IAFMM

international association of fish meal manufacturers

Hoval House, Mutton Lane, Potters Bar, Hertfordshire, EN6 3AR
Tel: (Potters Bar) 0707 42343

No.25 MARCH 1990

# THE ROLE OF FISH OIL IN FEEDS FOR FARMED FISH -

## ESTIMATED CURRENT AND POTENTIAL USE

*by* **I.H. PIKE**

## SUMMARY AND CONCLUSIONS

Lipids from wild fish, particularly marine fish, contain comparatively high levels of n-3 polyunsaturated fatty acids (PUFA). For many fish, and particularly marine fish, long chain n-3 PUFA's must be supplied in the diet. The marine fish studied so far can only meet their requirement for the n-3 series fatty acids from eicosapentaenoic (EPA) (C20:5 n-3) and decosahexanoic (DHA) (C22:6 n-3) acids, both of which occur in fish oils. These fatty acids (EPA and DHA) will meet requirements of fresh water and marine fish; for example, the requirement of trout for n-3 fatty acids may be met when the diet contains 0.5%, or 10% of dietary lipids, as long chain fatty acids from fish meal and fish oil. In many cases the fish meal in the fish feed, if it is antioxidant treated, will supply sufficient quantities of long chain n-3 PUFA's to meet the requirement of farmed fish for n-3 fatty acids.

Marine fish and rainbow trout have been shown to have a requirement for n-6 fatty acids. These should be sufficient in marine lipids where fish oil is the main source of added oil to provide these fatty acids. For omnivorous and herbivorous fish a minimum amount of vegetable oil (around 1%) as a source of n-6 fatty acids was found to be desirable, e.g. for tilapia.

Fish oils are highly digestible when fed to fish provided they have not oxidised.

For most fish and crustacea, comparing fish oil with other oils in the diet, better growth rates have been found with fish oils.

The composition of the lipid in fish generally reflects the composition of the dietary lipid. Using fish oils rich in n-3 fatty acids in the diet it should be possible to produce farmed fish with the same content of these fatty acids in their lipids as wild fish.

The long chain n-3 PUFA's, namely EPA and DHA, have been found to have beneficial health effects when included in human diets.

Farmed fish can provide a rich and palatable source of these fatty acids.

Current use of fish oil in fish feeds, estimated to be 88 thousand tonnes in 1987, is likely to rise rapidly with increasing farming of finfish and crustaceans and increasing intensification. With appropriate distribution of fish oils to avoid excessive distribution costs and active promotion amongst fish feed producers, it is forecast that usage might more than double to around 190 thousand tonnes by 1990. Around a quarter of this fish oil is likely to be supplied by the Japanese in view of the size of the market 'on their doorstep'.

The biggest individual consumer of fish oil by 1990 is likely to be the salmonids, salmon and trout each accounting for similar consumption. However in the 1990's salmon are likely to become the biggest consumer.

Although crustaceans are likely to become the biggest consumers of fish meal amongst fish, crustacea etc. by 1990, their limited capacity to utilise oil (max. 10% of diet) will limit their use of fish oil.

Other marine fish that will be farmed in Europe in increasing quantities and will require fish oil in their diets include seabass, turbot, halibut and cod. However, quantities farmed up to 1990 are expected to be small. Substantial production is likely by the mid 1990's.

# CONTENTS

# I. THE ROLE OF FISH OIL IN FEEDS FOR FARMED FISH

## 1. INTRODUCTION

The fish lipids contain predominantly unsaturated fatty acids - mono- and poly-unsaturated. The structure of these fatty acids is given by three numbers:

i) the number of carbon atoms in the chain.

ii) the number of double bonds and

iii) the number of carbon atoms from the terminal methyl group to the carbon atom of the first double bond, the omega $\omega$ number, e.g., $\omega$ 3 or n-3.

More details of the fatty acid nomenclature system are given in the appendix.

Whilst all animal species utilise fish oil, rich in n-3 fatty acids to a greater or lesser extent, including fish oil contributed by fish meal, problems with off-flavour in meat etc. limits use generally to under 1% of the diet. Most fish have a requirement for n-3 fatty acids. There is some evidence that the longer chain n-3 fatty acids which occur almost exclusively in fish oil, e.g. C20:5 eicosapentaenoic acid (EPA), and C22:6 docosahexaenoic acid (DHA) are more beneficial than the shorter chain n-3 fatty acids, e.g. C18:3 linolenic acid, which can be provided by some vegetable oils.

## 2. LIPIDS IN FISH FEEDS

### 2.1 Requirement for Fatty Acids

The difference in composition of lipids of fish and those of mammals and birds was the first indication that their requirements for essential fatty acids (EFA) might differ. Lipids from wild fish contain comparatively high levels of n-3 polyunsaturated fatty acids (PUFA), particularly marine fish. These fatty acids are synthesised in the photosynthetic membranes of phytoplankton, passing through the food chain to be retained by fish. Freshwater fish contain greater amounts of n-6 fatty acids possibly originating from land plants and insects. Even so, lipids in freshwater fish are rich in n-3 PUFA.

According to Cowey [1] both linoleic (n-6) and linolenic (n-3) acid, or their chain elongation metabolites, must be supplied preformed in the diet of fish because, as with mammals, fish cannot synthesise either parent fatty acid de novo for maintenance or cellular function. Whether or not these parent fatty acids, linoleic and linolenic, meet the EFA requirements of the fish depends partly on the capacity of the species concerned to chain elongate and further desaturate the parent acid to longer chain, more unsaturated members of the series with full EFA activity. The capacity of many marine fish to do this is very limited. Consequently long chain highly unsaturated fatty acids must be supplied in their diet - for example, for marine salmonids, red sea bream, black sea bream, opaleye, turbot, yellow tail and some prawns. Wholly marine fish so far studied can only meet their requirement for n-3 series fatty acids from C 20:5 n-3 (EPA) and C22:6 n-3 (DHA). Turbot, red sea bream, black sea bream, opal eye and yellow tail do not grow well with diets containing 18:3 n-3, 18:2 n-6 and 20:4 n-6. (Cowey et al, [2]; Yone and Fujii [3]; Fujii and Yone, [4], Yone, [5]).

