JOURNAL OF CURRENT RESEARCH IN FOOD SCIENCE

E-ISSN: 2709-9385
P-ISSN: 2709-9377
JCRFS 2020; 1(2): 27-31

www.foodresearchjournal.com
Received: 04-05-2020
Accepted: 21-06-2020

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Proximate chemical compositions and nutritional value of Fish: Review

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Abstract

The current study aims to give an overview of the chemical composition of fish; protein, lipids, vitamins and minerals also their nutritional value. The protein contents of most raw finfish flesh are in the range of 17–22%, with an average of 19/100 g, while the cooked portions may have as much as 35% protein. The amount of lipids in fish may vary widely from 0.2 to 24%, depending upon anatomical position, sex, and location in body, age, season, and diet. Fish oils are rich sources of vitamins A, D, and E. Vitamin A is concentrated mostly in fish liver oils. Seafood items are rich in important minerals and trace elements such as selenium and iodine, as compared with red meat.

Keywords: Chemical composition, nutritional value, protein, lipids

Introduction

Fish and fishery products have been recognized as very important sources for human nutrition. Fishes are characterized by their high contents of high quality, easily digestible protein and essential amino acids. Moreover, they are low in the saturated fatty acids and contain considerable amounts of the unsaturated fatty acids, especially omega-3 fatty acids, which are regarded as oxidation preventive compounds. The oil-soluble vitamins are known to be rich in fish. Also, they are good source of several minerals particularly fluorine and iodine, which are needed for the development of strong teeth and the prevention of goiter in man [1, 2]. Chemical composition and quality criteria of raw fish are among the major factors that affect the overall acceptability of processed fish products. Several factors included; species, age, physical state, fed type and time of catching and region of catch have been reported to affect chemical composition of fish [3]. Fish and fishery products have long been recognized as healthy foods with excellent nutritional value, providing high-quality protein, minerals, vitamins, essential fatty acids and trace elements. Fish is widely consumed in many parts of the world by humans due to its high content of good protein that characterizes by an excellent amino acid composition and easily digestibility [4].

Proteins

The protein contents of most raw finfish flesh are in the range of 17–22%, with an average of 19/100 g, while the cooked portions may have as much as 35% protein. Fresh water fish have generally slightly higher moisture and lower protein contents than marine fish. Crustacean (crab, shrimp, and oysters) flesh is slightly higher in proteins [4]. The contents of proteins in crustaceans and cephalopods are as follows(table 1): shrimp, 17.0–22.1%; scallop, 14.8–17.7%; squid, 13.2–19.6%; crab, 15.0–18.4%; lobster, 18.2–19.2%; krill, 12.0–13.0%; and mussel and oyster, 8.9–11.7% [5]. The myofibrillar protein contents of fish range between 65 and 75%, while sarcoplasmic (soluble proteins including enzymes) are in the range of 20–35%. Myosin constitutes50–58% of the myofibrillar proteins of fish. Even though there is a slight difference in the composition of amino acids, the myosins of all vertebrates such a rabbit, chicken, cod, and tilapia are similar [6, 7].

However, compared to carcass meat fish myosins are unstable, being more sensitive to denaturation, coagulation, degradation, or chemical changes. Nevertheless, some exceptions have been noted. Myosins from some species such as tuna, sea mullet, and tilapia have been reported to be almost as stable as rabbit or beef myosins [8]. In the white adductor muscle of some oysters and clams, 38–48% of the myofibrils are paramyosins, which form a core with a surface layer of myosin. The protein has a molecular weight of 200–258 kDa, consisting of two subunits of 95–125 kDa with a glutamic acid content as high as 20–23%.

The comparative biochemistry of paramyosins including those from mollusks has been reviewed [9]. As compared with red meat, fish meat contains only 3% stroma proteins, except sharks, rays, and skates, which may contain up to 10%. The non-protein nitrogen content of fish muscle is normally higher than that of terrestrial animals, and range between 10 and 40%, which contain amino acids, small peptides, trimethylamine oxide (TMAO), trimethylamine, creatine, creatinine, and nucleotides [7].

Amino acid compositions of 60 commercially important fish and shellfish have been summarized. 4 Shrimp, lobster, crab, squid, and other shellfish generally contain larger amounts of arginine, glutamic acid, glycine, and alanine than finfish [7]. the higher contents of these amino acids during the winter season make squids more palatable as compared with those harvested in summer. Shark extractives contain 100–150 mg betaine per 100 g meat. Demersal fish generally contain larger quantities of TMAO than pelagic fish, and its contents vary from 19 to 190 mg%. Elasmobranchs also contain high amounts of TMAO, while its content is small in mollusks and rather insignificant in freshwater fish species. Even though this compound is negligible in most freshwater fish, some species such as Nile perch and tilapia may contain 150–250 mg TMAO per 100 g [4].

