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Research on the Correlation Between Fatty Acid Composition of Aquaculture Fish and Human Health

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Abstract The fatty acid composition of aquaculture fish is of great importance in enhancing their nutritional value and human health. With the development of the aquaculture industry, researchers are increasingly focusing on how to optimize the fatty acid composition of fish through genetic and biochemical strategies. This study aims to explore the correlation between the fatty acid composition of aquaculture fish and human health. The study found that the fatty acid profiles of different fish are influenced by their diets, with marine fish generally having higher levels of n-3 polyunsaturated fatty acids such as EPA and DHA, compared to freshwater fish. The type of feed used significantly affects the nutritional value of the fish, with sustainable feeds often resulting in lower levels of EPA and DHA. Selective breeding has shown potential to increase the levels of beneficial fatty acids in fish muscle, and alternative lipid sources such as microalgae and genetically modified crops may serve as future sources of essential fatty acids. The study indicates that both genetic and biochemical strategies can effectively enhance the fatty acid composition of aquaculture fish, thereby improving their nutritional value, which is significant for the prevention of cardiovascular diseases. This research aims to provide theoretical basis and practical guidance for future studies and practical applications.
Keywords Aquaculture fish; Fatty acid composition; Human health; Genetic strategies; Biochemical strategies

Fatty acids, particularly long-chain polyunsaturated fatty acids (LC-PUFAs) such as eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), are essential components of a healthy diet. These fatty acids play crucial roles in various physiological processes, including the development and function of the brain and eyes, as well as the regulation of inflammation and cardiovascular health (Zheng et al., 2012; Tocher et al., 2019). The beneficial effects of marine n-3 PUFAs on mitigating pathological conditions such as type 2 diabetes and cardiovascular diseases have been well-documented (Zheng et al., 2012; Dvoretsky et al., 2022). Despite their importance, the global supply of these essential nutrients is insufficient to meet human nutritional requirements, necessitating the exploration of alternative sources (Tocher et al., 2019).

Aquaculture fish have emerged as a significant source of LC-PUFAs, particularly EPA and DHA, for human consumption. The fatty acid composition of farmed fish is largely reflective of their diet, making it possible to tailor the fatty acid profiles of aquaculture fish through dietary modifications (Lei et al., 2013; Xu et al., 2020). Studies have shown that different fish species and their feeding habits significantly influence their fatty acid content, with some species exhibiting higher concentrations of beneficial fatty acids (Gladyshev et al., 2017; Dvoretsky et al., 2022). The ability to manipulate the diet of farmed fish to enhance their LC-PUFA content presents a valuable opportunity to address the gap between the supply and demand of these essential nutrients (Glencross, 2009; Tocher et al., 2019).

This study aims to comprehensively analyze the correlation between the fatty acid composition of aquaculture fish and human health. By integrating data from multiple studies, it seeks to explore how dietary interventions in aquaculture can enhance the nutritional quality of farmed fish, thereby promoting human health (Glencross, 2009; Lei et al., 2013; Xu et al., 2020). Additionally, this study emphasizes the potential of aquaculture as a sustainable source of essential fatty acids to address the current challenges in meeting global nutritional needs (Tocher et al., 2019). It is hoped that the findings of this study will provide valuable references for stakeholders in the aquaculture industry, nutritionists, and policymakers in formulating strategies to improve the nutritional quality of aquaculture products and promote public health.

1 Fatty Acid Composition in Aquaculture Fish

1.1 Types of fatty acids found in aquaculture fish

Aquaculture fish are known to contain a variety of fatty acids, which are crucial for both the fish's health and their nutritional value to humans. The primary types of fatty acids found in aquaculture fish include:

1) Omega-3 Fatty Acids: These include eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), which are essential for human health and have been shown to reduce the risk of cardiovascular diseases (Gladyshe et al., 2017; Innes and Calder, 2020). EPA and DHA are particularly abundant in marine fish species (Xie et al., 2017).

2) Omega-6 Fatty Acids: Arachidonic acid (ARA) is a significant omega-6 fatty acid found in aquaculture fish. It plays a crucial role in the growth and development of fish, especially in tropical species (Ogata et al., 2004).

3) Saturated Fatty Acids (SFA): These include palmitic acid, which is the most abundant fatty acid in many fish species (Jabeen and Chaudhry, 2011).

