Taylor & Francis
Taylor & Francis Group

Reviews in Fisheries Science & Aquaculture

ISSN: 2330-8249 (Print) 2330-8257 (Online) Journal homepage: https://www.tandfonline.com/loi/brfs21

Fish for Health: Improved Nutritional Quality of Cultured Fish for Human Consumption

Albert G. J. Tacon, Daniel Lemos & Marc Metian

To cite this article: Albert G. J. Tacon, Daniel Lemos & Marc Metian (2020): Fish for Health: Improved Nutritional Quality of Cultured Fish for Human Consumption, Reviews in Fisheries Science & Aquaculture, DOI: 10.1080/23308249.2020.1762163

To link to this article: https://doi.org/10.1080/23308249.2020.1762163

Published online: 13 May 2020.

REVIEWS IN FISHERIES SCIENCE & AQUACULTURE
https://doi.org/10.1080/23308249.2020.1762163

Taylor & Francis
Taylor & Francis Group

REVIEW

Fish for Health: Improved Nutritional Quality of Cultured Fish for Human Consumption

Albert G. J. Tacon[a], Daniel Lemos[b], and Marc Metian[c]

[a]Aquaculture Nutrition Consultant, Aquahana LLC, Kailua, Hawaii, USA; [b]Aquaculture Laboratory, Oceanographic Institute, University of São Paulo, São Paulo, Brazil; [c]Radioecology Laboratory, International Atomic Energy Agency, Monaco, Principality of Monaco

ABSTRACT
In a global fight against over-nutrition, obesity and associated ailments, identification and consumption of healthier food than processed red meat products and fast-foods is crucial. Fish and seafood products appear as the healthier alternative animal products and the present paper highlight their nutritional merits and health attributes in a world where malnutrition but also under-nutrition is still negatively affecting the health and well- being of many people. The paper also provides the major studies conducted to enhance the nutritional profile of farmed fish through dietary fortification, and highlights the need to increase consumer awareness and understanding concerning the health benefits of fish and seafood products as an essential component of a healthy diet.

KEYWORDS
Malnutrition; Undernutrition; Aquatic foods; Aquaculture; Nutrient supply; Dietary fortification

1. The growing epidemic of obesity

Over the past 50 years, there has been a marked increase in the incidence of malnutrition, and in particular over-nutrition and associated ailments within developed and developing countries, including obesity, coronary heart disease, diabetes, and hypertension due primarily to the increased consumption of lower cost fast-foods (and to a lesser extent red meats and dairy produce), coupled with a more sedentary and less active lifestyle (Forouhi et al. 2018; Inyang and Stella 2015; Murray 2001; OECD, 2017; Prentice 2006; Roth et al. 2018; WHO, 2018a, 2018b; Zhong et al. 2020).

For the purposes of this paper fast-foods refers to food items that can be prepared and served quickly, and may include processed red meat products (hot-dogs, hamburgers, sausages, bacon, ham, spam, etc.), processed/refined carbohydrates (biscuits, cookies, donuts, pan cakes, muffins, crackers, bread, pizza, pasta), fried foods (french fries, hash browns, fried chicken, chicken nuggets), sugary drinks, and candy/ice cream (De Vogli et al. 2014);

It is generally believed that the increased proportion of total caloric intake derived from fast food has been due to a variety of factors, including (but not limited to) lower cost/affordability, bigger portion sizes, increased convenience, taste, and accessibility (Finkelstein et al. 2014; Powell and Chaloupka 2009; Khan et al. 2012; Murray 2001; Xu et al. 2014);

According to the World Health Organization (WHO), the current global status of over-nutrition and obesity, and related ailments, can be listed as follows:

- Worldwide, obesity has tripled since 1975; 13% of the worlds adult population were obese in 2016, including 650 million adults, 340 million children and adolescents aged between 5 and 19, and 40 million children under 5 being overweight or obese in 2016 (WHO, 2020);
- Worldwide, cardiovascular diseases account for over 17.8 million deaths annually (increasing by 21.1% between 2007 and 2017, with Ischemic heart disease, stroke, and hypertensive heart disease accounting for 8.93, 6.17 and 0.92 million deaths respectively in 2017; Roth et al. 2018), followed by cancers (9.0 million deaths), and diabetes (1.6 million deaths, with diabetes being a major cause of blindness, kidney failure, heart attacks, stroke and lower limb amputation; OECD, 2017; WHO, 2018b, 2018c);

Apart from the obvious human cost of over-nutrition and obesity to humanity in terms of lives lost,

CONTACT Albert G. J. Tacon agjtacon@aquahana.com Aquahana LLC, Kailua, HI 96734, USA

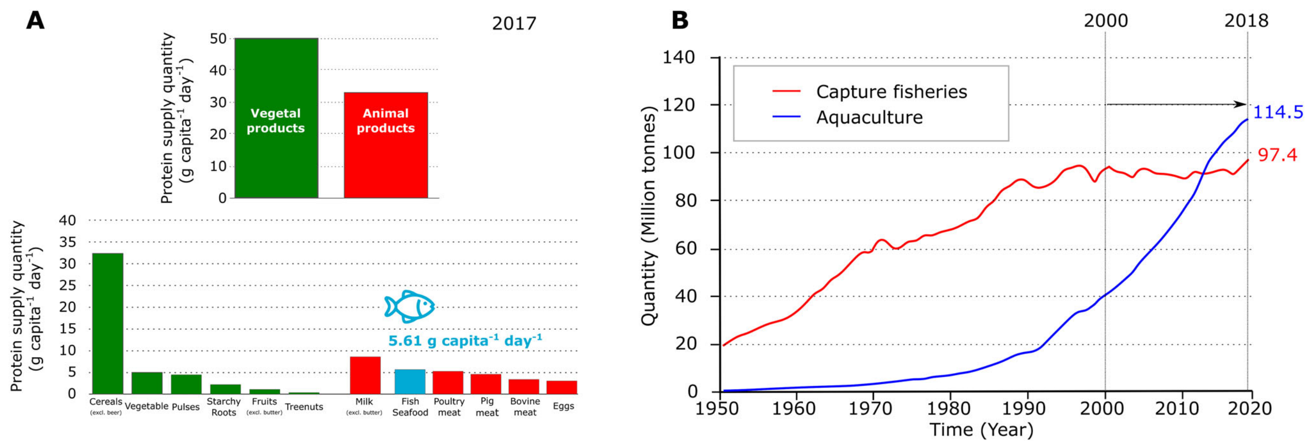

Figure 1. Daily per capita protein intake by animal and vegetal products (global and the top 6 for each category; A; FAO, 2020a) and the trends of global landings from capture fisheries and aquaculture (1950-2018; B; FAO, 2020).

the economic cost to society of dealing with these ailments is considerable (Cawley and Meyerhoefer 2012; Finkelstein et al. 2014; Xu et al. 2014). For example, the estimated cost of treating obesity in the U.S. between 2005 and 2010 reportedly increased by 48.7% from $212.4 billion to $315.8 billion, with the share of total health care spending of non-institutionalized adults devoted to treating obesity-related illness rising from 20.6% in 2005, to 27.5% in 2010, and to 28.2% in 2013 (Biener et al. 2017). According to these authors, the increase in expenditure costs has been due to a combination of factors, including increased costs, increased population growth, and an increase in the prevalence of obesity in the U.S. (Biener et al. 2017; Finkelstein et al. 2014). Moreover, dental caries (mainly due to the high dietary intake of free sugars) has been the most common noncommunicable disease worldwide and an expensive disease to treat, reportedly consuming 5-10% of the healthcare budgets in industrialized countries (WHO, 2017).

