Innovations

# Exploring the Significance of Fish Nutrients in Human Health: A Review

**Komal and Sharali Sharma**
Biosciences-UIBT, Chandigarh University, Gharuan Mohali, Punjab, India

***Abstract***

*The present review explains the importance of fish for human nutrition and health by thoroughly examining their nutritional and biochemical makeup. This study emphasizes the distinct nutritional profile of fishes by means of a thorough evaluation of the literature and an investigation of important biochemical elements such proteins, carbohydrates, fats, minerals, amino acids and omega-3 fatty acids. The possible health advantages of fish consumption were also examined, including the prevention of cardiovascular disease, improvement of cognitive function, and anti-inflammatory qualities. Fish is a nutritionally significant food, providing essential omega-3 fatty acids, DHA and EPA, crucial for brain development, coronary protection, and immune response. Rich in vital minerals and vitamins like iron, zinc, magnesium, and Vitamins A, $B_{12}$, C and D, fish supports immune function and overall health, particularly important as people age. Comprehending the complex makeup of fishes is crucial for making informed dietary recommendations, as well as for developing sustainable fishing methods and aquaculture tactics that advance environmental preservation and public health. Fish consumption helps address nutrient deficiencies, especially in populations with limited food diversity, and supports broader socio-economic and environmental goals through sustainable fisheries and aquaculture. Establishing fishing industries in rural areas further enhances regional development and well-being.*

***Keywords:*** *Amino acid, fish, minerals, omega-3- fatty acid, Protein.*

## Introduction

Freshwater fishes are an excellent and low-cost animal protein with high biological significance for human populace. Fishes dwell in both marine and fresh water ecosystem. Fish makes up around 16% of all animal proteins and significantly improves the fatty acid, amino acid, lipid-soluble vitamin, and micronutrient requirements of people's everyday lives worldwide FAO (2000). Fish is more affordable and easily accessible, even in impoverished areas than other protein

sources. Aquaculture is also thought to be the most sustainable and effective method of producing high-quality proteins for human consumption (Maulu *et al.,* 2021).

Fish is a rich source of macronutrients such as proteins, fats, and carbohydrates, as well as micronutrients like vitamins and minerals. These nutrients are essential for maintaining good health (Srivastava and Srivastava, 2008). Macro and micro nutrients like protein, lipids, carbohydrates, vitamins and minerals add significant value to fish flesh (Kumar *et al*., 2020). Nutrients, including macronutrients such as amino acids, fatty acids, and carbohydrates, play a crucial role in providing energy and essential building blocks necessary for the body's proper growth and development. Fish can be a good source of various essential micronutrients that are vital for overall health. Different fish species contain varying levels of vitamins and minerals, including vitamin D, vitamin B12, iodine, selenium, and zinc. These nutrients are important for immune function, energy metabolism, brain health, and the maintenance of healthy bones, among other functions. Micronutrient deficiencies can cause metabolic disorders which can be reduced by inclusion of fish in the daily diet (Lips, 2001; Stoltzfus and Dreyfuss,1998).

Fish has the potential to increase protein and nutrient absorption from vegetables when added to the daily diet (Kawarazuka, 2010; Belton and Thilsted, 2013). Multiple studies have indicated that nutrients play significant roles in regulating energy expenditure, hormone secretion, and various metabolic processes in both humans and animals (Leathem, 1966; Da Poian et al., 2010; Chen et al., 2018; Lu et al., 2021). Fishes are easily digestible than meat and its daily consumption would be the enormousresource of calcium and fluorine required for the normal growth and development of strong teeth and bones (Springmann et al., 2018). Also, consumption of fatty fishes which contain omega-3 fatty acids in the form of docosahexaenoic (DHA) is necessary for optimal brain development and neural system in children (Hasselberg et al., 2020).