4) Polyunsaturated Fatty Acids (PUFA): Besides omega-3 and omega-6 fatty acids, other PUFAs are also present in varying amounts depending on the species and their diet (Glencross, 2009; Tocher et al., 2010).

1.2 Factors influencing fatty acid composition in aquaculture fish

The fatty acid composition in aquaculture fish is influenced by several factors, including species differences, diet and feed composition, environmental conditions, and farming practices.

1.2.1 Species differences

Different fish species exhibit significant variations in their fatty acid profiles. For instance, species like Labeo rohita are high in polyunsaturated fatty acids, while others like *Cyprinus carpio* are rich in saturated and mono-unsaturated fatty acids (Jabeen and Chaudhry, 2011). Additionally, species such as *Salvelinus boganidae* and *Salvelinus drjagini* have been identified to have high EPA and DHA contents, making them particularly valuable for human consumption (Gladyshev et al., 2022).

1.2.2 Diet and feed composition

The diet and feed composition play a critical role in determining the fatty acid profile of aquaculture fish. Fish that are fed diets rich in long-chain polyunsaturated fatty acids (LC-PUFA) tend to have higher levels of these beneficial fatty acids in their tissues (Glencross, 2009; Tocher, 2010). The use of alternative lipid sources, such as plant-derived oils, can alter the fatty acid composition, often reducing the levels of n-3 LC-PUFA in the fish (Glencross, 2009; Xie et al., 2017).

1.2.3 Environmental conditions

Environmental factors, including the water temperature and salinity, can influence the fatty acid composition of fish. For example, marine fish generally have higher requirements for long-chain PUFAs compared to freshwater species (Tocher, 2010). Additionally, fish from colder environments tend to have higher levels of unsaturated fatty acids to maintain membrane fluidity (ladyshev et al., 2017).

1.2.4 Farming practices

Farming practices, including the methods of rearing and the type of aquaculture system used, can also impact the fatty acid composition of fish. For instance, fish reared in controlled aquaculture environments may have different fatty acid profiles compared to their wild counterparts due to differences in diet and living conditions (Gladyshev et al., 2022). Sustainable farming practices that incorporate high-nutrient-density diets are essential to maintain the nutritional quality of farmed fish (Tocher, 2010).

2 Health Benefits of Fatty Acids from Aquaculture Fish

2.1 Cardiovascular health

The consumption of omega-3 fatty acids, particularly eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), has been extensively studied for its cardiovascular benefits. Numerous studies have demonstrated that these fatty acids, commonly found in fish and fish oil supplements, can significantly reduce the risk of cardiovascular diseases (CVD). For instance, a systematic review highlighted that increased intake of n-3 fatty acids from fish or fish-oil supplements is associated with reduced rates of all-cause mortality, myocardial infarction, cardiac and sudden death, and possibly stroke (Wang et al., 2006). Another comprehensive review found that long-chain omega-3 fatty acids (LCn3), including EPA and DHA, have little or no effect on all-cause mortality but may reduce the risk of coronary heart disease (CHD) events (Abdelhamid et al., 2018). Additionally, a meta-analysis indicated that fatty fish consumption is inversely associated with CHD incidence and mortality, underscoring the cardioprotective effects of these fatty acids (Giosuè et al., 2022).

2.2 Cognitive function and mental health

Omega-3 fatty acids, particularly DHA, play a crucial role in brain health and cognitive function. These fatty acids are integral components of neuronal membranes and are involved in neurogenesis and synaptic plasticity. Research has shown that EPA and DHA are important for proper fetal development, including neuronal and retinal function, which can have long-term implications for cognitive health (Swanson et al., 2012). Furthermore, the Mediterranean diet, rich in long-chain omega-3 fatty acids from fish, has been associated with a reduced risk of age-related cognitive decline and Alzheimer's disease (Román et al., 2019). The anti-inflammatory properties of these fatty acids may also contribute to their protective effects against neurodegenerative diseases.

