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Índice

The Role of Fish Nutrition in Improving Human Health and Global Food Security

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Abstract

Malnutrition represents the world's greatest preventable health challenge, including both undernutrition and overnutrition. The role play by fish and seafood in global food supply and within the Americas is discussed, with aquatic food products offering a much healthier alternative to farmed terrestrial meat products. The paper highlights the important role played by fish nutrition in the formulation of fish and shrimp feeds, and in particular for the nutritional enhancement of farmed fish products through dietary fortification with essential nutrients and improved health attributes,

Keywords: *malnutrition, aquaculture, food supply, human health, nutrient fortification*

The double burden of malnutrition

Malnutrition represents the world's greatest preventable health challenge; the term malnutrition covering both undernutrition (which includes wasting [low weight-for-height], stunting [low height-for-age], underweight [low weight-for age], and vitamin and mineral deficiencies) and overnutrition (which includes overweight, obesity and diet related noncommunicable diseases [NCDs] such as heart disease, hypertension and stroke, diabetes and some cancers).

According to the World Health Organization nearly one in three persons globally suffers from at least one form of malnutrition, with over 1.9 billion adults being overweight or obese (WHO, 2017; 2021a) and 928 million people suffering from severe food insecurity; over half of the world's undernourished living in Asia (418 million) and over a third in Africa (282 million; FAO *et al.*, 2021). Globally, an estimated 155 million children under the age of 5 years are suffer from stunting, while 41 million are overweight, and with around 45% of all deaths among children under 5 years of age being linked to undernutrition (WHO, 2021a).

In contrast to undernutrition, which is mainly linked to low income and poverty, the rapid rise of obesity and diet related NCDs within developed and developing countries has mainly resulted from the increased consumption of lower-cost processed fast foods and high energy-dense diets, coupled with a more sedentary life style (FAO, 2021a; FAO *et al.*, 2021; Tacon *et al.*, 2020; WHO, 2017, 2021a).

Role of fish in global food supply and within the Americas

Although oceans and freshwaters cover more than 71% of our planet, aquatic food products[1] represented less than 3.25 % of total global food supply in 2018 (171.44 million tonnes, live weight equivalent basis), and supplied 108.65 million tonnes of aquatic meat products to the global food basket (FAO, 2021a). Moreover, in terms of nutrient supply, fish and seafood supplied 6.8% of total animal calorific supply, 16.9% of total animal protein supply and 3.2% of total animal fat supply on a global basis in 2018; freshwater fish supplying over 42.9% of total fish and seafood animal protein supply, followed by pelagic fish (20.0%), demersal fish (15.0%), crustaceans (9.1%), other marine fish (5.9%), cephalopods (3.2%), other molluscs (3.2%) and other aquatic animals (0.36%; Table 1, FAO, 2021a).

[1] Includes wild and farmed fish and seafood, including crustaceans, molluscs (including cephalopods), other invertebrate aquatic animals, and aquatic plants;

Table 1. Contribution of fish & aquatic animal products to animal food supply by major geographic region in 2018 (FAO, 2021a)

Region	Total fish food supply 1000 tonnes	Total fish food supply kg/cap/yr	Plant/animal food supply kcal/cap/dy	Food fish supply kcal/cap/dy	Fish protein supply[6] g/cap/dy	Fish fat supply g/cap/dy
Asia	108,296 (71.4%)	23.95	2,373/476	40 (8.40%)	6.46 (22.7%)	1.33 (3.79%)
Africa	11,718 (7.7%)	10.27	2,403/200	19 (9.50%)	3.04 (20.0%)	0.70 (5.39%)
Europe	15,997 (10.5%)	21.39	2,436/948	46 (4.85%)	6.48 (11.1%)	1.99 (2.82%)
Oceania	865 (0.57%)	26.75	2,325/981	44 (4.48%)	6.73 (10.4%)	1.60 (2.23%)
Central America [a]	2,111 (1.4%)	12.03	2,409/612	24 (3.92%)	3.66 (9.23%)	0.83 (1.89%)
Northern America [b]	8,081 (5.3%)	22.19	2,747/1,013	36 (3.55%)	5.42 (7.55%)	1.29 (1.82%)
South America [c]	4,112 (2.7%)	9.71	2,350/734	17 (2.32%)	2.75 (5.79%)	0.62 (1.18%)
World	151,641	20.37	2,402/527	36 (6.8%)	5.59 (16.9%)	1.24 (3.25%)

