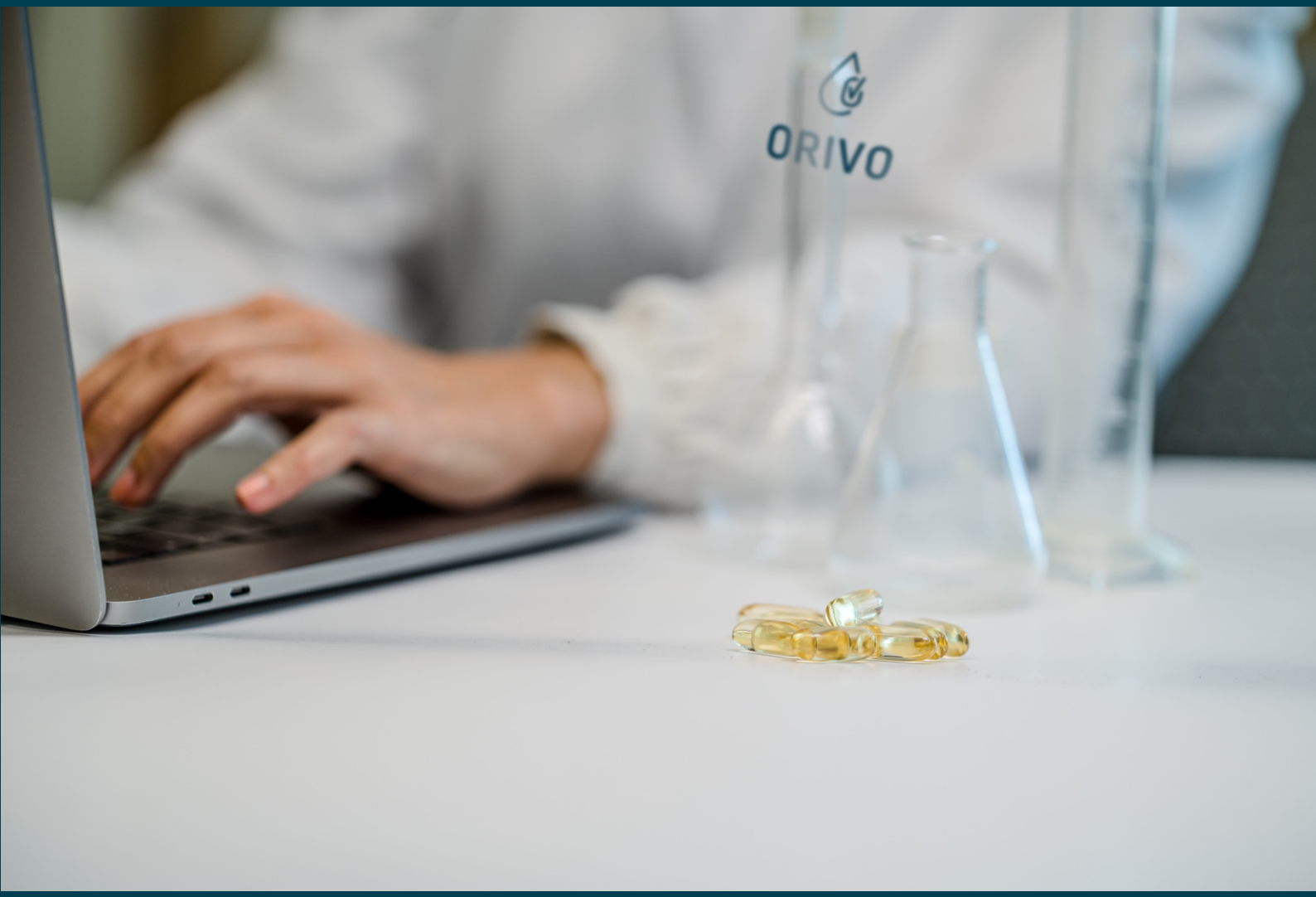
The ultimate guide to omega-3 sources



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The ultimate guide to omega-3 sources