The demand of high quality fishes and fisheries products is increasing day by day due to their high nutritional status (FAO, 1986). Fishes are among the low-cost dietary animal protein source worldwide (Allam et al., 2020) which contributes to food and nutrition security (FAO, 2020). Fish, as a food, accounts for 75% of animal protein in developing countries (Willett et al., 2019). Less intake of protein leads to severe health problems. In children low intake of proteinous food causes stunted growth and poor development (Schonfeldt and Hall, 2012). It is reported that around 47 million children suffer from malnutrition due to less intake of iodine, vitamin A and iron (Ruel et al., 2018). Fish and fisheries products can help in mitigating the issues of malnutrition around the world. In particular, fishes are known to have good amount of protein, lipids, minerals and also indirectly positive impact on household income by providing an additional source of food and potentially reducing the need

to purchase more expensive staple foods (Kawarazuka, 2010). Fisheries also provide livelihoods and income opportunities for many communities worldwide. Fishing activities can support local economies, promote job creation, and contribute to the overall economic well-being of communities, particularly in coastal areas. This review considers the importance of fish nutrient diversity in maintaining the human health (Figure 1).

**Composition of biochemical components**

A vital component of human health is nutrition. Fish is a vital food source for humans. The minerals included in fish are essential for enhancing human health and preventing a host of ailments from developing. Nutrients such as micronutrients, fats, and proteins support human health in a variety of ways. However, a large number of human populace are not aware of health advantages of fish consumption (Balami *et al*., 2019). The nutritional profile, which is made up of proximate components of fish meat, provides an initial indication of the commercial standards of the fish that are necessary for food regulations (Marichamy *et al*., 2012). Appropriate knowledge of fish's proximate composition is now being applied in a growing number of profound fields, and nutritionists can identify easily accessible sources of high-protein, low-fat fish sources for human consumption by using knowledge of fish's chemical composition (Foran *et al*., 2005).

Fish varies in terms of their nutritional makeup; some are fatty and lean and some are more useful than others. A growing number of fish species are falling into the category of food fish as a result of information being available about the nutrient makeup of native fish from around the globe (Bogard *et al*., 2015). By analyzing the chemical makeup of fish flesh, scientists can reliably predict the fish's quality, nutritional value, physiological status, and habitat (Ravichandran *et al*., 2011). This analysis provide critical information for understanding overall health and environmental conditions of fish, which is required for developing high-quality, nutritious food products and ensuring sustainable fishery practices. It is stated that ash, fat, protein and moisture make up 96%–98% of a fish's body composition. The term "proximate composition" of fish refers to the assessment of these components (Begum *et al*., 2012; Rani *et al*., 2016). Protein, fat, ash,moisture, are the four key components that make up the biochemical composition of fish (Ahmed *et al.,* 2022). Fish typically contain 66–81% water, 16–21% protein, 1.2–1.5% minerals, 0.2–25% fat and 0–0.5% carbohydrates (Love, 1970). Fig. 1 shows the biochemical components of fish muscle tissue and their significance in maintaining human health.

**Moisture**

Water makes up the majority of any organism's body, including fish tissues and serves as a pathway for the transference of chemical energy, various nutrients and

other cytoplasmic processes (Aberoumand, 2014). According to Jolaoso *et al*. (2016) a good way to determine the relative quantity of protein, energy and fat is to look at the percentage of water. Moisture content has an inverse relationship with energy, lipid and amount of protein *i.e.* lower the percentage of water, higher the energy density and amount of proteins and lipids in the fish Aberoumand and Pourshafi (2010). The moisture content in the muscle of fish tends to increase as the fish matures. Immature muscles have the lowest moisture percentage, and this percentage tends to rise with the maturity stages (Ahmed *et al*., 2022).

**Fish as a protein rich source**

After moisture, protein is found to be high in fish muscle tissue.Proteins are an integral part of every cell and so make up the majority of muscle tissues, internal organs, brain, nerves, and skin. They are also the most abundant class of molecules in the organism. Since both too little and too much protein in the diet can impact growth and overall body maintenance, it is critical to gather information about fish's true protein needs in order to create ecologically friendly, affordable, and well-balanced meals (Zehra and Khan, 2012). Being composed of amino acids joined by peptide bonds, proteins are thought to be the most adaptable biomolecules. Fish proteins are known for their high digestibility, with about 85% to 95% of the protein being easily digested by the body. Additionally, they have a rich concentration of amino acids, making them a valuable source of this essential nutrient (Pal *et al.,* 2018).

