White Paper

OPTIMUM OMEGA NUTRITION™

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A JOINT VENTURE OF DSM AND EVONIK

IMPROVING AQUACULTURE PRODUCTIVITY BY MEETING DIETARY OMEGA-3 AND OMEGA-6 REQUIREMENTS OF ATLANTIC SALMON

SUMMARY

Eicosapentaenoic acid (EPA), docosahexaenoic acid (DHA), and arachidonic acid (ARA) are essential fatty acids (EFA) that play a critical role in ensuring optimal animal health, welfare, performance and product quality in Atlantic salmon aquaculture. However, due to supply and environmental constraints, the salmon industry is facing increasing pressure to move towards more sustainable and consistent alternatives to fish oil, which is the traditional source for these EFA in aquafeeds. The Omega-3 fatty acids, EPA and DHA, are in particularly short supply, with annual production from marine fisheries being extremely limited and unlikely to show any marked increase over time.

Alternatives to fish oil exist. Vegetable oils are very different products to fish oils, typically deficient in EPA & DHA Omega-3, but high in Omega-6 which when oversupplied in feed can negatively impact fish health, welfare, product quality, and therefore productivity and profitability of salmon farming. Additionally, low dietary levels of EPA & DHA Omega-3 are known to change the Omega-3 content of salmon fillets, impacting the 'high in Omega-3' attribute of salmon, which must be protected for consumer health benefits as well as the continuing success of the salmon farming sector.

Veramaris® natural marine algal oil is a sustainable and consistent alternative source of EPA, DHA, and ARA with a profile that is superior to other sources of omega 3 and/or even highly concentrated fish oil. It enables precise feed formulation and effectively enhances Atlantic salmon production. Optimum Omega Nutrition™ by Veramaris® is a guideline for meeting EPA & DHA Omega-3 and ARA Omega-6 requirements, whilst maintaining the Omega-3 to Omega-6 ratio in salmon diets, leading to improved salmon health and welfare throughout production. By using Veramaris® algal oil in conjunction with the Optimum Omega Nutrition™ guidelines, fish farmers not only stand to improve productivity, product quality, and yield but also lower their marine footprint.

WHY SOME FATTY ACIDS ARE ESSENTIAL

Dietary lipids are vital elements in fish nutrition as energy sources, chemical messengers, and sources of essential fatty acids (EFA) (1). EFA are polyunsaturated fatty acids (PUFA) that cannot be synthesized in the body and thus must be obtained through the diet. There are two main families: Omega-3 (n-3) and Omega-6 (n-6); Omega-3 PUFA include eicosapentaenoic acid (EPA; 20:5n-3), docosahexaenoic acid (DHA; 22:6n-3), and alpha-linolenic acid (LNA; 18:3n-3), whilst arachidonic acid (ARA; 20:4n-6) and linoleic acid (LOA; 18:2n-6) are Omega-6 PUFA.

EFA are required physiologically for animal growth, reproduction, immunity, and product quality and they must be supplied in the diet at appropriate concentrations. They are key for endocrine and immune function, including the protective barrier function of the intestine, development and function of the nervous system, brain, vision, pigmentation, resistance to diseases and stress, cellular synthesis and ionic regulation, and for maintaining gut microbiome diversity and balance by enhancing the proportion of beneficial bacteria (2–5).

The influence of PUFA on the immune system is a particular area of interest because they have a key role as precursors of eicosanoids, which act as mediators of the immune response. More specifically, eicosanoids derived from ARA promote inflammatory responses while eicosanoids derived from EPA produce an anti-inflammatory response that antagonizes ARA-derived eicosanoids. Eicosanoids derived from both EPA and DHA are involved in the anti-inflammatory response and terminate it (6). Given the role of EPA in mediating inflammatory responses, it is best to maintain the EPA:DHA ratio at 1.5:1 because insufficient EPA levels can result in an insufficient anti-inflammatory response (7). High inclusion levels of ARA and DHA, in the absence of EPA, have been associated with negative effects on the liver of fish (8), while increasing the levels of EPA and DHA, thereby increasing the Omega-3:Omega-6 ratio, have been shown to strengthen the intestinal barrier function in response to chronic stress (5). Thus, it is important that ARA levels are kept lower than those of either EPA or DHA.

THE QUEST TO MEET EFA DEMAND IN SALMON FEED SUPPLY

Fish requirements for EFA have historically been met with fish meal and fish oil (FO). Salmon farming is highly dependent on FO and approximately 70 % of the annual FO supply goes towards aquaculture (9). This is because FO is characterized by a relatively high content of Omega-3 long-chain PUFA (LC-PUFA), presenting an ideal fatty acid (FA) profile to meet fish requirements and support fish survival, growth, and health.