Rainbow trout have been shown to have a requirement for 0.83% to 1.66% linolenic acid (C18:3 n-3) in the diet, the total lipid content of which was 5% (Watanabe et al,)[6]. Takeuchi and Watanabe [7] showed the requirement for linolenic acid increased as dietary lipid increased - with 10% to 15% purified lipid in the diet some 20% of it should be C18:3 n-3. Subsequently they showed C20:5 n-3 (EPA) and C22:6 n-3 (DHA) were more effective than C18:3 n-3 and their effects were additive, 0.25% of each being sufficient to meet EPA requirement (5% lipid in the diet). **The requirement of rainbow trout for n-3 fatty acids may be met when the diet contains 0.5%, or 10% of dietary lipids, as long chain fatty acids from fish meal and fish oil (Watanabe) [8].**

The requirement of fish for fatty acids was reviewed in IAFMM Technical Bulletin No. 22, (see p15). It was concluded that for several fish species including salmon the quantitative requirement for n-3 fatty acids is not fully known and that it may be prudent to use those amounts appropriate for rainbow trout (see above).

In a comprehensive review of fatty acid requirements, Cowey [1] concluded that there may be a small but significant requirement for n-6 fatty acids in rainbow trout and marine fish. There should be sufficient n-6 fatty acids in marine lipids to supply this requirement in diets where fish oil is the main source of oil added to the diet.

### 2.2 The Composition of Fish Oils

The fatty acid composition of fish oils is characterised by their high content of long chain polyunsaturated n-3 fatty acids. Values for the major types of fish used in producing fish oil are given in Appendix Table 1, taken from Technical Bulletin No. 22.

### 2.3 Digestibility of Fish Oils

As the fatty acid chain length increases from C18 to C22, digestibility in fish increases; digestibility of unsaturated fatty acids is higher than that of saturated fatty acids of the same chain length (Austreng et al., [9]). Fish oils are highly digestible when fed to fish provided they have not oxidised (see IAFMM Technical Bulletin No. 22).

### 2.4 Effect of Dietary Lipids on Fish Growth

According to the U.S. National Research Council 'Nutrient Requirements of Coldwater Fishes' not less than 10% lipid and not more than 20% is optimum for coldwater fish. However in many trials the maximum levels of lipid tested may have been restricted by physical limitations of pellet quality. Also, although high lipid levels may have been tested with high protein levels, the type of protein may not have been optimum. For example, it may be possible to use higher lipid levels in conjunction with a diet in which most of the protein is supplied by a high quality low temperature produced fish meal, compared with a blend of undefined animal and vegetable proteins. Some fish feed producers using these fish meals claim to have found that in diets for salmon 25% to 30% lipid content is optimum. These lipid contents were achieved using a cooker-extruder to produce the feeds.

Higher levels of fish oil in diets of salmonids do not always give superior results to other lipids provided the requirement for n-3 fatty acids is met. For example, rainbow trout were fed diets with 5% fat as fish oil, or 9% fat as animal fat, fish oil plus animal fat or soyabean oil plus animal fat. Essential fatty acids were met. There were no differences in growth (Reinitz and Yu)[10]. In a trial at the Institute of Aquaculture, Aas in Norway, salmon fed diets with 7% fish oil plus 13% oils of different origin - high and low erucic acid rapeseed oil, soyabean oil or fish oil - growth was similar with the four oils (Røjø and Thomassen) [11]. However, commercial salmon feed producers in Europe claim to get better growth results with diets where most of the oil added is fish oil.

Channel catfish grew better with diets containing cod liver oil than with vegetable oils rich in either linolenic acid (18:3 n-3) or linoleic acid (18:2 n-6). It was suggested that the n-3 highly unsaturated fatty acids in the cod liver oil may be responsible for the enhanced growth. In consequence, Wilson et al [12] who did the work at Mississippi State University are doing further trials with fish oils.

Fish oil was superior to corn oil for yellow tails, according to Tsukahara et al, 1967 [13]. Comparing oil obtained from farmed catfish (high n-6:n-3 ratio, with virtually no EPA or DHA) with menhaden oil (high n-3:n-6 ratio with 21% EPA + DHA) fed to tilapia, growth was similar with both oils fed up to 5% of the diet [14]. However, at higher levels of added oil (10%), growth was significantly better with menhaden oil. Final weights were 13.1g v 10.2g ($P < 0.05$) respectively. It was concluded that 10% menhaden oil added to the diet gave the best results. Higher levels were not tested because of difficulties producing diets.

Feeding redfish (channel bass) diets with 1.7% to 18.8% lipid mainly from menhaden oil, growth and feed conversion were best with between 7.4% and 11.2% lipid content [15].

The fatty acids EPA and DHA were found to be more efficiently utilised than linoleic and linolenic acids by the freshwater fish common carp [16], ayu [17] and crustaceans - lobster [18] prawn, Penaeus japonicus [19] and monodon [20], indicus [21], Palaemon serratus [22] and crab [23]. In most of these trials fish oil was shown to be superior to vegetable oils.

Increasing lipid content (cod-liver oil/soyabean oil 1:1 mix) in diets for prawns (Penaeus monodon) above 10% reduced growth and increased abnormalities of the hepatopancreas with increased fat deposition. This was considered synonymous, it was suggested, to fatty liver in other animals (Bautista [24]). Previous work had shown dietary lipid levels to 15% and 12% were detrimental to the prawn (Palaemon serratus [25]) and Penaeus japonicus [26] respectively).

Growth of Atlantic and Coho salmon fry was depressed as a result of feeding diets with increasing levels of oxidative rancidity [27]. Oxidised fish oils depressed growth of rainbow trout, especially if the vitamin E content of the diet was inadequate [28].

It would appear that the optimum lipid content of a fish feed depends on many factors including the species of fish, content of protein and other nutrients in the diet, the type of lipid, the physical form of the feed, and feed intake. For salmonids, levels between 20% and 30% of the diet are considered optimum by fish feed producers. For several other species e.g. catfish and tilapia, a level of 10% would appear optimum. For shrimp and prawns, optimum dietary lipid content is below 10%.

For most fish and crustacea, the majority of trials comparing fish oil with other oils in the diet have shown better growth rates with fish oil. A minimum amount of vegetable oil (around 1%) as a source of n-6 fatty acids was found desirable for certain omnivorous and herbivorous fish.