Oils from fish and other marine species make up a popular category of ingredients used as sources of omega-3´s for both human consumption and feed. What you may not be aware of is that there are numerous sources of these valued products available on the market, and each of them has some distinct features. These features can for example be related to content of the essential omega-3 fatty acids EPA, DHA and DPA, the form these fatty acids occur in, the presence of antioxidants, or other features which could influence if an oil is suited for a particular application area. Supplements with a high DHA content is, for example, recommended to children and young adults, since DHA plays an important role in brain development. A high EPA content, on the other hand, is recommended to maintain a good eyesight. Whether you are a brand owner planning to launch a new omega-3 product line or a consumer looking to buy supplements for your family, it is important to understand which source best fits your needs. To help you determine the source best suited for you, we have listed the most common fish oil sources and what describes them in this guide. We have also added an omega-3 glossary, explaining the most commonly used words and expressions related to omega-3 supplements.

Content

Omega-3 glossary

Omega-3's = A class of fatty acids, defined by the position of the first double (unsaturated) bond in the fatty acid being three carbons from the end of the chain. Found in both plant and fish sources in either short-chain or long-chain forms and provides a range of health benefits.

Essential omega-3 fatty = Fatty acids that are important for human health but must be provided through the diet because they cannot be efficiently synthesized by the human body.

EPA = (Eicosapentaenoic acid; 20:5n-3) is a long-chain essential omega-3 fatty acid abundant in marine oils that has an important role as the substrate for several hormones.

DHA = (Docosahexaenoic acid; 22:6n-3), is a long-chain essential omega-3 fatty acid abundant in marine oils that has an important role as the substrate for several hormones and as an important building block for brain, nerve and eye tissues.

DPA = (Docosapentaenoic acid; 22:5n-3), is long-chain essential omega-3 fatty acid found in some fish oil sources. DPA´s role has in recent years been discussed more frequently in the scientific community as a very potent omega-3 fatty acid, similar to the more well-known omega-3 fatty acids EPA and DHA

Natural oil = An oil where it´s chemical structural composition has not been altered during processing and refining.

Omega-3 concentrate = An oil where the chemical structural composition has been altered during processing and refining in order to yield a product with a higher concentration of certain omega-3 fatty acids, typically EPA and DHA.

Triglyceride = (Triacylglycerol, TAG, TG), is an ester derived from glycerol and three fatty acids. Triglycerides are the main constituents of body fat in humans and other vertebrates, as well as vegetable fat. Many types of triglycerides exist. One specific classification focuses on saturated and unsaturated types. Saturated fats have no C=C groups; unsaturated fats feature one or more C=C groups. Unsaturated fats tend to have a lower melting point than saturated analogues; as a result, they are often liquid at room temperature.

Ethyl ester = A chemically modified version of the natural triglyceride form where the original glycerol backbone has been replaced with an ethyl group. Some omega-3 concentrates are in this form.

Wax ester = Is an ester (combination) of a fatty acid and a fatty alcohol.