FO is limited in supply, varies in quality and cost, and cannot respond to the growing demand of the expanding aquaculture industry (2,3). In addition, there are increasing ecological and ethical objections to the exploitation of wild fisheries to feed the growth of aquaculture (10) so the industry is calling for alternative Omega-3 sources that have consistent EPA & DHA profiles and allow farmers to meet claims for Omega-3 FAs in the final salmon product. As a result, almost twenty years ago, the industry started using alternative lipid sources including a variety of vegetable oils (VOs) from different sources (such as rapeseed, soybean, and sunflower) (2). This led to negative effects on the Omega-3 content of salmon fillets (11). More recently, marine algal oils have also been used to supplement aquaculture feed and these are recognised as having great potential to close the gap in global Omega-3 supply (12–14).

VEGETABLE OILS

Whilst VOs can support fish growth, they are characterized by a high content of Omega-6 but a low content of the Omega-3 which occurs in the form of the shorter chain LNA rather than LC-PUFA EPA and DHA (2,7,10). The dietary replacement of FO for VOs dilutes the Omega-3 content of the Atlantic salmon feed, modifying fish FA composition and fillet lipid content (10,15,16). Accordingly, the increase of Omega-6 PUFA in fish tissues promotes the synthesis of pro-inflammatory eicosanoids, affecting the immune response and resulting in fish that are less resistant to infection, diseases (10,17,18), and stress (5,19). It is therefore important to keep the levels of Omega-3 and Omega-6 PUFA balanced in the feed; for Atlantic salmon, the Omega-3:Omega-6 ratio should be maintained as high as possible to avoid any negative effects (20,21). However, the current use of VOs to meet the feed energy requirements, rather than to optimise nutrition and health, results in an undesired over-supplementation of Omega-6 PUFA, compromising the nutritional quality of the product for the consumers. For example, the Omega-3:Omega-6 ratio in Norwegian farmed salmon already decreased from 2.6 in 2006 to 1.0 in 2020 (22). So, to overcome these challenges, salmon feed formulation practises need to pair VOs with sources rich in Omega-3 PUFA, such as algal oil.

ALGAL OIL

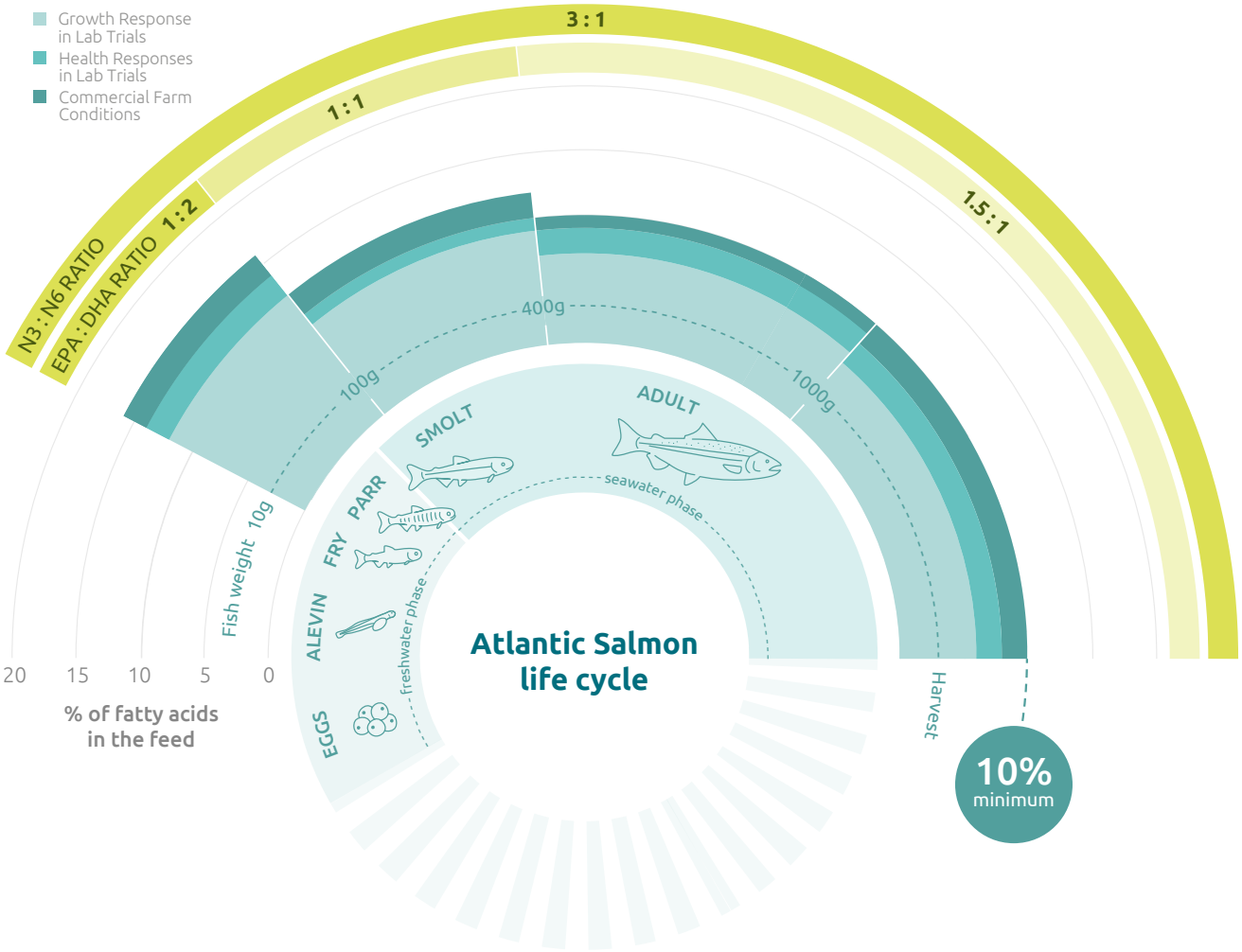
Marine algae are the original sources from which wild salmon obtain n-3 PUFA. In nature, marine algae are eaten by zooplankton, which are consumed by wild fish that are in turn consumed by salmon. Based on this knowledge, Veramaris® went back to the original source (i.e. marine algae) to produce a sustainable alternative that improves fish health, welfare, quality, and productivity to upgrade aquafeed. Veramaris® algal oil is more concentrated than FO: one tonne of Veramaris® algal oil yields the same amount of EPA & DHA as up to 66 tonnes of forage fish (12,13).

