Nutritional Value of Fish

Subjects: Food Science & Technology

Contributor: Ahtisham Ali , Shuai Wei , Adnan Ali , Imran Khan , Qinxiu Sun , Qiuyu Xia , Zefu Wang , Zongyuan Han , Yang Liu , Shucheng Liu

Fish are considered highly nutritious products of the aquaculture system due to the presence of well-balanced macronutrients such as proteins, lipids and micronutrients such as vitamins and minerals

fish nutrition preservation processing by-products

1. Introduction

Fish is a widely cultivated food product with highly economical trading in Southeast Asian countries such as Hong Kong, Singapore, Malaysia and Thailand [1]. Fish production has been predicted to reach 196 million tons in 2025 worldwide [2]. Fish is a very diversified food commodity mostly cultured in tropical and subtropical regions. The demand for fish is significantly increasing with the increase in the world population because of their favourable taste, efficient feed conversion and high commercial value [3].

Fish are considered highly nutritious products of the aquaculture system due to the presence of well-balanced macronutrients such as proteins, lipids and micronutrients such as vitamins and minerals [4]. These fish are a good source of human food that promotes growth and protection of the body from a variety of health diseases such as cardiovascular and coronary heart diseases and prevents rickets and mental diseases in children [5]. The protein present in fish has high nutritional value because essential amino acids serve as antioxidant elements in various nutraceutical industries. These amino acids possess many properties such as gel formation, oil adsorption, water-holding capacity and health-related properties. Amino acids also have antihypertensive, blood quality maintenance, muscle tissue repairing and system-regulating properties in humans [6]. Lipids are important for health and are rich in polyunsaturated fatty acids (PUFAs), especially eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) which help to prevent cardiovascular diseases and coronary heart diseases and maintain mental health in children [7]. Similarly, fish contains a perfect balance of all essential vitamins, especially vitamins A and D, and are also a significant source of vitamin B. Vitamin B mostly prevents calcium-deficient diseases and rickets in children. Minerals are micronutrients that vary from species to species, including calcium, iron, zinc, selenium, iodine, phosphorus and potassium. These micronutrients have high bioavailability and antioxidant properties that are useful for curing various diseases [8].Fish and their products can be spoiled easily if not preserved properly. Fish and fish product quality deteriorates because of digestive enzymes, lipid oxidation and microbes which actively contribute to fish spoilage [9]. Compositional changes in protein and lipids lead to the development of new products that cause physiological and chemical changes. Therefore, it is necessary to understand and minimize the factors that contribute to fish spoilage by using active preservation techniques to sustain the freshness of fish and fish-

containing products [10]. Various preservation techniques are used to preserve and process fish at an industrial level such as pulsed electric field pulsed electric field (PEF), fluorescence spectroscopy, hyperspectral imaging technique (HSI) and high-pressure processing (HPP) while traditional techniques include cooling, freezing and super-chilling [11]. Excellent food preservation techniques effectively prevent microbial spoilage and prolong the product shelf life with limited adverse changes in the quality and nutritional values, texture and flavour. Many studies have focused on chemical and low-temperature storage methods for fish preservation. Fish is a part of a healthy diet and provides essential components such as proteins, vitamins, polyunsaturated fatty acids and minerals that are necessary for healthy growth. Fish is a highly perishable food and its quality is adversely affected during storage by several factors such as enzymatic autolysis, microbial growth and oxidation [12].

Extensive amounts of by-products are produced as a result of fish processing and are estimated to be up to 60% of the total fish weight [13]. Usually, fish processing by-products are dumped as waste in oceans and on land and contain highly valuable components that can cause serious environmental pollution. These by-products are also used as dietary components in fish meal, silage and fertilizer production. Fish processing by-products contain components such as the skin, scales, viscera, head, trimmings, roe and bones which are unfit for human consumption and are discarded as waste [14]. These by-products are a good source of nutritional components, especially lipids and proteins as well as functional components (**Figure 1**).