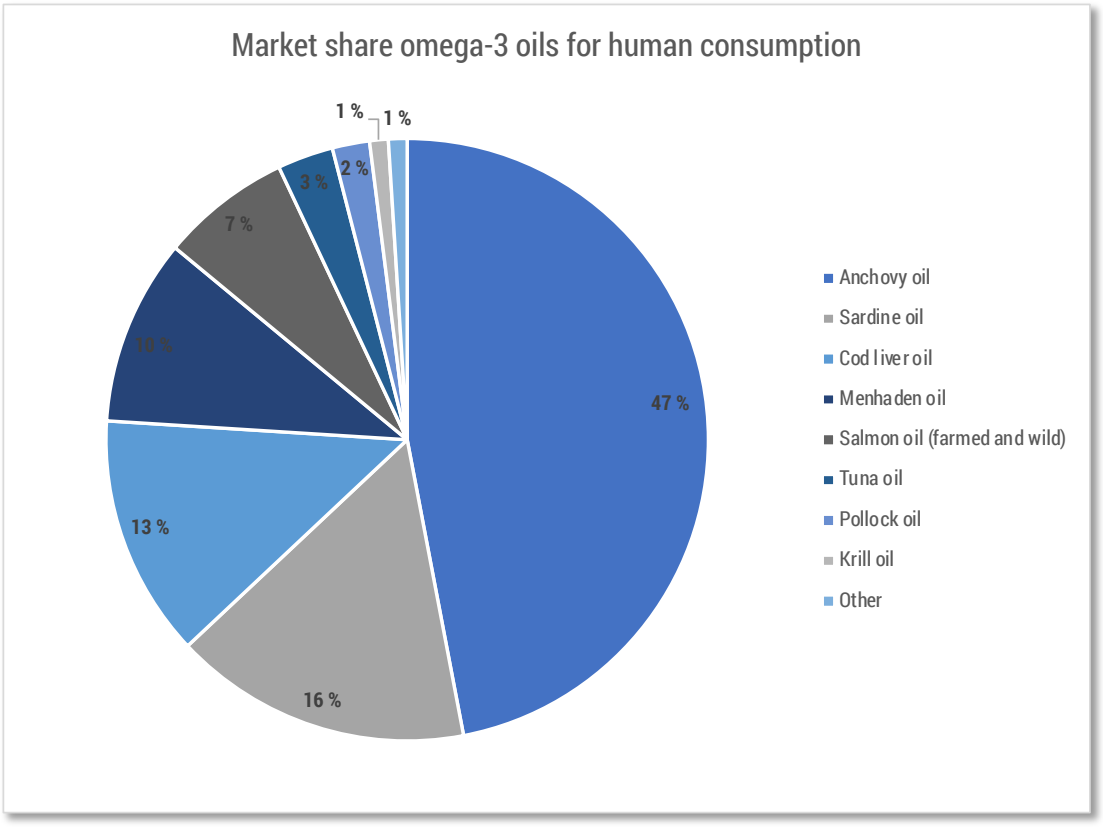
Phospholipid = A molecule that has a hydrophilic "head" containing a phosphate group and two hydrophobic "tails" derived from fatty acids, joined by an alcohol residue (usually a glycerol molecule). The phosphate group can be modified with simple organic molecules such as choline, ethanolamine or serine.

Astaxanthin = A powerful antioxidant produced naturally by certain microalgae and yeast strains. Animals who feed on the algae subsequently reflect the red-orange astaxanthin pigmentation in fat-containing tissue, for instance salmon.

An overview of the most common omega-3 sources

Below you can find an overview of the most common omega-3 sources and some of their features. More details can be found in the following sections.

Omega-3 sourcd	Omega-3 content	EPA/DHA ratio	Geographic origin	Market share (human consumption)	Used as natural oil	Used as omega-3 concentrate
Anchovy oil	High	1.5	South America/Europe	47 %	X	X
Sardine oil	High	1.5	Multiple	16 %	X	X
Cod liver oil	Medium	0.8	Europe/North America	13 %	X	
Pollock oil	Medium	1.9-2.1	North America	2 %	X	X
Salmon oil (wild)	Medium	1.2	North America	7 %	X	
Salmon oil (farmed)	Low	0.7	Europe/South America		X	
Krill oil	Medium		Antarctica	1 %	X	
Tuna oil	Medium	0.3	Multiple	3 %	X	
Menhaden oil	Medium		North America	10 %	X	
Algal oil	High/medium	Multiple	Multiple	<1 %	X	X
Herring oil	Medium	0.5-0.8	Europe	<1 %	X	
Mackerel oil	Medium	0.6-0.7	Europe	<1 %	X	
Calanus oil	Low	1.2	Europe	<1 %	X	



Anchovy oil

Anchovy is small and relatively bony fish, making it less suited for direct human consumption. At the same time, it has a very high fat-content, and this is why it is considered sustainable to use the whole fish for the production of fish oil and fishmeal. Because of the enormous biomass of anchovies, the species is by far the most common source of fish oil for commercial applications today.

The most common source of anchovy oil used for fish oil production is the anchoveta (*Engraulis ringens*) of the South Pacific Ocean, mainly harvested in Peru and Chile. Another source is the European anchovy (*Engraulis encrasicolus*), mainly caught around the Mediterranean Sea.

The content of the two essential fatty acids, EPA and DHA, of anchovy oil is about 25-30%, with the EPA content being somewhat higher than the DHA content (see Table 1).

Anchovy oil is also the most common raw material used in the production of concentrated omega-3 products, valued for its high EPA/DHA content as dietary supplements.

