Role of aquatic resources in food and nutrition

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Our food systems are predominantly focused on agriculture and livestock. Aquatic resources or the diversity of aquatic foods, both nutritionally and ecologically can be harvested in various contexts and geographies to improve local and regional food security. Though large commercial fish species tend to receive the majority of attention in diverse aquatic foods from coastal and inland waters. These are crustaceans, seaweeds, oysters, cockles or small indigenous fish species.

Aquatic foods are diverse and packed full of micronutrients and essential fatty acids, which also increase the bioavailability of other nutrients. They support the uptake and absorption of nutrients from other foods. Furthermore, they provide over 3.3 billion people with 20 percent or more of their animal protein intake.

Capture fisheries constitute the largest wild-food resource, providing a critical nutrient-rich food source to people in low- and middle-income countries. Their role is often overlooked in global food security initiatives. Aquatic foods are further left out of food system research, investments and policies. Yet they are essential in transforming food systems towards more equitable and sustainable outcomes—particularly in improving food access to the two billion people undernourished globally.

The variety of aquatic food systems also creates a range of jobs along supply chains in both primary activities and secondary postharvest activities like fish processing, transport or retail. In the case of aquaculture, there's also a host of external activities, such as developing fish feeds or breeding parent stock to create genetically improved fish seed.

Around the world, approximately 800 million people depend on small-scale fisheries and aquaculture for their livelihoods, particularly in underdeveloped regions.

Aquatic Foods

Foods like shrimp, salmon, squids and lobster are often categorized as "seafood" which are the resources from aquatic environment.

But how can we classify these foods when including a freshwater fishes?

The term *aquatic foods* (also called ***blue foods***), which include any animals, plants, and microorganisms that originate in bodies of water. Examples are as follows:

Finfish—small pelagic fish (herring, sardines, anchovies), medium pelagic fish (bonito, mahi-mahi), large pelagic fish (tuna, swordfish), salmonids (salmon, trout), carps, cichlids (tilapia), cods (cod, haddock, pollock), and demersal fish (flounder).

- **Crustaceans**—crabs, shrimp, krill, prawns, lobster.
- **Cephalopods**—octopus, squid.
- **Mollusks**—clams, cockles, sea snails, mussels, scallops.
- **Aquatic plants**—water spinach (*Ipomoea aquatica).*
- **Algae**—seaweed.
- **Other aquatic animals**—mammals, insects, sea cucumbers, mammals,

Aquatic foods can be farmed or wild-caught, and are sourced from inland waters like lakes, rivers, and wetlands; coastal areas like estuaries, mangroves, or near-shore; and marine or ocean waters. Despite currently being an important contribution to healthy diets for billions of people globally. But, aquatic foods are often undervalued nutritionally because their diversity tends to be restricted to protein or energy value, or framed as a monolithic category of "seafood or fish."

There is a broad diversity of aquatic foods produced throughout the world and available during every season. Currently, wild fisheries harvest over 2,370 species and aquaculture growers farm approximately 624 species.

Aquatic foods are so nutrient rich and food technologists have innovated methods to create processed fish products, including fish powders for infants, fish wafers as a snack, and fish chutneys.

Aquatic Foods and Health

Certain aquatic animal foods are a major dietary source of two polyunsaturated omega-3 fatty acids (PUFAs)—docosahexaenoic acid (DHA) and eicosapentaenoic acid (EPA). These fatty acids are initially produced by certain types of algae, which are then eaten by aquatic animals so that the fats accumulate in their tissues or organs. Omega-3s are found in all aquatic foods, but particularly in the fatty tissue of oily fish like salmon and mackerel, the liver of lean white fish like cod and halibut, and the blubber or thick layer of fat under the skin of marine animals like seals and whales. Smaller amounts are also found in crustaceans, bivalves, and cephalopods. Supplements of fish oil, algal oil, and krill oil also contain DHA and/or EPA. But, much of the research on aquatic foods and human health focuses on these omega-3s.

Human Health and The Planet's Health

Modern production of aquatic foods can be split into two different sectors: (1) wild capture and (2) aquaculture.

(1) **Wild capture** production involves harvested wild fish and other aquatic species from the ocean and freshwater sources.

(2) **Aquaculture** is the practice of farming aquatic plants and animals both in freshwater and marine environmental condition.