2.3 Anti-inflammatory properties

The anti-inflammatory properties of omega-3 fatty acids are well-documented. EPA and DHA can modulate inflammatory processes by influencing the production of eicosanoids, which are signaling molecules that play a key role in inflammation. Studies have shown that these fatty acids can reduce the production of pro-inflammatory cytokines and enhance the production of anti-inflammatory mediators (Liao et al., 2022). This anti-inflammatory effect is beneficial in managing chronic inflammatory conditions such as rheumatoid arthritis and inflammatory bowel disease. Additionally, the anti-inflammatory properties of omega-3 fatty acids contribute to their cardiovascular benefits by reducing vascular inflammation and improving endothelial function (Innes and Calder, 2020).

2.4 Other health benefits

2.4.1 Eye health

Omega-3 fatty acids, particularly DHA, are essential for maintaining retinal health. DHA is a major structural component of the retina, and its deficiency has been linked to visual impairments. Studies have shown that adequate intake of DHA can support visual development in infants and reduce the risk of age-related macular degeneration in adults (Swanson et al., 2012).

2.4.2 Prenatal development

The role of omega-3 fatty acids in prenatal development is well-established. DHA is crucial for the development of the fetal brain and retina. Pregnant women are often advised to consume adequate amounts of DHA to support the neurodevelopment of their unborn child. Research has shown that higher maternal intake of DHA is associated with better cognitive and visual outcomes in infants (Swanson et al., 2012).

The consumption of fatty acids from aquaculture fish offers a wide range of health benefits, including improved cardiovascular health, enhanced cognitive function, anti-inflammatory effects, and support for eye health and prenatal development. These benefits underscore the importance of including omega-3-rich fish in the diet.

3 Comparison Between Wild and Aquaculture Fish

3.1 Differences in fatty acid profiles

The fatty acid profiles of wild and aquaculture fish exhibit significant differences, primarily influenced by their diets and environmental conditions. Wild fish generally have higher levels of polyunsaturated fatty acids (PUFAs), particularly eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), which are crucial for human health (Sales, 2010; Zhang et al., 2020; Gladyshev et al., 2022). For instance, a meta-analysis revealed that farmed freshwater fish tend to have lower total n-3 fatty acid content compared to their wild counterparts, while seawater fish showed negligible differences in EPA and DHA levels between wild and farmed varieties (Sales, 2010). Additionally, the fatty acid composition of fish from natural ecosystems, such as those from the Pearl River Estuary, showed higher proportions of saturated fatty acids (SFAs) and lower PUFAs compared to other regions, likely due to dietary shifts (Zhang et al., 2020).

3.2 Nutritional implications

The nutritional implications of these differences are profound. PUFAs, especially n-3 fatty acids like EPA and DHA, are known for their cardiovascular benefits and overall positive impact on human health (Gladyshev et al., 2017). Wild fish, with their higher PUFA content, are generally considered more beneficial in this regard. However, aquaculture practices can be optimized to enhance the PUFA content in farmed fish. For example, feeding freshwater fish diets high in fish oil can significantly increase their n-3 PUFA levels, making them comparable to wild fish in terms of nutritional value. Moreover, certain aquaculture species, such as *Salvelinus*, have been identified to possess high EPA and DHA levels, making them promising candidates for farming to produce nutritionally superior fish (Gladyshev et al., 2022).

3.3 Consumer perceptions and preferences

Consumer perceptions and preferences play a crucial role in the market dynamics of wild versus farmed fish. There is a general perception that wild fish are healthier due to their natural diet and habitat, which often translates to a preference for wild-caught fish over farmed ones (Jabeen and Chaudhry, 2011; Gladyshev et al., 2022). However, with advancements in aquaculture practices and better understanding of nutritional requirements, farmed fish can be produced with fatty acid profiles that closely match those of wild fish, potentially shifting consumer preferences. For instance, the use of biomarkers such as branched fatty acids and non-methylene interrupted fatty acids can help verify the authenticity and quality of farmed fish, thereby enhancing consumertrust (Gladyshev et al., 2022).

While wild fish generally have a more favorable fatty acid profile, strategic aquaculture practices can bridge this gap, offering farmed fish with comparable nutritional benefits. Understanding and addressing consumer perceptions through transparency and quality assurance can further promote the acceptance of farmed fish as a healthy alternative.