The fish muscle has low-level connective tissue which makes it is more digestible than other animal protein (Ventakarman and Chezlian 2015). Regular consumption of fish protein, along with resistance exercise, can contribute to muscle growth, strength, and overall physical performance.Adequate amounts of fish protein in meals can help promote feelings of fullness and reduce overall calorie intake. This can be beneficial for weight management and weight loss efforts. It also supports the efficient functioning of metabolic processes and contributes to energy production in the body Unlike plant protein, fish protein is of high biological value as it possesses essential amino acid, especially methionine and cysteine. Fish protein is also known to have antioxidative, antithrombic and antihypertensive properties. It performs its role in preventing bacterial and viral infections and also maintains water balance in human body (Arino *et al*., 2012) Fish protein has an important role in combating malnutrition. Malnutrition occurs due to inadequate intake of proteins and energy rich food. A well known condition, Kwashiorkor, occurs when children do not get nutrient rich food, particularly proteins in their diet.

Fish is often thought to have a significantly better satiety impact and a lower unit cost of production when compared to other dietary protein sources like mutton, cattle, and chicken. In addition, for maintaining human water balance and

electrolyte systems, the protein immunoglobins play a crucial role in defending the body against bacterial and viral infection (Balami *et al*., 2019). Fish is a valuable source of high-quality animal proteins. Studies have shown that fish protein can provide a greater feeling of fullness compared to other animal proteins such as beef and chicken. Additionally, there is a wide variety of fish species available in tropical as well as temperate countries, making it an affordable dietary choice over another animal protein source. Therefore, fish offers a diverse selection, which can be advantageous for consumers. This is especially important considering the prevalence of two forms of child undernutrition - Kwashiorkor and marasmus - which are significant global health concerns.

**Fish as an amino acid source**

Amino acids are vital biomolecules that function as intermediates in a number of metabolic processes in addition to being the building blocks of proteins. They act as building blocks for the synthesis of several physiologically significant compounds, such as neurotransmitters, peptide hormones, and nucleotides (Mohanty *et al*., 2014). The human body requires nine amino acids that are considered essential for a healthy diet. These amino acids, including valine, isoleucine, leucine, lysine, methionine, threonine, tryptophan, histidine, and phenylalanine, cannot be synthesized by the body and must be obtained from protein-rich foods (Sheeshka and Murkin, 2002). All of the necessary, easily digested amino acids are found in fish protein. The majority of the digested and absorbed protein is found in the fish muscles (Rani *et al*., 2016). To facilitate the formation of non-essential amino acids, enzymes, antibodies, peptide hormones and proteins, nitrogen, which is essential for these processes, is sourced from protein. The precise ratios and levels of a protein's necessary amino acids, as well as the protein's bioavailability and digestibility, are the primary factors that determine its quality (Sarma *et al.,* 2018). The nutritional value of proteins primarily depends on the content of amino acids, and fish, like other animals, only need proteins to obtain the amino acids that form new proteins (Ahmed *et al*., 2022).

**Fish as a source of fats**

Fat, which is mostly found in the subcutaneous tissue, liver, muscle fibers, mesenteric tissue, belly region and head, is regarded as the third main component of fish muscle and is typically reported to be between 6% and 20% (Ahmed *et al*., 2022).Furthermore, membrane-mediated functions like osmoregulation, food absorption, and transport depend heavily on lipids and fatty acids (Sujatha*et al*., 2013). Fish's fatty acid content varies depending on a number of parameters, like fish species, nutrition and environmental elements like salinity, season, temperature and geographic features (Tasbozan and Gokce, 2017). Polyunsaturated fatty acids

(PUFA) such as EPA and DHA make up a major portion of fish oil and fat. In general, practically all fish have these fatty acids. Nonetheless, research has shown that marine fishes, especially those from high latitudes, have generally higher concentrations of these fatty acids than do tropical low-latitude species (Garrido*et al*., 2008; Ahmed *et al*., 2022)