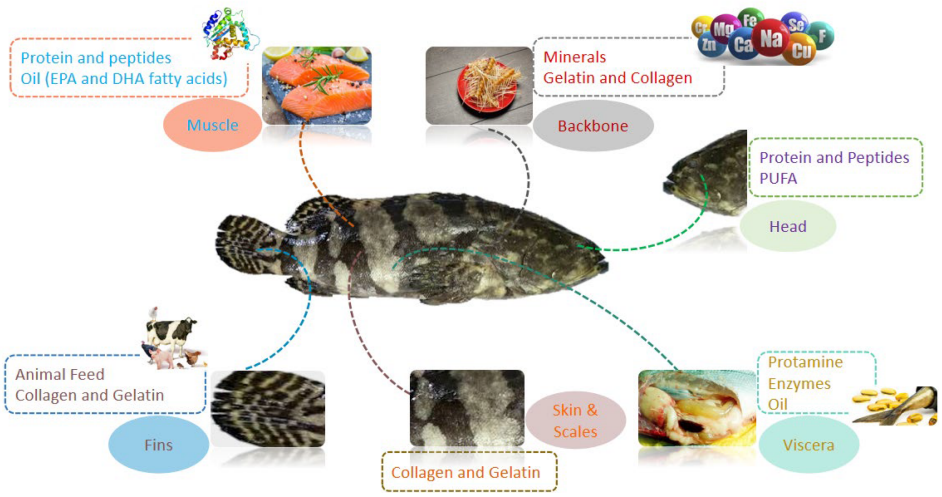

Figure 1. Bioactive compounds present in various parts of fish.

New processing technologies are being used to facilitate the production of highly valuable marketed products that can obtain high economic prices. In this way, discarded waste can be reduced and environmental pollution can also be reduced. Therefore, it is currently considered a necessary and challenging factor to develop new technologies to enable the recovery of valuable fish processing by-products for obtaining functional ingredients that can be used as high-value-added products for human consumption [15].

2. Nutritional Value of Fish

Fish are among the most commercially valuable species in Asia. Moreover, fish are considered key species in coastal ecosystems, and their decline due to fishing pressure has a significant impact on the ecosystem. Therefore, overfishing to meet market demand is a concern [16]. Furthermore, the nutritional value of fish has shown some beneficial effects on human health with efficient protective measures against cardiovascular diseases, cancer and Alzheimer's disease [17]. Fish has contained high nutritional value due to having rich contents of protein, water, amino acid composition and fatty acids [18].

2.1. Proteins

Fish protein has long been considered to have a high nutritional value due to its being rich in many bioactive peptides and essential amino acids. They are readily digested due to the presence of low connective tissues and can be used for various metabolic activities [19]. These proteins have various pharmaceutical and nutraceutical applications and are being efficiently used as functional ingredients in many food items. Even though they have some useful properties such as oil absorption, water-holding capacity, gel formation, emulsification and foaming properties [20]. In addition, fish protein has various significant bioactive properties such as antioxidative, antithrombic and antihypertensive properties (**Table 1**). Fish proteins are used to repair muscle tissues, and improve immunity and blood quality. Fish proteins can also be used to prevent protein–calorie malnutrition (PCM) in animals [21].

Table 1. Nutritional composition of fish muscle and their applications.

