Atlantic salmon (*salmo salar*)

Atlantic salmon (*Salmo salar*) is one of the most profitable and technologically advanced fish production industries globally. Strong market demand in almost every region of the world has resulted in Atlantic salmon becoming the largest single fish commodity by value (FAO, 2020). Norway and Chile lead the industry in terms of production, while the U.K. and Canada also play significant roles as major producers. Together, these four countries contribute over 90% of global Atlantic salmon production. Recent estimates indicate that global production is expected to reach 3 million tonnes by the end of 2024 (Fish Farming Expert, 2023; Global Seafood Alliance, 2024).

Atlantic salmon are an anadromous species, spending their juvenile life in freshwater before undergoing physiological processes that allow for adaptation to seawater, where they spend their adult life maturing for a return to freshwater to breed. The production cycle, therefore, mimics this freshwater to seawater lifecycle, typically lasting approximately three years and divided into two phases. First, Atlantic salmon are reared from eggs to smolts (the stage of physiological change to tolerate salt-water) over a period of 9 to 15 months in freshwater flow-through, semi-open recirculating, or closed recirculating aquaculture systems (RAS). Juveniles, weighing approximately 40 to 120 grams, that have undergone the physiological smolt transformation, are transitioned to sea cages or net-pens for the second (grow out) phase, where they remain for an extended period of 12 to 24 months until harvest (Glover, 2009). Atlantic salmon are typically harvested at sizes spanning from 2 to 5 kilograms. The primary consumer markets for Atlantic salmon are Japan, the European Union, and North America, with a variety of products including fresh, frozen, smoked, and filleted fish offered.

The feeding regimen for Atlantic salmon primarily comprises slow-sinking, high nutrient dense, extruded feeds. These feeds are meticulously formulated to cater to various developmental stages, both in freshwater and seawater. Categorically, these feeds include freshwater (starter, grower, and smolt transfer), seawater grower, and brood-stock feeds, each tailored to meet specific nutritional requirements. Starter, grower, and smolt feeds typically between 44% and 50% crude protein and 25% to 30% crude lipid. Grower feeds contain slightly less protein (36% to 42%) and higher lipid levels of up to 41%. The high nutrient density of these feeds requires the use of high-quality, nutrient dense feed ingredients such as fish meal, processed land animal proteins (poultry by-product meal, feather meal, meat, and bone meal, etc.), vegetable proteins such soy protein concentrate, wheat and corn gluten, fish oil, plant oils (e.g., canola oil).

Atlantic salmon are, primarily, farmed in the temperate regions of the world having a thermal preference for cool water temperatures (10°C to 18°C) (Elson, 1969; Elliot and Hurley, 1997). Different strains of the species, have however, through selective breeding, demonstrated the ability to tolerate more extreme water temperatures from as low as 4°C (in the North Sea in winter) to as high as 25°C (off the coast of Tasmania in summer). Despite exhibiting a wide thermal tolerance, Atlantic salmon, are less tolerant to variations in dissolved oxygen, requiring a consistent supply of at least 6mg L^{-1}.

The Atlantic salmon farming industry has faced and continues to face several challenges related to sustainability and environmental concerns such as escapes of farmed fish into the wild, fowling of the water bodies used for farming, diseases and the use of chemicals/antibiotics, and land use rights. Despite these, and other challenges, the Atlantic salmon industry is expected to continue growing due to the high demand for its high value flesh. Innovations in sustainable practices, including closed containment systems, integrated multi-trophic aquaculture systems, the

development and adoption of alternative, sustainable feed ingredients, enhanced net pen designs, the utilization of AI and data analytics, and the establishment of new regulatory frameworks, hold significant promise in mitigating several of these challenges and facilitating the growth of the Atlantic salmon production sector.

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Innovations in sustainable practices, including closed containment systems, integrated multi-trophic aquaculture systems, and the development of alternative, sustainable feed ingredients, are helping to mitigate environmental concerns. Enhanced net-pen designs, the utilization of Artificial Intelligence and data analytics, and the establishment of new regulatory frameworks also offer promising solutions to overcome challenges and support the industry's continued growth.

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