Aquaculture role in global food security with nutritional value: a review

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ABSTRACT: Food security is the main path to develop the socioeconomic status in any country in the world to defeat malnutrition. The present scenario in an under developed countries are still facing this problem. Hence the human nutrition deficiencies focus on the importance of animal protein in their regular diet. To overcome this problem, fisheries contribute a significant amount of animal protein to the diets of people worldwide. The aquatic animals are the highly nutritious and cheapest protein sources, which serves as a valuable supplement in diets by providing essential vitamins, proteins, micronutrients, and minerals, for the poor people. Aquaculture is playing a vital role in the developing countries in national economic development, and global food supply. Food and agricultural organization (FAO) declared that this aquaculture has the continuous potentiality to create a developmental goals for the country economy and better human welfare.

Key words: animal protein, aquaculture, food security, global economy, malnutrition

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INTRODUCTION

Food security can be defined as secure access to enough food at all times for everyone (Food and Agriculture Organization (FAO), 2000). A person needs adequate health, good environment, and food for their survivance, which is therefore closely linked to the economic and social health of a nation, society, and individual. The community-level food security is an essential matter to grow up the nation economically. Developing countries often lacking the resource, with the growing population, require adequate amount of food supply demands for food security and safety.

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IMPORTANCE OF FOOD SECURITY

Food security concerns are of utmost importance to developing countries such as India, where a large percentage of its population is poor and a high share of total household expenditure is devoted to food. The aquaculture sector has an important role to play as a high proportion of India's rural population depends heavily on this sector for its livelihood and income. The objective of this article was to analyze how an aquaculture sector plays a key role in food security at the household and national levels. India is forced to produce the food for its rapidly growing population through green revolution and blue revolution. Increases in food production were mainly achieved by the use of high-yielding varieties of rice and transgenic animals, accompanied by expansion of improved biotechnology applications in addition to aquaculture production (Srinivasan, 2003).

Food preferences change the concept of food security from mere access to enough food and high access to the food preferred. This implies that people with equal access to food, but different food preferences, could show different levels of food security.

Aquaculture role in Food Security

Fisheries play an important role in the world food economy. Fisheries are a source of employment for about 200 million people who depend directly on ocean fishing for their livelihoods (Gareth, 2001). Fishes is the primary source of protein for some 950 million people worldwide and represents an important part of the diet of many more. Several investigators have shown the relationship between population growth and total fish consumption speculated for a period from 1970 to 2010 (FAO, 2000; Delgado et al., 2002; Tacon, 2003).

In less than 50 yr, the world's average per capita consumption of fish has almost doubled (World Fish Center [WFC], 2002). Globally, fish provides about 16% of the animal protein consumed by humans and are a valuable source of minerals and essential fatty acids. Fish is the primary source of omega-3 fatty acids in the human diet.

Omega-3 fatty acids (Figure 2) are critical nutrients for normal brain and eye development of infants, and have preventative roles in a number of human illnesses, such as cardiovascular disease, lupus, depression, and other mental illnesses (Crawford and March, 1989). Asia predominates in capture fisheries and aquaculture production, whereas India is one of the leading aquaculture productions in worldwide, over 13 lakh tons (Table 1; FAO, 2011).

Most growth in the fisheries sectors is projected to occur in developing countries, which will account for 79% of food fish production in 2020 (Delgado et al., 2002).

Fish Production Relation to Food Security

Traditional extensive forms of aquaculture generally make a positive contribution. Fish production is also playing an important role on food security through its contribution to overall food supplies for the general population. Another impact that must be eminent is aquaculture's participation in the food security of the poor, those most susceptible to malnutrition. However, the major impact of aquaculture on world food supplies is conveyed in the aggregate tonnage figures increased from the year 2016 to 2018 (Figure 1 and Table 2) (FAO, 2018).

