**A review on nutritional benefits of fish on human health**

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**Abstract**

 Fish is one of the most important foods in human diet because of its high nutritional quality. Fish are a well-known source of a class of PUFAs, particularly omega-3 and omega-6, which can fend off thrombosis and atherosclerosis. These fatty acids have anti-inflammatory, anti-arrhythmic, anti-hypertensive, and anti-coronary heart disease characteristics. Fish contains almost all of the minerals that our bodies require. Minerals found in fish include iron (Fe), calcium (Ca), zinc (Zn), phosphorus (P), selenium (Se), fluorine (F), and iodine (I). Due to their high bioavailability, these minerals are easily absorbed by the body. Dietary habits, especially those connected to metabolic and endocrine abnormalities, are a major contributor to the development of chronic disease. Fish, a dietary group, contains many vital nutrients that are necessary for the metabolism and hormone function, including omega-3 fatty acids, iodine, selenium, vitamin D, taurine, and carnitine. Fish is also rich in protein and often has a low calorie density. It has been extensively studied how these nutrients affect cardiovascular risk, but it hasn't always been clear how important fish is for overall endocrine and metabolic health. Only a small portion of the numerous mechanisms that mediate these effects have been found. It is true that a low background fish consumption is linked to greater prospective benefits for the bulk of these consequences. In this review up-to-date information about importance of fish in human nutrition and beneficial effect of essential fatty acid in human health is also reviewed.

**Key words**: Nutritional value, Human health, PUFAs, Vitamins and Minerals

**Introduction**

 Fish are commonly grown as food in Southeast Asian countries including Hong Kong, Singapore, Malaysia, and Thailand, where the industry is highly efficient (Frisch et al. 2016). According to Pedro et al. 2019 fish production is expected to reach 196 million tonnes globally in 2025. Fish is a diverse food item that is mostly grown in tropical and subtropical regions. Fish are in high demand due to their wonderful flavour, efficient feed conversion, and high commercial value as the world's population rises (Tavares et al., 2021). Because they contain a well-balanced mix of macronutrients like proteins and fats and micronutrients like vitamins and minerals, fish are recognised as being among the most rich in nutrients aquaculture products (Hassanien et al., 2021) . The FAO (2016) estimates that a total of 167.2 million tonnes of fish are produced worldwide, of which 146.3 million tonnes are utilised for human consumption. The rest is used for non-food uses and thrown away as garbage. Because of their great nutritional content and abundance of beneficial components, high-quality fish and fishery products are in high demand (FAO, 1986). The most important of them are fish lipids, which frequently include considerable amounts of omega-3 fatty acids, particularly -linoleic acid, eicosapentaenoic acid (EPA), and docosahexaenoic acid (DHA). These fish are a healthy food source for people that promotes growth, protects the body from a variety of diseases like cardiovascular and coronary heart ailments, and protects kids from rickets and mental health conditions. (Sinn et al. 2007).

**Global overview of fish Consumption**

 Over 20% of the 3.3 billion people living in the world get their animal protein from fish, making it a crucial part of a nutrient-dense diet in many parts of the world. The increasing global population raises potential nutritional concerns, as fish is a major source of animal protein. According to an estimate for the entire world, fish for human use is expected to increase by 16.3% by the year 2029, which indicates that 90% of the fish produced will be used for human consumption (Hasselberg et al., 2020). Over 20% of the 3.3 billion people living in the world get their animal protein from fish, making it a crucial part of a nutrient-dense diet in many parts of the world. The increasing global population raises potential nutritional concerns, as fish is a major source of animal protein. According to an estimate for the entire world, fish for human use is expected to increase by 16.3% by the year 2029, which indicates that 90% of the fish produced will be used for human consumption. Not only has production increased, but consumption has also grown as a result of greater nutritional standards for the populace, decreased waste, better utilisation, enhanced distribution systems, and increased demand (FAO 2020). Therefore, the rise in global consumption is proof that eating fish has numerous health benefits that are well-known from both a scientific and nutritional standpoint. Fisheries and aquaculture will therefore continue to play a crucial role in meeting the needs of the global population for animal protein, with aquaculture acting as the primary source. (Fig. 1).