Notwithstanding the epidemic of overnutrition and obesity, at the same time there has also been a global concern for undernutrition and associated nutrient deficiencies (particularly within developing countries), including wasting (low weight-for-height; 49 million children under the age of 5 years), stunting (low height-for-age; 155 million children under the age of 5 years) and underweight (low weight-for age; 462 million adults), with over 45% of deaths among children under the age of 5 being linked to undernutrition (WHO, 2018a). In view of this double burden of both overnutrition and undernutrition, the United Nations (UN) Decade of Action on Nutrition (2016-2025) aims to address all forms of malnutrition, and in particular for policy action across 6 key areas:

- Creating sustainable, resilient food systems for healthy diets;
- Providing social protection and nutrition-related education for all;
- Aligning health systems to nutrition needs, and providing universal coverage of essential nutrition interventions
- Ensuring that trade and investment policies improve nutrition;
- Building safe and supportive environments for nutrition at all ages; and
- Strengthening and promoting nutrition governance and accountability, everywhere (FAO, 2017; WHO, 2018a).

2. Fish and seafood – a healthier alternative

Fish and seafood (includes all captured and farmed finfish, crustaceans, mollusks, and aquatic plants) offer a much healthier food source than terrestrial meat products (includes processed meats, red meat, poultry) in the global fight against malnutrition and obesity (Bogard et al. 2015; FAO 2018; Mohan Dey et al. 2005; Sargent and Tacon 1999; Solhelm 2010; Thilsted et al. 2014; Verbeke et al. 2005; VKM, 2014; Zhong et al. 2020); on a global basis fish and seafood products constituting the third major source of dietary protein consumed by humans after cereals and milk in 2017 and representing 17.1% of total animal protein supply (fish and seafood consumption being greater than the consumption of poultry meat, pig meat, bovine meat, or hens eggs; Figure 1A; FAO, 2020a). Compared with terrestrial meat products, 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 (including vitamins - Vitamin A, Vitamin D, Vitamin E, Vitamin B_{12}, Folic acid, Choline, Coenzyme Q_{10}, and minerals – Calcium, Magnesium, Iron, Copper, Zinc, Iodine, Selenium, and trivalent Chromium: Reames 2012; Tacon and Metian 2013; USDA, 2018). Moreover, considerable scientific data exists concerning the direct health benefits of consuming fish and fishery products (including farmed aquatic plants or seaweeds), including (but not limited to) reduced risk of death from coronary heart disease and stroke (FAO/WHO, 2011; Forouhi et al. 2018; He 2009; Hellberg et al. 2012; Verbeke et al. 2005; Wallin et al. 2012), reduced risk of diabetes (Wallin et al. 2012), increased duration of gestation and improved visual and cognitive development (Hellberg et al. 2012), improved neurodevelopment in infants and children when fish is consumed before and during pregnancy (FAO/WHO, 2011), and reduced risk of thyroid cancer in women through seaweed consumption (Michikawa et al. 2012). Table 1 shows the reported functions and health benefit of the key nutrients found in aquatic food products.

Despite the above positive nutritional and health attributes, it must also be stated however that like any other food product, there are potential health risks to fish and seafood consumption depending upon their origin and processing. For example, although the greatest risk to human health is believed to be from the consumption of raw and/or unprocessed fish and seafood contaminated with pathogens (including parasites, nematodes, cestodes, trematodes, bacteria, and/or biotoxins depending upon the species), these risks can be eliminated through proper cooking, handling and storage (FAO/FAO/World Health Organization (WHO), 2003; Hellberg et al. 2012). Notwithstanding the above, there may be a risk from the presence of environmental contaminants (depending upon the aquatic species and origin), including (but not limited to) heavy metals (methyl mercury), persistent organic pollutants (POPs - PCBs, dioxins), veterinary drug residues, and micro-plastics (Berntssen et al. 2010; Domingo et al. 2007; FAO/WHO, 2011; Hellberg et al.., 2012; Tacon and Metian 2008; Verbeke et al. 2005; VKM, 2014). 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, 2003, 2011; VKM, 2014). In addition, fish and seafood products have, like any other food products found on the market, been through food safety measures and verification (from national regulations to International food standards) although ensuring food safety and security in a highly globalized world presents increasingly difficult (Fukuda 2015).

3. All fish are not all created equal

It follows from the above discussion that not all fish are created equal, and that their nutritional composition, contaminant burden (if any), and consequently their potential health value, will vary depending upon the fish species, its position in the aquatic food chain and feeding habit, its longevity and size before being consumed, its geographical origin and source (if harvested from a river, lake, estuary, or open sea; recreational fishery, wild caught or farmed), and the nutrient profile and composition of the feed fed if farmed (Cladis et al. 2014; Kwasek et al. 2020; Maule et al. 2007; Mohan Dey et al. 2005; Tacon and Metian 2013; USDA, 2018; VKM, 2014). For example, Bogard et al. (2017) reported the lower overall nutritional quality (in terms of the nutrients iron and calcium) of lower trophic-level farmed freshwater fish compared with wild-caught marine fish in Bangladesh. Similarly, higher levels of the heart healthy long-chain omega-3 polyunsaturated fatty acids (eicosapentaenoic acid - EPA and docosahexaenoic acid - DHA) have also been reported in wild-caught marine small pelagic fish species (mackerel, herring, anchovy) and higher trophic-level marine/brackishwater farmed fish species, compared with lower trophic-level farmed freshwater fish species (Cladis et al. 2014; Tacon and Metian 2013; USDA, 2018).

Moreover, it is also evident that the rivers and oceans where our wild-fish are being caught or fished are also suffering from an ever-increasing torrent of environmental pollutants from wastewater treatment plants, urban and agricultural runoff, and from the air (Escher et al. 2020; Johnson et al. 2020; Schmid et al. 2007; Weber and Goerke 2003; Xanthos and Walker 2017). The net result of this has been the progressive accumulation of many of environmental pollutants within the aquatic food chain, including most of the wild-caught species currently being used as human food (Barber et al. 2006; Davis et al. 2004; Klumpp et al. 2002; VKM, 2014).

Table 1. Reported function and health benefits of key nutrients commonly found in aquatic food products.

