diet that is appropriate to their species"
EurepGap	No spec.	No spec.	No spec.	No spec.	Asks for a "Research and Implementation Plan…to reduce the amount of fishmeal and fish oil used".
SAC	Aquatic ingredients: i. of organic origin or, failing that, ii. from wild marine resources independently certified as sustainable (such as by the MSC) or, failing that, iii. made from the by-products of wild caught fish for human consumption. Feed ingredients of agricultural origin must be certified as organic.				While organic vegetable oil can be used, in practice farmers do not use this option as it is prohibitively expensive.
OFF	A minimum of 50% aquatic origin must be derived from by-products. The balance must be derived from wild marine resources independently certified as sustainable. Agricultural ingredients must be certified as organic.				While organic vegetable oil can be used, in practice farmers do not use this option as it is prohibitively expensive.

Notes:

FCS: Food Certification (Scotland) Ltd. TQM: Tartan Quality Mark.

SSQC: Shetland Seafood Quality Control. SQSS: Certification Scheme for Superior Quality Shetland Salmon.

AIC: Agricultural Industries Confederation.

UFAS: Universal Feed Assurance Scheme.

SAC: Soil Association Certification Ltd.

OFF: Organic Food Federation

Appendix D: Ipsos MORI Survey: Technical Details

Technical Details

Fieldwork

Interviewing for the pilot was carried out by Ipsos MORI interviewers using paper questionnaires in Manchester on 16th-17th June 2007.

Interviewing for the main stage was carried out in-home by Ipsos MORI interviewers between 6th and 13th July across Great Britain. The main stage questions were asked as part of Ipsos MORI's regular CAPIBUS survey and CAPI (Computer Assisted Personal Interviewing) machines were used to collect the data.

Sample Design

Ipsos MORI's CAPIBUS uses random location sampling to generate a sample that is representative of the British adult population.

Over 160 sample points are randomly selected to provide a fully dispersed sample covering the whole of Britain. For each sample point, a census enumeration district is randomly selected and allocated to an interviewer. Enumeration districts are small areas of local geography, made up of between 60 and 100 addresses.

ACORN is a commercially available tool which classifies postcodes into categories, groups and types according to the socio-demographic characteristics of the people living there. In order to ensure a representative CAPIBUS sample, enumeration districts are randomly selected such that the sample profile of ACORN groups within each region matches the population profile of the region. This produces a national sample that is balanced in terms of ACORN category and group at a regional level and ACORN type at national level.

Each enumeration district is defined by the list of addresses contained within it. Interviewers are given a randomly selected start address and a list of addresses within the district. Interlocking quota controls are set for age, sex and working status, based on the ACORN classification. Thus, quota controls are specifically tailored to each sampling point. The use of ACORN ensures that the sample selected is nationally representative in terms of social grade without the need for setting quotas at the interviewing stage.

The sampling frame itself is the Postal Address File (PAF), a frequently updated record of all addresses in GB recognised by the Royal Mail. The PAF is used because it provides a far more complete sampling frame than the electoral register and is not limited to members of the public aged 18+.

Weighting and Data Processing

The ACORN sampling methodology and the CAPI quota controls for age, sex and working status ensured that the raw survey data was a close match to the British profile. Fine adjustments were then applied to the data by weighting to the national profiles of sex split by: age, social grade, region and working status. The targets for this weighting were obtained from the National Readership Survey, for which Ipsos MORI conducts 36,000 interviews per year. Population data based on this survey is available every year, so profiles are more up-to-date than profiles based on the Office for National Statistics' ten-yearly censuses.

Weighting and processing of the data were performed by analysts in Ipsos MORI's internal Data Processing department.

Statistical Reliability

Because a sample, rather than the entire population, was interviewed the percentage results are subject to sampling tolerances – which vary with the size of the sample and the percentage figure concerned. For example, for a question where 50% of the people in a (weighted) sample of 4437 respond with a particular answer, the chances are 95 in 100 that this result would not vary by more than 2 percentage points, plus or minus, from the result that would have been obtained from a census of the entire population (using the same procedures). The tolerances that may apply in this report are given in the table below.

Approximate sampling tolerances applicable to percentages at or near these levels (at the 95% confidence level)			
	10% or 90% ±	**30% or 70% ±**	**50% ±**
Size of sample or sub-group on which survey result is based			
1,987	1	2	2
1,222	2	3	3
			Source: Ipsos MORI

Tolerances are also involved in the comparison of results between different elements of the sample. A difference must be of at least a certain size to be statistically significant. The following table is a guide to the sampling tolerances applicable to comparisons between sub-groups.

Differences required for significance at the 95% confidence level at or near these percentages			
	10% or 90%	**30% or 70%**	**50%**
Size of sample on which survey result is based			
Male **(967)** vs. Female **(1019)**	3	4	4
			Source: Ipsos MORI

Definition of Social Grades

The grades detailed below are the social class definitions as used by the Institute of Practitioners in Advertising, and are standard on all surveys carried out by Ipsos MORI.

