Feeds for Aquaculture

While all animals need to eat and all farmed animals need to be fed, aquaculture represents a very efficient method by which to convert feed to edible protein. Research at NOAA labs and through the NOAA–USDA Alternative Feeds Initiative has accelerated progress toward reducing fishmeal and fish oil use in aquaculture feeds while maintaining the important human health benefits of seafood consumption. The remarkable progress in developing alternatives has reduced reliance on wild fish caught for this purpose.

This series of answers address commonly asked questions related to feeds used in marine aquaculture. We discuss what farmed fish eat and examine issues such as fishmeal and fish oil use in aquaculture and research efforts underway to bring greater sustainability to feed production.

What type of food do farmed fish eat?

Farmed fish are fed diets specially designed for their nutritional needs. This feed contains all the essential nutrients needed to keep them healthy and growing. This feed usually is in the forms of dried pellets, similar in many ways to dry dog food.

Nutritionists who design feed for fish have to account for about 40 essential nutrients needed by the fish. These include vitamins, minerals, amino acids (the building blocks of protein), and some fats. These are provided in the feed through a number of ingredients including fishmeal, fish oil, plants, and animal trimmings. The purpose of the NOAA-USDA Alternative Feeds Initiative is to identify alternative dietary ingredients that will reduce the amount of fishmeal and fish oil contained in aquaculture feeds while maintaining the human health benefits of farmed seafood. It seems to be working. For example, it is estimated that the amount of fishmeals in salmon diets has dropped from being 70 percent of the diet in the 1980, to about 25 percent in 2017.

Do all farmed fish eat the same thing?

No. Fish nutritional needs vary by species. Herbivorous fish eat a feed mixture that may contain plant proteins (e.g., soy, corn), vegetable oils, minerals, and vitamins. In the wild, carnivorous fish such as salmon eat other fish. Therefore, feeds for farmed carnivorous fish (as well as many herbivorous fish) include fish oils and proteins as well as plant proteins, minerals, and vitamins that achieve the nutrition requirements of the fish and offer health benefits to humans. Traditionally, diets for carnivorous fish contained 30 to 50 percent fishmeal and oil; however, these ingredients are not a requirement. Continued research is leading to greatly reduced reliance on these ingredients to the point where even some carnivorous species are fed no fishmeal or oil.

Why use fishmeal and fish oil in the diets of farmed fish?

While fish and shrimp don't *require* fishmeal and oil in their diets, these ingredients have almost a perfect balance of the 40 or so essential nutrients that animals need to be healthy and grow—the same reason that seafood is so good for humans as well.

Fishmeal is a natural and well-balanced source of high-quality protein. As ingredients in aquaculture feed, fishmeal and fish oil supply essential amino acids and fatty acids reflected in the normal diet of fish. *Fish oil* is a major natural source of the healthy omega-3 fatty acids eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). These fatty acids are not made by the fish, but become concentrated in fish further up the food chain from the marine phytoplankton (microscopic marine algae and microbes) that do synthesize them.

Through research, we are learning that other combinations of ingredients can achieve the balance of the 40 essential nutrients. Affordable replacement ingredients for fishmeal and fish oil are becoming increasingly common, which is leading to declining percentage on those ingredients in farmed fish diets.

Including ingredients like oils from algae or marine microbes maintain the nutrient requirements of the final product without depending on fish oil. The economics of using blended oils is improving as fish oil prices rise and the technology to produce algae (and other replacement ingredients) improves.

Where does fishmeal and fish oil come from and what are the uses?

About 70 percent of the fishmeal and oil are produced from the harvest of small, open-ocean (pelagic) fish such as anchovies, herring, menhaden, capelin, anchovy, pilchard, sardines, and mackerel. These fish have short life cycles and are capable of rapid reproduction and stock replenishment. The other 30 percent is generated from the scraps produced when fish are processed for human consumption.

The United States is a small net producer of both fishmeal and fish oil. The largest U.S. fishmeal and oil production comes from menhaden caught in the east coast and Gulf, the second largest component of US production comes from fish processing trimmings produced in Alaska's seafood industry.

Fishmeal and fish oil supply several major industries because they are natural ingredients of high nutritional value. While they have been major ingredients of swine and poultry feeds for many decades, a growing percentage of these resources have been used to manufacture aquatic feeds. This is due to the worldwide growth of aquaculture over the past two decades. Demand for fish oil in the supplement industry is also rising rapidly.

Does aquaculture consume more wild fish than is produced?

