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Fish oil replacements shift fatty acid content of farmed fish

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Alternative oils significantly alter the nutritional profiles of farmed fish

Fillets from fish fed diets containing canola or other plant-based oils have fatty acid profiles with lower levels of omega-3s than those found in fillets from fish fed fish oil.

The annual global production of fishmeal and fish oil averages about 6.5 million metric tons and 130,000 metric tons (MT), respectively, except in years when El Niño events lower landings of anchovies in Peru. The proportion of annual fishmeal and oil production used in aquafeeds has increased from 15 percent and 25 percent in 1994 to 45 percent and 75 percent today.

Replacing marine-based protein and oil with alternative ingredients in aquafeeds is the focus of research around the world. Unlike replacements for fishmeal, however, alternative oils used to replace fish oil significantly alter the nutritional profiles of edible farmed fish products.

Fatty acid profiles

The problem with replacing fish oil with plant oils relates to the old adage "you are what you eat." Fish oils are excellent sources of omega-3 fatty acids, and fish fed diets containing fish oils deposit high levels of omega-3s in their tissues. In contrast, plant oils made from soy, rapeseed, or corn contain mostly shorter-chain omega-9 and omega-6 fatty acids. Fish fed diets containing these oils have tissue fatty acid profiles with lower levels of omega-3 fatty acids.

Consumers know that eating fish is healthy for them because fish fats are healthy. If the aquaculture industry switches to plant oils in place of fish oil in aquafeeds, consumers will no longer perceive fish as a healthy food. Yet the megatrends in oil supplies make using plant oils in aqua-feeds a necessity, at least during part of the production cycle. The challenge to fish nutritionists is to determine how and when during the production cycle to feed diets containing fish oil to maintain desirable omega-3 fatty acids in fillets.

Deposition rates

Researchers in Norway and Scotland have looked at fatty acid deposition rates in trout and salmon and found that fatty acids are deposited in tissues at a fairly steady rate that follows a dilution model. The model states that fatty acids are deposited in proportion to their levels in the diet as the fish grow. If dietary fatty acid profiles change, the new fatty acids dilute tissue fatty acids already deposited.

To understand how the dilution model works, imagine a trout is fed a diet to which canola oil is added. If the fish is fed the canola oil diet as it grows from 5 g to 500 g, the fatty acid profile of its tissues will resemble that of canola oil (Table 1).

Hardy, Selected fatty acid levels in fish, poultry fat, and plant oils, Table 1

Source	Palmitic C16:1	Stearic C18:1	Oleic C18:1w9	Linoleic C18:2w6	Linolenic C18:3w3	EPA C20:5w3	DHA C22:6w3
Menhaden	19.0	4.0	13.0	1.0	0.3	11.0	9.0
Poultry	22.0	6.0	37.0	19.0	1.0	–	–
Dehulled flax	4.3	3.3	20.4	13.1	58.1	–	–
Canola	3.0	2.0	60.0	20.0	12.0	–	–
Soybean	5.0	4.0	22.0	54.0	7.0	–	–

Table 1. Selected fatty acid levels in fish, poultry fat, and plant oils (% total fatty acids).

If the fish is then switched to a diet containing fish oil and fed until it reaches 1,000 g, the final fatty acid profile of the fish will reflect a mixture of what was fed for the first 500 g of weight gain and that which is fed for the second 500-g gain. In fact, if both fish oil and canola oil are added to the diet in equal amounts, and the trout is fed this diet from 5 g until reaching 1,000 g, the final fatty acid content of the trout will be about the same as if canola oil is fed for the first half of the growth and fish oil for the second half.

This situation raises several issues. First, can the parameters of the dilution model be changed such that fish fatty acid deposition in the tissues occurs more rapidly than in the dilution model? It is well known, for example, that fish from areas with temperate or cool water undergo seasonal changes in lipid deposition and maturation. Research to identify the factors that effect these changes may yield information that could be used in fish farming to accelerate fatty acid deposition over baseline rates seen in juvenile fish.

Second, some consensus is needed concerning what value is a desirable level of omega-3 fatty acids in fish, especially salmonids that deposit a significant proportion of storage lipids in muscle tissue. Researchers have shown that omega-3 levels in salmon and trout can be manipulated over a wide range by changing the diets of the fish. Farmed fish can easily be produced with higher levels of omega-3 fatty acids than their wild counterparts.

Should the goal be to mimic the omega-3 levels in wild fish? This could be difficult, given the fact that wild salmon differ greatly in the fatty acid content of their muscle tissue. Different species have different levels, and even within a single species, omega-3 levels vary greatly. Furthermore, wild fish tend to contain less total lipid in muscle than do farmed fish.

Therefore, comparing omega-3 fatty acid levels on a percentage of total lipid basis can lead to false conclusions regarding the healthful omega-3 fatty acid content of fish. Perhaps the way to approach this issue should be to base fish omega-3 levels on the number of grams of omega-3 fatty acids found in each 100-g serving the consumer eats.

New fatty acid sources

Finally, will new sources of omega-3 fatty acids answer the problem of limited and nearly fully utilized marine fish oil sources? Oil from marine algae is now being commercially produced, but at a price that is significantly higher than that for fish or plant oils. Perhaps, with time, commercial production costs will decrease and this source of omega-3 fatty acids will be more economical.

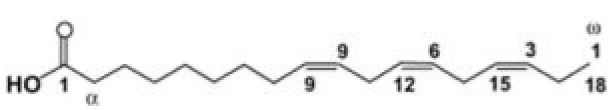
At present, genetically modified oilseeds are not commercially available, but research has demonstrated that oilseeds can be modified to produce the omega-3 fatty acid C18:4, sterodonic acid, which can be elongated by some fish species to long-chain omega-3 fatty acids found in marine lipids. The exciting aspect of this approach is that elongation and desaturation of this fatty acid occurs past the rate-limiting step in the pathway of conversion from C18 fatty acids to longer-chain fatty acids.

Chemical structure of fatty acids

The chemical structures – and potential health benefits – of fatty acids vary significantly among the omega-3, omega-6, and omega-9 classes. Some of these differences are illustrated below.

Omega-3 fatty acids

Omega-3 fatty acids are polyunsaturated fatty acids that are classified as essential because they can not be synthesized in the body and must be obtained from food sources. For human nutrition, important omega-3 fatty acids are α-linolenic acid, eicosapentaenoic acid, and docosahexaenoic acid.



Alpha-Linolenic Acid

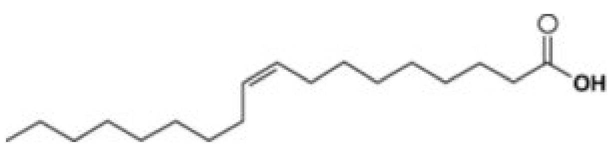
Omega-6 fatty acids

Omega-6 fatty acids are polyunsaturated fatty acids with important biological effects that are significantly mediated by their interactions with the omega-3 fatty acids. The optimal ratio is thought to be 4 omega-3:1 omega-6 or lower. Some important omega-6s are arachidonic acid, linoleic acid, gamma-linolenic acid, and eicosadienoic acid.

Arachidonic Acid

Omega-9 fatty acids

Unlike omega-3 and omega-6 fatty acids, the omega-9 unsaturated fatty acids are not classed as essential because they can be produced in the human body from unsaturated fats. Two commercially important ones are oleic acid and erucic acid.



Oleic Acid

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