**Fish as an Omega-3 fatty acid source**

Human immunosuppressive reactionsincluding pain and fever are elevated by eicosanoids synthesized from n-6 (PUFA), whereas eicosanoids synthesized from n-3 (PUFA) have pro-inflammatory qualities. But it has also been discovered that EPA has a significant role in enhancing cardiovascular health (KhaliliTilami and Sampels, 2018).According to numerous research, fish tissues contain significant amount of both docosahexaenoic acid and eicosapentaenoic acid. Human nutrition has been demonstrated to be significantly impacted by these polyunsaturated fatty acids. Furthermore, they have the ability to treat and prevent a wide range of illnesses in humans, including inflammation, cancer, rheumatoid arthritis, and cardiovascular disorders (Njinkoue *et al*., 2016). Since the human body and other higher species are unable to synthesize alpha-linoleic acid, it is known as a "essential fatty acid." ALA can be transformed into other longer n-3 fatty acids (eicosapentaenoic acid and docosahexaenoic acid). Since the human body cannot effectively generate longer n-3 fatty acids, adequate quantities must be obtained through fish diet (Derbyshire, 2019).

Fish is known for containing high levels of omega-3 fatty acids, particularly α-linolenic acid, eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). These omega-3 fatty acids have been extensively studied for their cardiovascular benefits, including reducing triglyceride levels, lowering blood pressure, decreasing the risk of abnormal heart rhythms, and improving overall heart health (Vandongen *et al.*, 1993). The omega-3 fatty acids can decrease the risk of myocardial infarction (Bucher *et al.*, 2002), prevent cardiovascular and coronary heart diseases (Innes and Calder, 2020). Signalling molecules, Resolvins and Marisen 1, derived from omega-3 fatty acids have their role in resolving inflammation and platelet aggregation inhibition. They also provide protection against psychological disorders, depression (Sinn, 2007), cancer (Caygill and Hill, 1995) and also boost the immune system (Damsgaard *et al.*, 2007). Omega-3 fatty acids are known for their anti-inflammatory and anti-thrombotic properties, which can help to reduce inflammation and prevent blood clots, on the contrary, omega-6 fatty acids promote inflammation and thrombus development (Lee, 2013). Fatty acids serve as ligands for G protein-coupled receptors and transcription factors of nuclear receptor family (Huang *et al*., 2010; Husted *et al*., 2017) thus regulating cellular processes and gene expression

(Georgiadi and kersten, 2012). Palmitic acid has been found to induce endoplasmic reticulum stress whereas oleic acid inhibits endoplasmic reticulum stress (Pardo *et al*., 2015; Ricchi *et al*., 2009).

Eating fish can positively impact eyesight. DHA, a major structural component of the retina, is crucial for maintaining optimal vision and eye health. Consuming sufficient omega-3 fatty acids, particularly DHA, has been linked to a decreased likelihood of developing age-related macular degeneration, a prevalent cause of vision impairment in the elderly. DHA play a crucial role during pregnancy and early childhood by supporting the optimal development of the fetal brain and eyes. Proper intake of omega 3 fatty acids reduces the risk of preterm delivery and low birth weight. Dietary fats provide energy and play a significant role in the absorption of fat-soluble vitamins A, D, E, and K. Additionally, EPA, a type of omega-3 fatty acid, is recognized for its ability to improve blood circulation and reduce cholesterol levels in the blood (Tani *et al*., 2013). DHA corresponds to 50% of fatty acids in phosphatidylethanolamine and phosphatidylserine which causes rapid transmission of light in eyes (Chouinard-Watkins *et al*., 2019). Fish consumption also assists in preventing cataracts in old age persons (Fernandes, 2012).

**Ash as main component**

It is said that, for fish, ash typically serves as a substantial source of nutrition (Ndome *et al*., 2010). Ash represents inorganic waste that refers to the residue left behind after the combustion of all organic materials. It typically accounts for about 0.5% to 5% of a fish's overall body weight, ranking fourth in terms of quantity (Adewumi *et al*., 2014). Ash, which reflects the entire inorganic content or mineral content of the fish edible tissue, is associated to the detection of minerals in fish, making it most dependable method for examining the mineral composition of fish (Ahmed *et al.,* 2022). According to Rahman *et al*. (2020), the mineral concentration in fish and shellfish can vary due to several factors such as species, diet, salinity, temperature, seasonal changes, and geographical location.Minerals play an important role in sustaining biological processes like the production of hemoglobin and acid-base equilibrium. Additionally, they play an essential role in the development of bone and teeth, regulation of water and salt balance in the body and act as both activators and inhibitors in a wide range of enzyme-catalyzed or metabolic processes (Duran *et al*., 2010; Njinkoue *et al*., 2016)