NUTRIENT	REPORTED FUNCTION & HEALTH BENEFITS
Vitamins	
Vitamin A[1,2,3]	Vitamin A is critical for vision as an essential component of rhodopsin, and the normal differentiation and functioning of the conjunctival membranes and cornea (preventing blindness in children); keeps tissues and skin healthy, and plays an important role in bone growth and is involved in immune function, vision, reproduction, and cellular communication; supports cell growth and differentiation, playing a critical role in the formation and maintenance of the heart, lungs, and kidneys; and may play a protective role against cancer, age-related macular degeneration, and measles.
Vitamin D[1,2,3]	Vitamin D aids calcium absorption in the gut and maintains normal levels of calcium and phosphorus in the blood, the mineralization of bone (bone health), and the formation of teeth and bones; Vitamin D sufficiency preventing rickets in children and osteomalacia in adults (together with calcium, vitamin D also helps protect older adults from osteoporosis); plays a role in the modulation of cell growth, neuromuscular and immune function, and reduction of inflammation; and may play a protective role in the prevention and treatment of diabetes, hypertension, glucose intolerance, and multiple sclerosis.
Vitamin E[1,3]	Vitamin E functions as an antioxidant, protecting cells and susceptible chemicals (Vitamin A) and lipids (rich in unsaturated fatty acids) from free radicals and consequent oxidative damage; plays a role in anti-inflammatory processes, inhibition of platelet aggregation, and immune function; and by limiting free-radical production may help prevent and/or delay the chronic diseases associated with free radicals such as cardiovascular disease, cancer, eye disorders, cognitive decline, and Alzheimers disease.
Vitamin B_{12}[1,3]	Vitamin B_{12} is required for proper red blood cell formation, neurological function, and DNA synthesis; assists in making new cells and breaking down some fatty acids and amino acids; aids in lowering homocysteine levels and the possible risk of heart disease; and low tissue Vitamin B_{12} levels have been positively associated with cognitive decline.
Choline[1,2]	Choline is needed to produce acetylcholine, an important neurotransmitter for memory, mood, muscle control, and other brain and nervous system functions; plays a key role in metabolizing and transporting fats; serves as a metabolic source of methyl groups, including the synthesis of the phospholipids phosphatidylcholine and sphingomyelin vital for cell membranes; plays important roles in modulating gene expression, cell membrane signaling, and early brain development; and may play a protective role in cardiovascular and peripheral artery disease, neurological disorders, and nonalcoholic fatty liver disease.
Coenzyme Q_{10}[3]	Coenzyme Q_{10} functions as an endogenous antioxidant, and is used by cells in aerobic metabolism, and for the production of energy for cell growth and maintenance; and also plays a role as an cells immune enhancer (low blood levels of coenzyme Q_{10} have been detected in patients with some types of cancer).
Folic acid[1,3]	Folic acid is essential for new cell creation, for preventing brain and spine defects when taken early in pregnancy, and functions as a coenzyme in amino acid metabolism and for the synthesis of nucleic acids (RNA, DNA; a folate deficiency leading to megaloblastic anemia; and may play a protective role against reduce the risk of cardiovascular disease and stroke, colon cancer, autism spectrum disorder, dementia, cognitive function, Alzheimer's disease, depression, preterm birth, and congenital heart defects.
Minerals	
Calcium (Ca)[1, 3]	Calcium is essential for building and protecting bones and teeth, is required for muscle contraction and relaxation, nerve impulse transmission, blood clotting, hormonal secretion, enzyme activation, maintaining healthy blood pressure; and may have a protective role on bone health and osteoporosis, cardiovascular disease, hypertension, cancer of the colon, rectum, and prostate, kidney stones, and weight management.
Chromium (Cr)[3,4]	Trivalent Chromium is an essential component of the hormone insulin and is actively involved in carbohydrate, fat and protein metabolism, helps to maintain normal blood glucose levels, is needed to free energy from glucose; and may have a protective health effects on diabetes, reduced blood lipid levels, and weight loss.
Copper (Cu)	Copper plays an important role as a cofactor in iron metabolism and red blood cell formation, immune function, energy production, iron metabolism, neuropeptide activation, connective tissue synthesis, neurotransmitter synthesis, regulation of gene expression, brain development, pigmentation, and oxidative damage; and may play a protective role against cardiovascular disease, Alzheimer's disease, and dementia.
Iodine (I)	Iodine is an essential component of the thyroid hormones which regulate many important metabolic activities, including protein synthesis, the regulation of body temperature, nerve and muscle function, reproduction, and growth; and may have a beneficial effect on mammary dysplasia and fibrocystic breast disease, fetal and infant development, cognitive function during childhood, fibrocystic breast disease, and radiation-induced thyroid cancer.
Iron (Fe)	Iron is an essential component of hemoglobin and myoglobin and assists with the transport of oxygen in the body, supporting muscle metabolism and healthy connective tissue; required for the synthesis of amino acids, collagen, neurotransmitters and neurodevelopment, cellular functioning, hormone synthesis; and the prevention of iron deficiency anemia in pregnant women and infants.
Magnesium (Mg)[1,3]	Magnesium functions as a cofactor for numerous enzyme systems and metabolic processes, including protein synthesis, blood glucose control, blood pressure regulation, and energy production; contributes to the structural development of bone and is required for the synthesis of DNA, RNA, and the antioxidant glutathione; plays a role in the active transport of calcium and potassium ions across cell membranes, nerve impulse conduction, muscle contraction, and normal heart rhythm; and may have a protective role against hypertension and cardiovascular disease, diabetes, osteoporosis, and migraine headaches.

(*Continued*)

Table 1. Continued.

NUTRIENT	REPORTED FUNCTION & HEALTH BENEFITS
Selenium (Se)[1,3]	Selenium is an integral part of selenoproteins which play important roles in reproduction, thyroid hormone metabolism, DNA synthesis, and protection from oxidative damage and infection; and may play a protective role against cancer, cardiovascular disease, cognitive decline, and thyroid disease.
Zinc (Zn)	Zinc is important for cellular metabolism, and plays an important role in immune function, protein synthesis, wound healing, DNA synthesis, and cell division; supports normal growth and development during pregnancy, childhood, and adolescence; required for proper sense of taste and smell, and immune function; and may have a protective role against age-related macular degeneration.
Lipids	
Long chain omega-3 polyunsaturated fatty acids - EPA & DHA[1,3,4,5]	Long chain omega-3 polyunsaturated fatty acids are an integral part of phospholipids and an essential component of all cell membranes; serve as an energy source for the body, are used for the synthesis of eicosanoids that regulate blood clotting, contraction and relaxation of artery walls, and inflammation; and have been shown to reduce the risk of cardiovascular disease, cancer, Alzheimer's disease, dementia, cognitive function, age-related macular degeneration, dry eye disease, and rheumatoid arthritis.
Protein	
Protein [3]/	Proteins are essential components of all living cells, enzymes, hormones, are necessary to build, maintain, and repair muscle, and are important for neural function, digestive function, and are composed of essential and non-essential amino acids.
Taurine [6]/	Taurine is an amino acid involved in cell volume regulation, serving as a precursor of the bile salts, and is one of the most abundant amino acids in the brain, retina, muscle tissue, and body organs; and taurine deficiency associated with cardiomyopathy, renal dysfunction, developmental abnormalities, and severe damage to retinal neurons.

[1]HHPS (2009).
[2]Solhelm 2010.
[3]NIH, 2020.
[4]Anderson (1992).
[5]HHPS (2011).
[6]Ripps and Shen (2012).