In general, the production of any animal-based food tends to have higher greenhouse gas emissions than the production of plant-based foods, with red meat (especially beef and lamb) standing out for its disproportionate impact.

But, the production of aquatic foods (through both wild capture and aquaculture) not only produces fewer greenhouse gas emissions and uses less land than red meat production, but many aquatic animal foods also have less environmental impact than poultry production. So, it is important to consider where and how aquatic foods are produced, since environmental as well as social and economic impacts can vary widely in both wild capture and aquaculture sectors.

Fish nutrition

Aquatic resources play an important role in food and nutrition by providing fish and other marine and freshwater products.

Fish is an excellent source of high quality animal protein that is easily digestible.

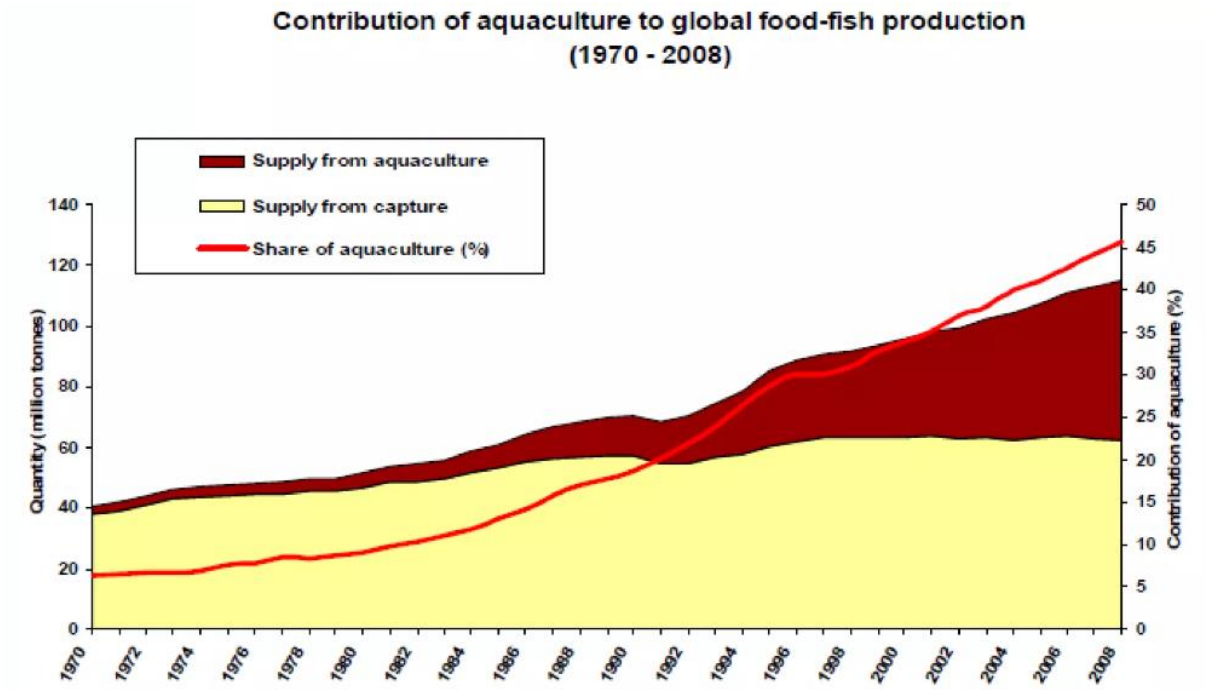
Fat of fish is the rich source of essential fatty acids which are important for normal growth and mental development.

Global aquaculture

Aquaculture is the fastest growing food-producing sector in the world.

Global aquaculture production all-time high of 90.4 million tonnes in 2012, including 66.6 million tonnes of food fish and 23,8 million tonnes of aquatic algae.

China alone produced 43.5 million tonnes of food fish.



Nutritional Facts of Fish

Fish (1 oz, boneless, uncooked; yield after cooking) has:

- 30 calories
- 0.7g of fat
- 5.5g of protein

0g of net carbohydrates

Fish is a low-fat high quality protein. Fish is filled with omega-3 fatty acids and vitamins such as D and B2 (riboflavin). Fish is rich in calcium and phosphorus and a great source of minerals, such as iron, zinc, iodine, magnesium, and potassium.