This breakthrough innovation can either supplement or even replace FO because of the high concentration (>60 %) of PUFA (EPA, DHA, and ARA), allowing the aquaculture industry to better control its dependency on marine resources and consistently achieve a lower Forage Fish Dependency Ratio (FFDRoil). This way, Veramaris® helps to maintain high-quality feeds and supply-chain security, whilst improving aquaculture productivity without compromising the conservation of natural resources. The consistent FA profile of Veramaris® allows feed nutritionists to formulate the desired levels of both EPA & DHA in fish feeds in a very precise way.

OPTIMUM OMEGA NUTRITION™
FOR ATLANTIC SALMON

Veramaris® analysis supported by Prof. Brett Glencross based on latest available information and science

TOTAL EPA & DHA REQUIREMENT



OPTIMUM OMEGA NUTRITION™

Supported with Veramaris® natural marine algae oil rich in EPA, DHA & ARA essential fatty acids

Figure 1. Expert opinion on essential fatty acid (EFA) requirements in Atlantic salmon throughout the production cycle, more specifically EPA & DHA Omega-3 requirements, as well as the EPA:DHA ratio, and the n-3:n-6 ratio.

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FARMING CONDITIONS CALL FOR OPTIMUM OMEGA NUTRITION™

EPA and DHA requirements are significantly higher during the early life stages of salmon as these are involved in fry, parr and smolt growth and development; more specifically, DHA plays a key role in neural growth and development (23). During the first year, salmon are also transferred from freshwater to seawater, the so-called smoltification, which is a significant physiological challenge. During this phase, changes in the lipid metabolism cause alterations in FA composition within tissues to prepare salmon to adapt to their new marine environment: the typical freshwater FA profile, relatively low in PUFA, is replaced by the marine profile particularly rich in EPA & DHA Omega-3 PUFA (24,25). Fish have consistently been shown to require higher levels of ARA and DHA when approaching smoltification, whereas EPA requirements increase post-transfer to the sea. These changes in LC-PUFA composition affect systems involved in adaptation to salinity and indicate a need for changing FA profiles in salmon feed over the production cycle to optimise growth and survival (25).