4. Need for aquaculture and nutrient fortification

In view of the dilemma of rising and un-controllable environmental pollutant levels within wild-caught fish (depending on their geographical origin and position in the aquatic food chain; Nicklisch et al. 2017), and the general stagnation of capture fisheries worldwide (FAO 2020b; Figure 1B), it is clear that aquaculture is the only long-term solution and hope for the increased mass global production of safe and wholesome aquatic food products (Tacon 2020). Moreover, in marked contrast to wild-caught fish, with aquaculture it is also possible to improve the nutritional quality of the flesh of the cultured fish or shrimp species, and consequently enhance its potential health value, by dietary manipulation and/or nutrient fortification (Lie 2001, 2008; Rosenlund et al.; 2011).

Thus, there is considerable scientific evidence for the health benefits of omega-3 polyunsaturated fatty acids (PUFA), and in particular EPA and DHA, against coronary heart disease, stroke, and diabetes (Table 1; Calder 2004; Rosenlund et al. 2011; Ruxton et al. 2007; Sargent and Tacon 1999; Wallin et al. 2012). As a consequence of these known health benefits, considerable research effort has focused on the enrichment of fish fillets with heart-healthy PUFA through dietary manipulation prior to harvest, 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; Ng et al. 2013; Petenuci et al. 2018; Sarker et al. 2016; Stoneham et al. 2018; Watters et al. 2013) and shrimp (*Litopenaeus vannamei*; Nonwachai et al. 2010).

Other nutrients with potential health-benefits which have been shown to be enhanced within fish flesh through dietary fortification, include (but not limited to), 1) Iodine: Atlantic salmon *S. salar* (Julshamn et al. 2006; Schmid et al. 2003), Chars *Salvelinus* sp. (Schmid et al. 2003), Rainbow trout *Oncorynchus mykiss* (Ribeiro et al., 2017), 2) 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), Rainbow trout *O. mykiss* (Ribeiro et al., 2017), 3) trivalent Chromium: Nile Tilapia *O. niloticus* (Li et al. 2018), 4) 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), and 5) Taurine: African catfish *Clarias gariepinus* (Luten et al. 2008) and Rainbow trout *O. mykiss* (Anderson 1992; Aksnes et al. 2006).

In addition to nutrient enrichment, the levels of environmental pollutants such as POPs and heavy metals, and possible adventitious dietary toxins (such as mycotoxins), can be reduced within fish fillets through

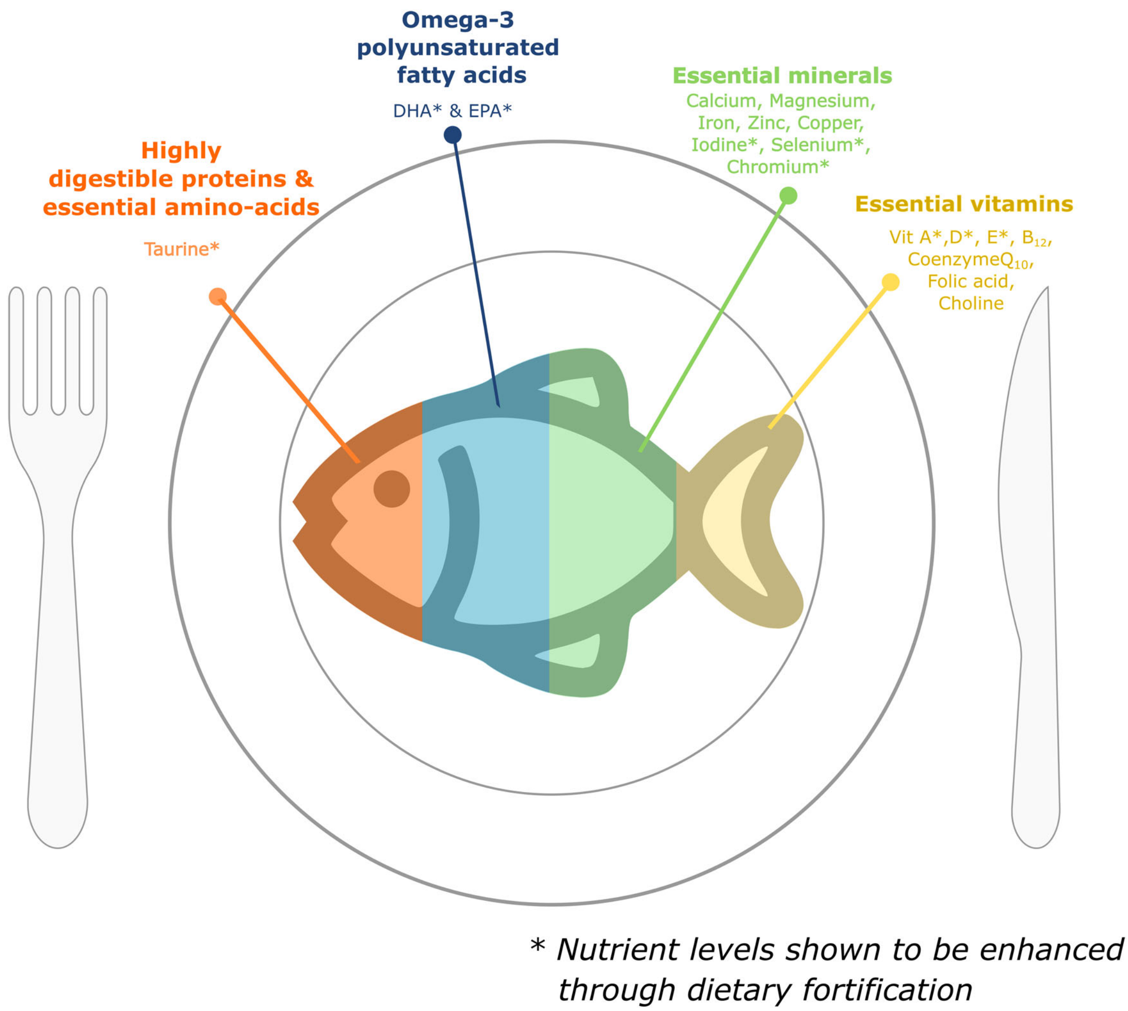

Figure 2. Farmed fish: a superfood with multiple health attributes.

dietary formulation changes, by substituting contaminated fish oils and fish meals with alternative less contaminated or adulterated dietary lipid and protein sources (Bell et al. 2005; Berntssen et al. 2005; Berntssen et al. 2011; Goncalves et al. 2020; Haldorsen et al., 2017; Heshmati et al. 2019; Turchini et al. 2019).

5. Need for improved communication

In view of the above review, there is an urgent need to increase public awareness and understanding concerning the nutritional merits and health-benefits of increased consumption of fish and seafood products, including the inclusion of fish and aquatic foods as an essential component of a healthy diet and national dietary nutrient requirement guidelines (HHP, 2011; Mozaffarian and Ludwig 2010; NHMRC, 2013; Skerrett and Willett 2010; USDHHS/USDA, 2015; Figure 2).