4 Impact of Aquaculture Practices on Fatty Acid Composition

4.1 Influence of feed formulation

Feed formulation plays a critical role in determining the fatty acid composition of aquaculture fish. The replacement of traditional fish oil (FO) with plant-based oils in fish diets has been a common practice to reduce costs and promote sustainability. However, this substitution often results in a decrease in the levels of health-promoting long-chain polyunsaturated omega-3 fatty acids (n-3 LC-PUFA) such as eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) in fish tissues (Horn et al., 2018; Katan et al., 2021). Studies have shown that varying the dietary omega-6 to omega-3 (6:3) fatty acid ratios can significantly influence the lipid metabolism and gene expression in fish, which in turn affects the fatty acid composition of the fish muscle and liver (Katan et al., 2021). Additionally, the use of plant oils, which are rich in C18 polyunsaturated fatty acids but lack C20 and C22 highly unsaturated fatty acids, necessitates the fish to biosynthesize these essential fatty acids, a process that can be nutritionally regulated (Tocher et al., 2004).

4.2 Effects of farming conditions (e.g., temperature, water quality)

Farming conditions such as water temperature and quality also have a profound impact on the fatty acid composition of aquaculture fish. Temperature, in particular, has been shown to modulate the activity of fatty acid desaturase enzymes, which are crucial for the biosynthesis of highly unsaturated fatty acids (HUFA) from their precursors (Tocher et al., 2004). For instance, in rainbow trout, higher water temperatures were found to reduce the activities of fatty acid desaturation and elongation in both hepatocytes and intestinal enterocytes, leading to lower levels of HUFA in the fish tissues (Tocher et al., 2004). This suggests that optimal water temperature management is essential for maintaining the desired fatty acid profile in farmed fish.

4.3 Role of genetic selection and breeding

Genetic selection and breeding strategies offer promising avenues for enhancing the fatty acid composition of aquaculture fish. Research on Atlantic salmon has demonstrated that there is significant additive genetic variation in the muscle content of individual fatty acids, indicating the potential for selective breeding to increase the levels of n-3 LC-PUFA in fish tissues (Horn et al., 2018). The heritability of specific fatty acids such as DHA and EPA varies, with DHA showing higher heritability compared to EPA, suggesting that different selection strategies may be required to optimize the levels of these essential fatty acids (Horn et al., 2018). Moreover, genetic correlations between fatty acid proportions and other traits, such as muscle fat and visceral fat, provide insights into the complex interactions between genetics and fatty acid metabolism, further informing breeding programs aimed at improving the nutritional quality of aquaculture fish (Horn et al., 2018).

5 Public Health Implications

5.1 Contribution of aquaculture fish to dietary fatty acid intake

Aquaculture fish are a significant source of omega-3 long-chain polyunsaturated fatty acids (LC-PUFA), particularly eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), which are essential for human health. These fatty acids are known to support cardiovascular health, reduce inflammation, and contribute to brain function (Kris-Etherton et al., 2002; Gladyshev et al., 2017; Innes and Calder, 2020). The variability in EPA and DHA content among different fish species is influenced by phylogenetic and ecological factors, with species like salmon and trout being particularly rich in these beneficial fatty acids (Gladyshev et al., 2017). The increasing reliance on aquaculture to meet the global demand for fish has the potential to enhance the intake of these essential nutrients, provided that the fish are fed diets that promote high levels of EPA and DHA (Glencross et al., 2009; Katan et al., 2019).

5.2 Recommendations for fish consumption

Given the health benefits associated with omega-3 fatty acids, public health guidelines often recommend regular consumption of fish. The American Heart Association, for instance, suggests eating fish, particularly fatty fish, at least twice a week to reduce the risk of cardiovascular disease (Kris-Etherton et al., 2002; Innes and Calder, 2020). However, it is crucial to balance the intake of omega-6 and omega-3 fatty acids, as an imbalanced ratio can negate some of the health benefits. Diets with a high omega-6 to omega-3 ratio have been linked to increased inflammation and a higher risk of chronic diseases (Katan et al., 2019; Katan et al., 2021). Therefore, it is recommended to choose fish species that are high in omega-3 and low in omega-6 fatty acids to optimize health benefits (Smith and Guentzel, 2010; Pan et al., 2019).