Sardine oil

With an EPA/DHA content of about 25-30% (see Table 1), the properties of sardine oil resemble those of anchovy oil, and because of this, so does the application areas. The production volumes compared to anchovy oil are, however, significantly smaller due to the less abundant biomass, making its use as an ingredient somewhat less widespread.

There are numerous sources of sardine oil around the world and several different species are included in this category. The European pilchard (*Sardina pilchardus*), the Madeiran sardinella (*Sardinella maderensis*) and the round sardinella (*Sardinella aurita*), are all commercially fished along the West coast of Africa, and together they represent one of the most important sources of sardine oil globally. Another country that produces significant volumes of sardine oil is Chile, which base the oil mainly on the Araucanian herring (*Strangomera bentincki*). Other important areas include Mexico and Central America, as well as several countries in the Asia-Pacific region.

Cod (liver) oil

Perhaps one of the fish oil sources with the longest tradition of being used as a dietary supplement for humans is the cod liver oil. This oil is sold as a natural oil and can be divided into several sub-categories based on which raw material is being used; oil based on pure Artic cod (*Gadus morhua*), oil based on a mixture of species from the cod family (*gadidae* family), and oil based on Pacific cod (*Gadus macrocephalus*). Norway and Iceland are the biggest producers of cod liver oil of the two former types, while the US is the predominant producer of the latter.

Unlike the reduction fisheries, where the whole fish is processed into fish oil and fishmeal, cod liver oil is, as implied by the name, only based on oil from the fish livers. The fresh livers are usually extracted in processing facilities located along the shore

before the crude oil is either refined at the same location or transported to a more centralized refining and storage facility.

Cod liver oil has a typical EPA/DHA content of around 15-25% with more DHA than EPA. The oil is also a source of DPA, another essential omega-3 fatty acid (see Table 1).

Another source of oil from cod is the so-called cod-body oil. Here, the raw material includes all the offcuts and offal from the cod filet industry, in addition to the livers. Compared to cod liver oil, the volumes produced are relatively small, and the main use for the oil is currently as raw material for the production of omega-3 concentrates.

Pollock oil

Pollock oil is produced from the offcuts from the pollock filet industry. The main species used is the Alaska pollock (*Gadus chalcogrammus*), which is fished in the Bering Sea close to Alaska. The oil is predominantly sold as a natural oil, either as crude or refined. The main use is currently as an ingredient for aquaculture feed or as a pet supplement. Pollock oil is also used as a raw material for the production of concentrated omega-3 dietary supplements.

In its natural form, pollock oil has a typical EPA/DHA content of around 10-15% where the ratio is in favor of EPA (see Table 1).

Salmon oil

Salmon oil is produced from the offcuts and offal from the salmon filet industry. The main source is Atlantic salmon (*Salmo salar*) and rainbow trout (*Oncorhynchus mykiss*) from the aquaculture industry, where the major countries are Norway, Chile, Scotland, Ireland, Iceland, New Zealand and Canada. However, a small portion of the produced salmon oil originates from wild caught fish. Most of this oil is produced in Alaska, where wild salmon is caught and processed on an industrial scale. This oil has a higher EPA/DHA content compared with the oil from farmed salmon because of the natural high omega-3 content of the diet of the wild salmon.

Salmon oil can roughly be divided into three quality categories; crude, virgin and refined. In general, the crude quality is used as a feed ingredient, refined is mostly produced for pet food, while virgin quality is made for human consumption.

The typical EPA/DHA content of oil from farmed salmon is around 5-8%, while oil from wild salmon is around 15-20% (see Table 1). The oil is rich in the natural antioxidant astaxanthin which is valued for its many health benefits and responsible for the red color of the salmon oil.

Krill oil

Antarctic krill (*Euphasia superba*), a small crustacean found in Antarctic waters is the raw material used for krill oil. The commercial fishery takes place in regulated areas in Antarctica under strict supervision.

Krill oil has some distinct properties that makes it different from regular fish oil. In addition to the relatively high content of EPA/DHA, krill oil also has a high content of phospholipids (see Table 1). Unlike triglycerides, which is the main constituent of fish

oil, phospholipids are so-called polar lipids, which have different biological properties from triglycerides. Among other things, phospholipids are important materials in cell membranes in the human body. Krill also contains the natural antioxidant astaxanthin, in addition to the essential nutrient choline.