Finally, although fish and seafood currently constitute the main source of animal protein consumed within most Asian countries (FAO, 2020a; Tacon and Metian 2018), at the same time, there is also a rapid rise and adoption of western-style fast-foods within these countries, and consequent increased risk of obesity and related ailments (Henry et al., 2020; Pan et al. 2012; Wallin et al. 2012, 2016). It follows therefore, that education of the consumer is key, and that more healthy fast-food options be developed and promoted, including fast-food products derived from fortified farmed fish or shrimp.

Funding

The International Atomic Energy Agency is grateful for the support provided to its Environment Laboratories by the Government of the Principality of Monaco. Daniel Lemos acknowledges CNPq (National Council for Scientific and Technological Development, 303259/2017-5).

ORCID

Marc Metian http://orcid.org/0000-0003-1485-5029

References

Aksnes A, Hope B, Albrektsen S. 2006. Size-fractionated fish hydrolysate as feed ingredient for rainbow trout (*Oncorhynchus mykiss*) fed high plant protein diets. II: Flesh quality, absorption, retention and fillet levels of taurine and anserine. Aquaculture. 261(1):318–326. doi:10.1016/j.aquaculture.2006.07.026

Anderson RA. 1992. Chromium, glucose tolerance, and diabetes. Biol Trace Elem Res. 32(1-3):19–24. doi:10.1007/BF02784583

Barber LB, Keefe SH, Antweiler RC, Taylor HE, Wass RD. 2006. Accumulation of contaminants in fish from wastewater treatment. Environ Sci Technol. 40(2):603–611. doi:10.1021/es0514287

Bell JG, McGhee F, Dick JR, Tocher DR. 2005. Dioxin and dioxin-like polychlorinated biphenyls (PCBs) in Scottish farmed salmon (*Salmo salar*): effects of replacement of dietary marine fish oil with vegetable oils. Aquaculture. 243(1-4):305–314. doi:10.1016/j.aquaculture.2004.10.016

Berntssen MHG, Lundebye A-K, Torstensen BE. 2005. Reducing the levels of dioxins and dioxin-like PCBs in farmed Atlantic salmon by substitution of fish oil with vegetable oil in the feed. Aquac Nutr. 11(3):219–231. doi:10.1111/j.1365-2095.2005.00345.x

Berntssen MHG, Maage A, Julshamn K, Oeye BE, Lundebye A-K. 2011. Carry-over of dietary organochlorine pesticides, PCDD/Fs, PCBs, and brominated flame retardants to Atlantic salmon (*Salmo salar* L.) fillets. Chemosphere. 83(2):95–103. doi:10.1016/j.chemosphere.2011.01.017

Berntssen M, Betancor MB, Caballero MJ, Hillestad M, Rasinger JD, Hamre K, Sele V, Amlund H, Ørnsrud R. 2018. Safe limits of selenomethionine and selenite supplementation to plant-based Atlantic salmon feeds. Aquaculture. 495:617–630. doi:10.1016/j.aquaculture.2018.06.041

Biener A, Cawley J, Meyerhoefer C. 2017. The high and rising costs of obesity to the US Health care system. J Gen Intern Med. 32(S1):6–8. doi:10.1007/s11606-016-3968-8

Bogard JR, Thilsted SH, Marks GC, Wahab MA, Hossain MA, Jakobsen J, Stangoulis J. 2015. Nutrient composition of fish species in Bangladesh and potential contribution to recommended nutrient intakes. J Food Compost Anal. 42:120–133. doi:10.1016/j.jfca.2015.03.002

Bogard JR, Farook S, Marks GC, Waid J, Belton B, Ali M, Toufique K, Mamun A, Thilsted SH. 2017. Higher fish but lower micronutrient intake: temporal changes in fish consumption from capture fisheries and aquaculture in Bangladesh. PLOS One. 12(4):e0175098. doi:10.1371/journal.pone.0175098

Calder PC. 2004. Long-chain fatty acids and cardiovascular disease: further evidence and insights. Nutr Res. 24(10):761–772. doi:10.1016/j.nutres.2004.04.008

Cawley J, Meyerhoefer C. 2012. The medical care costs of obesity: an instrumental variables approach. J Health Econ. 31(1):219–230. doi:10.1016/j.jhealeco.2011.10.003

Cladis DP, Kleiner AC, Freiser HH, Santerre CR. 2014. Fatty acid profiles of commercially available finfish fillets in the United States. Lipids. 49(10):1005–1018. doi:10.1007/s11745-014-3932-5

Davis JA, Ross J, Fairey R, Roberts C, Ichikawa G, Negrey J, Crane D. 2004. Cisnet technical report: contaminant accumulation in forage fish. Oakland, California: San Francisco Estuary Institute. p. 12. Contribution No. 413, June 30th, 2004.

De Vogli R, Kouvonen A, Gimeno D. 2014. The influence of market deregulation on fast food consumption and body mass index: a cross-national time series analysis. Bull World Health Organ. 92(2):99–107A. doi:10.2471/BLT.13.120287

Domingo JL, Bocio A, Falco G, Llobet JM. 2007. Benefits and risks of fish consumption. Part 1. A quantitative analysis of the intake of omega-3 fatty acids and chemical contaminants. Toxicology. 230(2-3):219–226. doi:10.1016/j.tox.2006.11.054

Escher BI, Stapleton HM, Schymanski EL. 2020. Tracking complex mixtures of chemicals in our changing environment. Science. 367(6476):388–392. doi:10.1126/science.aay6636

Finkelstein EA, Strombotne KL, Zhen C, Epstein LH. 2014. Food prices and obesity: a review. Adv Nutr. 5(6):818–821. doi:10.3945/an.114.007088

Food and Agriculture Organization of the United Nations (FAO). 2017. United nation's decade of action on nutrition 2017-2025. Rome: FAO. p. 15. 5 May 2017, www.fao.org/3/a-bs726e.pdf.

FAO. 2018. The state of world fisheries and aquaculture 2018 - meeting the sustainable development. goals. Rome: FAO. p. 210.

Food and Agriculture Organization (FAO). 2020a. FAOSTAT - food balance sheets. Rome: FAO, Statistics Division. http://www.fao.org/faostat/en/#data/FBS.

FAO. 2020b. FishStatJ, a tool for fishery statistics analysis. Release: 4.00.10. Universal Software for Fishery Statistical Time Series. Global aquaculture production: Quantity 1950–2018; Value 1950–2018; Global capture production. Rome, Italy: FAO. p. 1950–2018.

FAO/World Health Organization (WHO). 2003. Code of practice for fish and fishery products joint FAO/WHO food standards programme. Rome: FAO. Report CAC/RCP 52-2003. (Rev.2004, 2005, 2007).

FAO/WHO. 2011. Report of the joint FAO/WHO expert consultation on the risks and benefits of fish consumption, 25–29 January 2010. Rome, Italy: FAO. p. 50. Fisheries and Aqua- culture Report No. 978 FIPM/R978 (En).

Forouhi NG, Misra A, Mohan V, Taylor R, Yancy W. 2018. Dietary and nutritional approaches for prevention and management of type 2 diabetes. BMJ. 361:k2234.

