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Feature

Fish oil: production and use now and in the future

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Summary

The global production of fish oil is around one million tonnes. This production is expected to be maintained. Rich in long-chain omega-3 fatty acids, especially EPA and DHA, it can supplement diets inadequate in these fatty acids such as those in many Western countries. Farmed fish, especially oily fish such as salmonids fed on fish oil provide an excellent source of these acids. Fish oil can be used directly in a purified form (nutraceuticals) in a wide range of foods. The daily recommended intake of EPA plus DHA of 0.25 to 0.50 g can then be met.

Production of fish oil

Over a quarter of wild fish that can be caught sustainably is unappetizing for direct human consumption – typically small boney and oily fish such as capelin, sand eel, anchovy, horse mackerel, pilchard and menhaden. This valuable resource is fished under carefully controlled limits set by government agencies based on stock assessments. These limits are effectively policed by government agencies in most of the countries producing fish oil. At the Food and Agriculture Organisation (FAO) World Conference on Environment and Development 1992 sustainable development was defined as 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs'. Global fish oil production has remained between 1 and 1.25 million tonnes for many years demonstrating the sustainable nature of the fisheries. To allow producers to demonstrate their responsible production IFFO is developing an independently audited standard based on the FAO Code of Responsible Fishing.

From wild caught fish, plus trimmings from edible fish (around 25% of total), production of fish oil is around one million tonnes. The main producing countries are shown in Figure 1. Production of fish oil in the future is not expected to change. More oily fish are expected to be processed for direct human use, thus reducing that available for fishmeal and fish oil production. However, growing by-product production from farmed fish will maintain the total production.

The fat content of fish is unique in its quantities of long chain omega-3 fatty acids (LC omega-3s). Because of their degree of unsaturation they help fluidity in membranes at low temperatures. These acids are produced by marine algae which are consumed first by zoo- plankton and then by fish.

Composition of fish oils

Fish oils are liquid at room temperature but generally solidify below 15°–10°C. Their composition is dependent on the type of fish. Most of the inedible fish are pelagic – that is, swim and shoal in the upper layers of the sea. These species generally store oil in the body rather than the liver. The species caught in America – South (Peru and Chile) and North (USA) have a high content of LC omega-3 fatty acids which can be up to 35% of the total fat

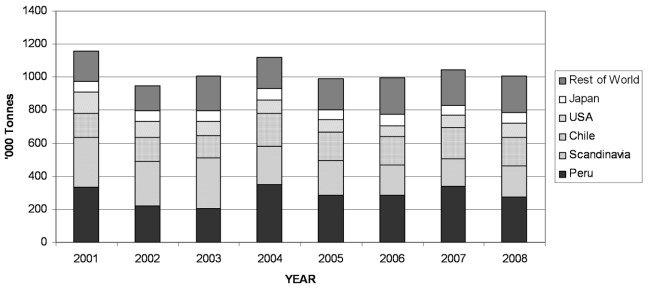


Figure 1. Major producers of fish body oil

in the fish. They are mainly eicosapentaenoic and decosahexaenoic acids (EPA and DHA) with some decosapentaenoic acid (DPA) at around 10%. The European fish species such as capelin, herring, sand eel and sprat are intermediate, have between 18% and 25% LC omega-3 fatty acids (Table 1). The demersal fish store oil in the liver, e.g. cod and halibut and have a low content of LC omega-3s (15% to 20%). The more unsaturated fish oils with a higher content of LC omega-3 fatty acids also have a higher content of saturated fatty acids such as myristic and palmitic. The unsaturated oils are susceptible to oxidation. For storage, all fish oils have to be out of contact with air, pro-oxidant metals, especially those high in iron and copper, and preferably treated with an antioxidant, such as butylated hydroxy-toluene (BHT).

Quality control of fish oil

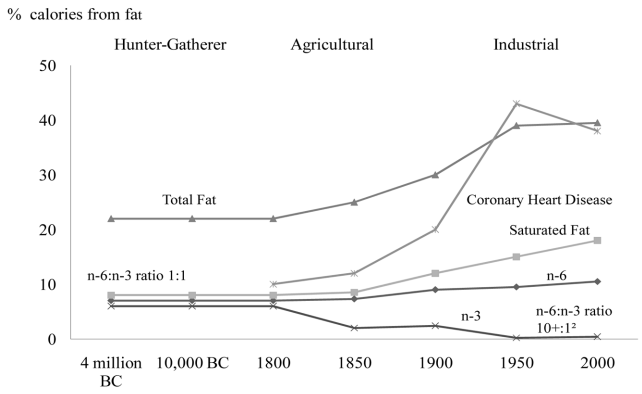
It is important to produce fish oil from fresh fish. As fish spoils, enzymes split the oil into its component fatty acids. Ideally, free fatty-acid content should be below 2%, and there should be little oxidation. Oxidation produces peroxides, aldehydes and ketones. The degree of oxidation can be determined by methods which measure these – giving the so-called TOTOX value based on peroxide and anisidine values. Ideally, it should be below 20. For human use, further refining is carried out.