**Fig:1** Global fish (A) production in 2018 and projected production in 2030, and (B) consumption in 2018 and projected consumption in 2030, from capture fisheries and aquaculture. Source: Adapted from FAO (FAO 2020)

**Nutritional Value of Fish**

 In Asia, fish are among the species with the highest commercial value. Additionally, fish are regarded as essential species in coastal ecosystems, and the ecology is significantly impacted by their reduction as a result of fishing pressure. As a result, there is a concern about overfishing to satisfy market demand (Soyano et al.2022). Additionally, the nutritional content of fish has demonstrated certain positive impacts on human health, including effective safeguards against cancer, Alzheimer's illness, and cardiovascular disorders (Ye silsu, A.F. and zyurt, G

2019). Fish has a significant nutritional value due to its high protein, water, amino acid composition, and fatty acid content. (Ahmed et al 2022).

**Biochemical Composition of fish**

 Numerous nutrients, including both macro and micronutrients, are found in fish. Protein, fat, and a very small quantity of carbohydrate make up the macronutrients. Vitamins and minerals are among the micronutrients and are crucial components. According to Balami *et al.* (2019), various nutrients available in fish are as under:

**Table 1: Proximate** composition of fish Balami *et al.* (2019)

|  |  |
| --- | --- |
| **Constituent** | **Percentage** |
| Moisture | 65-80% |
| Protein | 15-20% |
| Fat | 5-20% |
| Ash/Minerals | 0.5-2% |

**Moisture**

 Water makes up the majority of fish flesh and often makes up around 80% of the weight of fresh fish meat. Bombay duck has the highest moisture content, at 90%, although the average moisture content of the flesh of fatty fish is around 70%. Even under great pressure, the water in fish muscle is incapable of easily escaping due to its strong molecular bonds with the proteins that make up the structure. However, during extended refrigerated or frozen storage, the proteins lose part of the water, some of which contains dissolved molecules, as drip. Pal et al 2018.Bombay duck fish *(Harpodon nehereus)* whether it is a catch from the Arabian Sea of the Bay of Bengal has the peculiarity of having very high moisture content (about 90 percent) and low protein content (about 10 percent). It is lean fish with < 1 percent fat in its flesh. (Nimish et al 2018)

**Protein**

 Approximately 14% of the world's demand for animal proteins and 4% to 5% of the total protein requirement are met by fish and shellfish (Venugopal, 1995). Fish proteins are highly digestible (85–95%) and contain a variety of amino acids. Fish are regarded as a fantastic source of high-quality protein since they are particularly rich in the essential amino acids lysine and methionine. The water-holding capacity and the gelling qualities that determine the textural attributes of the products are crucial quality parameters for goods like fish mince and surimi (Venugopal, 1995). In addition to having a high nutritional value, fish proteins also have good functional qualities like the ability to hold water, gel, emulsify, and have textural characteristics. Although the average protein content of fish muscle is between 16 and 21 percent, some species can occasionally have values as low as 16% or as high as 28%. Proteins are essential for the body's upkeep, tissue repair, and growth and development. The amount of protein in fish muscle depends on the species, nutritional status, and muscle type. Because they are abundant in lysine and other sulfur-containing amino acids like methionine and cysteine that are absent from plant proteins as well as other important amino acids in the right ratios, fish proteins have major biological relevance (as shown in table2).