When aquaculture is considered as an aggregate industry, the answer is no. Globally, aquaculture uses about half a metric ton of wild whole fish to produce one metric ton of farmed seafood, meaning that aquaculture is a net *producer* of fish protein. However, some species groups, do consume more by weight of fish meal and/or fish oil then they produce in their final product form. This is typical of carnivorous species new to aquaculture. Over time, and as the production for a given species grows, fish meal and fish oil are replaced by more cost-effective non-marine ingredients. At some point the species group becomes a net producer of fish. This is quickly becoming the case for farmed salmon and shrimp, two species groups that have been criticized for using more fish than they produce. Because the trimmings from farmed fish can be used to make fish meal and oil, aquaculture is also becoming a producer of these products.

Feed conversion ratios (the amount of feed eaten by a fish relative to the amount that fish provides for human consumption) vary among species, but farmed fish are far more efficient at converting feed than wild fish or other farmed animals such as cows and pigs.

Doesn't harvesting pelagic fish have a detrimental impact on the food chain and other animals that depend on them?

Small pelagic fish serve a dual function of contributing to overall ecosystem biomass and supporting global food supply, the latter through both direct human consumption and providing feed for terrestrial farming and aquaculture. There is concern that ecosystem function is reduced at current catch levels; addressing this concern happens through fishery management rules (such as catch quotas) within individual capture fisheries. For a discussion of marine resources and sustainability, visit the Marine Ingredients Organisation.

Aquaculture is the largest of many end-uses for harvested small pelagic fish, which also include providing fishmeal in diets of livestock, serving as baitfish for commercial and recreational fisheries, and—increasingly—as nutritional supplements and pet food ingredients. In the absence of aquaculture, these fish would be fully consumed by other industries.

The world supply of fish from pelagic fisheries has remained relatively constant over the past twenty years at around 6 million metric tons. These types of fish generally are capable of rapid reproduction and stock replenishment. Many pelagic fisheries are recognized as successfully regulated and many stocks are fished at levels below the biomass that achieves maximum sustainable yield (the maximum catch that can be extracted long-term without depletion). Careful fisheries management, including quota and catch limit systems, maintains the sustainability of these fisheries over time.

Because these fisheries are heavily regulated and the supply has remained relatively constant, increased demand for fishmeal and oil has dramatically increased prices over the last decade. As a result, alternatives have been developed that use less or no fishmeal and oil, decreasing the amount of fishmeal and oil used in aquaculture.

What are potential alternatives to feeding fish to fish?

Potential alternative include meals and oils from plants (the greatest source of protein and edible oil on earth), fish processing waste, yeast, bugs and other special meals, and even seaweed. Potential alternative ingredients already in use include soybeans, barley, rice, peas, canola, lupine, wheat gluten, corn gluten, other various plant proteins, yeast, insects and algae. Farmed seaweed has significant growth potential as a source of food and fiber for both aquaculture feed and human consumption. In 2018, the U.S. Food and Drug Administration approved a key ingredient for fish feed, called taurine, needed to make plant proteins similar to other animal proteins. Researchers have been successful in identifying alternatives that grow fish and help maintain the human health benefits of eating seafood.

Future growth of marine finfish and shrimp aquaculture will need protein and oil sources greater than current fishmeal and fish oil production can satisfy. NOAA labs are developing new ways to feed even the most finicky of carnivorous fish on non-marine based diets. NOAA, in partnership with the U.S. Department of Agriculture (USDA), launched the NOAA–USDA Alternative Feeds Initiative in 2007 to accelerate the development of alternative feeds for aquaculture. The purpose of the Alternative Feeds Initiative is to identify alternative dietary ingredients that will reduce the amount of fishmeal and fish oil contained in aquaculture feeds while maintaining the important human health benefits of farmed seafood.

In addition to looking for substitutes, research is examining how farmed fish utilize feed, varying formulations, timing dietary needs with developmental stages, and other strategies to improve feed use efficiency.

Ultimately, the initiative will lead to the commercialization of alternatives for some species that will result in reduced dependence on marine fish resources by feed manufacturers and seafood farmers worldwide. The biggest challenges for researchers are to develop alternative ingredients that fish will eat, that supply the nutrition fish require to grow, and to make available alternative ingredients that are commercially viable. Current research, including that being done through the NOAA–USDA Alternative Feeds Initiative, and directly at NOAA labs is making great strides toward overcoming these challenges.

Are farmed fish contaminated with mercury and other heavy metals?

No farmed fish are on the "avoid" list due to mercury. These compounds enter and concentrate in organisms largely through what they eat. Just like feeds for other domestic animals, aquaculture feeds are regulated by the U.S. Food and Drug Administration (FDA) and Departments of Agriculture in respective states, with advisement from the Association of American Feed Control Officials (AAFCO). The FDA and state agencies conduct inspections as well as collect and analyze feed and fish samples to help ensure that feeds and the fish that consume them meet strict state and federal requirements. Formulated feed ingredients used in aquaculture are regularly monitored to avoid possible contamination of feed with methyl mercury.