### 2.5 Effect of Dietary Lipids on the Lipid Composition of Farmed Fish

The composition of the lipid in fish generally reflects the composition of the dietary lipid. For example, fish oils rich in n-3 fatty acids increase the n-3:n-6 ratio; vegetable oils rich in n-6 decrease the ratio. Some comparisons of the lipid composition of wild and farmed fish have revealed a higher n-3:n-6 ratio in the former e.g. shellfish (prawns), crayfish and catfish [29], trout, eel, carp [30] and lobster [31]. This may have been due, in part, to the inclusion of some vegetable oils in the diets of farmed fish; oxidation of the lipid in the feed may also have been a factor.

Recent data from North America and Norway indicate that with diets in which most of the added oil was from fish, there was little difference in the composition of lipids in wild and farmed salmon in the U.S.A. [32] or wild and farmed salmon and trout in Norway [33]. Whilst the Norwegian data show a slightly higher content of 20:5 (EPA) and 22:6 (DHA) in lipids from wild salmon than those from farmed salmon and trout, because the farmed salmonids contained more lipid they provided more 20:5 and 22:6 per 100g portion than the wild fish [33]. Because phospholipids which are rich in EPA plus DHA remain more or less constant, as the lipid content in salmon increases a tendency for the proportion of EPA + DHA in the lipid to reduce would be expected.

## 3. FARMED FISH AS A SOURCE OF n-3 FATTY ACIDS FOR MAN

The consumption of fish and the fish oil it contains is believed to be beneficial to health. Some of the fatty acids in fish, in particular the EPA and DHA would appear to be of particular value.

In the past 10 years an increasing amount of research has been undertaken investigating n-3 fatty acids, especially EPA and DHA, in human nutrition [34]. These fatty acids are important components of human nerve tissue, the retina of the eye, sperm and brain [35]. Epidemiological, clinical and biochemical studies during this period have suggested that consumption of fish is beneficial in reducing the risk of coronary heart disease [36]. This beneficial effect is considered to be due primarily to the lipid in fish which is rich in n-3 fatty acids, especially 20:5 (EPA) and 22:6 (DHA).

These longer chain fatty acids are considered to be more beneficial than the shorter chain 18:3 n-3. Most animal and vegetable lipids have a low n-3 content; furthermore the n-3 fatty acids in vegetable lipids are short chain (18:3). The longer chain 20:5 (EPA) and 20:6 (DHA) occur almost exclusively in fish and marine products. Some EPA and DHA has been reported in chickens fed fish meal [37]. As the general public becomes more aware of the health benefits likely from fish consumption, the nutritional quality of fish with regard to its content of 20:5 (EPA) and 22:6 (DHA) is likely to become one of the factors determining consumer acceptance.

The contribution of a portion of fish (100g) to the intake of 20:5 (EPA) and 22:6 (DHA) in humans is given in Appendix Table 2. Of the farmed fish it would appear that salmon provide the highest intake, followed by trout. Norwegian analysis of farmed salmon show 100g muscle providing almost 2g of 20:5 (EPA) plus 22:6 (DHA) [33]. This is approximately double that found in Canadian salmon (see Appendix Table 2) which may reflect the higher content of fish oil in diets of Norwegian salmon. Clinical trials with fish oils have suggested 2g per day intake of EPA plus DHA may be about optimum [36].

Using good quality fish oils which are adequately protected against oxidation, it should be possible to increase the content of these fatty acids in the fish lipids of farmed salmon to similar or even higher concentrations than are found in wild salmon.

# II. FEEDS FOR FARMED FISH - ESTIMATED CURRENT AND POTENTIAL USE OF FISH OIL

## 1. INTRODUCTION

With a case for higher levels of fish oil in fish diets than in diets for other farmed animals, what quantities are currently being used, and what is the future use likely to be? Key aspects which will be considered in more detail are the future of aquaculture and the nutritional role of n-3 fatty acids for fish, and the humans consuming farmed fish. Also important is the availability to the fish feed producer of fish oil suitable in quality and quantity.

## 2. THE CURRENT USE OF FISH OIL

It is believed that currently, the majority of fish oil used in fish feeds goes into diets for carnivorous species, particularly marine fish. The highest use of fish oil currently is likely to be in diets for salmon[1] (around 12% on average though in some cases higher levels are used e.g. Ewos' 'Wextra' salmon feed contains 16.5% of capelin oil (Norsalmoil)) and eels (10% to 15%), both receiving diets in which use of vegetable oils will be generally low (1% to 2% in diets for Atlantic Salmon). For trout, the situation is less clear. A minimum requirement for n-3 fatty acids will be met from 2% to 3% fish oil (see Appendix 2.1). It is believed that part of the remaining oil may be of vegetable origin. Diets for crustacea are expected to contain 5% added fish oil but currently data is scant. Catfish diets are known to contain high levels of vegetable oil, oil from processing the catfish, and poultry fat, with most of the fish oil present being provided by fish meal (usually 5% to 8%, resulting in a fish oil content of 0.5% to 1%). The other major carnivorous marine fish farmed, yellow tails in Asia, especially Japan, and seabream and milk fish in Asia, are believed to be fed mainly on fish offal though there is a growing use of dry feeds. Crayfish production in North America (currently around 26,000 tons) is largely extensive, though intensification and the use of formulated feeds is now beginning. Consequently, the only fish currently receiving fish oil through their diets is believed to be as shown in Table 1.

Although the fish oil figures in Table 1 are 'guestimates' they serve to illustrate the very low usage of fish oil in fish feeds despite the strong nutritional case for use of higher levels, namely provision of essential n-3 fatty acids, and their high digestibility and high energy value leading to faster growth than with other oils. In many cases they will improve content of n-3 fatty acids (especially EPA + DHA) in the fish as a result of their content in fish oils (see Appendix Table 1).

The production of fish oil in 1987 was estimated to be around 1.5 million tonnes. Therefore the estimated consumption for fish feeds (Table 1) represented only approximately 6% of world production of fish oil.