**Fish as source of vitamins and minerals**

Vitamins are substances that the body needs in trace amounts. Vitamins are necessary for many bodily functions as well as the preservation of the blood, mucous membranes, skin, bone, eyes, nerves and brain. Fish is a great way to get vitamins. Fishes also found to be a rich source of vitamins namely, vitamins A, D, B1 (thiamin),

riboflavin (B2), and niacin (B3). Vitamin A assists in normal vision and teeth and bone growth, maintains cell development and also contributes to the treatment of various eye-related diseases (Hernandez and Hardy, 2020). Fatty fishes contains more amount of vitamin A than lean species. Fresh fish also holds little amount of vitamin C, which shows wound healing properties, maintains tissue integrity and assists in iron absorption in the nervous system (Thilsted *et al*., 2016).

Fish liver and fish oils contain Vitamin D which is crucial for bone growth. Many species of fishes store large amount of vitamin A and D in their liver due to their role in calcium absorption and metabolism (Roth *et al*., 2018; Pal *et al*., 2018). Vitamin D can also prevent skin diseases and cure skin diseases such as psoriasis. Vitamin D is also involved in muscle strength and contraction (Lisa, 2009) normal insulin production (Chertow *et al*., 1983). Vitamin D deficiency is associated with inflammatory vaginitis (Peacocke *et al*. 2008) and bacterial vaginosis (Bodnar *et al*. 2009). Thiamin, niacin and riboflavin are essential for energy metabolism (Roth *et al*., 2018). Vitamin K is known for blood coagulation and prevents internal bleeding in the body while Vitamin B speeds up enzyme functioning (Khalili and Sampels, 2018).Vitamins A and D (both $D_3$ and $D_2$) are found in fish, which is a very significant source for healthy vision and bone mineralization, particularly (Sarma *et al*., 2018).The smallest amount of vitamin C, which is necessary for wound healing, tissue integrity and helps the neurological system to absorb iron, can be found in fresh fish ( Thilsted *et al*., 2016).

Fish is the major contributor of mineral elements and contain a variety of mineral elements including sodium, potassium, calcium, iron, zinc, selenium, iodine, phosphorus (Marques *et al*., 2019) . Mineral elements are categorized as macro elements and micro elements depending upon their requirement inside the body. The essence of macroelements (calcium, magnesium, sodium and potassium) and microelements (copper, iodine, iron, manganese selenium and zinc) have been confirmed in fish. Macroelements are needed for human health (Ersoy and Çelik, 2009). The low intake of these mineral elements slows blood clotting procedure and causes osteoporosis, anemia, *etc.* (Mills, 1981; Watanable *et al*., 1997; Fumio *et al*., 2012). Various interactions between mineral–mineral and mineral–vitamin have also been reported in fishes (Hilton, 1989). Mineral nutritional status of fishes has received limited attention. The consumption of small fishes as a whole can contribute significantly towards micronutrients intakes.

The inorganic elements known as minerals are necessary for maintaining of important structural elements and metabolic functions in animals. These vital minerals are primarily responsible for the development of the fish's skeleton, for the appropriate functioning of the colloidal system, and the control of the acid-base equilibrium. They are also crucial parts of enzymes, hormones, and enzyme

activations. Muscle contraction and nerve impulse transmission both depend on minerals. They also function as soft tissue's structural components (Zehra *et al.,* 2022).The human body requires macro minerals, or significant amounts of inorganic elements including calcium, magnesium, phosphorous, sodium, and potassium, to carry out numerous critical physiological functions. Although necessary in trace levels, the microminerals (iron, copper, zinc, manganese, selenium, etc.) are crucial for the body's regular functioning (Mohanty et al., 2016).