[a] Belize, Costa Rica, El Salvador, Guatemala, Honduras, Mexico, Nicaragua, Panama

[b] Canada, USA

[c] Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, Guyana, Paraguay, Peru, Suriname, Uruguay, Venezuela

Regionally, the Asian region produced over 71.4% of total global food fish production in 2018, followed by Europe (10.5% by weight), Africa (7.7%), Northern America (5.3%), South America (2.7%), Central America (1.4%), and Oceania, respectively (0.57%; Table 1). However, in contrast to the Asian region where fish and seafood supply is mainly derived from increased aquaculture production (the Asian region producing over 110.03 million tonnes or 91.6% of total global aquaculture production in 2019; FAO, 2021b), fish and seafood supply within the other regions is still largely sourced from wild capture fisheries (FAO, 2020).

In terms of nutrient supply, the highest contribution of fish and seafood products to total nutrient supply was in the Asian region (22.7% of total animal protein supply, 3.79% of total animal fat supply, and 8.40% of total animal calorific supply), followed by the African region (20.0% of total animal protein supply, 5.39% of total animal fat supply, and 9.5% of total calorific supply; Table 1). By contrast, despite a high per capita fish and seafood supply within Oceania (26.75 kg/cap/year), Northern America (22.19 kg/cap/year), and Europe (21.39 kg/cap/year), fish and seafood supplied only 10.4% of total animal protein supply and 2.23% of animal fat supply in Oceania, 7.55% of total animal protein supply and 1.82% of animal fat supply in Northern America, and 11.1% of total animal protein supply and 2.82% of animal fat supply in Europe (Table 1).

By contrast, the lowest contribution of fish and seafood to nutrient supply was in South America (2.32%, 5.79% and 1.18% of total energy, protein and fat supply, respectively), followed by Northern America (3.55%, 7.55% and 1.82% of total energy, protein and fat supply, respectively) and Central America (3.92%, 9.23% and 1.89% of total energy, protein and fat supply, respectively; Table 1). On a country basis, fish and seafood supply in the region varied from a low of 0.9%, 2.1% and 0.5% of total energy, protein and fat supply in Bolivia, to a high of 14.2%, 24.1% and 9.9% of total energy, protein and fat supply in Peru, respectively (Table 2).

Moreover, within most countries where fish and seafood currently play a minor role in animal protein supply (supplying <10% of animal protein supply) there is a general over consumption of energy rich terrestrial animal food products, processed foods, and high energy beverages (sugars and sweetners supplying over 10% of total calorific supply; Figure 1; Table 2). As a consequence of these dietary food choices it is perhaps not surprising therefore that obesity, heart diseases and diabetes and NCDs have emerged as a major health risk and cause of death within most countries within the region, including Brazil, Mexico and the USA (Tacon *et al*., 2020; Cameron *et al*., 2021; Ferreira *et al*., 2021; Global Obesity Observatory, 2021; Lawrence *et al*., 2021; Silva *et al*., 2021; World Bank, 2021b; Fig. 2).