**Table 2**: Fishes Rich in Particular Amino Acid (Nimish et al 2018)

|  |  |
| --- | --- |
| **Amino Acids** | **Species Recommended for Particular Amino Acid Deficiency** |
| Arginine  | *Oncorhynchus mykiss, Tor putitora, Neolissochilus hexagonolepis* |
| Histidine | *Rastrelliger kanagurta,Catla catla, Stolephorus waitei,Amblypharyngodon mola, Puntius sophore* |
| Isoleucine | *Oncorhynchus mykiss, Labeo rohita, Stolephorus commersonii* |
| Lysine | *Stolephorus commersonii,Thunnus albacores, Tor putitora* |
| Methionine  | *Stolephorus waitei, Tor putitora, Rastrelliger kanagurata* |
| Phenylalanine | *Cirrhinus mrigala, Catla catla , Labeo rohita* |
| Threonine | *Thunnus albacores, Nemipterus japonicus, Stolephorus waitei, Stolephorus commersonii* |
| Tyrosine | *Oncorhynchus mykiss, Tor putitora* |
| Valine | *Nemipterus japonicus, Cirrhinus mrigala, Rastrelliger kanagurta* |
| Tryptophan | *Tor putitora* |
| Glutamine | *Cirrhinus mrigala, Catla catla , Labeo rohita* |
| Glycine | *Cirrhinus mrigala, Catla catla , Labeo rohita* |
| Alanine | *Nemipterus japonicus, Labeo rohita, Catla catla*  |
| Aspartic acid | *Stolephorus commersonii, Nemipterus japonicus,Clarius batrachus* |
| Serine | *Stolephorus commersonnii, Nemipterus japonicas, Thunnus albacares* |

**Lipids**

 Lipids are chemicals that are formed from living creatures and are insoluble in water but soluble in organic solvents like chloroform, ether, or benzene. Their compounds also contain long-chain hydrocarbon groups. By creating a barrier separating the live cell from the outside, they play a critical role in maintaining the integrity of plants and animals as structural compounds. They are the principal source of cellular energy and function in living species where they may be stored. Fish's lipid content varies depending on the species and the time of year, but overall, fish has less fat than red meat. Between 0.2 and 25% of food is on average fat-free. Water content reduces as fat content rises and vice versa. As lipid-soluble vitamins (A and D) and essential fatty acids (PUFA), which have been shown to play an important role in preventing a number of human diseases, including cardiovascular ones, fish lipids are known to contain high concentrations of these essential nutrients for the human diet (Simopoulos, 1997). Marine fish lipids, in contrast to other lipids, frequently have longer-chain fatty acids and a higher proportion of highly unsaturated fatty acids. (Ackman 1989).

Table 3**.** Lipid Content of Seafood. (Nimish et al 2018)

|  |  |
| --- | --- |
| **Types of fish** | **Fat (%)** |
| Fatty fish | 10 |
| Lean fish | 0.5 |
| Crustaceans | 2.1 |
| Mollusks | 1.5 |

**Vitamins**

 Fish contains appropriate amounts of all the vitamins needed for human health, however the amounts vary widely from species to species and season to season. The body needs a variety of vitamins, and fish is an excellent provider of those vitamins. Vitamins A and D, which are crucial for a child's healthy growth and development, are abundant in oily fish. B vitamins are in white fish. Normal growth and development, the development of bones and teeth, cell growth, the prevention of vision impairment, and the treatment of a number of eye illnesses all depend on vitamin A. In addition to vitamins A and C, vitamin D encourages the effective absorption of calcium and phosphorus, two nutrients essential for strong bones and teeth. Enzyme efficiency and the speeding up of biological chemical processes depend on vitamin B. The prevention of internal bleeding is made possible by vitamin K's support of healthy blood coagulation. Salmon, trout, mackerel, herring, and other fatty fish have high vitamin A and D concentrations. Fish oil and vitamin E both lessen the inflammation, swelling, discomfort, and tenderness associated with rheumatoid arthritis. Fish contain vitamin K, which is what produces the anti-haemorrhage factor. (Anon 2017).