Contribution of Fisheries to Food Security

Fisheries contribute a large share in regulating the food security problem. Fish provide the main source of animal protein to about 1 billion people globally. Food security does not just concern food production. It can be defined as the physical and economic access to sufficient, safe, and nutritious food to meet dietary needs (Gareth, 2001). Fisheries are an important part of food security, particularly for many poor people in developing countries. In low-income food deficient countries, they make up 22% of animal protein consumption overall. In coastal areas and around major river systems, the dependence on fish is usually higher (WFC, 2002). The importance of small-scale fisheries plays a vital

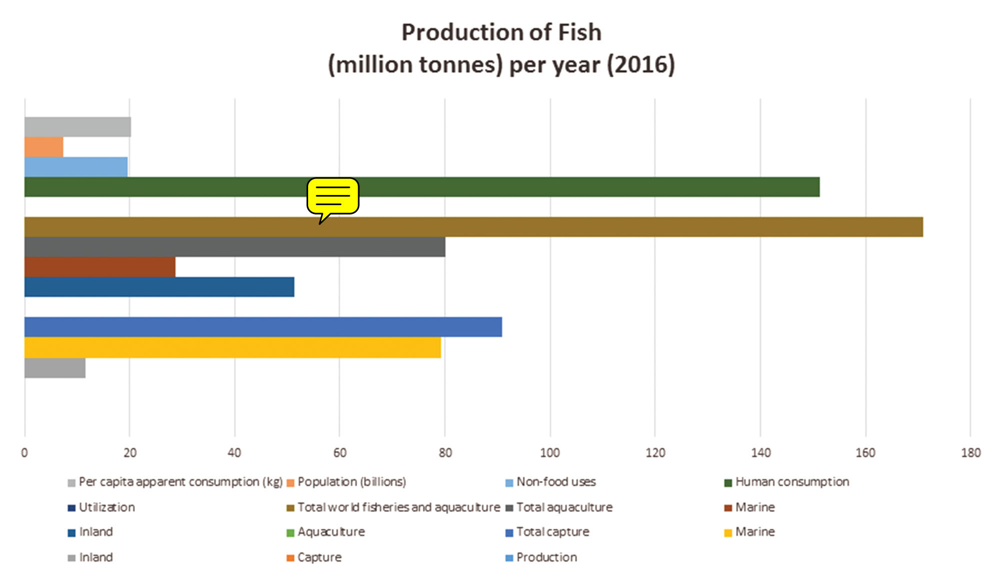

Figure 1. Global values of fish consumption and World Fisheries and Aquaculture latest FAO 2018 values in graphical representation.

Table 1. FAO in 2011 shows the global production of fish and sea foods utilized for direct human consumption

Sl. no.	Country	Production of fish (tons) per year
1	Asia total	18,826,453
2	China	11,315,492
3	Japan	1,397,020
4	India	1,395,444
5	Europe total	1,378,805
6	Korea, Democratic people's Republic	1,100,000
7	Republic of Korea	955,477
8	Americans total (North + South + Central)	810,110
9	Philippines	736,381
10	Indiana	645,368

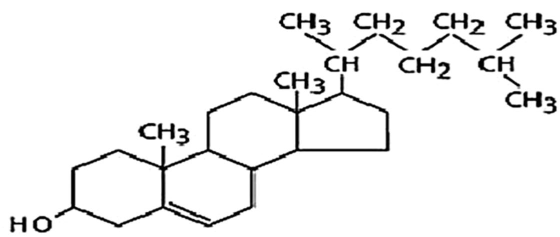

Figure 2. Structure of omega-3-fatty acid.

role in particular for food security is emphasized by FAO (Crawford and March, 1989).

Nutrition facts

Aquaculture research programme suggests that small, indigenous fish are particularly important for nutrition because they are eaten whole, "bones and all," thereby providing a source of calcium and other micronutrients. In addition, fish is a major source of protein, micronutrients, and essential fatty acids, providing an important complement to the predominantly carbohydrate-based diet of many poor people in developing countries (Bhaskar, 1994). The FAO (2011) reported that the percentage change of fish consumption to human diet is more than that of total animal protein intake (Table 1).