Social Grades

	Social Class	**Occupation of Chief Income Earner**	**Percentage of Population**
A	Upper Middle Class	Higher managerial, administrative or professional	2.9
B	Middle Class	Intermediate managerial, administrative or professional	18.9
C1	Lower Middle Class	Supervisor or clerical and junior managerial, administrative or professional	27.0
C2	Skilled Working Class	Skilled manual workers	22.6
D	Working Class	Semi and unskilled manual workers	16.9
E	Those at the lowest levels of subsistence	State pensioners, etc, with no other earnings	11.7

Appendix E: Ipsos MORI Survey: Topline Results

Ipsos MORI
Salmon Feed Survey J30766
Topline Results

- Results are based on 1987 adults aged 15 or over.
- Fieldwork took place between 6th and 13th July 2007.
- Where results do not sum to 100, this may be due to multiple responses, computer rounding or the exclusion of don't knows/not stated.
- An asterisk (*) indicates a percentage of less than 0.5% but greater than zero.
- A dash (-) indicates that no-one gave this answer.
- Data have been weighed to reflect the national profile
- Adding together two percentages from the topline may produce a slightly different number from a combined category quoted in the report. This is because the percentage figures are rounded. E.g. Q1 appears to show 41% who eat salmon at least once a month, but this is due to the figures appearing to only one decimal place. Working from the numbers of respondents, the percentage who eat salmon once a month is actually 40%.
- In Q1a respondents were allowed to give more than one answer, so percentages do not sum to 100.

Now some questions about salmon.

Q1. **Firstly, can you tell me how often, if at all, you eat salmon or salmon-based products..?**

	%
More than once a week	6
About once a week	15
Less than once a week, but at least once a month	20
Less than once a month, but sometimes	19
Never	38
Don't Know/Depends	2

ASK THOSE WHO EAT SALMON AT LEAST SOMETIMES (Q1) – 1155 RESPONDENTS

Q1a. **And where is your salmon mostly bought?** MULTICODE OK

	%
Aldi	2
Alldays	-
ASDA/Wal-Mart	17
Budgens	*
Co-op	4
Iceland	1
J Sainsbury	22
KwikSave	*
Lidl	1
Marks & Spencer	5
Morrisons	12
Netto	1
Somerfield	6
Spar	-
Tesco	29

Waitrose	5
At a local independent shop	1
At a market	5
At a fishmonger	9
Other	6
Don't Know	2

Q2. **Where do you think most of the salmon you eat comes from..? Please choose as many or as few answers as you think apply.** MULTICODE OK

	%
Caught in the wild	10
Reared in salmon farms	42
Reared in salmon farms (certified organic)	7
Alaska	12
Canada	12
Chile	1
Norway	5
Scotland	33
Don't Know	14
Depends/Varies	2

In fact, a lot of the salmon sold in Britain comes from fish farms, where salmon are reared in pens.

Q3. **Here are some reasons why people might choose to eat salmon instead of some other type of fish or meat.**
Which <u>one or two</u> if any are most important for you..?
(You can just read out the letter that applies)

I eat salmon because of…..	
Price	10
Health benefits	55
Environmental standards in the salmon industry	3
Animal welfare standards in the salmon industry	3
Ease of preparation / cooking	20
The type of feed that salmon are fed	1
Colour	4
Taste	55
Availability of <u>organic</u> salmon	3
Availability of <u>wild caught</u> salmon	5
Other	*
Don't know	2
None of these	2

Q4. **And which <u>one or two</u> if any are the *least* important..?**

	%
Price	18
Health benefits	4
Environmental standards in the salmon industry	6
Animal welfare standards in the salmon industry	5
Ease of preparation / cooking	11
The type of feed that salmon are fed	14
Colour	27
Taste	3
Availability of <u>organic</u> salmon	19
Availability of <u>wild caught</u> salmon	10
Other	*
Don't know	10
None of these	8

Q5. **As far as you know, what are most farmed salmon <u>fed</u> whilst being reared..?** SINGLE CODE ONLY

	%
A mainly fish-based diet	16
A mainly plant-based diet	11
A mixed fish-based and plant-based diet	26
Don't know	47

Q6. **Farmed salmon can be given various diets - some more fish-based and some more plant-based.**

All of these are designed to ensure that salmon itself is a healthy food for people. (For example, it contains Omega3 fatty acids which can help prevent heart disease).

In general, a fish-based diet is closer to what salmon would eat in the wild – while a more plant-based diet can help to ensure that stocks of fish used to feed salmon are conserved for the future.

Assuming price, taste, quality and health benefits were not affected - what is your preference (if any) for the type of diet that farmed salmon should be given..?

	%
Mainly fish-based diet (closer to salmon's diet in the wild)	21
Mainly plant-based diet (helping to conserve fish stocks)	13
Mix of fish-based and plant-based diet	21
No Preference	35
Don't Mind / Care	10

ASK Q7 IF SAID 'FISH-BASED' OR 'MIX' (CODES A OR C) AT Q6 – 477 RESPONDENTS

Q7. **Most farmed salmon in British supermarkets is actually fed a diet that is about three quarters fish-based and one quarter plant-based. If this changed to about half and half (with some fish-based feed replaced by plant-based feed), how if at all would this affect your salmon eating?**

Again, please assume that price, taste, quality and health benefits were not affected.

	%
Would eat a lot more salmon	2
Would eat slightly more salmon	7
Would make no difference	71
Would eat slightly less salmon	5
Would eat a lot less salmon	2
Don't Mind / Care	13