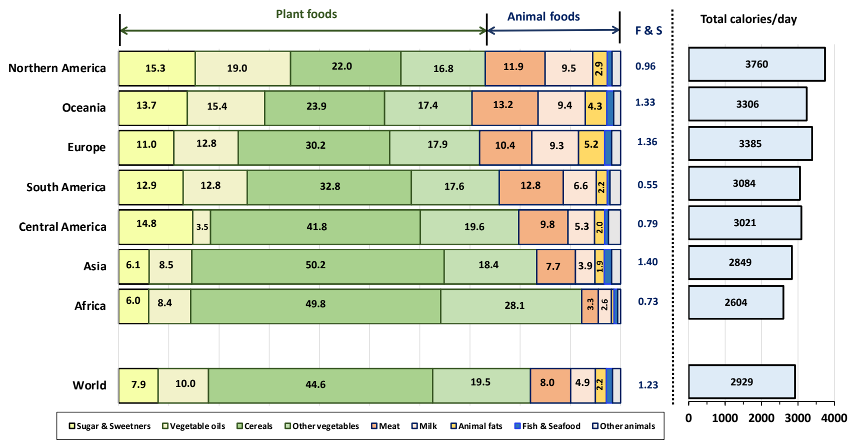

Figure 1. Contribution of the major food groups to total food supply by region (values expressed as % total calorie supply; FAO, 2021a)

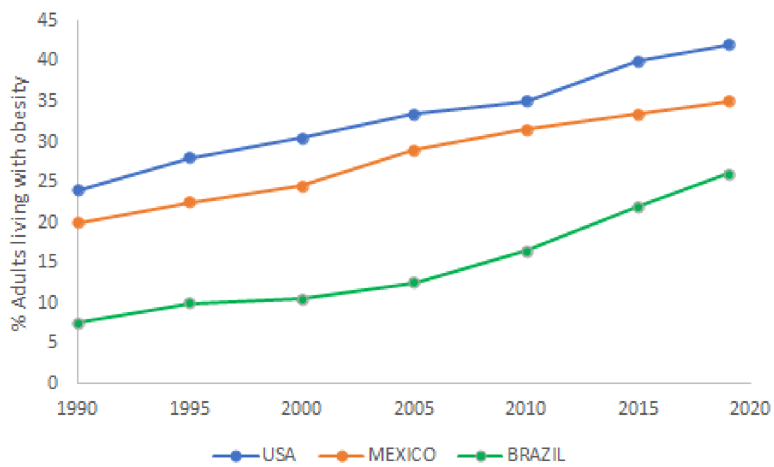

Figure 2. Adult obesity 1990-2019 (%) in the United States, Mexico and Brazil. Data source: Global Obesity Observatory (http://data.worldobesity.org). Brazil data 2015 and 2019 are author´s estimates and also based on Silva *et al.* (2021).

Table 2. Contribution of fish and seafood to food supply within countries within the Americas (contribution of fish and seafood toward nutrient supply expressed as %; FAO, 2021a)