Nutrients	Percentage	Applications	Reference
Protein	15–24%	Potential source of animal protein, antioxidants and metabolic activities; improve muscle tissues and immunity; application in biotechnology and pharmaceutical.	[22]
Lipid	0.1–22%	Provide lipid-soluble vitamins (A and D) and essential omega-3s (PUFAs) absent in the body, lowering blood pressure and triglycerides in the blood; helps to reduce cardiovascular, childhood asthma, hypertension and Alzheimer's disease.	[23]
- Docosahexaenoic acid (DHA)	6.1–10.3%	Helps to improve brain and neurodevelopment in children; involved in lipid metabolism and neural functioning and reduction in blood pressure and coronary heart disease.	[24]
Eicosapentaenoic acid (EPA)	3.7–4.5%	Protects against cardiovascular disease; involved in blood coagulation and aggregation of platelets; prevents dementia, atherosclerosis and rheumatoid arthritis.	[25]
Vitamins	0.1%	Improves growth and development of children; aids in bone, teeth and cell repair; prevents eyesight loss and blood coagulation; accelerates chemical processes in the body.	[26]
Minerals	1–2%	Have high bioavailability, easily absorbed by the body; helps in the synthesis of haemoglobin in RBCs and proper	[27]

Nutrients	Percentage	Applications	Reference
		functioning of the thyroid gland.	
-Calcium	0.5%	Mineralization and formation of bones; proper functioning of muscles and nervous system; involved in metabolic processes.	[28]
-Phosphorus	0.25%	Maintain teeth and bone structures; regulates acid–base equilibrium.	[28]

and viral infections and helps to maintain the water balance and regulatory system in the human body [29]. The amino acids of proteins have a variety of nutritional values, chemical actions and medicinal properties. For instance, amino acids are used in pharmaceuticals as an excipient for drug development and employed as a food additive in food and feed supplement sources. In the flavouring industry, amino acids such as alanine, aspartate, monosodium glutamate and arginine are the most commonly used flavour enhancer ingredients in a variety of foods. Amino acids have various applications in the pharmaceutical industry such as purifying proteins and are used in the formulation and production of many antibiotics [30].

2.2. Lipids

Lipids play an important role in the nutritional value of fish due to the presence of long-chain PUFAs which consist of omega-3 fatty acids, particularly EPA and DHA [26]. These fatty acids have great beneficial impacts on human health and nutrition and prevent various diseases [31]. PUFAs help to reduce blood pressure and high concentrations of triglycerides in blood vessels. The high intake of fatty acids proved to have a beneficial impact on preventing cardiovascular diseases. Omega-3 fatty acids are mostly recommended as an essential element in the growth of children and have some preventive effects against coronary heart diseases [32].

Among fatty acids, DHA is particularly good for optimizing brain growth and neurodevelopment in children while EPA is important for cardiovascular health [33]. Many other benefits include prevention against arrhythmias, therapeutics for asthma patients, protection against atherosclerosis and manic-depressive illness, reduced symptoms of cystic fibrosis and survival of cancer patients [34]. The American Heart Association has recommended at least two servings of fish per week to reduce the risk of cardiovascular diseases. In addition, these fatty acids are used in biodiesel production through enzymatic transesterification of fish oil. This type of biodiesel has become a newly trending nontoxic, biodegradable and renewable energy source [35].

2.3. Multi-Vitamins

Fish also contain the perfect balance of all essential vitamins which play an important role in human health. Fish is a rich source of vitamins (A and D) and a good source of B-group vitamins which are considered to be beneficial for the growth and development of children [36]. Vitamin A maintains cell development, the formation of bones and teeth and it also significantly contributes to improving weak eyesight as well as the treatment of various eye-related diseases [37]. Vitamin D present in fish was found in the form of vitamin D3 (cholecalciferol) which represents a three-fold higher potential efficiency ratio than that of vitamin D (ergocalciferol) and it was also found in the skin as 7-dehydrocholesterol after exposure to ultraviolet light [38]. Most children suffer from vitamin D deficiency that

causes rickets but it is also found common in adults where many other diseases such as osteoporosis, osteomalacia, osteopenia, low bone mineral density and diabetes have been reported [39]. Vitamin B accelerates enzyme functioning which facilitates chemical processes in the human body whereas vitamin K is important for blood coagulation and helps to prevent internal bleeding in the body [8].

2.4. Minerals

Most micronutrients with high bioavailability are present in fish within the range of approximately 0.4 to 1.5%. Fish contain high-nutritional-value minerals in widely varying quantities including calcium, iron, zinc, selenium, iodine, phosphorus and potassium [40].