## 3. REASONS FOR LOW USAGE OF FISH OILS IN FISH FEEDS

Discussions with feed companies producing fish feeds in mills not dedicated to fish feed production, but used for producing feeds for several species, has indicated the following possible reasons for low usage of fish oils in some fish feeds at the present time:

(a) High price of small batches of fish oils for mills with low production of fish feeds (under 10,000 tons per annum). For example, many mills producing trout diets in Europe are general purpose, with less than 5,000 tons fish feed production per annum.

(b) Difficulty in handling small batches of fish oil - most mills produced only a few hundred tons of fish feed per month. Justifying facilities to install separate storage tanks for fish oils is difficult. Consequently, it is easier to use minimal amounts of fish oil, either in drums or through the fish meal, taking general purpose vegetable oils for the bulk of the remaining oil added to the fish feeds.

(c) High levels of fish oil in conventional pellets lead to a poorer pellet structure than with vegetable oils. With the cooker-extrusion process however, which is being used

[1]Salmon are anadromous, in that they start life in fresh water and go into salt water at between 40g and 100g liveweight. As the majority of their feed is given whilst the fish is in sea water they have been considered a marine species.

increasingly for salmonid diets, this is not a problem. Some commercial salmon feeds, cooker extruded, now have a lipid content of 25%.

## 4. THE FUTURE OF AQUACULTURE

The explosive growth in the world harvest during the two decades after 1950 ceased in the early seventies. Thereafter small increases in the harvest were achieved, peaking at 90 million tons in 1987 (see Table 2).

The slowdown in fish production after 1970 reflects the encounter, at that time, of fishing industries around the world with a resource barrier to further rapid expansion. Almost all stocks of demersal species are believed now to be either fully exploited or over-utilised. There is little prospect of increasing the catch of demersal species.

It is estimated that the increase in demand for fish for direct human consumption will be an additional 30 million tons by the year 2000 [38]. This might be satisfied by better fisheries management (10 million tons), improved utilisation of resources (20 million tons) and possible increases from aquaculture (about 5 to 10 million tons). Supply constraints are likely to increase prices which will improve the viability of aquaculture, but, at the same time, constrain overall demand.

**TABLE 1**

**Production of Mixed Feed for Farmed Fish and Estimated Use of Fish Oil - 1987**

| Fish Species | Area | Feed Produced ('000 tonnes) | Inclusion of Fish Oil (%) | Amount of Fish Oil ('000 tonnes) |
|---|---|---|---|---|
| Trout | Europe | 250 | 10 | 25 |
| | N. America | 140 | 5 | 7 |
| | Asia | 40 | 10 | 4 |
| Salmon | W. Europe | 140 | 12 | 16.8 |
| | N. America | 30 | 10 | 3 |
| | S. America | 10 | 12 | 1.2 |
| | Asia | 15 | 15 | 2.3 |
| Eels | Asia | 120 | 12.5 | 15 |
| Shrimp and Prawn | Far East | 400 | 2.5 | 10 |
| | S. America | 60 | 2.5 | 1.5 |
| Yellow tails | Far East | Figures not yet available for dried feed produced. | | |
| Catfish | N. America | 250 | 1 | 2.5 |
| | | | TOTAL | 88 |

Aquaculture currently supplies about 10% of fishery production world-wide. It is expected to increase by around 5% per annum to double supplies from this source by the end of the century. However, intensive production of finfish species, particularly the more soughtafter carnivorous fish, and also the crustaceans, shrimps and prawns, are likely to increase much more rapidly.

[Further details of marine fish and crustacea production through aquaculture are given in the FAO Fishery Information Data and Statistics Service, a copy of which is available at IAFMM Headquarters. The data in Tables 2 and 3 is taken from this source].

**TABLE 2**

**World Fish Production, by Origin, 1950-87**

**(million tons)**

| Year | Marine | Fresh-water | Total |
|---|---|---|---|
| 1950 | 17.6 | 3.2 | 20.8 |
| 1960 | 32.8 | 6.6 | 39.4 |
| 1970 | 59.5 | 6.1 | 65.6 |
| 1975 | 59.2 | 7.2 | 66.4 |
| 1980 | 64.5 | 7.6 | 72.1 |
| 1985 | 74.8 | 10.1 | 84.9 |
| 1987 | | | 90.5 |

**TABLE 3**

**World Aquaculture Production by Continent and Major Resource Group 1987**

**('000 metric tons)**

| | Finfish | Crustaceans | Molluscs |
|---|---|---|---|
| Africa | 61 | - | - |
| America North | 267 | 44 | 139 |
| America South | 22 | 80 | 2 |
| Asia | 5,701 | 440 | 1,806 |
| Europe | 399 | 3 | 645 |
| Oceania | 3 | - | 27 |
| USSR | 289 | - | - |
| TOTAL | 6,793 | 575 | 2,672 |

## 5. ESTIMATED POTENTIAL FUTURE USE OF FISH OIL IN FISH FEEDS

Production of farmed finfish and crustaceans is currently over five million tonnes. Only a small part of this production (around 10%) receives mixed feeds; most is produced extensively from biomass within ponds and waste products etc. As aquaculture production increases there is likely to be an increase in intensification, increasing requirements for mixed feeds. For example, world production of farmed shrimps and prawns in 1988 was around 300 thousand tonnes per annum. This is expected to increase to over 500 thousand tonnes by 1990 [38], much of the increase being in semi-intensive production involving feeding about one ton of feed for the production of one ton of prawns/shrimps compared with three tons of feed for a ton of intensively produced prawns/shrimps and no mixed feed for extensive production.

In Table 4 those species of finfish/crustaceans which will receive mixed feeds are listed with an estimate of their production in 1990. The following assumptions are made:

(a) Fish oil of suitable quality will be available at a price at or below the price of good quality vegetable oils.

(b) Some of the species (especially salmonids) receive a cooker extruded feed allowing high dietary levels of oil.

(c) The advantages of the long chain polyethylenic n-3 fatty acids in fish oils in meeting the requirement of fish for n-3 fatty acids (where one exists) are made known to the fish feed formulators.

(d) Fish consumers in the U.S.A., W. Europe and Japan demand farmed fish with an n-3 fatty acid content at least as high as that in the equivalent wild fish.

Estimates of fish oil use in feeds for farmed fish based on these assumptions are given in Table 4 showing a predicted potential use of fish oil in 1990 totalling 190 thousand tonnes. Assuming world fish oil production remains at around 1.5 million tonnes, predicted use for fish feed represents around 13% of total world production.