It is a relatively cheap in cost and easily accessible source of animal protein for human consumption even in rural communities. It is critical for global food and nutrition security, and its consumption continues to increase. As a highly nutritious food, fish consumption is highly recommended for persons including children and expectant mothers for normal growth and development. The nutritional value of fish is a valuable source of essential amino acids (EAA) and polyunsaturated fatty acids (PUFAs) that play important physiological functions for maintenance and development of infant and adult brains. Therefore, it could be a valuable tool in the fight against food insecurity and malnutrition. Fish and fish products are highly susceptible by various organic and inorganic compounds which threaten public health. Particularly, heavy metals and biogenic amines (BAs) have shown adverse effects when

contaminated fish is consumed. Hence, while fish consumption is highly recommended for nutrition. The quality and safety of the product should always be checked to safeguard public health.

The American Heart Association recommends eating fish at least two times per week as part of a healthy diet. Fish is packed with protein, vitamins, and nutrients that can lower the blood pressure and help to reduce the risk of stroke or heart attack.

Fish Nutrition of different fishes

Comparing fish calories and nutrition data can be tricky because the way we prepare our fish can change its nutritional makeup significantly. The exact nutrition of fish also varies depending on the variety.

But as an example, 1/2 of a wild **Atlantic salmon** fillet (154g) contains 280 calories, 12.5g of fat, most of which is monounsaturated and polyunsaturated, 86mg sodium, 39.2g of protein, and no carbs, fiber, or sugars.

Calories: 280

Fat: 12.5g

Sodium: 86mg

Carbohydrates: 0g

Fiber: 0g

Sugars: 0g

Protein: 39.2g

We can compare other types of fishes using the following guide based on **USDA** nutrition data. Fish calories and nutrition are listed for a 100 gram (3.5-ounce) serving.

Halibut (raw with skin): 116 calories, 3 grams fat, 0 grams carbohydrate, 20 grams protein.

Tuna (yellowfin, fresh, raw): 109 calories, less than one gram fat, 0 grams carbohydrate, 24 grams protein.

Cod (Atlantic, raw): 82 calories, 0.7 grams fat, 0 grams carbohydrate, 18 grams protein.

Mahimahi (raw): 85 calories, 0.7 grams fat, 0 grams carbohydrate, 18.5 grams protein.

Ocean perch (Atlantic, raw): 79 calories, 1.4 grams fat, 0 grams carbohydrate, 15 grams protein.

The best fish for weight loss and improved health is fatty fish. But not just any fatty fish. Certain types of fish contain an essential fatty acid called omega-3. This polyunsaturated fat provides our body with important health benefits.

Fish that contain omega-3 fats help to reduce the risk of heart disease. According to the National Institutes of Health, studies show that people who eat seafood at least once per week are less likely to die of heart disease. Researchers also believe that the omega-3 fatty acids found in fish may help to reduce symptoms of rheumatoid arthritis and may even help to improve brain and eye health.

We can get essential omega-3 fatty acids by taking a supplement. But research has not been able to show that taking a supplement can provide the same benefits as eating omega-3 foods, like fish.