**Calcium**

Fish is also considered a significant source of calcium like other foods such as dairy products, leafy greens, and fortified plant-based milks. Calcium in fishes is found to be 80 times more than milk, and in fishes Ca has the similar bioavailability as milk (Larsen *et al.,*2000). Nearly 86% of the calcium intake from fish comes from small fish. However, certain fish, particularly those consumed with their bones, can provide a modest amount of calcium. It has been reported that small sized fishes contain higher amount of Ca than large sized fishes (Sharma and Singh, 2022). Also, in fish muscle Ca dominates other mineral elements as studied by Sharma and Singh (2020) and Sharma *et al*. (2020). Smaller fishes are reported to have a higher calcium content compared to larger fishes, making them an excellent source of this essential mineral. Calcium is useful for bone formation, muscle contraction and relaxation and the nervous system (Sihotang *et al*., 2019). Insufficient calcium intake can elevate the likelihood of developing hypertension, obesity, premenstrual syndrome, and polycystic ovarian syndrome. (Mayanglambam and Chungkham, 2018). Small sized fishes consumed with bones also provide a combination of nutrients beneficial for bone health. These include not only calcium but also vitamin D, omega-3 fatty acids, magnesium, and phosphorus. These nutrients work synergistically to support bone health and overall well-being. Adequate intake of vitamin D and other nutrients that support calcium absorption is important for optimal utilization of dietary calcium.

**Magnesium**

Magnesium plays vital role in the formation of cell and bone, activation of vitamin B, haemostasis, nucleic acid synthesis, muscle relaxation and energy metabolism (FAO/WHO, 1998; Quratulan and Levent, 2015).Increased consumption of magnesium has been linked to a reduced risk of developing respiratory issues.

**Potassium**

Fish is a valuable dietary source of potassium, an essential mineral that is important for maintaining overall health. Potassium is an essential electrolyte that works in conjunction with sodium to maintain fluid balance in the body. It is necessary for blood pressure regulation, cardiac diseases, proper functioning of kidneys,

carbohydrate metabolism, nerve and muscle impulse conduction and acid-base equilibrium (WHO, 2012). Moreover, potassium plays a crucial role in regulating muscle function, blood pressure, and maintaining the balance of minerals in the body (Bellows and Moore, 2013). Potassium helps counterbalance the effects of sodium and relaxes blood vessels, which promotes healthy blood pressure levels.Including fish food in the diet can be part of a strategy to support blood pressure regulation. Potassium has the ability to reduce the chances of cardiovascular diseases (IFIC, 2011). Adequate potassium intake contributes to promote heart, kidney and bone health.

**Sodium**

Sodium plays a crucial role in the body by aiding in the conduction of nerve impulses, facilitating muscle function, contributing to the production of adrenaline hormone, and helping to maintain electrolyte and acid-base balance. (Pirestani *et al*., 2009). Sodium is a vital electrolyte that is responsible for regulating fluid balance and controlling blood pressure within the body. Proper sodium levels are crucial for overall health, but consuming too much sodium can upset this balance and lead to high blood pressure, increasing the risk of developing cardiovascular diseases.

**Iron**

Fish is known to be an excellent source of iron, an essential mineral that plays a crucial role in various bodily functions.. Iron is an essential element needed for survival and growth of organisms (Valko *et al.*, 2005). Iron is a key component of enzymes involved in metabolic processes.Iodine is a vital component for the production of hormones, particularly thyroxin, and plays a crucial role in regulating the body's metabolism. Additionally, iodine is involved in the synthesis of hemoglobin, a protein that serves the important function of transporting oxygen throughout the body's tissues and organs. (Vuori, 1995).Iron assists in immunity, healing and growth. Deficiency of this microelement causes anemia and impaired brain function. It is estimated that the absorption of heme iron from fish can be as high as 15-35%, compared to non-heme iron found in plant-based foods, which is typically absorbed at a lower rate of around 2-20%. Iron is more needed by women and children than men. Children’s needs iron for proper growth of the body (Mogensen, 2001). Iron plays a vital role in the growth and survival of nearly all living organisms. Incorporating fish in daily diet can be particularly beneficial for individuals at risk of iron deficiency or those with increased iron needs, such as pregnant women, growing children, and individuals with certain medical conditions like anemia. Including fish in a balanced diet, along with other iron-rich foods like legumes, fortified cereals, and leafy green vegetables, can help meet the body's iron requirements and maintain optimal health.