In addition to the uses of fish oil shown, it is possible that other species which have not been shown to have a requirement for n-3 fatty acids may receive some fish oil because they appear to utilise fish oil more effectively than other oils. Of the 400 thousand tonnes of carp and 500 thousand tonnes of tilapia produced some receive mixed feed and this may eventually include fish oil. No figures have been found for production of feeds for these fish. Assuming the total is 100 thousand tons, inclusion of 5% fish oil would account for 5 thousand tons per annum usage. Total feed production for these fish could be several times higher.

**TABLE 4**

**Predicted Potential Use of Fish Oil in Fish Feeds, 1990.**

| Fish Species | Area | Fish Production '000 Tonnes | Dry Feed Required '000 Tonnes | Fish Oil Inclusion in Diet | Amount of Fish Oil '000 Tonnes |
|---|---|---|---|---|---|
| Salmon | W. Europe | 135 | 225 | 15 [1] | 34 |
| | Far East | 30 | 50 | 15 [1] | 8 |
| | N. America | 25 | 40 | 15 [1] | 6 |
| | S. America | 7 | 12 | 15 | 2 |
| Trout | Europe | 182 | 328 | 10 | 33 |
| | N. America | 80 | 145 | 10 | 15 |
| Catfish | N. America | 150 | 300 | 2.5 | 7 |
| Shrimp & prawns | | | | | |
| | Far East (Intensive) | 120 | 240 | 5 | 12 |
| | Far East (Semi intensive) | 180 | 180 | 5 | 9 |
| | S. America (Semi intensive) | 30 | 30 | 5 | 2 |
| Eels | Far East | 100 | 200 | 15 [5] | 30 |
| | Europe | 8 | 16 | 15 | 3 |
| Yellow Tails | Far East | 150 | 150 [3] | 12 [5] | 20 |
| Milk Fish | Far East | 300 | 150 [4] | 10 | 8 |
| Cray Fish | N. America | 50 | 10 [2] | 5 | 1 |
| TOTAL | | | 2,076 | | 190 |

1 - Assumes diets produced by cooker extrusion, allowing oil content of finished diet up to 25%.

2 - Only a small proportion of crayfish produced likely to receive mixed feed.

3 - Some fish oil likely to be used in moist feeds. Also will be move to dry feeds, because of pollution problems caused by moist feeds, especially in Japan.

4 - Low cost carbohydrate rich diet fed to milk fish with 10% to 15% fish meal in dry diets. However, in future, may be fish oil will also be included in the diet. Amount of mixed feed used is limited; also use waste products fed directly.

5 - From 'Intensive Fish Farming - Nutrition and Growth' T. Watanabe p. 172, 1988. BSP Blackwell Scientific Publications, Onsney Mead, Oxford OX2 OEL, UK.

## Appendix 1

### The Fatty Acids in Fish Lipids - Chemical Name, Family Name and Omega Prefix/n Number of Four Families of Fatty Acids

Fish lipids contain predominantly unsaturated fatty acids - mono-unsaturated and polyunsaturated, and also saturated fatty acids. There are four common families of unsaturated fatty acids in fish lipids - palmitoleic (n-7 series), oleic (n-9 series), linoleic (n-6 series) and linolenic (n-3 series). The structure of the unsaturated fatty acids is given by three numbers (i) the number of carbon atoms in the chain, (ii) the number of double bonds and (iii) the number of carbon atoms from the terminal methyl group to the carbon atom of the first double bond, the omega $\omega$ number, e.g. $\omega$ 3. More recently the number has been described as being subtracted from n, e.g. n-3, n designating the carbon atom carrying the terminal methyl group. Examples of the PUFA families in fish are given in Appendix Table 1. Generally, the more unsaturated the fatty acids in lipids (fats and oils) the lower the melting point. Highly unsaturated fish lipids are generally liquid at room temperature (oils) whereas saturated animal lipids are generally solid (fats) at room temperature.

For further details of the composition of fish lipids, see IAFMM Technical Bulletin No. 22 'Fish Lipids in Animal Nutrition' and IAFMM Fish Oil Bulletin No. 18 'The Chemical and Physical Properties of Crude Fish Oils for Refiners and Hydrogenators'.

**Appendix Table 1**

**Content (w/w%) of Nutritionally Important Fatty Acids in Lipids Extracted from Fish Meals[1]**

| Type of meal | South American Fish | | | | | | Herring Type Fish | | | | | | White fish |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species[a] | N.S. | A | P | A | Average | S.D.[b] | N.S. | C | M | H | Average | S.D. | N.S. |
| **Fatty acid** | | | | | | | | | | | | | |
| 14:0 | 2.8 | 8.7 | 6.2 | 7.4 | 6.3 | 2.5 | 3.2 | 4.8 | 6.1 | 5.5 | 4.9 | 1.3 | 3.2 |
| 16:0 | 12.9 | 23.3 | 20.5 | 22.8 | 19.9 | 4.8 | 10.3 | 16.6 | 15.9 | 16.3 | 14.8 | 3.0 | 11.1 |
| 18:0 | 2.9 | 6.4 | 5.5 | 4.2 | 4.8 | 1.5 | 0.6 | 1.6 | 4.1 | 2.0 | 2.1 | 1.5 | 1.7 |
| 16:1 | 4.6 | 8.7 | 8.6 | 7.2 | 7.3 | 1.9 | 7.0 | 6.9 | 4.9 | 4.2 | 5.8 | 1.4 | 6.8 |
| 18:1 | 20.2 | 10.5 | 11.7 | 13.1 | 11.4 | 7.0 | 11.5 | 17.6 | 13.8 | 14.7 | 14.4 | 2.5 | 16.9 |
| 20:1 | 4.7 | - | - | 1.3 | 3.0 | - | 10.3 | 8.9 | 10.1 | 12.9 | 10.9 | 1.7 | 9.7 |
| 22:1 | 4.2 | - | 0.4 | 0.7 | 1.8 | 2.1 | 8.7 | 7.1 | 14.7 | 16.9 | 11.9 | 4.7 | 9.1 |
| 20:5 n-3 | 9.3 | 18.7 | 14.1 | 16.3 | 14.6 | 4.0 | 18.0 | 10.4 | 5.8 | 6.3 | 10.1 | 5.6 | 12.0 |
| 22:6 n-3 | 25.9 | 14.7 | 15.4 | 13.5 | 17.4 | 5.7 | 19.1 | 16.8 | 12.1 | 13.4 | 15.4 | 3.2 | 19.2 |
| Total n-6 | 6.9 | 2.5 | 3.6 | 3.4 | 4.1 | 1.9 | 3.6 | 3.5 | 4.4 | 2.4 | 3.5 | 0.8 | 3.4 |
| Total n-3 | 38.5 | 33.4 | 33.8 | 31.5 | 34.3 | 2.3 | 41.6 | 27.8 | 18.6 | 20.2 | 27.1 | 10.5 | 35.5 |

[1]For source see IAFMM Technical Bulletin No. 22, page 6.