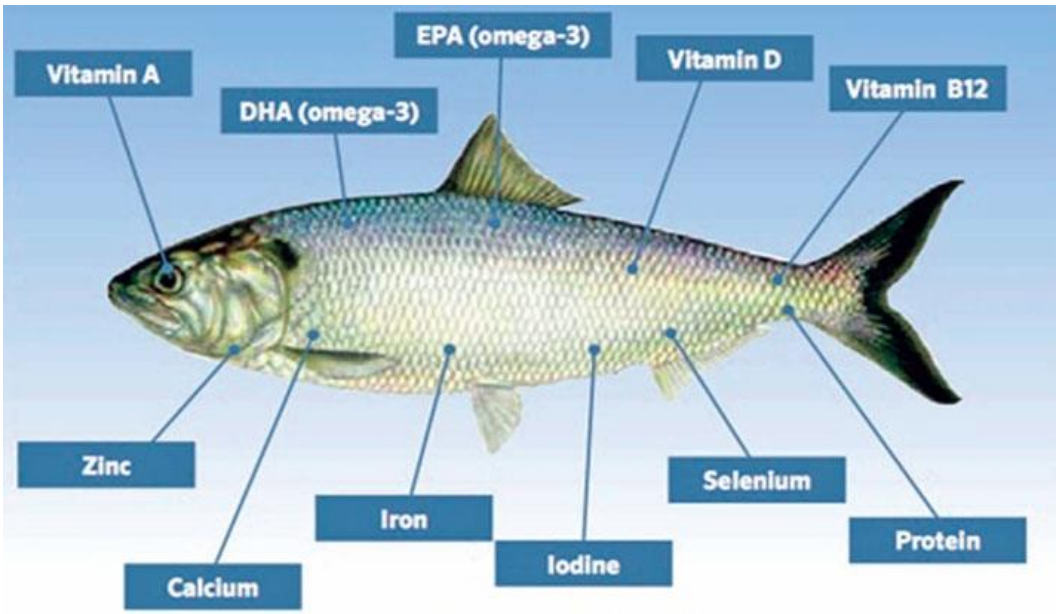


FIGURE 2. Fish as a vital source of vitamins and minerals for adults and mainly for children.

Overview of Fish Consumption

Fish is very crucial to a nutritious diet in many areas across the world and it provides about 3.3 billion people with almost 20% of their average per capita intake of animal protein. As the global population increases, potential nutritional concerns are raised, and fish represents an important source of animal protein. For this reason, global fish for human consumption is projected to increase by 16.3% indicating that 90% of the fish being produced will be utilized for human consumption by the year 2029. In 2018, fish accounted for about 17% of the total animal protein and 7% of this was animal protein consumed globally (**1**). The consumption of fish and the fish products has experienced major changes in the past decades. The world evident per capita fish consumption has been increasing steadily from an average of 12.5 kg in the 80's to 14.4 kg in the 90's and reaching 20.5 kg in 2017. This expansion in the consumption have been driven not only by the increase in production but also by the nutritional standards it has shown to provide to the people, reduced waste, better utilization, improved distribution

channels, and increased demand. Therefore, the increase in the consumption globally is an indication that the health benefits of fish consumption are manifold and well-understood from both scientific and nutritional perspectives. This also means that fisheries and aquaculture will continue to play a very crucial role in meeting the animal protein demands of the global population, with aquaculture being the dominant supplier (Figure 1).

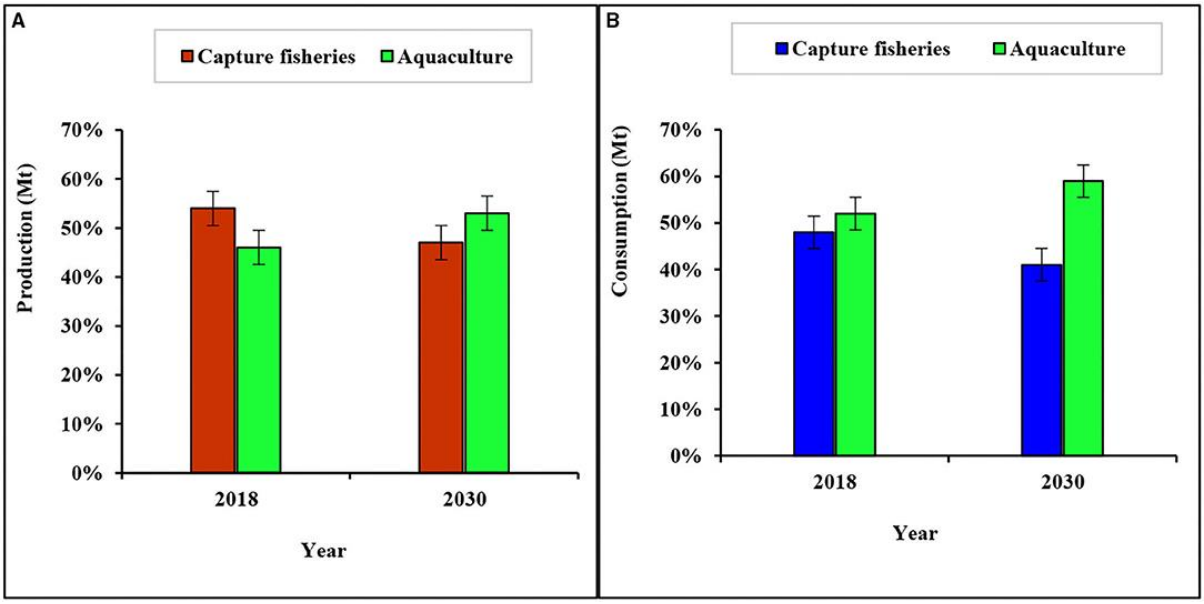


FIGURE 1. Global fish **(A)** production in 2018 and projected production in 2030, and **(B)** consumption in 2018 and projected consumption in 2030, from capture fisheries and aquaculture. [Source: Adapted from FAO].