Dietary requirements of LC-PUFA, specifically EPA and DHA, also vary according to the health status of animals. Compared to controlled conditions such as laboratory trials, our review of scientific literature shows that EPA and DHA requirements in commercial conditions are higher (Table 1). This is because farmed salmon are exposed to seasonal variations in biological and environmental stressors which change over time such as temperature, salinity and disease pathogens. In response to temperature changes, the composition of cellular membranes is modified; for instance, as temperature decreases the proportions of PUFA in the membranes, EPA and DHA requirements are increased (3). Pathogens in the farming environment cause an additional risk for infection resulting in high mortalities. However, fish response to diseases and infections can be enhanced through nutrition, resulting in economic savings through increased productivity and lower costs of disease management. For example, dietary EFA modulation can reduce the impacts of Heart and Skeletal Muscle Inflammation (HSMI), associated with Atlantic salmon reovirus infection, one of the most prevalent inflammatory diseases in Atlantic salmon farms (7).

It is therefore important that salmon farmers specify Optimum Omega Nutrition™ to improve fish health and welfare throughout the entire production cycle. Research shows that better omega nutrition delivers benefits such as enhanced immune system, response to pathogens, and resistance to stress, all shown to help fish respond to the major challenges they face during the production cycle (2). Additionally, better omega nutrition has been reported to result in better adaptation to smoltification, reduced vertebral deformities, improved skin integrity, increased robustness and wound healing, and increased flesh quality (including reduced melanin spots and improved fillet colour).

Overall, it is established that the dietary requirements for Omega-3 LC-PUFA by salmonids range from 10 to 25 g/kg of diet (2) but these requirements are relative to the total dietary lipid level (25). In laboratory conditions, post-smolt Atlantic salmon (~185–550 g) Omega-3 LC-PUFA requirements range between 5 to 8 % of the total fatty acids (TFA) (26). Whilst these are adequate in ideal conditions such as those in controlled laboratory environments, in challenging conditions the specific EPA and DHA requirements are no less than 10 % TFA (Figure 1).

TABLE 1

Fish weight	Linoleic acid (LOA, 18:2n-6)	Alphalinolenic acid (LNA,18:2n-3)	Arachidonic acid (ARA, 20:4n-6)	Eicosapentaenoic acid (EPA, 20:5n-3)	Docosahexaenoic acid (DHA, 22:6n-3)	EPA+DHA	Omega-3: Omega-6	EPA:DHA
1 – 10 g	7	7	3	6	16	22	3:1	1:3
10 – 100 g	7	7	3	6	10	16	3:1	1:2
100 – 400 g	7	8	3	6	6	12	3:1	1:1
400 – 1000 g	7	10	2	6	4	10	3:1	1.5:1
1000 – HARVEST	7	10	1	6	4	10	3:1	1.5:1

Expert opinion on requirements of essential fatty acids in Atlantic salmon under farm conditions during the different stages of the production cycle to support adequate growth, survival, and health. Values expressed in % total fatty acids, shaded values expressed in ratios.

Given the key roles of EPA and DHA in the development of normal bone and nervous systems, as well as in anti-inflammatory response, wound healing and disease resistance, specific levels for each of these EFAs should be included in feed formulations, as for other essential nutrients like vitamins and amino acids. Leading producers of Atlantic salmon in Norway are already increasing dietary levels of EPA & DHA Omega-3, seizing the opportunity to restore levels of these LC-PUFA to those when salmon diets were comprised of fishmeal and FO as the main sources of dietary protein and fat. In other parts of the world, such as The Faroe Islands, farmers have long recognised the importance of EPA & DHA Omega-3 in supporting the biological performance of salmon and its differentiation in the market.

IMPLEMENTING OPTIMUM OMEGA NUTRITION™

These guidelines for Optimum Omega Nutrition™ are based on an expert review of current science and aim to ensure all basic metabolic functions in farmed Atlantic salmon are supported, such as physiological homoeostasis and immune responses, fish growth and overall health; thus, enabling Atlantic salmon to deal with the challenging conditions of a commercial salmon farm.

These improvements in fish health have the potential to improve some of the key performance indicators for fish farms such as improving survival rate, FCR, and smolt yield whilst also reducing downgrades. Additionally, the consistency in quality that can be realised through implementing Optimum Omega Nutrition™ with Veramaris® algal oil, can provide substantiation to make impactful consumer product claims such as amount of EPA + DHA per fillet.

Veramaris® is the first and only ASC-MSC certified source of Omega-3 rich algal oil for aquaculture, with astonishingly high levels of the most important EFA. We invite salmon farmers to take full advantage of our algal oil to strengthen their sustainability credentials and improve the productivity of salmon farming, further reduce dependency on wild caught fish for feed, whilst at the same time protecting one of the main reasons why people love to eat farmed salmon…because its "Rich in Omega 3"!

→ CONTACT VERAMARIS® AND YOUR SALMON FEED SUPPLIER TO DISCUSS HOW THESE GUIDELINES CAN HELP WITH IMPROVING THE PRODUCTIVITY OF YOUR BUSINESS.

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