Nutritive value of proteins

The nutritive value of fish proteins is comparatively high because of the favorable essential amino acid pattern [8]. Fish proteins are rich in all the essential amino acids (particularly methionine and lysine), in contrast with most proteins from plant sources, which lack adequate amounts of one or more essential amino acids. There are no significant differences in the amino acid composition of freshwater and marine fish. As compared with red meat, fish proteins are considered nutritionally equivalent or slightly superior. They are highly sensitive to proteolytic digestion with a digestibility of more than 90% [4].

The in vivo digestibility of proteins of raw fish meat is in the range of 90–98%, and that of shellfish, about 85%. Protein efficiency ratio (PER, weight gained per g of protein consumed) of fish proteins, an index of protein quality, is slightly above that of casein, the major milk protein. The net protein utilization (NPU) of fish flesh is 83, as compared with values of 80 and 100 for red meat and egg, respectively [6]. A fish commercial collagen hydrolysate, Peptan F, has been found to enhance protein quality and flavor characteristics of beverages [10].

The nutritional values of proteins from different sources including fishery items have been compared [11]. The concentrated fish proteins or their hydrolyzates obtained by the action of proteolytic enzymes such as pepsin, trypsin, etc. have found applications as a protein supplement [12, 13]. Nutritive value of cereal proteins could be increased when combined with a quality fish protein. The fish-protein treatment reduced plasma cholesterol level, gave higher content of high-density lipoprotein (HDL), and altered the fatty acid composition in liver, plasma, and triglycerol-rich lipoproteins in obese zucker rats [13].

Lipids

Marine fish are commonly classified according to the fat content of their fillets and grouped as lean (under 3% fat), medium (3–7% fat), and high fat (over 7% fat). Lipids in fatty fish are mostly subcutaneous in nature, whereas, in lean fish they are deposited in the liver, muscle tissue, and mature gonads. Lean fish such as sole are usually whitish in color, whereas, fish with higher fat content (e.g., cod, haddock, halibut, and pollock) are white to off-white. The flesh of high-fat fish (e.g., herring, sardine, anchovy, and salmon) is usually pigmented (e.g., yellow, pink, and greyish). In an individual fish, lipid content increases from tail to head, with higher level of fat deposition in the belly flap and dark muscle.

The amount of lipids in fish may vary widely from 0.2 to 24%, depending upon anatomical position, sex, and location in body, age, season, and diet. In many pelagic fish, lipid contents ranging from 12 to 20% are found during winter as compared with 3–5% levels during summer [4]. The fat levels in some fish correlate with spawning cycles. For instance, anadromous fish store fat prior to migration to freshwater for spawning. On the other hand, the same amount of cooked portions of butterfish, herring, Spanish mackerel, salmon (Atlantic, coho, or sockeye), lake trout, tuna blue fin, and white fish provide 5–10 g of total fat [14].

Most of the variations in lipids are found in the triacylglycerol fraction while the phospholipids show much less variations. The marine steroids are composed of cholesterol, which is present at 50–90 mg per 100 g of fish meat. In some pelagic fish species such as anchovy, blue fin tuna, pilchards, and different mackerels, cholesterol may be up to 150 mg/100 g of meat, and may be as high as 250–650 mg in roe and liver. Squid and octopus may contain 250 and 120 mg of the steroid per 100 g, respectively [15-17].

The important EFAs, linoleic acid (LA, C18:2, n-6) and α-linolenic acid (ALNA, C18:3, n-9) are present in vegetables and plants. The LAs and ALNAs are subjected to chain elongation and desaturation to give long-chain polyunsaturated fatty acids(PUFAs) containing 20 or more carbon atoms such as arachidonic acid (AA, C20:4, n-6) and n-3 (also referred as omega-3) fatty acids, eicosapentaenoic acid (EPA, cis-5,8,11,14,17-eicosapentaenoic acid, C20:5) and docosahexaenoic acid (DHA, cis-4,7,10,13,16,19-docosahexaenoic acid, C22:6). (The letter "n" refers to the position of the first carbon atom where a point of unsaturation is found, starting from the methyl group of the fatty acid.).

Fish lipids are different from those of terrestrial origin in that they contain significant amounts of EPA and DHA; however, the quantities vary among species and within a species according to environmental variables such as diet and their habitats. [6, 17-19]. Table 3 shows omega-3 fatty acid contents of some seafood.

Nutritional role of fish lipids

In recent times, the role of fats and oils in consumer health has been well understood. It has been recognized that an ideal fat to meet then nutritional requirements of an adult should aim at maintenance of health and prevention of diseases. Since 1970s there has been an intense scientific interest in the health benefits of fish and fish oils, initiated with the studies on the longevity and coronary health of native Greenland Eskimos. These investigations led to the conclusion that longevity and coronary health of Eskimos was related to their diet, who consume an average 450 g fatty fish per day [20].

Later, large scale epidemiological studies suggested that individuals at a risk of coronary heart diseases (CHD) benefited from the consumption of plant and marine-derived omega-3 fatty acids [15, 16, 21]. The major therapeutically important omega-3 fatty acids were later identified as EPA and DHA.