[a]A = Anchoveta, P = Pilchard, C = Capelin, M = Mackerel, H = Herring, N.S. = not specified.

[b]S.D. = Standard deviation.

## Appendix Table 2

### Lipids of Some Nova Scotia Fish and Shellfish Food products

Lipid Analysis: Amount of Total Lipid, Eicosapentaenoic (EPA) and Docosahexaenoic (DHA) Acids, Total n-3 Acids, and Cholesterol, in Seafood Available from Nova Scotia Sources (Ackman, 1987)[1]

| | Total Lipid (g/100g) | EPA (20:5n-3) (g/100g) | DHA (22:6n-3) (g/100g) | Total n-3 (g/100g) | Cholesterol (mg/100g) |
|---|---|---|---|---|---|
| **Groundfish** | | | | | |
| Cod | 0.73 | 0.08 | 0.23 | 0.32 | 34.6 |
| Cusk | 0.67 | 0.03 | 0.09 | 0.13 | 31.8 |
| Haddock | 0.59 | 0.07 | 0.14 | 0.23 | 29.3 |
| Hake, white | 0.69 | 0.05 | 0.22 | 0.30 | 22.9 |
| Halibut | 2.04 | 0.16 | 0.22 | 0.45 | 19.8 |
| Monkfish | 0.42 | 0.03 | 0.07 | 0.11 | 16.7 |
| Pollock, Bluefish | 1.10 | 0.08 | 0.18 | 0.26 | 50.2 |
| Redfish, Ocean Perch | 0.15 | 0.14 | 0.07 | 0.21 | - |
| Turbot | 10.00 | 0.34 | 0.28 | 0.84 | - |
| Winter Flounder, Sole | 0.45 | 0.07 | 0.12 | 0.22 | 15.1 |
| Wolffish, Catfish | 0.59 | 0.11 | 0.06 | 0.20 | 32.1 |
| **Pelagic Estuarial** | | | | | |
| Capelin | 1.78 | 0.12 | 0.19 | 0.31 | 22.8 |
| Eel, frozen | 14.20 | 0.30 | 0.66 | 1.13 | 151.0 |
| Gaspereau | 3.49 | 0.10 | 0.27 | 0.51 | 42.0 |
| Herring | 12.00 | 1.05 | 1.29 | 3.12 | - |
| Mackerel | 20.60 | 1.45 | 2.16 | 5.10 | - |
| Mackerel, smoked | 21.20 | 1.47 | 2.30 | 5.25 | - |
| Salmon, farmed-reared | 8.33 | 0.25 | 0.73 | 1.28 | 34.7 |
| Smelt | 1.20 | 0.12 | 0.18 | 0.32 | 73.2 |
| Sturgeon | 7.20 | 1.40 | 0.57 | 2.56 | - |
| Swordfish, frozen | 11.40 | 0.14 | 0.44 | 0.90 | 43.7 |
| Trout, farm-reared | 3.90 | 0.12 | 0.50 | 0.72 | 44.9 |
| **Molluscs Crustaceans** | | | | | |
| Clam, Surf | 1.40 | 0.14 | 0.21 | 0.38 | 65.6 |
| Crab, Jonah | 1.10 | 0.28 | 0.10 | 0.38 | 78.4 |
| Crab, Queen | 0.75 | 0.20 | 0.09 | 0.30 | 76.0 |
| Crab, Rock | 1.20 | 0.27 | 0.15 | 0.42 | 70.9 |
| Lobster | 1.20 | 0.24 | 0.12 | 0.38 | - |
| Mussel | 1.27 | 0.13 | 0.17 | 0.36 | - |
| Oyster, American | 1.60 | 0.11 | 0.09 | 0.29 | 69.0 |
| Quahog, Bay | 1.62 | 0.11 | 0.09 | 0.23 | - |
| Quahog, Ocean | 0.80 | 0.09 | 0.08 | 0.20 | - |
| Scallop | 1.00 | 0.19 | 0.18 | 0.44 | - |
| Shrimp | 2.43 | 0.28 | 0.16 | 0.50 | - |
| Squid | 2.00 | 0.27 | 0.64 | 0.93 | - |

[1] (personal communication)

**References**


1. *COWEY, C.B., 1988.* The nutrition of fish: the development scene. Nutrition Research Reviews, 1, 255-280.

2. *COWEY, C.B., OWEN, J.M., ADRON, J.W. and MIDDLETON, C. 1976.* Studies on the nutrition of marine flat fish. The effect of different fatty acids on the growth and fatty acid composition of turbot. British Journal of Nutrition, 36, 479-486.

3. *YONE, Y. and FUJI, M., 1975.* Studies on nutrition of red sea bream - xi. Effect of w3 fatty acid supplement in a corn oil diet on growth rate and feed efficiency. Bull. Jap. Soc. of Sci Fisheries, 41, 73-77.

4. *FUJII, M. and YONE, Y., 1976.* Studies on the nutrition of red sea bream - xiii. Effect of dietary linolenic acid and w3 polyunsaturated fatty acids on growth and feed efficiency. Bull. Jap. Soc. of Sci. Fisheries, 42, 583-588.

5. *YONE, Y, 1978.* Essential fatty acid and lipid requirements of marine fish. In Dietary Lipids in Aquaculture, pp 43-45 (The Japanese Society of Scientific Fisheries, edt.) Koseisha-Koseikako, Tokyo.