Country	Total food supply per capita per day							
	Total calories (kcal)	Animal calories (kcal)	Animal protein (g)	Animal fat (g)	Sugar & sweeteners[1] (kcal)	Fish & seafood food supply/capita/day		
						Calories	Protein g	Fat g
Venezuela	2,210	347 (5.8%)	24.57 (12.2%)	24.30 (3.0%)	256 (12.1%)	20	2.99	0.74
Bolivia	2,412	544 (0.9%)	35.46 (2.1%)	40.97 (0.5%)	308 (12.8%)	5	0.75	0.21
Guatemala	2,551	289 (2.1%)	21.75 (4.6%)	19.12 (1.1%)	487 (19.1%)	6	1.00	0.21
Nicaragua	2,582	304 (3.6%)	19.66 (7.8%)	20.59 (2.2%)	407 (15.8%)	11	1.53	0.46
Ecuador	2,606	535 (2.6%)	30.73 (7.7%)	40.7 (1.2%)	207 (7.9%)	14	2.36	0.49
Honduras	2,673	344 (1.4%)	21.94 (3.5%)	23.28 (1.0%)	446 (16.7%)	5	0.76	0.24
El Salvador	2,696	439 (3.4%)	26.91 (8.1%)	30.89 (1.8%)	413 (15.3%)	15	2.19	0.57
Suriname	2,698	327 (10.1%)	24.71 (19.3%)	22.30 (5.8%)	402 (14.9%)	33	4.78	1.30
Paraguay	2,768	387 (2.1%)	28.08 (4.4%)	26.16 (1.2%)	286 (10.3%)	8	1.23	0.31
Peru	2,775	339 (14.2%)	29.78 (24.1%)	19.2 (9.9%)	222 (8.0%)	48	7.18	1.91
Panama	2,851	619 (5.8%)	42.74 (12.0%)	42.93 (3.5%)	341 (12.0%)	36	5.13	1.49
Guyana	2,913	470 (8.7%)	35.54 (19.7%)	27.47 (3.8%)	317 (10.9%)	41	7.01	1.05
Costa Rica	3,029	697 (6.2%)	45.97 (12.5%)	45.53 (4.4%)	503 (16.6%)	43	5.73	2.00
Chile	3,029	809 (3.0%)	49.6 (7.2%)	62.54 (1.4%)	444 (14.6%)	24	3.56	0.91
Colombia	3,114	545 (2.6%)	37.31 (5.5%)	37.02 (1.6%)	590 (18.9%)	14	2.05	0.59
Mexico	3,157	697 (3.9%)	44.78 (9.6%)	50.68 (1.8%)	445 (14.1%)	27	4.30	0.92
Uruguay	3,202	801 (2.2%)	46.22 (5.7%)	58.48 (1.2%)	477 (14.9%)	18	2.64	0.72
Brazil	3,301	860 (1.7%)	53.77 (4.5%)	61.44 (0.7%)	409 (12.4%)	15	2.45	0.46
Argentina	3,307	1,043 (1.2%)	69.05 (3.0%)	76.34 (0.5%)	453 (13.7%)	13	2.08	0.39
Canada	3,566	888 (4.0%)	56.75 (9.9%)	68.89 (1.8%)	447 (12.5%)	36	5.63	1.22
USA	3,782	1,027 (3.5%)	73.46 (7.3%)	71.18 (1.8%)	589 (15.6%)	36	5.40	1.30

[1] Expressed as percent total calories

Fish and seafood – a healthier alternative to terrestrial meat products

Aquatic food products offer a much healthier food source than terrestrial meat products in the global fight against malnutrition and obesity; aquatic animal foods (whether captured or cultured) having a higher protein content on an edible weight basis than most terrestrial meats, a lower caloric density and generally being much leaner than red and processed meats, having the highest content of long-chain omega-3 polyunsaturated fatty acids than any other animal foodstuff, and generally having a higher mineral and vitamin content than most terrestrial meats and processed meat products (Reames 2012; Sargent & Tacon, 1999; Tacon and Metian 2013; USDA, 2018). Moreover, considerable scientific data exists concerning the direct health benefits of consuming aquatic food products, either through the reduced risk of death from coronary heart disease and stroke, the reduced risk of diabetes, the increased duration of gestation and improved visual and cognitive development, the improved neurodevelopment in infants and children when fish is consumed before and during pregnancy, and the reduced risk of thyroid cancer in women through seaweed consumption (FAO/WHO, 2011; Forouhi *et al*., 2018; He, 2009; Hellberg *et al.*, 2012; Michikawa *et al*., 2012; Verbeke *et al*., 2005; Wallin *et al*., 2012).

Despite the above nutritional and health attributes, there are potential health risks from the consumption of aquatic food products. These can include specific health risks from the consumption of raw/under-cooked fish or shellfish (contaminated with live pathogens or parasites; FAO/WHO, 2011; Hellberg *et al.*, 2012) or from the consumption of aquatic food products sourced from polluted waters (contaminated with environmental pollutants such as heavy metals, persistent organic pollutants [POPs], veterinary drug residues, or micro-plastics; Barber *et al.* 2006; Domingo *et al*. 2007; Lie, 2008; Nicklisch *et al.* 2017; Schmid *et al.* 2007; Tacon & Metain, 2008; Verbeke *et al*. 2005; VKM, 2014; Weber & Goerke, 2003; Xanthos & Walker, 2017) or from the consumption of fish and shellfish sourced from waters containing algal biotoxins (Morabito et al. 2018). However, in most instances these risks can be eliminated or greatly reduced by the use of appropriate cooking, handling and/or processing techniques, or through the selection of wild aquatic food products from unpolluted waters. Notwithstanding the above risks, it is generally believed that the higher nutritional value and potential health benefits derived from increased fish consumption far out-way the potential negative risks to human health (FAO/WHO, 2011; VKM, 2014).