5.3 Potential risks and concerns

While the consumption of aquaculture fish offers numerous health benefits, there are potential risks and concerns that need to be addressed. One significant concern is the presence of environmental contaminants such as mercury, which can accumulate in fish and pose health risks, particularly to vulnerable populations like pregnant women and young children (Kris-Etherton et al., 2002; Smith and Guentzel, 2010). Additionally, the fatty acid composition of farmed fish can be influenced by their diet, with plant-based feeds often resulting in higher omega-6 to omega-3 ratios, which may not be optimal for humanhealth (Katan et al., 2019; Katan et al., 2021). It is essential to monitor and manage these factors to ensure that the health benefits of consuming aquaculture fish are maximized while minimizing potential risks (Glencross et al., 2009; Tocher et al., 2019).

6 Case Study

6.1 Detailed analysis of a specific case of aquaculture fish with enhanced fatty acid composition

In this case study, we focus on the Atlantic salmon (*Salmo salar*), a species that has been extensively studied for its fatty acid composition, particularly the levels of omega-3 long-chain polyunsaturated fatty acids (n-3 LC-PUFA) (Figure 1), such as eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). The replacement of traditional fish oil and fishmeal with plant-based ingredients in the diet of farmed Atlantic salmon has led to a reduction in these essential fatty acids in their fillets (Sprague et al., 2016; Tocher et al., 2019). However, selective breeding and dietary modifications have been explored to enhance the n-3 LC-PUFA content in farmed salmon (Horn et al., 2018).