Tuna oil

Tuna oil is produced from the offcuts and offal from the tuna canning industry. Tuna are migratory fish that can be found in many of our oceans, but the largest industrial fisheries take place in the Indian Ocean and in the Pacific Ocean in countries such as Ecuador, Mexico, Mauritius and Thailand. The principal species used are skipjack tuna (*Katsuwonus pelamis*), yellowfin tuna (*Thunnus albacares*), albacore (*Thunnus alalunga*), bigeye tuna (*Thunnus obesus*) and longtail tuna (*Thunnus tonggol*).

DHA is considered to be an important nutrient for the growth and maturation of an infant´s brain and retina. Because of the high content of DHA compared with EPA in tuna oil, it has become a key ingredient for infant nutrition products, which is by far the biggest application area of this oil.

Bulk tuna oil is often available in two different classes, based on which part of the raw-material that has been processed; a so-called white oil, based solely on tuna heads, and a black oil, which is based on a mixed raw-material (offcuts and offal).

Tuna oil has a typical EPA/DHA content of around 25-30% where the ratio is in favor of DHA (see Table 1).

Algal oil

Algal oil is produced by the microalgae strain *Schizochytrium sp.*, and is the only vegan source of triglyceride-bound EPA and DHA currently available on the market. It is produced through a fermentation process where the conditions and the specific microalgae strain used determine the content of EPA and DHA and the ratio between them. Thus, it is possible to produce both high EPA products and high DHA products from this source, which is produced in multiple locations in the world.

Algal oil is available both as natural oil and as omega-3 concentrates.

Menhaden oil

Menhaden are small oily fish that are migratory plankton surface-feeders. They are quite boney, so they are less suited for direct human consumption. Their main use is therefore as raw material (as whole fish) for the production of fish oil and fishmeal. The two most relevant species are Gulf menhaden (*Brevoortia patronus*), found mainly in the Gulf of Mexico, and Atlantic menhaden (*Brevoortia tyrannus*) found along the American East coast from Florida to Nova Scotia.

Menhaden oil is sold as a natural oil, either as crude or refined. The main use is currently as a feed ingredient, but it is also available for human consumption. The oil contains a balanced amount of EPA and DHA (a total of about 20-25%), and it is in addition a source of the essential fatty acid DPA (see Table 1).

Herring oil

Herring oil is produced from the offcuts and offal from the herring filet industry. The main species used is the Atlantic herring (*Clupea harengus*), which is fished throughout the North Atlantic (Norway, Iceland, UK, Canada). The oil is sold as a natural oil, either as crude or refined. The main use is currently as a feed ingredient, but it is also used as a human nutrition supplement.

The typical EPA/DHA content is around 15-20% with a balanced ratio between the two fatty acids. As most fish oils originating from the North Atlantic, herring oil is rich in monounsaturated long-chain fatty acids, which is valued for their health benefits.

Mackerel oil

Mackerel oil is produced from the offcuts and offal from the mackerel filet industry. The main species used is the Atlantic mackerel (*Scomber scombrus*), which is fished throughout the North Atlantic and in the Mediterranean Ocean. The oil is sold as a natural oil, either as crude or refined. The main use is currently as a feed ingredient, but it is also used as a human nutrition supplement.

Mackerel oil has a typical EPA/DHA content of around 15-20% with more DHA than EPA. As most fish oils originating from the North Atlantic, mackerel oil is rich in monounsaturated long-chain fatty acids, which is valued for their health benefits.

Calanus oil

One of the smaller categories in terms of annual production volume is produced from the zooplankton species *Calanus finmarchicus*, which is harvested in Norwegian waters.

A unique feature of the calanus oil is that it is the only natural marine oil where the fatty acids are in the form of wax esters, a property that is suggested to be advantageous in terms of the biochemical properties. The oil is also a source for the natural antioxidant astaxanthin, making the oil deep red in color. The main use of calanus oil is as a human nutrition supplement.

Calanus oil has a typical EPA/DHA content of around 10% with a balanced ratio between the two fatty acids.

Appendix 1: Typical fatty acid composition of named fish oils

Table 1: Typical fatty acid composition of named fish oil and fish liver oil categories as defined by Codex Alimentarius Fish Oil Standard of 2017. The composition was determined by gas liquid chromatography from authentic samples (expressed as percentage of total fatty acids).