Chemical Composition of Fish

Fish contains 18–20% protein, and contains eight essential amino acids including sulfur containing lysine, methionine, and cysteine. It provides easily digestible protein of high biological value that is important for the growth and development of the body, the maintenance and repair of worn out tissues and for the production of enzymes and hormones necessary for many of the body's processes, it's contains less fat than red meat.

The fat content ranges from 0.2 to 25%, especially polyunsaturated fatty acids (PUFAs), which are essential for the proper growth of children and are not associated with the occurrence of cardiovascular disease. Fats also contribute to the energy supply and aid in the adequate absorption of vitamins K, D, A, and E. Fish is a vital source of vitamins Figure 2, especially vitamins A and D of the fats, as well as thiamine, riboflavin, and niacin (vitamins B1, B2, and B3). Vitamin A found in fish is more available in the body compared to plant foods and is essential for normal vision and bone growth, also, fatty fish contains more vitamin A than the

lean types. Vitamin D, found in fish liver and oils, is essential for bone growth because, it is essential for calcium absorption and metabolism. Energy metabolism requires thiamin, niacin, and riboflavin. Fresh fish provides a small amount of vitamin C, which is essential for wound healing, maintaining the integrity of tissue, and assisting in the absorption of iron in the nervous system.

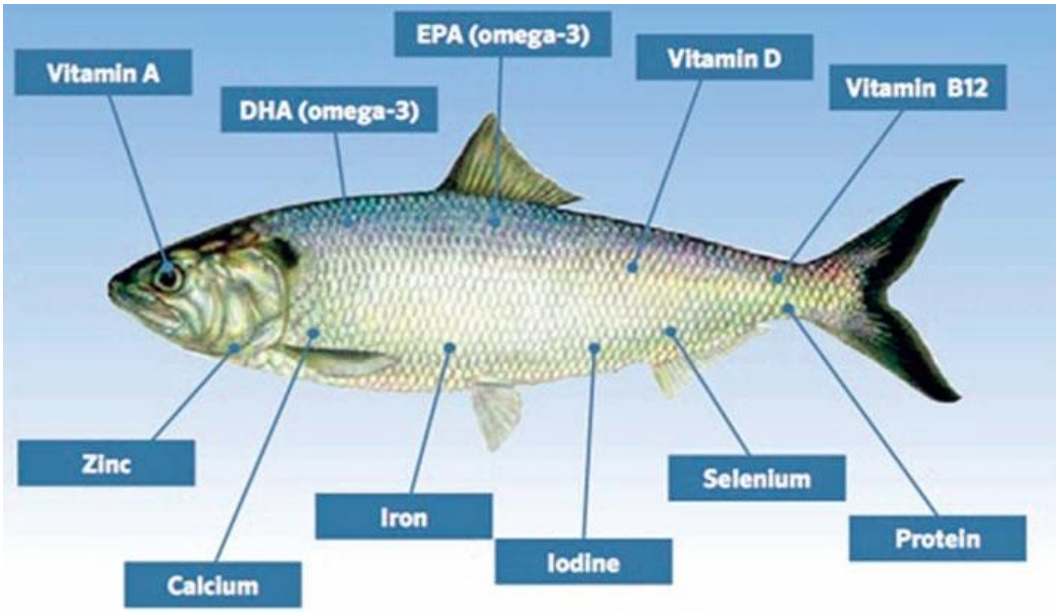


FIGURE 2. Fish as a vital source of vitamins and minerals for adults and mainly for children.

Phosphorus, calcium, iodine, iron, selenium, fluorine, and zinc are among the minerals found in fish and are extremely "bioavailable," ensuring that they are readily consumed by the organism. Iron is critical for the formation of haemoglobin in the blood, which would be responsible for distributing oxygen across the body. Calcium is critical for the development and mineralization of bones, as well as the normal operation of tissues and the central nervous. It also plays a significant role in the clotting of blood. When young fish are consumed with their bones, the phosphorus, calcium, and fluorine consumption is greatest (**2**). Zinc is needed for growth performance, function of immune system and the maintenance of healthy skin (**3**). Iodine, found in aquatic food, is necessary for hormones that control body metabolism, growth and proper behavioural development in children (**4**). Fish clearly provides more to people's diets than just high-quality protein **(5**). As a result, fish can be a staple to every diet, avoiding starvation which, make these nutrients readily accessible to absorption by organs.