Role of fish nutrition in improving human health

It follows from the above discussion that wild-caught fish and seafood products have a greater risk of being contaminated with environmental pollutants and algal biotoxins than farmed aquatic species, where strict controls are usually placed on feed quality and food safety (Barber *et al*., 2006; Escher *et al.,* 2020; Kwasek *et al*., 2020; Lie, 2008; Maule *et al*., 2007; Nicklisch *et al*., 2017; Schmid *et al*., 2007; Tacon & Metian, 2008, 2013; USDA, 2018; VKM, 2014; Weber & Goerke, 2003).

In view of the potential presence of environmental pollutants within wild-caught fish and the global stagnation of capture fisheries landings (FAO 2021b), it is clear that aquaculture is the only real long-term sustainable solution for increased fish and seafood production in the short or long term (Tacon, 2020). Moreover, in the case of aquaculture (in contrast to wild capture fisheries), it is also possible to enhance the nutritional profile of the flesh of the cultured by dietary manipulation and/or dietary fortification to meet potential consumer needs (Lie, 2008; Tacon *et al*., 2020).

Examples of research studies which have successfully demonstrated the nutritional enhancement of farmed fish through dietary fortification are numerous (Figure 2), and examples can be listed as follows:

- Dietary fortification with long chain omega-3 polyunsaturated fatty acids, including Atlantic salmon *Salmo salar* (Kousoulaki *et al*., 2016; Lie 2008; Nanton *et al*., 2012; Sprague *et al.,* 2016; Rosenlund *et al*., 2011; Torstensen *et al*., 2004), Channel catfish *Ictalurus punctatus* (Manning *et al*., 2006; Manning *et al*., 2007), Tilapia *Oreochromis* sp. (Jiratanan 2007; Jorge *et al*., 2021; Ng *et al.*, 2013; Petenuci *et al*., 2018; Sarker *et al.*, 2016; Stoneham *et al*., 2018; Watters *et al.*, 2013) and shrimp *Litopenaeus vannamei* (Kumar *et al*., 2018; Nonwachai *et al*., 2010; Wang *et al*., 2015);
- Dietary fortification with fat soluble vitamins, including vitamin E: Atlantic salmon *S. salar* (Harare *et al*., 1998; Sigurgisladottir *et al*., 1994; Waagbø *et al.*, 1993), Rainbow trout *O. mykiss* (Mihalca *et al*., 2011);
- Dietary fortification with essential trace minerals, including 1) Selenium: African catfish *Clarias gariepinus* (Luten *et al*., 2008; Schram *et al*., 2008), Atlantic salmon *S. salar* (Berntssen *et al*., 2018; Lorentzen *et al.*, 1994; Sele *et al*,. 2018), common carp and gilthead seabream (Barbosa *et al.*, 2020), Rainbow trout *O. mykiss* (Ribeiro *et al.*, 2017); 2) Iodine, including Atlantic salmon *S. salar* (Julshamn *et al.*, 2006; Schmid *et al*., 2003), Chars *Salvelinus* sp. (Schmid *et al*., 2003),

common carp and gilthead seabream (Barbosa *et al*., 2020),Rainbow trout *Oncorynchus mykiss* (Ribeiro *et al*., 2017); and 3) trivalent Chromium: Nile Tilapia *O. niloticus* (Li *et al*., 2018); and

- Dietary fortification with essential and non-essential amino acids, including Taurine: African catfish *Clarias gariepinus* (Luten *et al*., 2008) and Rainbow trout *O. mykiss* (Anderson 1992; Aksnes *et al*., 2006).