Table 2. World fisheries and aquaculture production and utilization (million tons) in latest FAO 2018 reports

	Category	Production of fish (million tons) per year (2016)
	Production	
	Capture	
1	Inland	11.6
2	Marine	79.3
	Total capture	90.9
	Aquaculture	
1	Inland	51.4
2	Marine	28.7
	Total aquaculture	80.0
	Total world fisheries and aquaculture	170.9
	Utilization	
1	Human consumption	151.2
2	Nonfood uses	19.7
3	Population (billions)	7.4
4	Per capita apparent consumption (kg)	20.3

DISCUSSION

Biotechnology role in Aquaculture

Biotechnology is playing a major role in improving the production of fish, leading to regularize the food security problem worldwide. Aquaculture is the production of aquatic organisms under controlled systems with technological applications that allow managing population densities higher than the natural ones, optimizing culture management, in other words, an intensive aquaculture.

Transgenic Fish

Biotechnology can be used to introduce desirable genetic traits into the fish, thereby creating harder stock. Transgenic involves the transfer of genes from one species of fish to another species. Using different transgenic techniques, researchers are seeking to improve the genetic traits of the fish used in aquaculture. Researchers are trying to develop fish that are larger and grow faster, more efficient in converting their feed into muscle, resistant to disease, tolerant to low oxygen levels in the water, and tolerant to freezing temperatures. Growing fishes that are longer and heavier is the goal of researchers who are experimenting with applying various types of growth hormone in fish. One method of doing this is to dip the fish in a solution that contains the hormone. However, there are some problems with this technique. First, it may be difficult to produce large quantities of purified growth hormone, the method is labor intensive, and it is difficult to determine whether the fish are getting the right amount of growth hormone. Therefore, researchers have developed new strains of transgenic fish that naturally produce just the right amount of growth hormone to speed their growth. Such fish are more cost-effective because they would produce higher levels of growth hormone on their own, and they would pass this trait to their offspring.

There are two main techniques that researchers use to transfer genetic material in fish. One is called microinjection, in which the genetic material is injected into newly fertilized fish eggs. However, this method is time-consuming, so researchers may prefer to use electroporation. This involves transferring the genetic material, or DNA, into fish embryos through the use of an electric current. A foreign gene can be transferred into fish in vivo by introducing DNA either into embryos or directly into somatic tissues of adults (Sudha et al., 2001). Direct delivery of DNA into fish tissues is a simple approach, providing fast results and eliminating the need for screening transgenic individuals and selecting germ line carriers. Gene transfer and expression following intramuscular direct injection of foreign DNA into skeletal muscles of fish has been achieved by several studies (Hansen et al., 1991; Maclean et al., 2002). Genetic engineering is a vague term that has come to be nearly synonymous with gene transfer, that is, the production of transgenic fish or genetically modified organism. This technology is progressing rapidly and it is now possible to move genes between distantly related species. Since the development of the GE fish in the early 1990s (Aken, 2000), researchers and aquaculture companies have concentrated on genetically engineering fish that would grow faster and need less feed. As mentioned earlier, many research groups have successfully introduced growth hormone genes from human or animal sources into several fish species such as salmon, carp, trout, and tilapia, causing them to grow several times faster than their natural counterparts.

Hybridization

Hybridization is a simple genetic technology that has become easier with the development of artificial breeding techniques, such as the use of pituitary gland extract and other hormones to initiate gamete gland extract and other hormones to initiate gamete development, induced spawning (the depositing of eggs) and an increased understanding of environmental cues that influence reproduction, such as day length, temperature, or water current. Many of the natural reproductive isolating mechanisms that species develop in the wild can now be overcome by fish farmers. These improvements in reproductive technologies have also assisted aqua culturists greatly in their effort to domesticate aquatic species. In addition, by making it possible to remove the natural constraints and timing of breeding, farmers are able to mate many more species at the times that are most beneficial and thus help to ensure a steady and consistent supply of fish to the market. Hybridization can also be used to produce single sex groups of fish when the sex-determining mechanisms in the parental lines are different, for example, hybridization of Nile tilapia, *Oreochromis niloticus*, and the blue tilapia, *Oreochromis aureus*.