In recent decades, as people's concerns about their health have grown, so has their concern about fats (**6**). Fatty acids are molecules consisting of one glycerol and three fatty acids that serve as a source of energy in our body and are deposited in the meat, muscles and liver (**7**). When fat is ingested, lipase breaks it down into one glycerol and three fatty acids, while a

few fatty oils molecules are pass through intact through the intestine (**8**). The ingested fat is at initial storage in the liver, the muscular or subcutaneous inner layer and then broken down as needed to provide energy (**9**).

Saturated and unsaturated fatty acids are distinguished by the presence or absence of an intramolecular double bond (**10, 11**). Saturated fatty acids are found in animal oils and are harmful to an individual's health, while unsaturated fatty acids are found in vegetable oils and are beneficial to an individual's health (**11, 12**). As a result, polyunsaturated fatty acids (PUFAs), such as omega-3s, have received significant attention (**12**). There are several medications and able to pay foods on the market, and the number of products aimed at children has risen as well (**14**). However, since there is concern about indiscriminate and excessive PUFA intake, it is critical to understand the correct use of PUFAs (**15**).

Health Benefits of Fishes

The American Heart Association suggests that people can eat varieties of fishes such as salmon, mackerel, herring, lake trout, sardines and albacore tuna to get your healthy dose of omega-3.1

Here's a **list of some of the most nutritious, lower-calorie fish varieties as follows**:

Salmon (3 ounces) 175 calories, 10 grams fat, 1.7 grams of omega-3 fatty acids

Anchovies (3 ounces) 111 calories, 4 grams fat, 1.7 grams of omega-3 fatty acids

Pacific and jack mackerel (3 ounces) 134 calories, 7 grams fat, 1.6 grams of omega-3 fatty acids

Pacific black cod (3 ounces) 70 calories, 1 gram fat, 1.5 grams of omega-3 fatty acids

Whitefish (3 ounces) 115 calories, 5 grams fat, 1.5 grams of omega-3 fatty acids

Albacore tuna (3 ounces, canned, packed in water) 109 calories, 3 grams fat, 0.7 grams of omega-3 fatty acids

Atlantic herring (3 ounces) 134 calories, 8 grams of fat, 1.4 grams of omega-3 fatty acids

Tilapia (4 ounces) 145 calories, 3 grams of fat, 0.1 grams of omega-3 fatty acids.

Health Benefits :

- Lowers the risk of heart disease – A lower risk of heart disease has also been linked to omega fatty acids. Regular consumption of omega-3 fatty acids seems to be linked to

preventing and decreasing coronary heart disease. These fatty acids aid to lessen blood pressure, reducing triglyceride levels, and limit coronary plaque.

- Decreases the risk of depression – Omega-3 fatty acids are also good for your mental wellness. Omega-3 fatty acids have a strong connection to a decline in depressive symptoms. Some anti-depressant drugs have been shown to be more successful when taken with omega fatty acids, probably because these fats improve brain function.
- Boosts brain health – As you age, your brain function frequently deteriorates. Mild mental deterioration is common, however, there are also significant neurodegenerative illnesses like Alzheimer's disease. Numerous observational studies reveal that those who consume more fish age mentally more slowly.
- Helps prevent and treat depression – Low spirits, sorrow, less energy, and a lack of enthusiasm in life and activities are its hallmarks. Depression is currently one of the largest health issues in the world while receiving far less attention than heart disease or obesity.
- One of the world's healthiest foods is fish. Important nutrients like protein and vitamin D are abundant in it. Omega-3 fatty acids, which are vital for your body and brain, are also abundant in fish.

The calorie counts listed are for the raw form of each omega-3-rich fish. Unless cooked with flour or another ingredient that contains carbohydrate, fish itself, as a protein, does not contain any carbohydrate. The way that we prepare our fish will change the calorie count. Baked fish, grilled fish, and broiled fish are usually lowest in calories.

And what about shellfish and other types of seafood? A single serving of shrimp (three ounces) provides about 100 calories and only 1.5 grams of fat, so they can be a healthy addition to our diet. And calories in scallops are low as well. Three ounces of steamed scallops provide about 95 calories and less than one gram of fat.