In particular, iodine and selenium are considered to have significant nutritional value due to their high bioavailability. Iodine is essential for hormone production, especially thyroxin which helps to regulate the body's metabolism. It is also important for the psychological and growth development of children. Selenium possesses some antioxidant properties and is an important micronutrient in the human body that only performs various functions in the form of selenoproteins. These proteins are directly responsible for normal thyroid function and the inactivation of antioxidant enzymes such as glutathione peroxidase [41]. Calcium is significantly used for bone formation and mineralization, and the proper functioning of muscles and the nervous system [42]. Iron is directly involved in the synthesis of haemoglobin in red blood cells (RBCs) that can assist in the regulation of oxygen in every body part [43].

References

1. Frisch, A.J.; Cameron, D.S.; Pratchett, M.S.; Williamson, D.H.; Williams, A.J.; Reynolds, A.D.; Hoey, A.S.; Rizzari, J.R.; Evans, L.; Kerrigan, B.; et al. Key aspects of the biology, fisheries and management of Coral grouper. Rev. Fish Biol. Fish. 2016, 26, 303–325.
2. Pedro, S.; Nunes, M.L. Reducing salt levels in seafood products. In Reducing Salt in Foods, 2nd ed.; Woodhead Publishing: Thorston, UK, 2019; pp. 185–211.
3. Tavares, J.; Martins, A.; Fidalgo, L.G.; Lima, V.; Amaral, R.A.; Pinto, C.A.; Silva, A.M.; Saraiva, J.A. Fresh Fish Degradation and Advances in Preservation Using Physical Emerging Technologies. Foods 2021, 10, 780.
4. Hassanien, H.A.; Al-Rashada, Y. Assessment of genetic diversity and phylogenetic relationship among grouper species Epinephelus spp. from the Saudi waters of the Arabian Gulf. Saud. J. Biol. Sci. 2021, 28, 1779–1786.
5. Luo, J.; Amenyogbe, E.; Fu, W.-j.; Huang, J.-s.; Chen, G. Hepatic transcriptome profiles reveal the hepatoprotective effects of dietary quercetin and sodium quercetin-5′-sulfonates supplementation

in hybrid grouper (Epinephelus fuscoguttatus♀× Epinephelus polyphekadion♂). Aquaculture 2022, 2022, 738483.