Cryopreservation

The development of cryopreservation or low-temperature technology allows the short- and long-term storage of gametes. Currently, these low-temperature techniques can only be used on male gametes eggs and embryos and generally not be stored in this way. Freezing gametes can increase the flexibility of a fish breeder, especially when breeding species where the sexes mature or migrate at different times, when the breeding season is very short, when the breeders are far apart, or when one sex is exceptionally rare (Hagedorn et al., 1997). This technique is helpful to store and preserve species in aquaculture breeders and farmers.

Health Improvement of Species

Biotechnology offers substantial opportunities to improve the health and well-being of cultivated aquatic organisms. More than 50 diseases, for instance, affect fish and shell fish cultured in the United States, causing losses to tens of millions of dollars annually (Shelton, 1996). Biotechnology not only improves the survival, growth vigor, and well-being of cultivated stocks, but also can reduce disease transfer between cultivated and wild stocks. New products and market opportunities can be developed related to aquatic animal health and well-being. Genetics & biotechnology applications are being used to improve fish health through conventional selection for disease resistance and through the use of molecular investigation and diagnosis. Genetically engineered vaccines are also being developed to protect fish against pathogens.

Malnutrition

Malnutrition is defined as such a condition when the intake of proteins and energy foods, the latter measured in joules or calories, is critically inadequate for the needs, especially of a growing child. According to Sobharani et al. (1986), malnutrition results from an inadequate intake of energy and protein, as well as other nutrients. Perhaps the most important consequences of malnutrition are the diseases closely associated with deficiency in nutrient intake. The kwashiorkor and marasmus, both which mainly affect children in the first 2 yr of life, are most common, hence, economically important. They represent the extreme forms of protein energy malnutrition. Kwashiorkor often results when children are not getting a particular nutrient, mainly proteins, in their diet, even though they may be eating enough food. On the other hand, marasmus arises when a child is not getting enough food of any kind, as in a situation of starvation. Undernutrition refers to reduced food intake in relation to recommended dietary levels. Nutritional status of young children is a sensitive indicator of health status and nourishment level of a population. Malnourished children are vulnerable to infectious diseases and grow slowly. Fish diet plays a vital role in controlling the malnutrition problem especially in young children.

Malnutrition can be caused by a number of interrelated factors. The two immediate causes, which often occur together, are inadequate diet and infectious diseases. Young and Jaspers (1995) explain that the immediate causes stem from three groups of underlying causes. These are food security, basic health services, and maternal and childcare. In practice, the three groups of underlying causes interact with one another. In the past, malnutrition was thought to be a protein-deficiency problem that could be cured by intake of high protein foods. By the mid-1970s, the interaction between energy and protein was recognized, and energy intake became a focus in nutrition matters. This changed the dimensions of understanding nutrition, to include social and economic issues such as access to food, poverty, and related issues.

Fish and Macronutrients Proteins

Proteins are important for growth and development of the body, maintenance and repairing of worn-out tissues, and production of enzymes and hormones required for many body processes. The importance of fish in providing easily digested protein of high biological value is well documented. In the past, this has served as a justification for promoting fisheries and aquaculture activities in several countries. On a fresh weight basis, fish contains a good quantity of protein, about 18%–20%, and contains all the eight essential amino acids including the sulfur-containing lysine, methionine, and cysteine (Sobharani et al., 1985). As most maize-based diets lack these compounds, rural households in Africa dependent on maize greatly benefit by increasing their fish consumption.

Fats

The fat content of fish varies depending on the variety of species as well as the season, but, in general, fish have less fat than red meat (Bhaskar, 1983; Murthy et al., 2000). The fat content ranges from 0.2% to 25%. However, fats from fatty fish species contain the polyunsaturated fatty acids (PUFAs) namely EPA (eicosapentaenoic acid, Figure 3a) and DHA (docosahexaenoic acid, Figure 3b [omega 3 fatty acids]) (Figure 2), which are essential for proper growth of children and are not associated with the occurrence of cardiovascular diseases such as coronary heart disease.

