# FACTS ABOUT FINFISH AQUACULTURE

## Development of feeds for sustainable fish farming

### *How to Feed the Fish of the Future?*

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The formulation and management of feed significantly influence the economic, environmental, and social sustainability of fish farming. Each dimension of sustainability is affected by feeding practices, ingredient choices, and the overall aquaculture system (Garlock et al., 2024). With an expected increase in aquafeed demand, it is important (now more than ever) to investigate and utilize aquafeed ingredients with minimal impact on natural resources and, instead, may have positive impacts to help control climate change.

The economic viability of European fish farming largely depends on feed costs, which represent a significant portion of operational expenses. Rising demands for raw materials, especially fishmeal and fish oil are jeopardizing the profitability of aquaculture, with fluctuating feed prices leading to financial instability for fish farmers (Arru et al., 2019). Volatile agricultural product prices also significantly impact fish feed costs, influencing the economic sustainability of aquaculture operations. Fluctuations in the prices of key feed ingredients, such as soybean meal and corn, directly affect the cost of producing aquafeeds (Colombo and Turchini, 2021).

The role of feed in the environmental sustainability of aquaculture is a critical aspect, impacting efficiency, resource use, and ecological consequences of aquaculture practices. Feed production is responsible for more than 70% of emissions of most aquaculture technologies. The growing demand for aquatic food, driven by population increases and dietary shifts, necessitates sustainable feed strategies to mitigate environmental impacts, including resource depletion and pollution.
Alternative feed sources and other ingredients produced through the circular bioeconomy can improve aquaculture's sustainability by reducing its environmental footprint in terms of water and land use, $CO_2$ conversion, GHG emissions, nutrient recycling and wastewater remediation. These alternatives also can help stabilize the economic conditions for fish farming while lowering the pressure on natural fish stocks, thus fostering long-term profitability (Colombo and Turchini, 2021).

The social sustainability of aquaculture feeds is often closely tied to the environmental and economic sustainability of the sourcing of their raw materials. For example, fish meal and fish oil is socially sustainable when sourced from by-products of fish processing or from responsibly managed, renewable wild fish stocks, without compromising the domestic human consumption. (FAO, 2024).
Reflecting on these sustainability challenges, the development of fish feeds has undergone a significant transformation in recent years, also driven by the increasing demand for aquaculture. One of the main focuses of these developments is to reduce the heavy reliance on marine resources as traditional fish feed ingredients. In recent years, there has been a notable shift towards incorporating terrestrial plant materials and animal by-products into aquafeeds, as well as improving circularity and efficiency in the use of fish trimmings and by-products from the seafood processing industry.



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For example, as a result of intensive research and development efforts, the composition of salmon feed has changed significantly since 1990. In that year, the average salmon feed consisted of 65.4% marine protein, which decreased to 24.8% by 2010 and further dropped to just 12.1% in 2020 for salmon feeds produced in Norway (Aas et al., 2022).
However, the reduction of fish meal and fish oil does not necessarily improve the overall sustainability of fish feeds. For instance, locally produced and sourced marine ingredients typically have a lower carbon footprint compared to soy protein purchased from overseas (Ziegler et al., 2024).

The concept of circularity emphasizes the importance of reusing and recycling materials within the food system, thereby minimizing waste and resource depletion is also an important development goal in aquafeed production. Supported by improved logistic and preservation techniques a growing share of fishmeal and fish oil is produced from fish by-products of the processing industry, thus reducing waste and improving resource valorization. According to the estimates of the Marine Ingredients Organisation (IFFO), in 2022, 34 percent of the global production of fishmeal and 53 percent of the total production of fish oil were obtained from by-products (FAO, 2024).

To optimize feed conversion ratios and reduce the environmental impact of fish production, different species require varying amounts of fish meal and fish oil in their diets. Predatory fish need higher levels of marine protein and oil for optimal growth, while omnivorous and herbivorous species can thrive with little to no fish meal content.

The Forage Fish Dependency Ratio (FFDR) is a widely used metric to evaluate how efficiently aquaculture utilizes wild-caught forage fish. It measures the amount of direct wild fish used in fish feed relative to the amount of farmed fish produced.

Over the past few decades, the use of marine ingredients across all species groups has been significantly reduced. As a result, producing 1 kg of farmed salmonid fish now requires only 0.67 kg of wild-caught fish. In contrast, the average FFDR for marine fish is 0.52, while farming cyprinid fish requires just 0.01 kg of wild fish per kilogram of farmed fish. (Glencross et al., 2024).

The aquaculture industry is also actively seeking alternative feed ingredients to reduce dependency on marine resources and decrease competition for land-based feed ingredients with livestock feed. Promising options include insect meal, single-cell proteins, fermented products, and microalgae (Aas et al., 2022), as well as improved use of marine zooplankton and mesopelagic fish (Almås et al., 2020). Some of these ingredients are made from waste materials, supporting sustainability and a circular economy. However, challenges like high production costs and scalability limit their widespread use. In Norway, single-cell proteins derived from natural gas and wood biomass show potential, but they often contain indigestible cell wall material, reducing their nutritional value and increasing waste. Insect meal, particularly from black soldier fly larvae, has been introduced as a soy protein substitute, but replacing current soy use entirely would require massive production on par with salmon farming itself. Microalgae offer a potential source of omega-3 fatty acids and astaxanthin, but cost-effective production methods are needed for broader adoption. These constituted 0.4 % of the ingredients recently in the salmon and trout feeds. There is a large ongoing effort to develop production technologies enabling these ingredients to be produced in sufficient quantities and at a low enough cost to be used in significant amounts in feed. (Aas et al., 2022).

The efficiency of farmed fish in converting feed into food is another critical aspect of the evolving landscape of fish feeds. For instance, species like Atlantic salmon exhibit feed conversion efficiencies



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comparable to those of chickens, making them more efficient than many other farmed animals (Van Riel et al., 2023). This efficiency underscores the potential of aquaculture to contribute to global food security while minimizing environmental impacts. By optimizing feed formulations and prioritizing species that have lower environmental impacts, aquaculture can play a pivotal role in creating a more sustainable food system (Chary et al., 2023).

In parallel with the continuous improvement of fish farming technology, the development of fish feeds in recent years has been characterized by a shift towards sustainability and circularity. The exploration of alternative ingredients, optimization of feed formulations, and integration of nutrient recycling practices are all essential components of this transformation. As aquaculture continues to expand, it is imperative to prioritize sustainable practices that not only enhance food security but also protect the environment. By embracing circularity and fostering collaboration between aquaculture and agriculture, the industry can pave the way for a more resilient and sustainable future.

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