Are there growth hormones in U.S. farmed fish?

Growth hormone is not used in U.S. aquaculture. Although growth hormones may be given to other farm animals such as cattle and sheep, their use in food fish is prohibited by the U.S. Food and Drug Administration (FDA). Certain additives such as pigments, antioxidants, and other nutritional supplements have been proven safe and their use in fish feeds is permitted by FDA regulation.

Are antibiotics used at all in U.S. aquaculture?

In the United States, antibiotics are not fed to fish for non-therapeutic reasons through their feed or any other mechanism. The use of antibiotics for non-therapeutic purposes in aquaculture is prohibited by law. Incidentally, antibiotics do not improve growth or efficiency in fish (like they do in cows, swine, and chickens) and they are expensive, so there is no incentive for industry to use them. However, antibiotics have been known to be added to fish food in other countries.

As vaccines have been developed for the major diseases that impact aquaculture (including salmon), antibiotic use has all but disappeared in the U.S. There occasionally is still a need to use them in special cases approved by a vet. All drugs, including antibiotics, to be used in aquatic species farmed in the U.S. have to have been proven safe and effective and must be undetectable at the time of harvest (as prescribed by FDA withdrawal times). At present, only three antibiotics are registered and sold for use in the United States as feed additives for disease control in farmed fish. The use of parasiticides is similarly restricted by FDA regulations.

Are farmed salmon fed or injected with dyes?

No. In the wild, salmon eat krill and other tiny shellfish that contain natural pigments called carotenoids, which are powerful antioxidants and precursors of vitamin A. Carotenoids, specifically astaxanthin and canthaxanthin, give salmon flesh its distinctive pigment. Farmed salmon are supplemented with natural and/or synthetic astaxanthin that is identical to the pigment that salmon get in the wild. Both natural and synthetic astaxanthin are processed and absorbed by wild and farmed fish in exactly the same manner.

Why don’t we just eat fish from these pelagic fisheries (i.e. further down the food chain)?

To a certain extent, we do. Increasingly, species like mackerel, herring, sardines, and anchovies are sold for human consumption. As well, fish oil in the dietary supplement industry is the fastest growing segment of that market. However, consumer demand for species such as salmon, grouper, cod, and tuna drives the market for both farmed and wild fish. Pelagic fish (such as anchovy and menhaden) generally are in far less demand (especially in western countries) for direct human consumption.

Doesn’t uneaten fish food accumulate on the ocean floor and pose an environmental risk?

Jurisdictions that regulate net-pen aquaculture set limits to what can accumulate under aquaculture facilities. In the U.S., this is typically set at “no net accumulation” on an annual basis. Feed for farmed animals is the most expensive input to fish farming (about 60 percent of the cost of growing fish). For this and environmental considerations, fish farmers take extreme precautions to avoid over-feeding. Farmers use advanced technology including automated feeders and underwater cameras to provide feed and monitor consumption. Fallowing (removing equipment and leaving the site undisturbed) between crops, like land-based farmers, can allow the bottom to recuperate from any potential impacts. Due to these advances in technology and careful siting, feed accumulation on the ocean floor is much less of a consideration than it once was. Additionally, fish farmers work with state regulators to monitor the benthic effects of their operations. For a complete review of the current state of nutrient impacts from farming fish in net pens, see the nutrient impacts page.

Does NOAA fund research on alternative feeds?

The National Oceanic and Atmospheric Administration (NOAA), in partnership with the U.S. Department of Agriculture (USDA), launched the NOAA–USDA Alternative Feeds Initiative in 2007 to accelerate the development of alternative feeds for aquaculture. The purpose of the Alternative Feeds Initiative is to identify alternative dietary ingredients that will reduce the amount of fishmeal and fish oil contained in aquaculture feeds while maintaining the important human health benefits of farmed seafood. NOAA and USDA's *The Future of Aquafeeds* (PDF, 103 pages) report provides a comprehensive view on the state of knowledge and the challenges and opportunities associated with developing various alternative aquaculture feeds.

Since 1998, NOAA has been supporting alternative feeds research through the National Marine Aquaculture Initiative, a competitive grants program. Through this program, the agency has funded nutrition projects for a variety of marine fish species including black sea bass, cobia, cod, flounder, shrimp, snapper, sablefish and tuna. This research generated information on use of probiotics, identification of dietary requirements, and use of alternative proteins and processing byproducts. Since the 1950s, NOAA Fisheries Service labs have worked on diet development for Atlantic and Pacific salmon, sablefish, black sea bass, lingcod, rockfish, and several other marine species. NOAA labs helped develop methods for improved recovery and use of seafood processing waste and invasive species meals for use in aquaculture feeds.