In pregnant women, the presence of PUFAs in their diets has been associated with proper brain development among unborn babies. In other studies, omega 3 fatty acids have also been associated with reduced risk of preterm delivery and low birth weight. The fat also contributes to energy supplies and assists in the proper absorption of fat-soluble vitamins namely A, D, E, and K (Figure 4).

Micronutrients Vitamins

Fish is a rich source of vitamins, particularly vitamins A and D from fatty species, as well as thiamin, riboflavin, and niacin (vitamins B1, B2, and B3). Vitamin A from fish is more readily available to the body than from plant foods. Vitamin A is required for normal vision and for bone growth. Fatty fish contains more vitamin A than lean species. Studies have shown that mortality is reduced for children under five with a good vitamin A status. As sun drying destroys most of the available

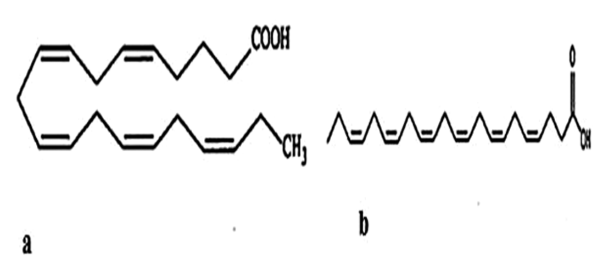

Figure 3. Structures of (a) eicosapentaenoic acid (EPA) and (b) docosahexaenoic acid.

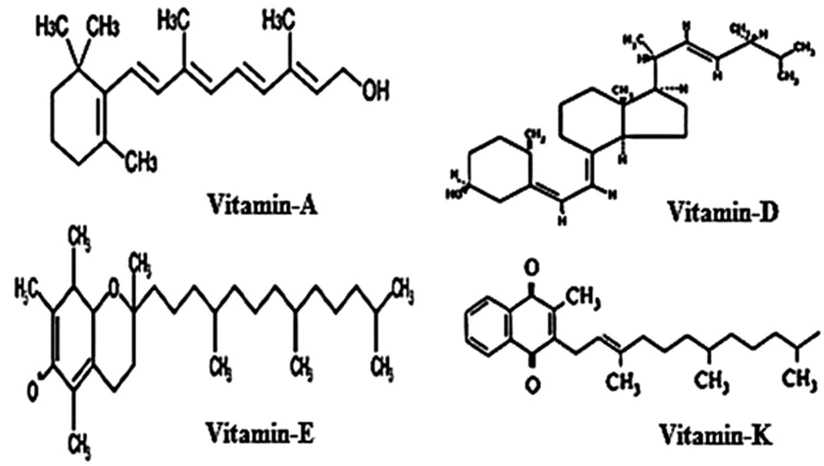

Figure 4. Structures of vitamins A, D, E, and K.

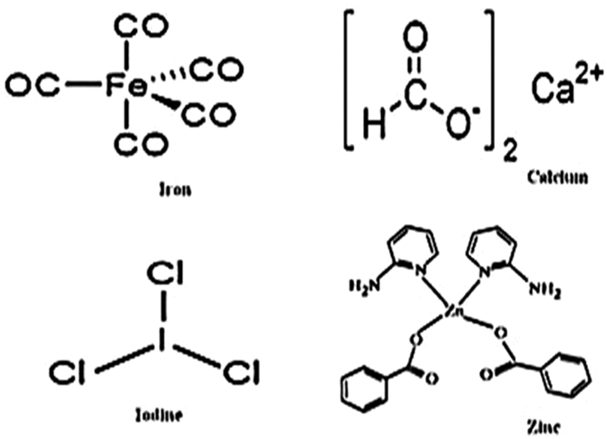

Figure 5. Structure of iron, calcium, iodine, and zinc.

vitamin A, better processing methods are required to preserve this vitamin.

Vitamin D present in fish liver and oils is crucial for bone growth because it is essential for the absorption and metabolism of calcium. Thiamin, niacin, and riboflavin are important for energy metabolism. If eaten fresh, fish also contains a little vitamin C, which is important for proper healing of wounds, normal health of body tissues, and the absorption of iron in the human body.