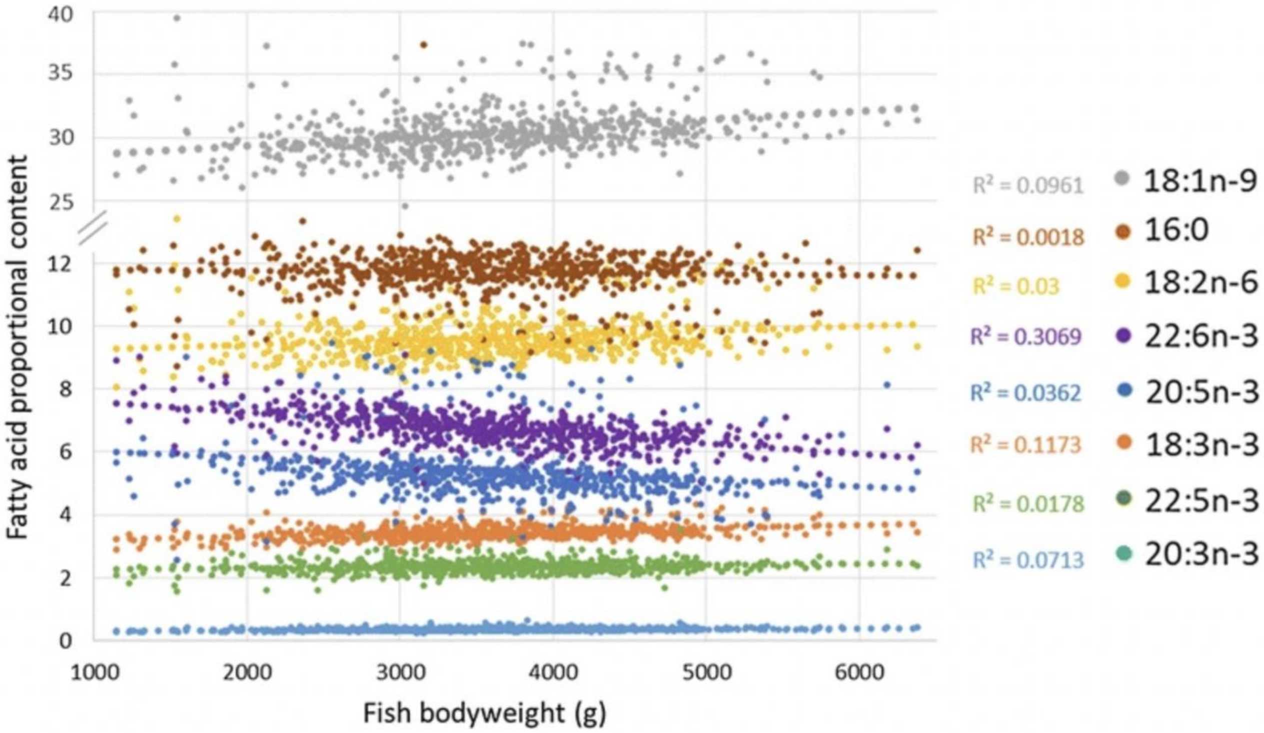


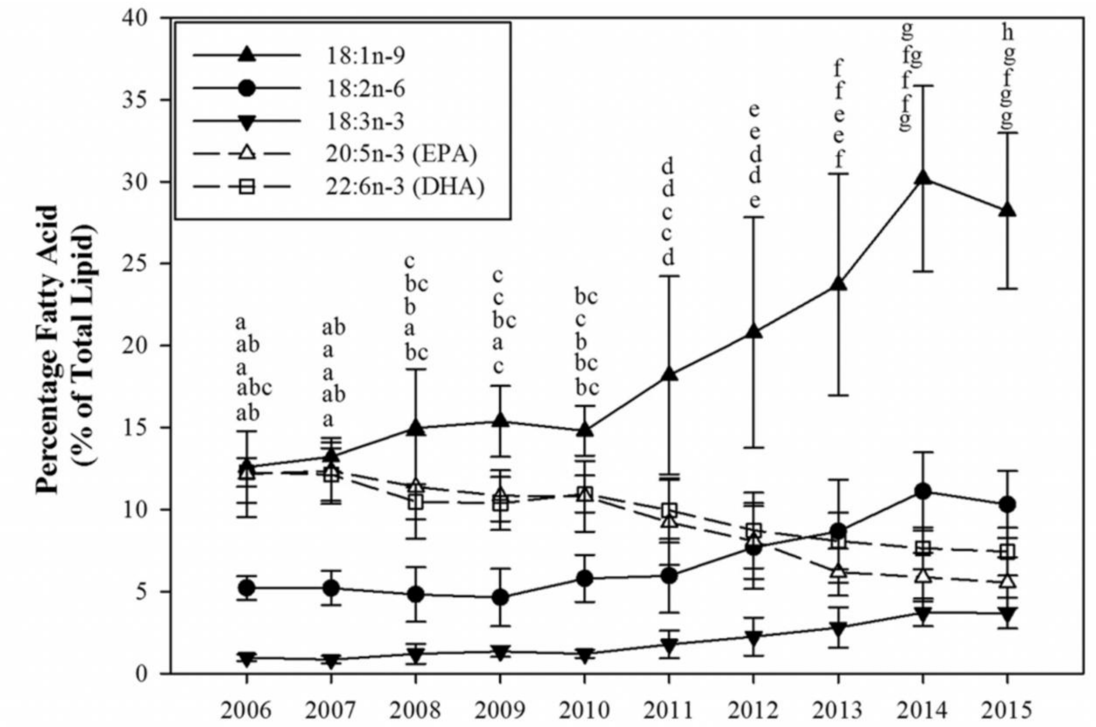
Figure 1 Relationship between fish body weight and proportional content of fatty acids in the muscle (Adopted from Horn et al., 2018)

Based on the data in the figure by Horn et al. (2018), the relationship between fish body weight and the proportional content of different fatty acids in the muscle can be summarized as follows: As the fish body weight increases, the content of 16:0 (palmitic acid) remains stable, while the content of 18-carbon fatty acids (such as 18:1n-9 and 18:2n-6) shows an upward trend. However, the proportions of EPA (20:5n-3) and DHA (22:6n-3), which are n-3 polyunsaturated fatty acids, decrease with increasing fish body weight. This indicates that during fish growth, the accumulation and utilization of different types of fatty acids in the muscle vary, with a particularly higher utilization of n-3 polyunsaturated fatty acids. All estimates have been adjusted for body weight, ensuring the accuracy and comparability of the data.

6.2 Analysis of the impact of feed formulation changes on the fatty acid composition of atlantic salmon

This approach combines dietary intervention and genetic selection. Researchers compared the fatty acid composition of over 3,000 farmed Scottish Atlantic salmon from 2006 to 2015, analyzing the impact of changes in feed formulations on the fatty acid composition of the salmon (Figure 2). Additionally, genetic parameters for muscle content of individual fatty acids were estimated to evaluate the potential for selective breeding to increase n-3 LC-PUFA levels in salmon tissues (Horn et al., 2018). The dietary interventions included the use of microalgae and genetically modified crops as alternative sources of EPA and DHA (Sprague et al., 2016; Tocher et al., 2019).