**Minerals**

 Fish is an excellent source of these nutrients since it includes between 0.4 and 1.5% (wet basis) of almost all the minerals found in seawater. Among the minerals contained in fish are iron, calcium, zinc (from marine fish), phosphorus, selenium, fluorine, and iodine. According to Balachandan (2002), these minerals have a high level of "bioavailability," which means that the body can easily absorb them. From a nutritional perspective, the iodine and selenium levels of marine fish is particularly significant. Children's growth and mental development, as well as the hormone thyroxin, which controls the body's metabolism, require iodine. Selenium is a crucial trace element for antioxidants. Iron is necessary for the production of haemoglobin, which transports oxygen throughout the body, in red blood cells. Calcium is important for the growth and mineralization of strong bones as well as for the proper operation of the neurological and muscular systems. The intake of calcium, phosphorus, and fluorine is increased when little fish are eaten alongside their bones as opposed to discarding fish bones (as shown in table 4).

 **Table 4: Some important mineral constituent of fish muscle Pal *et al.,* (2018).**

|  |  |
| --- | --- |
| **Element** | **Average value(mg/100g)** |
| Sodium (Na) | **72** |
| Potassium(K) | **278** |
| Calcium (Ca) | **79** |
| Magnesium (Mg) | **38** |
| Phosphorus (P) | **190** |

**Marine collagen**

 Collagens are a large family of triple helical proteins that are wide spread thought the body and are important for a broad range of functions for a board range of functions, including tissue scaffolding, cell adhesion, cell migration, angiogenesis, tissue morphogenesis and tissue repair. Collagen is well known as the primary tensile component of vertebrate tissues like tendon, cartilage, bone, and skin. It appears as elongated fibrils in the extracellular matrix. The presence of collagen in basement membranes, such as the renal glomerulus, where it is involved in molecular filtration, is another well-known property of the protein (Nimish et al 2018). Different types of collagen as shown in table 5.

 **Table 5:** The common five types of Collagen. (Nimish et al 2018)

|  |  |
| --- | --- |
| **Type** | **Source** |
| Type I | Skin, tendon, vascular ligature organ, bone |
| Type  II  | Main collagenous component of cartilage |
| Type III | Main component of reticulate fibres |
| Type IV | Forms basal lamina |
| Type V | Cell surfaces, hair and placenta |

**Beneficial role of fishes in human diet**

 Fish and fish products are great foods that are good for human health because of their nutritional qualities. Because they are a great source of nutrients, have a good balance of protein, vitamins, and minerals, and have a relatively low calorie content, fish and fish products play a huge role in the nutritional picture. Additionally, these qualities make them excellent sources of polyunsaturated fatty acids, which have been linked to positive outcomes in a variety of pathological conditions, including some forms of cancer and arthritis, and which seem to have beneficial effects in lowering the risk of cardio-vascular diseases. Pal *et al.,* (2018). Almost all the minerals present in fish which is required our body. The minerals present in fish iron (Fe), Calcium (Ca), Zinc (Zn), Phosphorus (P), Selenium (Se), Fluorine (F), Iodine (I). These minerals are with high bioavailability; they can easily have absorbed by the body.

According to FAO (1986), the strong demand for high-quality fish and fisheries products is largely a result of the nutrients and other beneficial elements they contain. The most important of them are fish lipids, which frequently include considerable amounts of omega-3 fatty acids, particularly -linoleic acid, eicosapentaenoic acid (EPA), and docosahexaenoic acid (DHA). Numerous ways the omega-3 fatty acids are beneficial to human health. These include lowering blood pressure and lipid levels in the blood, decreasing the risk of myocardial infarction Bucher et al., 2002, boosting the immune system Damsgaard et al., 2007, and maintaining healthy brain function in humans. They also guard against cancer and a variety of mental illnesses (1995) Caygill and Hill. Fish is an essential component in the human diet because of its outstanding nutritional content. They are an established source of polyunsaturated fatty acids (PUFAs), especially omega-3 and omega-6, which help prevent atherosclerosis and thrombosis. They are also a good source of B vitamins and fat-soluble vitamins, according to Erkan and Bilen (2010). These fatty acids have protective properties against autoimmune illnesses, arrhythmias, elevated blood pressure, and coronary heart disease. However, fish and fishery products offer more vital nutrients than only fatty acids; they are also a rich source of easily digestible protein and often have an amino acid profile that includes the majority of the essential amino acids needed by humans for a balanced diet.