Minerals

The minerals present in fish include iron, calcium, zinc, iodine, phosphorus, selenium, and fluorine (Figure 5). These minerals are highly "bioavailable," meaning that they are easily absorbed by the body. Iron is important in the synthesis of hemoglobin in red blood cells, which is important for transporting oxygen to all parts of the body. Iron deficiency is associated with anemia and impaired brain function, and in infants, it is associated with poor learning ability and poor behavior. Due to its role in the immune system, its deficiency may also be associated with increased risk of infection. Calcium is required for strong bones (formation and mineralization) and for the normal functioning of muscles and the nervous system. It is also important in the blood-clotting process. Vitamin D is required for its proper absorption. The intake of calcium, phosphorus, and fluorine is higher when small fish are eaten with their bones rather than when the fish bones are discarded. Deficiency of calcium may be associated with rickets in young children and osteomalacia (softening of bones) in adults and older people. Fluorine is also important for strong bones and teeth. Zinc is required for most body processes as it occurs together with proteins in essential enzymes required for metabolism.

Zinc plays an important role in growth and development as well in the proper functioning of the immune system and for a healthy skin. Zinc deficiency is associated with poor growth, skin problems, and loss of hair among other problems. Iodine, present in seafood, is important for hormones that regulate body metabolism and in children it is required for growth and normal mental development. A deficiency of iodine may lead to goiter (enlarged thyroid gland) and mental retardation in children. It is evident that fish contribute more to people's diets than just the high quality protein they are so well known for. Fish should therefore be an integral component of the diet, preventing malnutrition by making these macro- and micronutrients readily available to the body.

Health Benefits of Fish Oils

Fish contains high levels of nutrients having health benefits, particularly oily fish, such as salmon

Table 3. Fish oil contents and sources, derived components, and their health and biological functional properties

Sl. no.	Contents	Properties
1	EPA	Lower serum levels of these two fatty acids
2	DHA	Designation of any fatty acid
3	Resolvin D1	Resolve inflammation
4	Resolvin D2	Resolve inflammation
5	Marisen 1	Macrophage mediators in resolving inflammation
6	Neuroprotectin D1	Anti-inflammatory properties
7	Protectins	Metabolites with a pentacyclic structure
8	Prostaglandins	PPARγ activation and platelet aggregation inhibition

and tuna. Fish also provides vitamins and minerals, including zinc, and iron. The various beneficial effects of fish protein have primary been attributed to n-3 PUFAs such as EPA and DHA. Fishes have been identified as the only foods that contain a naturally high amount of these fatty acids. This arises from the fact that fishes have a high ratio of EPA and DHA, and thus these fatty acids are accumulated in the food chain. Fish oil contents and sources EPA and DHA are omega-3 PUFAs that are 20 and 22 carbons in length, respectively. These EPA and DPA dietary supplementation acts on triglycerides, reesterified triglycerides, ethyl ester, and phospholipids. Resolvins and Marisen 1 are potent signaling molecules derived from omega-3 fatty acids involved in resolving inflammation, macrophage mediators in resolving inflammation, and prostaglandins in PPARγ activation and platelet aggregation inhibition (Table 3).

CONCLUSIONS

The problem of food insecurity is multidimensional, arising from a number of causes that put constraints to food availability or limits local people's access to it. Fish is central to the food insecurity problem for lakeside communities. As a protein-rich food, it offers a solution to the protein-deficiency conditions affecting children in the lake area. It is also a potential income source for those engaged in fish production, processing, and marketing. Despite these advantages, fish is lowly regarded in the national food policies. The fisheries policy objectives see the role of fish in improving local food security, but the desperation of the country to earn foreign exchange has superseded the interest for domestic food security. Factors constraining food security are related to transformation of the fishery into an industrial and commercial venture, fishery management problems, low agricultural productivity, and sociocultural impediments. Because of the large investment already made in industrial fish processing, it would be in order to allow some amount of exports to continue. However, the quantities of exportable fish must be limited to ensure sustainable fisheries and reconciliation with the food security needs.

Conflict of interest statement. None declared.

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