For Healthy Heart and Brain

Eating fish is an important source of omega-3 fatty acids. These essential nutrients keep our heart and brain healthy. Two omega-3 fatty acids found in fish are EPA (eicosapentaenoic acid) and DHA (docosahexaenoic acid). Our bodies don't produce omega-3 fatty acids so we must get them through the food we eat. Omega-3 fatty acids are found in every kind of fish, but are especially high in fatty fish. Some good choices are salmon, trout, sardines, herring, canned mackerel, canned light tuna, and oysters.

Role of Omega-3 Fatty Acids:

1. Help maintain a healthy heart by lowering blood pressure and reducing the risk of sudden death, heart attack, abnormal heart rhythms, and strokes.
2. Aid healthy brain function and infant development of vision and nerves during pregnancy.
3. May decrease the risk of depression, ADHD, Alzheimer's disease, dementia, and diabetes.
4. May prevent inflammation and reduce the risk of arthritis.

Less Healthy Fish Options

Even though eating fish can be good for us, not all fish is good for our diet. There are some times when skipping fish is the better diet choice, even if the fish is high in omega-3 fatty acids.

When fish is battered and fried it is usually full of saturated fat.

These are fats that we should limit in our diet. Convenience products like breaded fish sticks, fish tenders, and fish patties are often higher in fat and calories and don't provide as many health benefits as fish that is prepared using low-calorie methods. For example, a breaded fish fillet provides approximately 350-400 calories and 17-25 grams of fat and up to 5 grams of sugar.

Food Fish Quality and Safety

The quality and safety of food products determines the protection of public health, social stability as well as the food and nutrition security. Fish is vulnerable to contamination by pollutants such as heavy metals that threaten their safety for human consumption. Heavy metals are classified as elements having a high atomic weight and a density of at least five times greater compared to that of water and are present in nature from the earth's crust. Despite numerous heavy metal elements present in nature, mercury (Hg), arsenic (As), cadmium (Cd), chromium (Cr), and lead (Pb) are considered the most toxic elements and threat to public health. The widespread contamination of heavy metals in aquatic environment results mainly from anthropogenic activities including agricultural, industrial (such as mining), medical, and domestic applications. Fish accumulate heavy metals by uptake through the gills and the skin when in contact and can bioaccumulate and bio-magnify them to toxic levels for human consumption. However, the risks associated with consuming fish depends on the levels of contamination. The Food and Agriculture Organization (FAO) has set limits within which fish

contaminated with heavy metals is considered safe for consumption (Table 2). As indicated, some elements could be toxic even at low levels while others at higher levels.

Table-2 -

Heavy metal	Value (wet weight)	Value (dry weight)
Cr	0.15–1.0 ppm	0.65–4.35 ppm
Zn	30.0 ppm	130.43 ppm
Mn	1.00 ppm	4.35 ppm
Fe	100.00 ppm	434.78 ppm
Co	0.04–0.26 ppm	0.17–1.13 ppm
Cu	30.00 ppm	130.43 ppm
Se	1.00 ppm	4.35 ppm
Hg	0.50 ppm	2.17 ppm
Pb	0.50 ppm	2.17 ppm
Ni	80.00 ppm	347.82 ppm
As	1.00 ppm	4.35 ppm

TABLE 2. Recommended values of some heavy metal elements by the food and agriculture organization FAO.

The consumption of fish and fish products contaminated with heavy metals at levels beyond safe limits could have adverse effects in humans. However, children are more vulnerable due to their low body weight and behavior. For example, exposure to Pb in children could cause learning deficit, intelligence quotient (IQ) lowering, and severe damages in the brain and kidneys (**16**). Consuming excess Cd levels in fish products could result in kidney failure and bones softening, as well as prostate cancer in males (**17, 18**). Consumption of As in food products above safe level causes cardiovascular diseases, developmental anomalies, hearing defects, carcinoma, and hematologic disorders (**19, 20**). Hg is known to cause permanent damage to the central nervous system in children (**21, 22**). Effects such as heart function alteration, leukemia, kidney damage, neurocognitive defects and neuromotor disabilities have been reported in children exposed to Hg in sea food (**23.24.25**). Besides, Hg could affect children during any stage of development including maternal exposure particularly from methyl mercury (MeHg) species (**26**). Exposure to Cr could affect the functions of the heart, hematological parameters, kidneys, liver, and the central nervous system (**27**). Therefore,

it is suggested that regular monitoring of heavy metals accumulation levels in aquatic environments and fish be conducted to safeguard public health (**28, 29**).