6. Ghaly, A.E.; Ramakrishnan, V.; Brooks, M.S.; Budge, S.M.; Dave, D. Fish Processing Wastes as a Potential Source of Proteins, Amino Acids and Oils: A Critical Review. J. Microb. Biochem. Technol. 2013, 5, 107–129.
7. Innes, J.K.; Calder, P.C. Marine Omega-3 (N-3) Fatty Acids for Cardiovascular Health: An Update for 2020. Int. J. Mol. Sci. 2020, 21, 1362.
8. Khalili Tilami, S.; Sampels, S. Nutritional Value of Fish: Lipids, Proteins, Vitamins, and Minerals. Rev. Fish. Sci. Aquac. 2018, 26, 243–253.
9. Ekonomou, S.I.; Parlapani, F.F.; Kyritsi, M.; Hadjichristodoulou, C.; Boziaris, I.S. Preservation status and microbial communities of vacuum-packed hot smoked rainbow trout fillets. Food Microbiol. 2022, 103, 103959.
10. Hematyar, N.; Rustad, T.; Sampels, S.; Kastrup Dalsgaard, T. Relationship between lipid and protein oxidation in fish. Aquac. Res. 2019, 50, 1393–1403.
11. Rathod, N.B.; Nirmal, N.P.; Pagarkar, A.; Özogul, F.; Rocha, J.M. Antimicrobial Impacts of Microbial Metabolites on the Preservation of Fish and Fishery Products: A Review with Current Knowledge. Microorganisms 2022, 10, 773.
12. Rathod, N.B.; Ranveer, R.C.; Benjakul, S.; Kim, S.K.; Pagarkar, A.U.; Patange, S.; Ozogul, F. Recent developments of natural antimicrobials and antioxidants on fish and fishery food products. Compr. Rev. Food Sci. Food Saf. 2021, 20, 4182–4210.
13. Dekkers, E.; Raghavan, S.; Kristinsson, H.G.; Marshall, M.R. Oxidative stability of mahi mahi red muscle dipped in tilapia protein hydrolysates. Food Chem. 2011, 124, 640–645.
14. Rustad, T.; Storrø, I.; Slizyte, R. Possibilities for the utilisation of marine by-products. Int. J. Food Sci. Technol. 2011, 46, 2001–2014.
15. Ghosh, S.; Sarkar, T.; Pati, S.; Kari, Z.A.; Edinur, H.A.; Chakraborty, R. Novel Bioactive Compounds From Marine Sources as a Tool for Functional Food Development. Front. Mar. Sci. 2022, 9, 10-3389.
16. Soyano, K.; Amagai, T.; Yamaguchi, T.; Mushirobira, Y.; Xu, W.-G.; Phạm, N.T.; Murata, R. Endocrine Regulation of Maturation and Sex Change in Groupers. Cells 2022, 11, 825.
17. Yeşilsu, A.F.; Özyurt, G. Oxidative stability of microencapsulated fish oil with rosemary, thyme and laurel extracts: A kinetic assessment. J. Food Eng. 2019, 240, 171–182.
18. Ahmed, I.; Jan, K.; Fatma, S.; Dawood, M.A.O. Muscle proximate composition of various food fish species and their nutritional significance: A review. J. Anim. Physiol. Anim. Nutr. 2022, 106, 690–719.

19. Sathivel, S.; Bechtel, P.J.; Babbitt, J.; Prinyawiwatkul, W.; Negulescu, I.I.; Reppond, K.D. Properties of protein powders from arrowtooth flounder (Atheresthes stomias) and herring (Clupea harengus) byproducts. J. Agric. Food Chem. 2004, 52, 5040–5046.
20. Ryu, B.; Shin, K.H.; Kim, S.K. Muscle Protein Hydrolysates and Amino Acid Composition in Fish. Mar. Drugs 2021, 19, 377.
21. Lees, M.J.; Carson, B.P. The Potential Role of Fish-Derived Protein Hydrolysates on Metabolic Health, Skeletal Muscle Mass and Function in Ageing. Nutrients 2020, 12, 2434.
22. Mohanty, B.P.; Mahanty, A.; Ganguly, S.; Mitra, T.; Karunakaran, D.; Anandan, R. Nutritional composition of food fishes and their importance in providing food and nutritional security. Food Chem. 2019, 293, 561–570.
23. Holma, K.A.; Maalekuu, B. Effect of traditional fish processing methods on the proximate composition of red fish stored under ambient room conditions. Amer. J. Food Nutr. 2013, 3, 73–82.
24. Mohanty, B.P.; Ganguly, S.; Mahanty, A.; Sankar, T.V.; Anandan, R.; Chakraborty, K.; Paul, B.N.; Sarma, D.; Syama Dayal, J.; Venkateshwarlu, G.; et al. DHA and EPA Content and Fatty Acid Profile of 39 Food Fishes from India. BioMed Res. Int. 2016, 2016, 4027437.
25. Jamshidi, A.; Cao, H.; Xiao, J.; Simal-Gandara, J. Advantages of techniques to fortify food products with the benefits of fish oil. Food Res. Int. 2020, 137, 109353.
26. Mesias, M.; Holgado, F.; Sevenich, R.; Briand, J.; Márquez-Ruiz, G.; Morales, F. Fatty acids profile in canned tuna and sardine after retort sterilization and high pressure thermal sterilization treatment. J. Food Nutr. Res. 2015, 54, 171–178.
27. Suganthi, A.; Venkatraman, C.; Chezhian, Y. Proximate composition of different fish species collected from Muthupet mangroves. Int. J. Fish. Aquat. Stud. 2015, 2, 420–423.
28. Hantoush, A.; Al-Hamadany, Q.; Al-Hassoon, A.; Al-Ibadi, H. Nutritional value of important commercial fish from Iraqi waters. Int. J. Mar. Sci. 2015, 5, 1–5.
29. Ariño, A.; Beltrán, J.; Herrera, A.; Roncalés, P. Fish and seafood: Nutritional Value. Encycl. Human Nutr. 2012, 2012, 254–261.
30. Nirmal, N.P.; Santivarangkna, C.; Rajput, M.S.; Benjakul, S.; Maqsood, S. Valorization of fish byproducts: Sources to end-product applications of bioactive protein hydrolysate. Compr. Rev. Food Sci. Food Saf. 2022, 21, 1803–1842.
31. Maulu, S.; Nawanzi, K.; Abdel-Tawwab, M.; Khalil, H.S. Fish Nutritional Value as an Approach to Children’s Nutrition. Front. Nutr. 2021, 8, 780844.
32. Balami, S.; Sharma, A.; Karn, R. Significance of Nutritional Value of Fish for Human Health. Malay. J. Halal Res. 2019, 2, 32–34.