Fukuda K. 2015. Food safety in a globalized world. Bull World Health Organ. 93(4):212–212. doi:10.2471/BLT.15.154831

Goncalves RA, Schatzmayr D, Albalat A, Mackenzie S. 2020. Mycotoxins in aquaculture: feed and food. Rev Aquacult. 12(1):145–175. doi:10.1111/raq.12310

Haldorsen A-K, Lock E-J, Rasinger JD, Nøstbakken OJ, Hannisdal R, Karlsbakk E, Wennevik V, Madhun AS, Madsen L, Graff IE, et al. 2017. Lower levels of Persistent Organic Pollutants, metals and the marine omega 3-fatty acid DHA in farmed compared to wild Atlantic salmon (*Salmo salar*). Environ Res. 155:49–59. doi:10.1016/j.envres.2017.01.026

Harare K, Berge RK, Lie Ø. 1998. Oxidative stability of Atlantic salmon (*Salmo salar*, L.) fillet enriched in alpha

-, gamma -, and delta -tocopherol through dietary supplementation. Food Chem. 62(2):173–178. doi:10.1016/S0308-8146(97)00209-4

Harvard Health Publishing (HHPS). 2009. Staying healthy - listing of vitamins. Harvard Medical School. [accessed 2018 November 14]. https://www.health.harvard.edu/staying-healthy/listing_of_vitamins.

Harvard Health Publishing (HHPS). 2011 September 14. Harvard to USDA: check out the healthy eating plate. Harvard Medical School. [accessed 2020 February 28]. https://www.health.harvard.edu/blog/harvard-to-usda-check-out-the-healthy-eating-plate-201109143344.

He K. 2009. Fish, long-chain omega-3 polyunsaturated fatty acids and prevention of cardiovascular disease-eat fish or take fish oil supplement? Prog Cardiovasc Dis. 52(2):95–114. doi:10.1016/j.pcad.2009.06.003

Hellberg RS, De Witt CAM, Morrissey MT. 2012. Risk-benefit analysis of seafood consumption: a review. Compr Rev Food Sci F. 11(5):490–517. doi:10.1111/j.1541-4337.2012.00200.x

Henry CJ, Kaur B, Quek RYC. 2020. Are Asian foods as "fattening" as western-styled fast foods? European J Clin Nutr. 74(2):348–350. 2010). doi:10.1038/s41430-019-0537-3

Heshmati A, Sadati R, Ghavami M, Khaneghah AM. 2019. The concentration of potentially toxic elements (PTEs) in muscle tissue of farmed Iranian rainbow trout (*Oncorhynchus mykiss*), feed, and water samples collected from the West of Iran: A risk assessment study. Environ Sci Pollut Res. 26(33):34584–34593. doi:10.1007/s11356-019-06593-x

Inyang MP, Stella O-O. 2015. Sedentary lifestyle: health implications. IOSR J Nurs Health Sci. 4(2):20–25.

Jiratanan T. 2007. Development of omega-3 fatty acid enhanced tilapia (*Oreochromis niloticus*) (alpha-Linolenic acid). Dissertation Abstr Int. 68(3, suppl. B):92.

Johnson AC, Jin X, Nakada N, Sumpter JP. 2020. Learning from the past and considering the future of chemicals in the environment. Science. 367(6476):384–387. doi:10.1126/science.aay6637

Julshamn K, Maage A, Waagbo R, Lundebye A-K. 2006. A preliminary study on tailoring of fillet iodine concentrations in adult Atlantic salmon (*Salmo salar* L.) through dietary supplementation. Aquac Nutrition. 12(1):45–51. doi:10.1111/j.1365-2095.2006.00380.x

Khan T, Powell LM, Wada R. 2012. Fast food consumption and food prices: evidence from panal data on 5th and 8th grade children. J Obes. 2012:1–8. doi:10.1155/2012/857697

Klumpp DW, Huasheng H, Humphrey C, Xinhong W, Codi S. 2002. Toxic contaminants and their biological effects in coastal waters of Xiamen, China.: I. Organic pollutants in mussel and fish tissues. Mar Pollut Bull. 44(8):752–760. doi:10.1016/S0025-326X(02)00053-X

Kousoulaki K, Mørkøre T, Nengas I, Berge RK, Sweetman J. 2016. Microalgae and organic minerals enhance lipid retention efficiency and fillet quality in Atlantic salmon (*Salmo salar* L. Aquaculture. 451:47–57. doi:10.1016/j.aquaculture.2015.08.027

Kwasek K, Thorne-Lyman AL, Phillips M. 2020. Can human nutrition be improved through better fish feeding practices? A review paper. Crit Rev Food Sci Nutr. 25:1–14.

Li H, Meng X, Wan W, Liu H, Sun M, Wang H, Wang J. 2018. Effects of chromium picolinate supplementation on growth, body composition, and biochemical parameters in Nile tilapia *Oreochromis niloticus*. Fish Physiol Biochem. 44(5):1265–1274. doi:10.1007/s10695-018-0514-0

Lie Ø. 2001. Flesh quality – the role of nutrition. Aquac Res. 32:341–348. doi:10.1046/j.1355-557x.2001.00026.x

Lie, Ø. editor. 2008. Improving farmed fish quality and safety. Cambridge: Woodland Publishing Ltd. p. 648.

Lorentzen M, Maage A, Julshamn K. 1994. Effects of dietary selenite or selenomethionine on tissue selenium concentrations of Atlantic salmon (*Salmo salar*). Aquaculture. 121(4):359–367. doi:10.1016/0044-8486(94)90270-4

Luten J, Schram E, and E. Elvevoll 2008. Tailor-made functional seafood for consumers: dietary modulation of selenium and taurine in farmed fish pp.343–362. In: Lie, Ø. editor. Improving farmed fish quality and safety. Cambridge: Woodland Publishing Ltd. p. 648.

Manning BB, Li MH, Robinson EH. 2007. Feeding Channel catfish, *Ictalurus punctatus*, diets amended with refined marine fish oil elevates omega-3 highly unsaturated fatty acids in fillets. J World Aquaculture Soc. 38(1):49–58. doi:10.1111/j.1749-7345.2006.00072.x

Manning BB, Li MH, Robinson EH, Peterson BC. 2006. Enrichment of channel catfish (*Ictalurus punctatus*) fillets with conjugated linoleic acid and omega-3 fatty acids by dietary manipulation. Aquaculture. 261(1):337–342. doi:10.1016/j.aquaculture.2006.07.029

Maule AG, Gannam AL, Davis JW. 2007. Chemical contaminants in fish feeds used in federal salmonid hatcheries in the USA. Chemosphere. 67(7):1308–1315. doi:10.1016/j.chemosphere.2006.11.029

Mihalca GL, Tiţ, O, Tiţa M, Mihalca A. 2011. Effect of dietary alpha-tocopheryl acetate on alpha-tocopherol content of novel omega-3-enhanced farmed rainbow trout (*Oncorhynchus mykiss*) fillets. J Agroaliment Processes Technol. 17(3):295–302.