6. *WATANABE, T., TAKASHIMA, F. and OGINO, C., 1974.* Effect of dietary methyl linolenate on growth of rainbow trout. Bull. Jap. Soc. of Sci. Fisheries, 40, 181-188.

7. *TAKEUCHI, T., and WATANABE, T., 1977.* Effect if eicosapentaenoic acid and docosahexaenoic acid in pollock liver oil on growth and fatty acid composition of rainbow trout.

8. *WATANABE, T., 1982.* Lipid nutrition in fish. Comparative Biochemistry and Physiology, 73B, 3-15.

9. *AUSTRENG, E., SKREDE, A. and ELDEGARD, A., 1979.* Effect of dietary fat source on the digestibility of fat and fatty acids in rainbow trout and mink. Acta Agric. Scand. 29, 119-126.

10. *REINITZ, S.L. and YU, T.C., 1981.* Effects of dietary lipids on growth and fatty acid composition of rainbow trout. Aquaculture 22 (4) 359-366.

11. *RØJØ C. and THOMASSEN, M.S., 1987.* Different fats in feed for salmon. Influence on growth rate and sensory parameters. Proc. of Int. Symp. on Feeding and Nutrition in Fish, Bergen, Aug. 1987.

12. *WILSON, R.P., SATOH, S. and POE, W.E., 1987.* Proc. of Int. Symp. on Feeding and Nutrition in Fish. Bergen, Aug. 1987.

13. *TSUKAHARA, H., FURUKAWA, A. and KUNAE, K., 1967.* Studies on feed for fish VII. The effects of dietary fat on the growth of yellow tail. Bull. Naikai Reg. Fish. Res. Lab. 24, 29-50.

14. *STICKNEY, R.R. and WURTS, W.A., 1986.* Growth response of blue tilapias to selected levels of dietary menhaden and catfish oils. The Progressive Fish - Culturist, *48*, 107-109.

15. *WILLIAMS, C.D. and ROBINSON, E.H., 1988.* Response of red drum to various dietary levels of menhaden oil. Aquaculture, 70, 107-120.

16. *TAKEUCHIA, T. and WATANABE, T., 1977.* Requirement of carp for essential fatty acids. Bull. Japan Soc. Sci. Fish, 43: 541-551.

17. *OKA, A., ZUZUKI, N. and WATANABE, T., 1980.* Effect of fatty acids in rotifers on growth and fatty acid composition of larval oyu Bull. Japan Soc. Sci. Fish., 46, 1413-1418.

18. *CASTELL, J.D. and COVEY, J.F., 1976.* Dietary lipid requirements of adult lobsters. J. Nutr. 106, 1159-1165.

19. *KANAZAWA, A.S., TESHIMA, S. and ENDO, M., 1979a.* Requirement of prawn Penaeus japonicus for essential fatty acids. Mem. Fac. Fish, Kagoshima Univ. 28, 27-33.

20. *KANAZAWA, A.S., TESHIMA, S., KAYAMA, M. and HIRATA, M., 1979b.* Essential fatty acids in the diet of prawn. Bull. Jpn. Soc. Sci. Fish, 45, 151-1153.

21. *READ, G.H.L., 1981.* The response of Penaeus indicus (Crustacea Penaeidae) to purified and compounded diets of varying fatty acid composition. Aquaculture, 24, 245-256.

22. *MARTIN, BJ., 1980.* Croissance et acides gras de la crevette Palaemon serratus (Crustacea, Decapoda) nourrie avec des aliments composes contenant differentes proportions d'acide linoleique et linolenique. Aquaculture, 19, 352-333.

23. *PONAT, A., and ADELUNG D., 1980.* Studies to establish an optimal diet for Carcinus maenas II Protein and lipid requirements. Mar. Biol. 60, 115-122.

24. *BAUTISTA, M.N., 1986.* The response of Penaeus monodon juveniles to varying protein/energy ratios in test diets. Aquaculture, 53, 229-242.

25. *FORSTER, J.R.M. and BEARD, T.W., 1973.* Growth experiments with prawns, Palaemon serratus Pennant, fed with fresh and compounded foods. Fishery Invest., London, Ser. 2, 27 (7).

26. *DESHIMARU, O. and KUROKI, K., 1974.* Studies on a purified diet for prawn I basal composition of diet. Bull. Jpn. Soc. Sci. Fish 40, 413-419.

27. *KETOLA, G., SMITH, C.E. and KIND SCHI, G.A., 1989.* Influence of diet and oxidative rancidity on fry of Atlantic and Coho Salmon. Aquaculture 79, 417-423.

28. *COWEY, C.B., BEGENER, ELIZABETH, TACON, A.G.J., YOUNGSON, A. and BELL J.G. (1984).* The effect of vitamin E and oxidised fish oil on the nutrition of rainbow trout grown at natural, varying water temperatures. British Journal of Nutrition, 51, 443-451.

29. *CHANMUGAM, P., BOUDREAU, M. and HWANG, D.H., 1986.* Differences in the w3 fatty acid contents in pond-reared and wild fish and shellfish. J. Fd. Sci., 51, No. 6. 1556-7.

30. *SUZUKI, H., OKAZAKI, K., HAYAKAWA, S., NADA S. and TAMURA, S., 1986.* Influence of commercial dietary fatty acids on polyunsaturated fatty acids of cultured freshwater fish and comparison with those of wild fish of the same species. J. Agric. Fd. Chem. 34, 60-62.

31. *D.ABRAMO, L.R., BORDNER, C.E., DAGGETT, G.R., CONKLIN, D.E. and BAUM, N.A., 1980.* Relationships among dietary lipids, tissue lipids and growth in juvenile lobsters. Proc. of the World Mariculture Society, 11, 335-345.

32. *ROCH, M., TESAR, B. and PATTERSON, J., 1988.* Omega-3 and the farmed fish. Canadian Aquaculture, pages 49-53.

33. *THOMASSEN, M.S. and AUSTRENG, E., 1986.* Sunne fettsyrer i nork oppdsettsfisk (Lipid composition in farmed Norwegian fish). Nørsk Fiskeoppdrett nr, 11, 47.

34. *CRIMMINS, CAROLYN.* Edt. In 'Omega 3 News'. Published by Dept. of Preventive Medicine, Massachusetts General Hospital, Boston, MA02114, U.S.A.