According to the study by Sprague et al. (2016), the proportions of different fatty acids in the muscle of farmed Atlantic salmon in Scotland changed significantly from 2006 to 2015. The trends in the content of marine and terrestrial fatty acids (Figure 2). With the rise in fish oil prices and the increased use of plant ingredients in salmon feeds, the proportions of terrestrial fatty acids (such as oleic acid 18:1n-9, linoleic acid 18:2n-6, and α-linolenic acid 18:3n-3) in salmon muscle increased significantly, from 15%, 5%, and 2% in 2010 to approximately 30%, 10%, and 5% in 2015, respectively. Meanwhile, the proportions of marine fatty acids, EPA (20:5n-3) and DHA (22:6n-3), decreased by about half. This trend indicates that changes in feed formulations have had a profound impact on the fatty acid composition of salmon. Similar changes have been observed in the salmon farming industries in Norway and Tasmania.



Figture 2 Changes in the levels of fatty acids (% of total fatty acids), of either marine or terrestrial origin, in the flesh of Scottish Atlantic salmon farmed between 2006-2015 (mean ± SD) (Adopted from Sprague et al., 2016)

6.3 Health outcomes and benefits observed

The health benefits of consuming Atlantic salmon with enhanced n-3 LC-PUFA levels are significant. These fatty acids are essential for human health, contributing to the prevention of cardiovascular diseases and supporting overall well-being (Yu et al., 2014). Despite the reduction in EPA and DHA levels due to dietary changes, farmed Scottish salmon still delivers more of these essential fatty acids than most other fish species and terrestrial livestock (Sprague et al., 2016). Clinical tests have demonstrated the effectiveness of consuming farmed fish in promoting human health, highlighting the antiatherosclerotic efficacy and other beneficial effects of long-chain unsaturated n-3 fatty acids (Steffens, 2015).

6.4 Lessons learned and implications for future practices

Several lessons can be drawn from this case study. The importance of maintaining high levels of n-3 LC-PUFA in aquaculture fish through dietary and genetic interventions is crucial for ensuring the nutritional value of the final product (Sprague et al., 2016; Horn et al., 2018). The use of alternative lipid sources, such as microalgae and genetically modified crops, presents a viable solution to the global shortfall of EPA and DHA (Steffens, 2015; Tocher et al., 2019). Selective breeding strategies can be effectively employed to enhance the fatty acid composition of aquaculture fish, thereby improving their health benefits for human consumers (Horn et al., 2018).

Future practices should focus on optimizing the balance between sustainable feed ingredients and the nutritional quality of aquaculture fish. Continued research into alternative sources of n-3 LC-PUFA and the genetic potential for enhancing fatty acid composition will be essential for meeting the growing demand for health-promoting seafood (Sprague et al., 2016; Horn et al., 2018; Tocher et al., 2019).

7 Future Directions in Research

7.1 Emerging trends in aquaculture nutrition

Recent studies have highlighted the critical role of essential fatty acids (EFAs) in aquaculture nutrition, emphasizing their impact on growth, reproduction, immunity, and product quality of aquaculture species. The nutritional value of specific fatty acids such as docosahexaenoic acid (DHA) and eicosapentaenoic acid (EPA) has been well-documented, with DHA providing the greatest EFA value to most species. However, the optimal dietary inclusion levels and balance among fatty-acid classes (n-3 and n-6) and chain lengths vary among species, influenced by environmental origins such as freshwater, estuarine, or marine habitats. Future research should focus on refining the dietary requirements of EFAs for various aquaculture species, particularly in light of recent changes in high-nutrient-density diets and the declining dependence on marine-origin lipid sources.

7.2 Technological innovations for enhancing fatty acid profiles

Technological advancements in aquaculture feed formulation are crucial for enhancing the fatty acid profiles of farmed fish. The use of alternative lipid resources such as grain, algal, and rendered oils has been proposed to meet the growing demand for aquaculture products while preserving the n-3 polyunsaturated fatty acid (PUFA) content. Additionally, the development of biomarkers to differentiate wild and farmed fish based on their fatty acid composition can improve the accuracy of trade label information and ensure the quality of aquaculture products (Gladyshev et al., 2022). Future research should explore innovative feed ingredients and processing techniques that can enhance the nutritional quality of aquaculture fish, particularly focusing on increasing the levels of beneficial fatty acids such as DHA and EPA (Gladyshev et al., 2022).