Long-chain, polyunsaturated fatty acids (LC-PUFAs; acids with 20 or more carbon atoms and at least three double bonds) are the main components of cellular membranes. Graham and others, 2007.The majority of fish's nutritional advantages come from its extraordinarily beneficial fatty acid composition. LC-PUFAs are crucial for controlling physiological and metabolic processes. For these reasons, LC-PUFAs are included as one of the food components that are good for human health, according to Pond (1998). Fish lipids are essentially the only source of EPA and DHA. Adults who consume fish are known to experience health benefits. There is substantial evidence to support the claim that eating fish, particularly oily fish, lowers the risk of dying from coronary heart disease (CHD). The risk of dying from coronary heart disease can be decreased by up to 36% by consuming long-chain omega-3 fatty acids, which are mostly found in fish and fishery products. All demographics are affected by the widespread public health problem of CHDs.

The majority of the Inuit diet was made up of fatty fish and other sea creatures, which are rich in EPA and DHA among other things. According to Connor in 2000, EPA and DHA have a variety of properties that are advantageous to human health. They can enhance a number of bodily processes in addition to lowering the risk of some malignancies and cardiovascular disorders Calo et al., 2005; Wolk et al., 2006; and Berbert et al., 2005. Adults who consume 250 mg of EPA+DHA per day are most protected from coronary heart disease. Only 150 mg per day are necessary for children's brain growth to be at its best. This is important as the prevalence of brain diseases is sharply increasing and the expense of mental disorders is now more than the combined cost of CHD and cancer in the developed nations. Since fish are thought to be easily digestible, many of the nutrients are actually advantageous to the consumer. Fish that has been ethically farmed and in the wild makes for a healthy substitute for meat.

**Fish Consumption and the Metabolic Syndrome**

 The metabolic syndrome is a collection of often observed changes that are connected to insulin resistance, or a poor response to the hormone insulin. Obesity, especially abdominal obesity, is a significant risk factor for the emergence of insulin resistance and the metabolic syndrome. In addition to abdominal obesity, the metabolic syndrome also consists of hyperglycemia, high blood pressure, hypertriglyceridemia, low plasma HDL cholesterol (HDLc), and high plasma uric acid. According to Aguilar et al. (2019), having metabolic syndrome raises the chance of developing ischemic heart disease, stroke, and diabetes, including diabetic nephropathy, retinopathy, and neuropathy.

The impact of fish diet on the likelihood of developing metabolic syndrome has been examined in several research. The SEAFOOD Plus research (Ramel et al. 2009), which randomised 126 overweight people aged 20 to 40 to receive a diet with a 30% calorie restriction with or without 150 g/day of fish (cod), five times per week, for eight weeks, is one of the most significant interventional studies in this area. In addition to losing an additional 1.7 kg of body weight in comparison to the control group, participants who included fish in their diets also saw 3.4 cm drops in waist circumference and 5.2 mmHg drops in systolic blood pressure. Another important study is the Spanish WISHCARE experiment, in which 273 patients with metabolic syndrome were randomly assigned to receive either the same dietary counselling programme without the addition of fish for 8 weeks or the same programme with 100 g/day of white fish (Namibia hake). Waist circumference, diastolic blood pressure, and LDL cholesterol all decreased more dramatically after the fish group intervention (Vázquez et al. 2014).