Michikawa T, Inoue M, Shimazu T, Sawada N, Iwasaki M, Sasazuki S, Yamaji T, Tsugane S. 2012. Seaweed consumption and the risk of thyroid cancer in women: The Japan Public Health Center-based Prospective Study. Eur J Cancer Prev. 21(3):254–260. doi:10.1097/CEJ.0b013e32834a8042

Mohan Dey M, Rab MA, Paraguas FJ, Piumsombun S, Bhatta R, Ferdous Alam M, Ahmed M. 2005. Fish consumption and food security: a disaggregated analysis by types of fish and classes of consumers in selected Asian countries. Aquacult Econ Manage. 9(1-2):89–111. doi:10.1080/13657300590961537

Mozaffarian D, Ludwig DS. 2010. Dietary guidelines in the 21st century: a time for food. JAMA. 304(6):681–682. doi:10.1001/jama.2010.1116

Murray B. 2001. Fast-food cultures serves up super-sized Americans. American Psychol Assoc. 32(11):3.

Nanton DA, Ruohonen K, Robb DHF, El-Mowafi A, Hartnell GF. 2012. Effect of soy oil containing stearidonic acid on growth performance and fillet fatty acid composition of Atlantic salmon. Aquacult Nutr. 18(6):640–650. doi:10.1111/j.1365-2095.2011.00922.x

National Health and Medical Research Council (NHMRC). 2013. Eat for health: Australian dietary guidelines. Canberra, Australia: National Health and Medical Research Council. p. 210.

National Institutes of Health (NIH). 2020. Dietary supplement fact sheets, fact sheet for Health professionals – Vitamin A, Vitamin D, Vitamin E, Vitamin B_{12}, Folate, Choline, Coenzyme Q_{10}, Calcium, Chromium, Copper, Iodine, Iron, Magnesium, Selenium, Zinc, Omega-3 fatty acids, Dietary Supplements for Exercise & Athletic Performance. Office of Dietary Supplements, National Institutes of Health, U.S. Department of Health & Human Services. https://ods.od.nih.gov/factsheets/.

Ng W-K, Chong C-Y, Wang Y, Romano N. 2013. Effects of dietary fish and vegetable oils on the growth, tissue fatty acid composition, oxidative stability and vitamin E content of red hybrid tilapia and efficacy of using fish oil finishing diets. Aquaculture. 372-375:97–110. doi:10.1016/j.aquaculture.2012.10.030

Nicklisch SCT, Bonito LT, Sandin S, Hamdoun A. 2017. Geographic differences in persistent organic pollutant levels of Yellowfin Tuna. Environ Health Perspect. 125(6): 067014. doi:10.1289/EHP518

Nonwachai T, Purivirojkul W, Limsuwan C, Chuchird N, Velasco M, Dhar AK. 2010. Growth, nonspecific immune characteristics, and survival upon challenge with *Vibrio harveyi* in Pacific white shrimp (*Litopenaeus vannamei*) raised on diets containing algal meal. Fish Shellfish Immun. 29(2):298–304. doi:10.1016/j.fsi.2010.04.009

Organization for Economic Cooperation and Development (OECD). 2017. Obesity update: 2017. Paris: OECD Publishing. p. 13. www.oecd.org/health/obesity-update.htm.

Pan A, Malik V, Hu FB. 2012. Exporting diabetes to Asia: the impact of western-style fast food. Circulation. 126(2): 163–165. doi:10.1161/CIRCULATIONAHA.112.115923

Petenuci ME, Schneider VVA, Lopes AP, Gonçalves RM, Dos Santos VJ, Matsushita M, Visentainer JV. 2018. Effect of alpha-linolenic acid sources in diets for Nile Tilapia on fatty acid composition of fish fillet using principal component anlysis. J Aquat Food Prod Technol. 27(4):464–476. doi:10.1080/10498850.2018.1448917

Powell LM, Chaloupka FJ. 2009. Food prices and obesity: evidence and policy implications for taxes and subsidies. The Milbank Quarter. 87(1):229–257. doi:10.1111/j.1468-0009.2009.00554.x

Prentice AM. 2006. The emerging epidemic of obesity in developing countries. Int J Epidemiol.35(1):93–99. doi:10.1093/ije/dyi272

Reames E. 2012. Nutritional benefits of seafood. Stoneville, MS: Southern Regional Aquaculture Center (SRAC) Publication No. 7300. p. 6.

Ribeiro A. R., Gonçalves A, Bandarra N, Nunes ML, Dinis MT, Dias J, Rema P. 2017. Natural fortification of trout with dietary macroalgae and selenised-yeast increases the nutritional contribution in iodine and selenium. Food Res Internat. 99(3):1103–1109. doi:10.1016/j.foodres.2016.10.030

Ripps H, Shen W. 2012. Review: taurine: a "very essential" amino acid. Mol Vis. 18:2673–2686.

Rosenlund, G., G. Corraze, M. Izquierdo, and B.E. Tortensen. 2011. The effects of fish oil replacement on nutritional and organoleptic qualities of farmed fish, pp.487-522. In: Turchini G.M., Ng W.-K., Tocher D.R., editors. Fish oil replacement and alternative lipid sources in aquaculture feeds. CRC Press, Taylor & Francis Group. p. 551.

Roth GA, Abate D, Abate KH, Abay SM, Abbafati C, Abbasi N, Abbastabar H, Abd-Allah F, Abdela J, Abdelalim A, et al. 2018. Global, regional, and national age-sex-specific mortality for 282 causes of death in 195 countries and territories, 1980–2017: a systematic analysis for the Global Burden of Disease Study 2017. The Lancet. 392(10159):1736–1788.,.

Ruxton CHS, Reed SC, Simpson MJA, Millington KJ. 2007. The health benefits of omega-3 polyunsaturated fatty acids: a review of the evidence. J Hum Nutr Dietet. 20: 275–285.

Sargent JR, Tacon AGJ. 1999. Development of farmed fish: a nutritionally necessary alternative to meat. Proc Nutr Soc. 58(2):377–383. doi:10.1017/S0029665199001366

Sarker PK, Kapuscinski AR, Lanois AJ, Livesey ED, Bernhard KP, Coley ML. 2016. Towards sustainable aquafeeds: complete substitution of fish oil with marine microalga S*chizochytrium sp.* improves growth and fatty acid deposition in juvenile Nile Tilapia (*Oreochromis niloticus*). Plos One. 11(6):e0156684. doi:10.1371/journal.pone.0156684

Schmid P, Kohler M, Gujer E, Zennegg M, Lanfranchi M. 2007. Persistent organic pollutants, brominated flame retardants and synthetic musks in fish from remote alpine lakes in Switzerland. Chemosphere. 67(9):S16–S21. doi:10.1016/j.chemosphere.2006.05.080

Schmid S, Ranz D, He ML, Bukard S, Lukowics MV, Reiter R, Arnold R, LeDeit H, David M, Rambeck WA. 2003. Marine algae as natural source of iodine in the feeding of freshwater fish: a new possibility to improve iodine supply in man. Rev Med Vet. 154:645–648.