7.3 Interdisciplinary research opportunities

The correlation between the fatty acid composition of aquaculture fish and human health presents numerous interdisciplinary research opportunities. Studies have shown that fish with higher levels of n-3 PUFAs, particularly DHA and EPA, are beneficial for cardiovascular health and other clinical conditions. However, variations in fatty acid profiles among different fish species and environmental factors necessitate a comprehensive analysis of the nutritional status of aquaculture fish (Rodrigues et al., 2017; Gladyshev et al., 2017; Zhang et al., 2020). Collaborative research involving nutritionists, aquaculture scientists, and health professionals can provide valuable insights into optimizing fish diets to enhance their health benefits for human consumption. Additionally, investigating the ecological and phylogenetic drivers of fatty acid composition in fish can further our understanding of how to improve the nutritional quality of aquaculture products (Zhang et al., 2014; Gladyshev et al., 2017).

By addressing these emerging trends, technological innovations, and interdisciplinary research opportunities, future studies can significantly contribute to the advancement of aquaculture nutrition and the enhancement of the health benefits of aquaculture fish for human consumption.

8 Concluding Remarks

The research on the correlation between the fatty acid composition of aquaculture fish and human health has yielded several significant findings. It has been established that both marine and freshwater fish are valuable sources of essential fatty acids, particularly n-3 polyunsaturated fatty acids (PUFAs) such as eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). These fatty acids are crucial for human health, offering benefits such as cardiovascular disease prevention and anti-inflammatory properties.

However, the fatty acid composition of fish can vary significantly based on their diet and environmental factors. For instance, fish from the Pearl River Estuary were found to have higher proportions of saturated fatty acids (SFAs) and lower contents of PUFAs, likely due to changes in their diet over the past decades. Similarly, the replacement of traditional marine ingredients in farmed fish diets with terrestrial alternatives has led to a decrease in EPA and DHA levels in farmed Atlantic salmon, compromising their nutritional value.

Moreover, the genetic potential for increasing n-3 LC-PUFA levels in farmed fish through selective breeding has been demonstrated, suggesting that it is possible to enhance the health benefits of aquaculture fish. Additionally, the impact of fish oil with high n-3 PUFA content on gut microbiota has been explored, indicating significant changes that may contribute to the health benefits of fish oil consumption.

The findings of this study aim to provide valuable insights for various stakeholders. For researchers, it is recommended to further investigate the nutritional requirements and optimal dietary levels of fatty acids for different aquaculture species, including reassessing EFA needs and exploring alternative lipid sources. Policymakers should develop policies that support sustainable aquaculture practices, ensuring the production of fish with high levels of beneficial fatty acids. This includes encouraging the use of sustainable feed ingredients and supporting research into alternative sources of n-3 LC-PUFA, such as microalgae and genetically modified crops. The aquaculture industry is advised to prioritize the development of cost-effective diets to maintain the n-3 PUFA content of farmed fish, which may involve incorporating alternative lipid sources and implementing selective breeding programs.

Given the importance of n-3 PUFAs for human health and the challenges of maintaining their levels in aquaculture fish, there is a clear need for ongoing research and collaboration among researchers, policymakers, and the aquaculture industry. Future research should focus on developing and optimizing sustainable feed ingredients to maintain or enhance the n-3 PUFA content in farmed fish. Additionally, it is important to investigate the genetic factors that influence the fatty acid composition in aquaculture species and implement selective breeding programs to improve their nutritional value. Exploring the effects of fish oil and other n-3 PUFA-rich products on human health, including their impact on gut microbiota and disease prevention, is also essential. Collaboration among stakeholders is key to addressing these challenges and ensuring that aquaculture continues to provide a valuable source of essential fatty acids for humans. By working together, we can develop innovative solutions to promote both human health and sustainable aquaculture practices.

Conflict of Interest Disclosure

The authors affirm that this research was conducted without any commercial or financial relationships that could be construed as a potential conflict of interest.

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