**Copper**

Copper is a crucial microelement needed for proper cell functioning of all organisms. Copper is involved in iron metabolism and utilization. It helps in the absorption of dietary iron from the intestines and its transport within the body.Cu is a cofactor for numerous enzymes involved in various physiological processes Copper metalloenzymes- cytochrome c oxidase, superoxide dismutase and tyrosinase have their role in cellular energy production, cell protection from free radical damage and melanin production (Linder, 2002). Various pathophysiological conditions can arise due to metabolic changes in Cu-requiring proteins (Harris, 2003). Copper is necessary for proper immune system function and have role in the development and activity of immune cells and contributes to the body's defense against infections and diseases. Ingesting high amounts of copper can lead to oxidative stress, which can cause damage to cells and tissues in the body. It can also result in a loss of sense of smell and disrupt the balance of acids and bases in the body. (Grosell, 2012; Bury *et al*., 2003). Copper, along with other minerals like zinc and manganese, is involved in bone formation and maintenance. It supports the activation of enzymes needed for collagen synthesis, which is important for bone health and integrity

**Selenium**

Selenium has antioxidant properties and performs variety of functions in the form of selenoproteins which have their role in normal thyroid function and acts as cofactor for inactivation of glutathione peroxidase, an oxidant enzyme (Gorini *et al*., 2021). It plays a crucial role in preventing cellular damage and supports the proper functioning of the immune system.

**Manganese**

Manganese plays a crucial role in the metabolism of proteins, the mineralization of bones, and the protection of cells from damage caused by free radicals (Aschner and Aschner, 2005). Manganese is needed for enzyme activities and constitutes several metalloenzymes (Leach *et al*., 1997).

**Zinc**

Fish is indeed a rich source of zinc After Fe, Zinc is most crucial microelement important to all cells in most organisms (Vallee and Falchuk, 1993). Small fish species are an excellent source of zinc, an essential mineral that plays a crucial role in various bodily functions (Thilsted, 2012). Zn shows its ubiquitous distribution among cells and is the most abundant intracellular microelement that performs catalytic, structural and regulatory functions. Zinc along with proteins plays a role in

signaling and metabolic pathway (Maret, 2013) and deficient zinc level is associated with growth retardation, skin changes and loss of appetite (Tuzen, 2009). Zinc assists in gene expression and regulatory functions like apoptosis and synaptic signaling (Hotz and Brown, 2004).

**Phosphorus**

Phospholipids, the major component of cell membrane, contains Phosphorus. This micro element is also a part of adenosine triphosphate (ATP) in the body (Soetan *et al.*, 2010). Like calcium, Phosphorus assists in bone and teeth formation. Small fishes eaten whole, represents the good source of phosphorus (Michaelsen *et al.*, 2009). Phosphorus deficiency leads to osteomalacia In adults (Soetan *et al.*, 2010).

**Immunological functions of minerals and vitamins**

It is evident that minerals and vitamins play important role in immune function and human health. It is prudent to note that vitamins and minerals have their contribution in boosting the immune system to protect against inflammation, infections and diseases. Fe has a role in the proliferation of T-cells, and development of cytokines (Ginefra *et al*., 2021)). Zinc plays a crucial role in supporting the optimal function of the immune system by contributing to the development of cytokines in monocytes and T-cells. Inadequate zinc intake can negatively impact both innate and acquired immunity, affecting processes such as phagocytosis, the development of natural killer cells, and the reduction in the number of T-cells (Fraker and King, 2004; Allen *et al*., 1983). During aging, low intake of zinc can result in reduced activity of the thymus and thymic hormones, leading to a decreased response to vaccinations and impaired functions of innate immune cells (Haase and Rink, (2009). Magnesium is also found to involve in both innate and acquired immune response (Tam *et al*., 2003) andMagnesium plays a crucial role as a co-factor in the synthesis of immunoglobulins, antibody-dependent cell lysis, binding of IgM to lymphocytes, and the adherence of T helper cells to B cells (Galland, 1988).