**Conclusion**

 The nutritional makeup of fish has been interestingly explored in the current review, along with the many applications of using by-products of fish processing and preservative technologies to increase the shelf life of fish. To preserve the fish for a longer period of time, numerous processing procedures are being used. The three main causes of fish spoilage are enzymatic autolysis, microbiological decay, and chemical deterioration. Regulating these factors is essential if the fish are to be maintained for a long period. Appropriate procedures include freezing, employing antimicrobials and antioxidants, and super-chilling. Low-temperature treatments can efficiently inhibit enzymatic and non-enzymatic breakdown activities in addition to effectively suppressing microbial development. While several antimicrobial medications are successfully used to prevent bacterial growth, antioxidants are also used to minimise lipid oxidation. The most economical fish products are processed using a variety of technologies, including thermal and non-thermal treatments, to meet consumer demand with the least degree of quality loss. With little processing and the inclusion of chemical preservatives, the major goals of these technologies are to increase the shelf life of fish products, improve their nutritional value, extract items with a high added value, and prevent any negative consequences. Fish and fish products are important in the nutritional picture since they are a great source of nutrients, have a good balance of protein, vitamins, and minerals, and have a low calorie content. In addition to these advantages, it contains a lot of polyunsaturated fatty acids, which are thought to reduce the risk of cardiovascular and vascular illnesses and have beneficial effects on a number of other pathological disorders, such as some types of cancer and arthritis.

**Scope and Future Perspectives**

 The future of fish with respect to preservation and processing depends upon the industrial utilization of new technologies and progressive management of the factors related to fish parameters such as quality, nutritional requirements, prolonged shelf life, new developmental products, freshness and high yield. In order to make fish and fish products more dependable and user-friendly for future development, additional research is required to understand the impacts of processing and preservation factors on fish and fish products. In order to recover extremely valuable and novel products for the long-term advantage of society and the environment, it is still necessary to work on subsequent work and developing technology to discard diverse fish by-products.

**References**

Ackman, R., Fatty Acids, in Marine Biogenic Lipids, Fats, and Oils, Vol. 1, Ackman R, ed, CRC Press, Boca Raton, FL, 1989, 103.

Aguilar-Salinas CA, Viveros-Ruiz T. Recent advances in managing/understanding the metabolic syndrome. *F1000Res*. 2019; 8:370.

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, 10, pp. 690–719.

Anon 2017 https://www.delamaris.si/healthy-diet/that-fish-are-an-important-source-of-vitamins-and-minerals.

Balachandan K. Post-Harvest Technology of Fish and Fish Products, Daya Publishing House, New Delhi, 2002, pp.1-28.

Balami, S.; Sharma, A.; Karn, R. Significance of Nutritional Value of Fish for Human Health. Malay. J. Halal Res. 2019, pp. 32–34.

Berbert, A. A., Kondo, C. R., Almendra, C. L., Matsuo, T., and Dichi, I. (2005). Supplementation of fish oil and olive in patients with rheumatoid arthritis. *Nutrition,* 21(2), pp. 131–136.

Bucher HC, Hengstler PSC, Meier G. Polyunsaturated fatty acids in coronary heart disease: a meta-analysis of randomized controlled trials. American Journal of Medicine. 2002; 112 pp. 298-304.

Calo, L., Bianconi, L., Colivicchi, F., Lamberti, F., Loricchio, M. L., de Ruvo, E., *et al.,* (2005). Fatty acids for the prevention of atrial fibrillation after coronary artery bypass surgery: A randomized, controlled trial*. Journal of the American College of Cardiology,* 45(10), pp. 1723–1728.

Caygill CPJ, Hill MJ. Fish, n-3 fatty-acids and human colorectal and breast-cancer mortality. European Journal of Cancer Prevention. 1995; 4, pp. 329-332.

Connor, W. E. (2000). Importance of n 3 fatty acids in health and disease. *American Journal of Clinical Nutrition,* 71, pp. 171–175.

Damsgaard CT, Lauritzen L, Kjaer TMR, Holm PMI, Fruekilde MB, Michaelsen KF *et al*. Fish oil supplementation modulates immune function in healthy infants. The Journal of Nutrition. 2007; 137 pp. 1031-1036.