33. Abraha, B.; Tessema, H.A.; Mahmud, A.; Tsighe, K.N.; Shui, X.; Yang, F. Effect of processing methods on nutritional and physico-chemical composition of fish: A review. MOJ Food Process. Technol. 2018, 6, 376–382.
34. Bowen, K.J.; Harris, W.S.; Kris-Etherton, P.M. Omega-3 Fatty Acids and Cardiovascular Disease: Are There Benefits? Curr. Treat. Opt. Cardiovascular Med. 2016, 18, 69.
35. Aworanti, O.; Ajani, A.; Agarry, S.; Babatunde, K.; Akinwumi, O. Evaluation of process parameters for biodiesel production from vegetable and palm waste frying oils using a homogeneous catalyst. Int. J. Ener. Eng. 2019, 9, 25–35.
36. Sangija, F.; Martin, H.; Matemu, A. African nightshades (Solanum nigrum complex): The potential contribution to human nutrition and livelihoods in sub-Saharan Africa. Compr. Rev. Food Sci. Food Saf. 2021, 20, 3284–3318.
37. Hernandez, L.H.; Hardy, R.W. Vitamin A functions and requirements in fish. Aquac. Res. 2020, 51, 3061–3071.
38. Hawk, J.L.M. Safe, mild ultraviolet-B exposure: An essential human requirement for vitamin D and other vital bodily parameter adequacy: A review. Photodermatol. Photoimmunol. Photomed. 2020, 36, 417–423.
39. Lilly, T.T.; Jeyasanta, I.; Jamila, P. Macro and micronutrients of selected marine fishes in Tuticorin, South East coast of India. Int. Food Res. J. 2017, 24, 191–201.
40. Marques, I.; Botelho, G.; Guiné, R.P.F. Comparative study on nutritional composition of fish available in Portugal. Nutr. Food Sci. 2019, 49, 925–941.
41. Gorini, F.; Sabatino, L.; Pingitore, A.; Vassalle, C. Selenium: An Element of Life Essential for Thyroid Function. Molecules 2021, 26, 7084.
42. Sihotang, M.; Sinuhaji, P.; Aisyah, D. Synthesis and characterization of pure natural hydroxyapatite from fishbone biowaste of coastal communities. IOP Conf. Ser. Ear. Environ. Sci. 2019, 305, 012072.
43. Antony Jesu Prabhu, P.; Schrama, J.W.; Kaushik, S.J. Mineral requirements of fish: A systematic review. Rev. Aquac. 2016, 8, 172–219.