35. *CRAWFORD, M. and MARSH, D., 1989.* In 'The driving force: food, evolution and the future'. Publ. Heinemann.

36. *LANDS, W.E.M., 1986.* In 'Fish and Human Health'. Academic Press Inc., London.

37. *HULAN, H.W., ACKMAN, R.G., RATNAYAKE, W.M.N. and PROUDFOOT, F.G., 1988.* Omega-3 fatty acids levels and performance of broiler chickens fed redfish meal or redfish oil. Con. J. Anim. Sci., 68, 533-547.

38. *FAO, 1987.* 'Agriculture Toward 2000' ref. C87/27, July 1987, Rome.

39. *Fish Farming International, Dec. 1989.*

## TECHNICAL ADVISORY SERVICE

The IAFMM is a non-profit organisation whose members include the world's leading fish meal and oil manufacturers who are dedicated to quality and reliability.

The industry is served by many research laboratories located in different parts of the world. Research work on fish meal quality is conducted in these laboratories and in addition in universities and independent research Institutes with projects jointly funded by IAFMM members.

For many years the IAFMM has provided a Technical Advisory Service mainly for feed producers and agriculture/aquaculture institutions. The Staff at IAFMM Headquarters in the UK in conjunction with its Scientific Committee, representing an international group of experts in nutrition, biochemistry, bacteriology, engineering and product development will provide up-to-date information on any aspect of fish meal and its uses. Backed by extensive technical publications advice on the availability of fish meals, including special products for particular species, their nutrient specifications, quality control, and computer formulation of diets is available at no cost to users and potential users of fish meal, their advisers, and those involved in research/development work and teaching. All enquiries should be directed to:

**Dr. Ian H. Pike,**
**INTERNATIONAL ASSOCIATION OF FISH MEAL MANUFACTURERS,**
Hoval House, Orchard Parade, Mutton Lane, Potters Bar,
Hertfordshire EN6 3AR, U.K.

Tel: (Potters Bar) 0707 42343
Telex: 94013381(IAFM G)
Fax: 0707 45489

### Members of IAFMM

Australian Fisheries Development Pty Ltd.
P.O. Box 72, Triabunna,
Tasmania 7190, **AUSTRALIA**.
*Tel: Australia 571407*
*Telex: Australia 57151*
*Fax: Australia 0257 1247*

Fishery Products International Ltd., 70, O'Leary Avenue,
P.O. Box 550, St. John's,
Newfoundland, **CANADA** A1C 5L1.
*Tel: Canada 709 570 0000*
*Telex: Canada 26 0163151*
*Fax: Canada 709 570 0479/0209*

Corpesca S A, Huerfanos 863,
9th Floor, Santiago, **CHILE**.
*Tel: Santiago 395244*
*Telex: Chile 340502*
*Fax: Santiago 391816*

Pesquera Oceanica Ltda,
Torre Santa Maria Piso 14,
Los Conquistadores 1700,
Santiago, **CHILE**.
*Tel: 562 2315431*
*Telex: 341117*
*Fax: 562 2310162*

Foreningen for Danmarks Fiskemel-0g Fiskeolie-industrie, Vestergade 11,
DK-1456, Copenhagen K,
**DENMARK**.
*Tel: Copenhagen 145800*
*Telex: Denmark 19452*
*Fax: Copenhagen 931337*

I/F Havsbrun, Sildamjolsvirki,
3813 Fuglafjordur,
**FAROE ISLANDS**.
*Tel: Faroe Islands 44160*
*Telex: Faroe Islands 81252*
*Fax: Faroe Islands 44400*

Verband Deutscher Fischmehl- -und Fischolfabriken E.V.,
Postfach 290403, Lengstrasse, 2850
Bremerhaven 29, **GERMANY**.
*Tel: 471 72022*
*Telex: Germany 238633*
*Fax: 471 792215*

Icelandic Association of Fishmeal Manufacturers, P.O. Box 916,
Reykjavik, **ICELAND**.
*Tel: Reykjavik 28066*
*Telex: Iceland 2046*
*Fax: Reykjavik 25820*

The Irish Association,
P.O. Box No. 12, Crofton Road,
Dun Leoghaire, Co. Dublin,
**IRELAND (EIRE)**.
*Tel: Dublin 841544*
*Telex: Dublin 93237*
*Fax: Dublin 841123*

Fletcher Fishing Limited,
P.0. Box 4143,
Auckland, **NEW ZEALAND**.
*Tel: 64 9 795002*
*Telex: 2970*
*Fax: 64 9 598021*

Compania
Pesquera San Pedro SACI
Av.11 de Septiembre 1480,
Piso 14, Santiago 9, **CHILE**
*Tel: Chile 56 2 711086*
*Fax: Chile 56 2 711081*

Norsildmel, Conrad Mohrsvei 11,
Postboks 23, 5032 Minde,
**NORWAY**.
*Tel: Norway 284900*
*Telex: Norway 42179*
*Fax: Norway 282051*

Pesca Peru, Av. Petit Thouars 115,
Lima, **PERU**.
*Tel: Lima 320454*
*Telex: Peru 20328*
*Fax: Lima 311259*

The South African Fish Meal Producers Association (Pty) Ltd.,
Pearl Assurance House, Heeren-gracht, P.O. Box 2066, Cape Town
8000, **SOUTH AFRICA**.
*Tel: South Africa 21 25 1500*
*Telex: South Africa 527259*
*Fax: South Africa 21 4181378*

Vastkustfisk SVC Aktiebolag,
Box 4030, 400 40 Göteborg 4,
**SWEDEN**.
*Tel: Sweden 3112 4530*
*Telex: Sweden 21086*
*Fax: Sweden 122716*

United Kingdom Association of Fish Meal Manufacturers,
Hoval House, Orchard Parade,
Mutton Lane, Potters Bar,
Hertfordshire, EN6 3AR, **U.K.**
*Tel: 0707 42343*
*Telex: 94013381*
*Fax: 0707 45489*

Zapata Haynie Corporation,
P.O. Box 2868, Hammond,
Louisiana 70404, **U.S.A.**
*Tel: USA 504 345 2035*
*Telex: USA 469695*
*Fax: USA 504 3459393*

Printed by Citadel Litho Plates, London