Vitamin B 12 has role in developing the cellular immune response and restores increased CD4/CD8 ratio (Tamura *et al*., 1999). Adequate intake of Vitamin A helps to slowdown aging, immunity of cell and degenerative diseases (Huang *et al*., 2018). Vitamin C increases the strength and defense of organisms ultimately stimulate the immune system. Vitamin D has its crucial role in eliciting immune response. It is involved in innate response by activating Toll-like receptors (TLR) which increases the expression of vitamin D receptors (Di Rosa *et al*., 2011). Vitamin D also has an inhibitory effect on B cell proliferation, thereby preventing their differentiation. (Medrano *et al*., 2018). The immune response generally declines as people age due to reduction in number and quality of immune cells which ultimately

leads to chronic or acute diseases. So, a proper nutrient rich food may be helpful to mitigate health problems.

**Conclusion**

Fish is a crucial part of a diet that is rich in nutrients, providing important pre-formed long-chain polyunsaturated fatty acids like DHA and EPA, which are unmatched by any other food sources. These omega-3 fatty acids are important for brain development, protection against heart disease, and immune response. Fish also contains valuable minerals and vitamins such as iron, zinc, magnesium, Vitamin B12, A, C, and D, all of which play vital roles in supporting immune function and overall health. As individuals age, the decrease in immune response highlights the significance of nutrient-rich foods, and fish consumption can help address nutrient deficiencies, especially in populations with limited access to diverse and nutrient-dense foods. Additionally, sustainable management of fisheries and responsible aquaculture practices are crucial for conserving fish populations and protecting ecosystems. The creation of a fishing industry, particularly in rural areas, can promote regional development and improve infrastructure, transportation networks, and access to basic services, thereby enhancing the socio-economic well-being of these communities. Therefore, fish not only significantly contributes to public health and human well-being through its high protein and omega-3 fatty acid content, but also supports broader socio-economic and environmental objectives.

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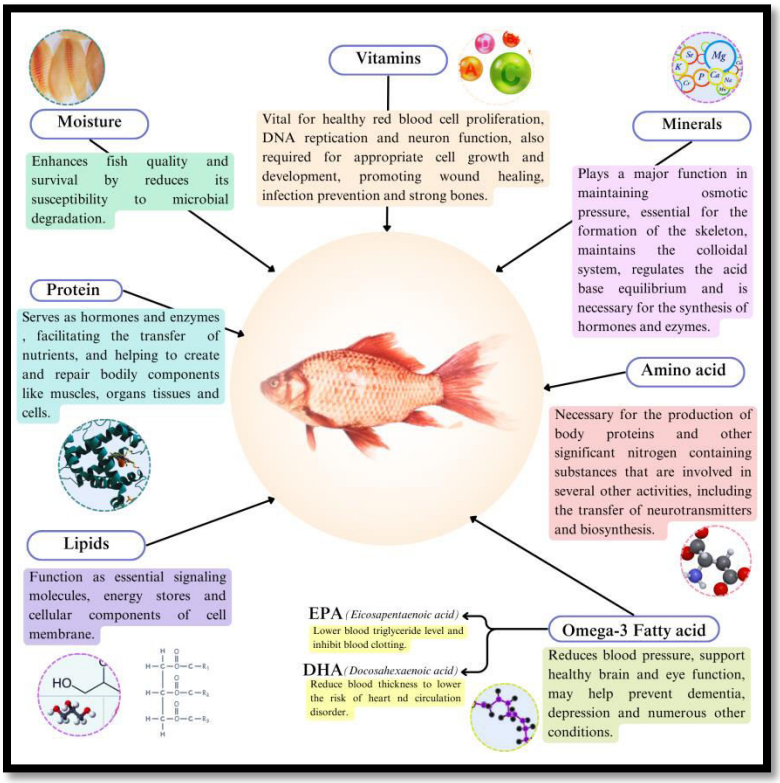


**Fig.1: Various biochemical components in fish and their significance**


**Fig. 2: Significance of different mineral elements**