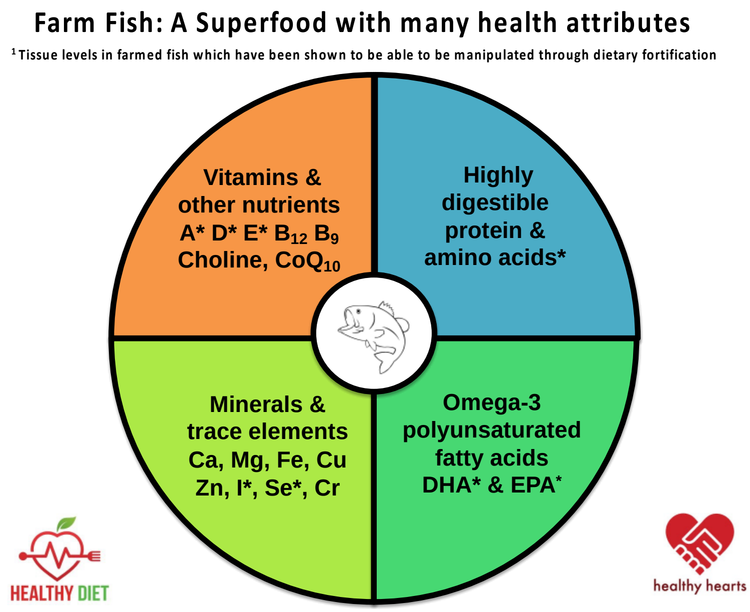

Figure 2. Tissue levels in farmed fish which can be manipulated through dietary fortification

Moreover, in addition to the above, the concentration of environmental pollutants, including heavy metals and POPs, can be reduced within farmed fish (if deemed a problem) through the dietary substitution of contaminated fish oils and fish meals with less contaminated lipid and protein meals (Bell *et al*., 2005; Berntssen *et al*., 2005; Berntssen *et al*., 2011; Haldorsen *et al*., 2017; Heshmati *et al*., 2019; Turchini *et al*., 2019).

Need for improved communication & consumption of farmed aquatic food products

Fish and seafood needs to be viewed by policy makers and governments as an important contributor to the global food basket, and the increased consumption of fish and seafood products actively promoted as a high-health and heart-healthy alternative to processed foods and terrestrial animal food products; the latter being particularly true for those countries suffering from a high incidence of obesity, coronary heart disease, diabetes and associated ailments (Henry *et al*., 2020; HHP, 2011; Mozaffarian and Ludwig 2010; NHMRC, 2013; Pan *et al.*, 2012; Skerrett and Willett 2010; Tacon, Lemos & Metian, 2020; USDHHS/USDA, 2015; Wallin *et al.*, 2012, 2016; Willett *et al.*, 2019).

Table 3 presents recommended targets for a 2,500 Kcal healthy reference diet, including the possible ranges for different food groups, including fish. Moreover, it has been estimated that dietary changes from current high energy dense diets toward more healthy diets are likely to have significant health benefits, including averting between 7.4 to 10.8 million premature deaths per year (Willett *et al*., 2019).

Table 3. Recommended targets for a healthy reference diet, with possible ranges, for an intake of 2,500 Kcal/day (compiled from Willet *et al*., 2019)

Food group	Food subgroup	Reference diet (g/day)	Kcal/day	Posssible ranges (g/day)
Whole grains	Rice, wheat, corn, beans, lentils	232	811	Total grains 0 to 60% of energy
Starchy roots	Potatoes, cassava	50	39	0 to 100
Vegetables	All vegetables	300		200 to 600
Fruits	All fruit	200	126	100 to 300
Dairy foods	Dairy foods	250	153	0 to 500
Protein sources	Beef, lamb	7	15	0 to 14
	Pork	7	15	0 to 14
	Chicken, other poultry	29	62	0 to 58
	Eggs	13	19	0 to 25
	Fish	28	40	0 to 100
	Beans, lentils & peas	50	172	0 to 100
	Soy foods	25	112	0 to 50
	Tree nuts & peanuts	50	291	0 to 75
Added fats	Unsaturated plant oils	40	354	20 to 80
	Dairy fats	0	0	
	Lard/tallow	5	36	0 to 5
Added sugars	All sweeteners	31	120	0 to 31

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