Fatty acids	Anchovy (Section 2.1.1)	Tuna (Section 2.1.2)	Krill (Section 2.1.3)	Menhaden (Section 2.1.4)	Salmon (Section 2.1.5)		Cod Liver (Section 2.3.1)
					Wild	Farmed	
C14:0 myristic acid	2.7-11.5	ND-5.0	5.0-13.0	8.0-11.0	2.0-5.0	1.5-5.5	2.0-6.0
C15:0 pentadecanoic acid	ND-1.5	ND-2.0	NA	ND-1.0	ND-1.0	ND-0.5	ND-0.5
C16:0 palmitic acid	13.0-22.0	14.0-24.0	17.0-24.6	18.0-20.0	10.0-16.0	6.5-12.0	7.0-14.0
C16:1 (n-7) palmitoleic acid	4.0-12.6	ND-12.5	2.5-9.0	9.0-13.0	4.0-6.0	2.0-5.0	4.5-11.5
C17:0 heptadecanoic acid	ND-2.0	ND-3.0	NA	ND-1.0	ND-1.0	ND-0.5	NA
C18:0 stearic acid	1.0-7.0	ND-7.5	NA	2.5-4.0	2.0-5.0	2.0-5.0	1.0-4.0
C18:1 (n-7) vaccenic acid	1.7-3.7	ND– 7.0	4.7-8.1	2.5-3.5	1.5-2.5	NA	2.0–7.0
C18:1 (n-9) oleic acid	3.6-17.0	10.0-25.0	6.0-14.5	5.5-8.5	8.0-16.0	30.0-47.0	12.0-21.0
C18:2 (n-6) linoleic acid	ND-3.5	ND-3.0	ND-3.0	2.0-3.5	1.5-2.5	8.0-15.0	0.5-3.0
C18:3 (n-3) linolenic acid	ND-7.0	ND-2.0	0.1-4.7	ND-2.0	ND-2.0	3.0-6.0	ND-2.0
C18:3 (n-6) γ-linolenic acid	ND-5.0	ND-4.0	NA	ND-2.5	ND-2.0	ND-0.5	NA
C18:4 (n-3) stearidonic acid	ND-5.0	ND-2.0	1.0-8.1	1.5-3.0	1.0-4.0	0.5-1.5	0.5-4.5
C20:0 arachidic acid	ND-1.8	ND-2.5	NA	0.1-0.5	ND-0.5	0.1-0.5	NA
C20:1 (n-9) eicosenoic acid	ND-4.0	ND-2.5	NA	ND-0.5	2.0-10.0	1.5-7.0	5.0-17.0
C20:1 (n-11) eicosenoic acid	ND-4.0	ND-3.0	NA	0.5-2.0	NA	NA	1.0-5.5
C20:4 (n-6) arachidonic acid	ND-2.5	ND-3.0	NA	ND-2.0	0.5-2.5	ND-1.2	ND-1.5
C20:4 (n-3) eicosatetraenoic acid	ND-2.0	ND-1.0	NA	NA	1.0-3.0	0.5-1.0	ND-2.0
C20:5 (n-3) eicosapentaenoic acid	5.0-26.0	2.5-9.0	14.3-28.0	12.5-19.0	6.5-11.5	2.0-6.0	7.0-16.0
C21:5 (n-3) heneicosapentaenoic acid	ND-4.0	ND-1.0	NA	0.5-1.0	ND-4.0	NA	ND-1.5
C22:1 (n-9) erucic acid	ND-2.3	ND-2.0	ND-1.5	0.1-0.5	ND-1.5	3.0-7.0	ND-1.5
C22:1 (n-11) cetoleic acid	ND-5.6	ND-1.0	NA	ND-0.1	1.0-1.5	NA	5.0-12.0
C22:5 (n-3) docosapentaenoic acid	ND-4.0	ND-3.0	ND-0.7	2.0-3.0	1.5-3.0	1.0-2.5	0.5-3.0
C22:6 (n-3) docosahexaenoic acid	4.0-26.5	21.0-42.5	7.1-15.7	5.0-11.5	6.0-14.0	3.0-10.0	6.0-18.0