Schram E, Pedrero Z, Camara C, van der Heul JW, Luten BJ. 2008. Enrichment of African catfish with functional selenium originating from garlic. Aquaculture Res. 39(8): 850–860. doi:10.1111/j.1365-2109.2008.01938.x

Sele V, Ørnsrud R, Sloth JJ, Berntssen MHG, Amlund H. 2018. Selenium and selenium species in feeds and muscle tissue of Atlantic salmon. J Trace Elem Med Bio. 47: 124–133. doi:10.1016/j.jtemb.2018.02.005

Sigurgisladottir S, Parrish CC, Lall SP, Ackman RG. 1994. Effects of feeding natural tocopherols and astaxanthin on Atlantic salmon (*Salmo salar*) fillet quality. Food Res Internat. 27(1):23–32. doi:10.1016/0963-9969(94)90174-0

Skerrett PJ, Willett WC. 2010. Essentials of healthy eating: a guide. J Midwifery Womens Health. 55(6):492–501. doi:10.1016/j.jmwh.2010.06.019

Solhelm WAA. 2010. Sea of health: nutritional content and health benefits of seafood. Tromso, Norway: NOFIMA. http://www.nofima.no/en/nyhet/2010/05/a-sea-of-health.

Sprague M, Dick JR, Tocher DR. 2016. Impact of sustainable feeds on omega-3 long-chain fatty acid levels in farmed Atlantic Salmon, 2006–2015. Sci Rep. 6(1):21892. doi:10.1038/srep21892

Stoneham TR, Kuhn DD, Taylor DP, Neilson AP, Smith SA, Gatlin DM, Chu H, O'Keefe SF. 2018. Production of omega-3 enriched tilapia through the dietary use of algae meal or fish oil: Improved nutrient value of fillet and

offal. Plos One. 13(4):e0194241. doi:10.1371/journal.pone.0194241
Tacon AGJ. 2020. Trends in global aquaculture and aquafeed production: 2000–2017. Rev Fish Sci Aquacult. 28(1):43–56. doi:10.1080/23308249.2019.1649634
Tacon AGJ, Metian M. 2008. Aquaculture feed and food safety: the role of FAO and Codex Alimentarius. Ann Newyork Acad Sci. 1140(1):50–59. doi:10.1196/annals.1454.003
Tacon AGJ, Metian M. 2013. Fish Matters: importance of aquatic foods in human and global food supply. Rev Fish Sci. 21(1):1–17.
Tacon AGJ, Metian M. 2018. Food Matters: fish, income and food supply – a comparative analysis. Rev Fish Sci Aquacult.26(1):15–28. doi:10.1080/23308249.2017.1328659
Thilsted SH, James D, Tippe J, Subasinghe R, and I. Karunasagar. 2014. Paper Presented at the FAO/WHO ICN2 Second International Conference on Nutrition – Better Nutrition Better Lives, 19-21 November 2014, Rome, Italy. p. 15.
Torstensen B, Froyland L, Ornsrud R, Lie O. 2004. Tailoring of a cardioprotective fillet fatty acid composition of Atlantic salmon (*Salmo salar*) fed vegetable oils. Food Chem.87(4):567–580. doi:10.1016/j.foodchem.2004.01.009
Turchini GM, Trushenski JT, Glencross BD. 2019. Thoughts for the future of aquaculture nutrition: realigning perspectives to reflect contemporary issues related to judicious use of marine resources in aquafeeds. North Am J Aquacult. 81(1):13–39. doi:10.1002/naaq.10067
U.S. Department of Health & Human Services and U.S. Department of Agriculture (USDHHS/USDA). 2015. 2015–2020 Dietary Guidelines for Americans. 8th Edition. December 2015. http://health.gov/dietaryguidelines/2015/guidelines/.
US Department of Agriculture (USDA). 2018. Composition of Foods: raw, processed, prepared. USDA National Nutrient Database for Standard Reference, Legacy April 2018, Slightly revised July 2018. http://www.ars.usda.gov/nutrientdata.
Verbeke W, Sioen I, Pieniak Z, Van Camp J, De Henauw S. 2005. Consumer perception versus scientific evidence about health benefits and safety risks from fish consumption. Public Health Nutr.Nutr8(4):422–429. doi:10.1079/PHN2004697
Vitenskapskomiteen (VKM). 2014. Benefit-risk assessment of fish and fish products in the Norwegian diet – an update. Scientific Opinion of the Scientific Steering Committee. VKM Report 15. Oslo, Norway. p. 293. ISBN: 978-82-8259-159-1. www.vkm.no.
Waagbø R, Sandnes K, Torrissen OJ, Sandvin A, Lie Ø. 1993. Chemical and sensory evaluation of fillets from Atlantic salmon (*Salmo salar*) fed three levels of N-3 polyunsaturated fatty acids at two levels of vitamin E. Food Chem.46(4):361–366. doi:10.1016/0308-8146(93)90005-Z
Wallin A, Di Giuseppe D, Orsini N, Patel PS, Forouhi NG, Wolk A. 2012. Fish consumption, dietary long-chain n-3 fatty acids, and risk of type 2 diabetes-systemic review and met-analysis of prospective studies. Diabetes Care.35(4):918–929. doi:10.2337/dc11-1631
Wang Y, Wang L, Xue H, Qu W. 2016. A review of the growth of the fast food industry in China and its potential impact on obesity. IJERPH. 13(11):1112. doi:10.3390/ijerph13111112
Watters CA, Rosner LS, Franke AA, Dominy WD, Klinger-Bowen R-E, Tamaru CS. 2013. Nutritional Enhancement of long-chain omega-3 fatty acids in Tilapia (*Oreochromis honorum*). Bamidgeh. 65(869):1–7.
Weber K, Goerke H. 2003. Persistent organic pollutants (POPs) in Antarctic fish: levels, patterns, changes. Chemosphere. 53(6):667–678. doi:10.1016/S0045-6535(03)00551-4
World Health Organization (WHO). 2017. Sugars and dental caries. [accessed 2017 November 9]. https://www.who.int/news-room/fact-sheets/details/sugars-and-dental-caries.
World Health Organization (WHO). 2018a. Malnutrition. [accessed 2018 February 16]. https://www.who.int/news-room/fact-sheets/details/malnutrition.
World Health Organization (WHO). 2018b. Noncommunicable diseases. [accessed 2018 June 1]. https://www.who.int/news-room/fact-sheets/details/non-communicable-diseases.
World Health Organization (WHO). 2018c. Diabetes. [accessed 2018 October 30]. https://www.who.int/news-room/fact-sheets/details/diabetes.
World Health Organization (WHO). 2020. Obesity and overweight. [accessed 2020 March 3]. https://www.who.int/news-room/fact-sheets/details/obesity-and-overweight.
Xanthos D, Walker TR. 2017. International policies to reduce plastic marine pollution from single-use plastics (plastic bags and microbeads): A review. Mar Pollut Bull. 118(1-2):17–26. doi:10.1016/j.marpolbul.2017.02.048
Xu X, Variyam JN, Zhao Z, Chaloupka FJ. 2014. Relative food prices and obesity in U.S. Metropolitan areas: 1976-2001. PLOS One. 9(12):e114707. doi:10.1371/journal.pone.0114707
Zhong VW, Van Horn L, Greenland P, Carnethon MR, Ning H, Wilkins JT, Lloyd-Jones DM, Allen NB. 2020. Associations of processed meat, unprocessed red meat, poultry, or fish intake with incident cardiovascular disease and all-cause mortality. JAMA Intern Med. 180(4):503–512. doi:10.1001/jamainternmed.2019.6969