Fish, also being a perishable product, is vulnerable to fermentation and decomposition resulting in biogenic amines (BA) that threaten fish safety for consumption. BA refer to toxicants non-volatile amines resulting from amino acids decarboxylation (**3**0). They are produced either by proteolytic activities of certain microorganisms or naturally during the metabolism of related precursor amino acids (**31**). However, in fish, histamine (HIS), cadaverine (CAD), and putrescine (PUT) are the only biogenic amines of concern when it comes to food safety and quality control (**30**). HIS is a monoamine produced from histidine precursor amino acid via a one-step decarboxylation reaction (**31).** CAD is a diamine produced from lysine and putrescine via a decarboxylation reaction (**32**). PUT is also a diamine but is produced either through a single-step decarboxylation from agmatine and ornithine, or indirectly after arginine hydrolysis (**33**). Although BA, at their physiological levels, play important roles in various cells process such as cell growth, gene expression, and tissue repair (**34, 35**), their ingestion at higher levels, although unlikely, could pose serious health hazards like symptoms of histamine poisoning including anaphylaxis, hypertension, nervous manifestation, and even death (**36)**. Besides, Doeun et al. (**37**) reported that CAD and PUT could give way to gastric cancer during its conversion into carcinogenic N-nitroso compounds by microorganisms present in the digestive tract. Furthermore, in Europe, consumption of fish containing elevated levels of BAs was associated with widespread cases of intoxication (European Food Safety Authority EFSA (**38**) Therefore, it is very important that fish products are screened for BAs before administered for consumption to safeguard public health. This can be done 2-fold: maintaining high level of hygiene during fish harvesting, storage, processing and distribution to consumers, and by controlling total mesophilic (TMC) and total psychrophilic (TPsC) bacterial counts in fish products. El-Ghareeb et al. (**32)** observed a positive correlation between total BAs and TMC, suggesting that microorganisms play a major role in contaminating fish products with BAs.

Conclusion

Aquatic foods, especially aquatic animals, have long been valued as a rich source of animal protein and thus, considered a key constituent of nutritious diets (39) but the policies on aquatic foods tend to focus primarily on production, economic efficiency, resource management, environment and climate issues whilst paying less attention to value chains and the contribution of aquatic foods to people's nutrition and health. Ahern et al. (**40**)

recommended that aquatic foods are part of the solution to building resilient food systems and sustainable healthy diets for all, but for this to be fully achieved, they need to be available, accessible, affordable and desired. The nutritional value and health benefits of the fishes are unrecognized and undervalued. Despite a lot of benefits in the health of humans particularly the children, some people are still unaware of these benefits (**41**). The contribution of capture fisheries for instance to diet quality is poorly understood in most contexts, particularly where small-scale fisheries remain undocumented and overlooked in both fisheries and food system development (**42,43**) hence limiting the nuanced assessment of fisheries contribution to diet quality of children under 12 years of age which is the critical age at which interventions have the greatest long-term effects for growth and health (44, 45). In contrast, Crona et al. (46) and HLPE (47) records that fish and other aquatic foods are gaining attention for their potential to efficiently provide two fundamental components of sustainable, nutritious food systems. Fish from inland fisheries are an important source of animal source foods (ASF) in monotonous diets for children in the sub-Saharan Africa and Asia (48), especially in land-locked African countries such as Malawi (**49, 50**) and Zambia (**51**). Therefore, there is a need to realize the importance of fish for human nutrition, in addition to its role in reducing poverty and hunger. This will ensure a greater impact by improving the nutritional status of children.

Fish is an important animal protein source and its consumption is likely to increase over the coming years. This will be driven primarily by population increase and the demand for healthy and high-quality protein for human nutrition. The polyunsaturated fatty acids (PUFAs) that are highly present in fish play an important physiological role in the growth and development of fetuses, newborns, and children's brains. As a result, they should be provided in the diets of children for normal development. Besides, in situations including auto-immune illnesses diseases, PUFAs have been found to enhance blood flow, minimize chronic inflammation and decrease coronary artery disease.

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