Uses of fish oil

The main use of fish oil is for aquaculture – especially for carnivorous fish such as salmonids (salmon and trout) and marine

Table 1. Principal Fatty Acids in Fish Oils (% Total Lipid)

	Capelin	Norway Pout	Mackerel	Sardine/ pilchard	Horse mackerel	Anchovy
Myristic 14:0	7	6	8	8	8	9
Palmitic 16:0	10	13	14	18	18	19
Palmitoleic 16:1	10	5	7	10	8	9
Oleic 18:1	14	14	13	13	11	13
Eicosenoic 20:1	17	11	12	4	5	5
Cetoleic 22:1	14	12	15	3	8	2
LC Omega-3s						
EPA 20:5	8	8	7	18	13	17
DHA 22:6	6	13	8	9	10	9



[1]From Leaf, A. and Weber, P.C. (1987) American Journal of Clinical Nutrition 45 (Suppl) 1048-1053

[2] n-6:n-3 ratio now 15+:1

Figure 2. Changing fat and fatty acid intake and human nutrition[1]

species. Direct use in human foods and capsules is an increasingly significant outlet – the so-called 'nutraceuticals'. Other outlets include use as a carrier for pesticides, in paints, and in leather making.

Aquaculture is growing rapidly at between 4% and 6% per annum. Already world production of farm fish plus crustacea has reached 50% of world fisheries. By developing special feeding strategies up to 50% of the fat in the feed can be supplied by vegetable oils, such as rape seed oil, being substituted for fish oil. The substitution takes place during the middle period of growth. The composition of fat in fish generally reflects that being fed. Feed companies ensure that the content of LC omega-3s stay similar to that in wild fish. They do so by substituting fish oil with vegetable oils in the growing period and replacing with fish oils in the finishing period of 10 to 12 weeks. Farmed fish such as salmon may have a high proportion of omega-6 fatty acids and plant derived linolenic acid (omega-3).

The use in nutraceuticals had been increasing even more rapidly than that in aquaculture, at around 15% per annum. The past year saw growth increases reduced, but they may recover as countries pull out of the recession.

The importance of fish oil

Fish oil is a virtually unique source of natural LC omega-3 fatty acids – EPA, DPA and DHA. Farm animals on free range and/or fed fresh forage can deposit trace amounts of these fatty acids, in the milk and eggs. But intensification of animal husbandry has led to the virtual disappearance of fresh forage. As a result, the content of LC omega-3 fatty acids in land animal products has almost disappeared. This gradual decline can be seen in the next figure (Figure 2). It shows the changes in fatty acid intake over thousands of years based on paleo-nutrition studies. As man turned from hunter-gatherer to farmer intake of LC omega-3 fatty acids began to fall, and this accelerated as farming became intensive. More recently, the increase in plant oils consumed has led to an increase in omega-6 fatty acids. As a result, the ratio of omega-6 to omega-3 fatty acids in our foods has risen to around 15:1; the optimum is considered to be in the range 3:1 to 5:1. Fish oil, either through fish or nutraceuticals can restore this balance and provide more satisfactory amounts of LC omega-3s- especially DHA.

There are indications that genetically engineered crops could provide EPA; obtaining DHA this way is proving more difficult, and likely to take longer.

Recommended intake of LC omega-3s

The majority of recommendations for LC omega-3s are for a daily intake in the range of 0.25 g to 0.5 g per person per day. Several authorities such as the UK Government have recommended people eat fish twice a week, including oily fish, to provide 3 g weekly of LC omega-3s. A similar recommendation has been made by the US Heart Association.

Some health benefits of LC omega-3s

The consumption of LC omega-3s derived from fish oil, either in fish (wild and farmed) or as encapsulated fish oil has been shown to help maintain health, especially cardiovascular health. Benefits have been shown in ameliorating inflammatory disorders such as asthma, eczema, psoriasis and Crohn's disease. But perhaps the most important effects in the future will be in neurological development and mental health, including cognitive function. With the important function of EPA and DHA as a component of brain and nervous tissue, and in particular in the development of these organs, dietary LC omega-3 inclusion has an important role to play in the last trimester of pregnancy and in infant nutrition. There are already numerous studies showing positive benefits in these areas, but there are not yet sufficient dietary intervention studies to convince the authorities such that health claims can be made.