Erkan N, Bilen G. Effect of essential oils treatment on the frozen storage stability of chub mackerel fillet. Journal fur Verbraucherschutz und Lebensmittelsicherheit. 2010; 5(1) pp.101-110

FAO, FAO Food and Nutrition paper manuals of food quality control food analysis: quality, adulteration and tests of identity. Food and Agriculture Organization of the United Nations, Rome, Italy, 1986.

FAO. The State of World Fisheries and Aquaculture. Food and Agriculture Organization Rome, 2016, 200

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, pp. 303–325.

Graham, I. A., Larson, T., and Napier, J. A. (2007). Rational metabolic engineering of transgenic plants for biosynthesis of omega-3 polyunsaturates. *Current Opinion of Biotechnology*, 18, pp. 142–147

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, pp. 1779–1786.

Hasselberg AE, Aakre I, Scholtens J, Overå R, Kolding J, Bank MS, et al. Fish for food and nutrition security in Ghana: challenges and opportunities. Global Food Security. (2020) 26:100380. doi: 10.1016/j.gfs.2020.100380

Kates M. Techniques of Lipidology: Isolation, Analysis and Identification of Lipids, 1986.

Maulu S, Nawanzi K, Abdel-Tawwab M and Khalil HS . Fish Nutritional Value as an Approach to Children’s Nutrition. Front. Nutr. 8:780844. doi: 10.3389/fnut.2021.780844

OECD-FAO Agricultural Outlook 2018-2027. Paris; Rome: OECD Publishing /Food and Agriculture Organization of the United Nations (2018). doi: 10.1787/agr\_outlook-2018-en

Pal, J., Shukla, B., Maurya, A.K., Verma, H.O., Gayatri, Pandey, & Amitha (2018). A review on role of fish in human nutrition with special emphasis to essential fatty acid.

Pedro, S.; Nunes, M.L. Reducing salt levels in seafood products. In Reducing Salt in Foods, 2nd ed.; Wood head Publishing: Thorston, UK, 2019; pp. 185–211.

Pond, C. M. (1998). The fats of life. Cambridge, United Kingdom: Cambridge University Press

Ramel A, Jonsdottir MT, Thorsdottir I. Consumption of cod and weight loss in young overweight and obese adults on an energy reduced diet for 8-weeks. *Nutr* *Metab Cardiovasc Dis*. 2009; 19, pp. 690-696.

Simopoulos A. Nutritional aspects of fish, in Seafood from Producer to Consumer, Integrated Approach to Quality, Luten, J., Borrensen, T. and Oehlenschlager, J., eds., Elsevier Science, London, U.K., 1997, 589.

Sinn N. Physical fatty acid deficiency signs in children with ADHD symptoms. Prostaglandins, Leukotrienes and Essential Fatty Acids. 2007; 77, pp. 109-115.

Soyano, K.; Amagai, T.; Yamaguchi, T.; Mushirobira, Y.; Xu,W.-G.; Ph¤m, N.T.; Murata, R. Endocrine Regulation of Maturation and Sex Change in Groupers. Cells 2022, 11, 825.

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.

Vázquez C, Botella-Carretero JI, Corella D, et al. White fish reduces cardiovascular risk factors in patients with metabolic syndrome: the WISH-CARE study, a multicentre randomized clinical trial. *Nutr Metab Cardiovasc Dis*. 2014; 24, pp. 328-335.

Venugopal V. Methods for processing and utilization of low cost fishes: A critical appraisal. Journal of Food Science & Technology. 1995; 32, pp. 1-12.

Wolk, A., Larsson, S. C., Johansson, J. E., & Ekman, P. (2006). Long-term fatty fish consumption and renal cell carcinoma incidence in a population-based prospective cohort of women. *The Journal of the American Medical Association*, 296, pp. 1371–1376.

Ye¸silsu, A.F.; Özyurt, G. Oxidative stability of microencapsulated fish oil with rosemary, thyme and laurel extracts: A kinetic assessment. J. Food Eng. 2019, 240, pp. 171–182.