Cardiovascular health (CV)

There is a vast literature showing the benefits of fish oil or its component LC omega-3 fatty acids on CV health. This is covered by several review papers in refereed journals in recent years.

Most trials reported fish oil or LC omega-3s significantly reducing all cases CHD mortality, myocardial infarction, cardiac and sudden death and strokes (1). One review of trials (2) included three large trials with 32,000 participants. Those receiving an EPA plus DHA supplement showed 19% to 45% reductions in cardiovascular events. Both EPA and DHA were found to be effective, though it was indicated that more work was needed to determine an optimum ratio of these two acids. A recent review (3) reported four large dietary intervention trials involving 40,000 participants. This showed benefits in both primary and secondary CV disease prevention. A further recent review (4) found evidence of a substantially reduced risk of CHD death and sudden cardiac deaths (36% lower risk) with a 'modest' intake of EPA plus DHA (0.25 g/day) from fish or fish oil.

Some of these groups considered there is a dietary requirement for LC omega-3s which is not effectively met by the shorter chain alpha-linolenic acid present in some plant oils. A literature review has shown that the synthesis of LC omega-3s from alpha-linolenic acid is extremely limited with virtually no production of DHA (5). The synthesis is believed to be almost prevented when the ratio of omega-6 to omega-3 fatty acids in the diet becomes high (over 10:1). This is already exceeded in many Western diets (see Figure 2).

It is claimed that a deficiency of LC omega-3s in the diet causes up to 96,000 preventable annual deaths in the USA (6). – similar to the effect of high *trans*-fatty acid intake (97,000 deaths) and high salt levels (107,000 deaths).

Mechanisms by which EPA plus DHA benefit health

The CV benefits of EPA plus DHA are largely through enrichment of membrane phospholipids (2). Via this mechanism arrhythmic thresholds are increased, blood pressure reduced and arterial and endothelial function are improved. Platelet aggregation (clotting) is improved as is autonomic tone. Fish oil is known to reduce clotting and increase bleeding time. However, this does not seem to result in problems in those societies where intake of oily fish is extremely high.

The recommended levels of fish oil

To maintain the CV health in normal adults, most recommendations fall in the range 0.25 to 0.5 g per day of EPA plus DHA. EPA plus DHA in fish oils from the different species ranges from 11% in herring oil to 26% in and anchovy oil. So taking the lower end of the recommendations, this would be met by 2.5 g/day herring oil or 1 g/day anchovy oil. By concentrating fish oils, e.g. by winterisation, the amounts needed can be considerably reduced. Alternatively, one portion of cooked oily fish such as sardine, pilchard, mackerel, salmon or trout provides over 15 g fish oil. Several authorities, such as the UK's food standards agency, recommend eating fish twice a week, one portion of which should be oily.

Meeting LC omega-3 recommended intakes from fish oil in the future

Existing supplies of fish oil would provide the minimum LC omega-3 requirement for only1.25 billion people – just under a quarter of the world's population. Average fish intake in many countries provides over two grams per day fish oil. But these are averages. There is a shortage of fish and fish oil, despite increases in fish farming. Wild fish catches are not increasing. As mentioned already, so far genetic engineering of plants does not appear to have achieved DHA production which will be needed if the growing population is to be provided with recommended levels.

Conclusions

Of the one million tonnes of fish oil produced annually, mainly from sustainably caught unpalatable fish and from fishery by-products, most goes to aquaculture. In this way, much of the valuable LC omega-3s from the original inedible fish goes back into human food. Increasing amounts are going into nutraceuticals for direct human consumption. As fish oil production is unlikely to increase, the growing fish farming industry in future will have to use less fish oil, whilst maintaining the LC omega-3 content of farmed fish. To achieve this, fish oil has become a strategic ingredient. Levels in fish feeds are increased in the finishing period to restore the LC omega-3 fatty acid content.

There is robust evidence that fish oil and its component fatty acids, especially EPA plus DHA, are beneficial in maintaining cardiovascular health in normal adults and reducing the incidence of recurrence of problems in those who have been suffering from CHD. Several authorities are now accepting these benefits and limited claims can be made. To maintain cardiovascular health several groups now recommend an intake of between 0.25 g and 0.5 g of EPA plus DHA per day.

Extensive evidence of the benefits of fish oil consumption on neurological development, brain health and cognitive function and anti-inflammatory properties exist. More dietary intervention studies are needed for authorities to accept these benefits, and the claims that foods containing EPA plus DHA might carry.

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