A beneficial effect of dietary omega-3 fatty acids on coronary heart events including nonfatal myocardial infarction and stroke has been observed in a recent study [22]. Consumption of cod oil helped to maintain the elasticity of artery walls, prevent blood clotting, reduce blood pressure, and stabilize heart rhythm. Studies conducted in India in experimental animals and men suggested that consumption of both oil sardine (*Sardinella longiceps*) and its oil lowered serum-total cholesterol, LDL-cholesterol, and triglycerides [23].

More evidence has shown that fish consumption favorably affects CHD mortality, especially no sudden death from myocardial infarction [24-26]. Recent studies have shown that fish intake is associated with a reduced progression of coronary artery atherosclerosis in postmenopausal women with CHD [26].

Other studies have also reported an inverse relation between fish intake and CHD death [32-35]. An amount of 4–6 g of EPA (20–30 ml fish oil or 300–400 g fatty fish per day) has been recommended to control CHD, although the ideal intake of omega-3 fatty acids for the therapeutic effect is not clear.

The effective dose could be reduced to2–3 g EPA per day when fat intake was reduced to approximately 20% of calories as exemplified by Japanese diets [15]. The U.S. FDA recommends that consumers not exceed more than 3g of EPA and DHA per day from a dietary supplement [19].

Aqua cultured fish generally are not good sources of n-3 fatty acids. However, it is possible to rear fish such as salmon to have significant levels of PUFAs and the antioxidant, astaxanthin, by selective feeding techniques.

A daily serving of 8 oz (227 g) of the fish provides5 times the effective adequate intake of C20:5 and C22:6 (0.14 and 0.13 g/day, respectively) for pregnant or lactating women [27]. Prostaglandins synthesized from omega-3 acids, as well have additional therapeutic uses including control of blood pressure and relieving of bronchial asthma [28]. Supplementation of mother's diet with sardines and other fish oils at a level of 2.6 g n-3 fatty acids per day resulted in an increase in DHA in maternal red blood cells from 4.6 to 7.2%, with a corresponding increase in maternal plasma. This subsequently enhanced DHA level in infant red blood cells. An amount of 500 to 600 mg of DHA per day has been recommended for expecting women [29, 30].

On the tests conducted using a sample of approximately 3600 adolescents, it was found that consuming DHA and whole fish were independently related to lower hostility rates compared to those who had consumed no DHA or fish.40 In spite of the health benefits of fish lipids mentioned above, preliminary studies have indicated additional advantages of consumption of fatty fish [31, 32-34].

Figures 1 depict schematic diagrams on the role of fish in human nutrition.

In view of the recognized nutritional advantages, marketing campaigns have been launched Incorporation of the oil in encapsulated for many fish products that tend to affirm that consumption of fish is an appropriate method of satisfying consumer's need for a variety nutritious, tasty, and healthy foods. These campaigns have resulted in positive changes in consumer attitude towards seafood [35, 36].

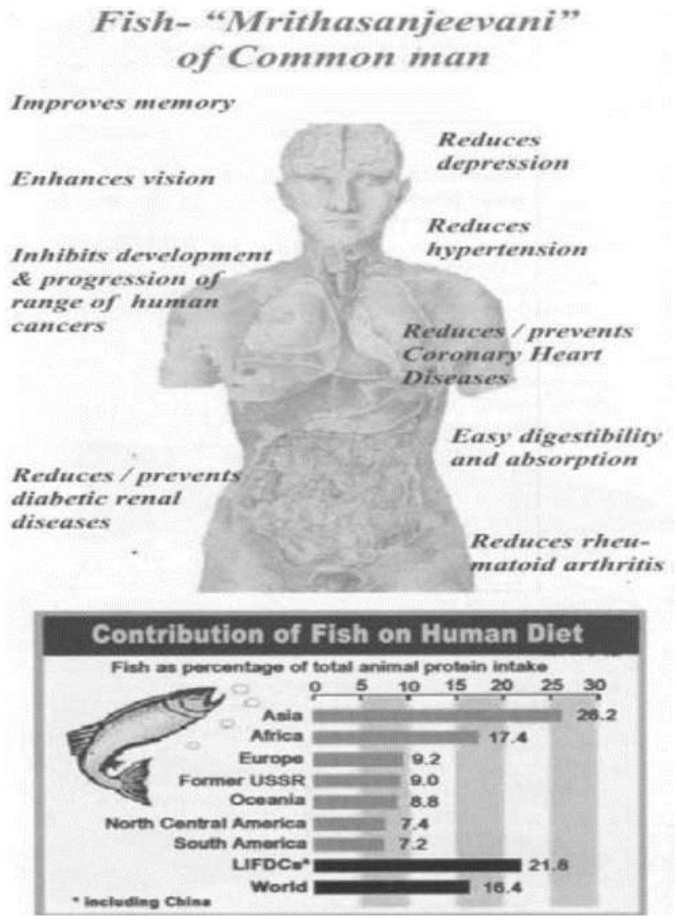

Fig 1: Schematic diagram on the role and contribution of fish in human nutrition and diet.

Calorie

Fish contributes few calories to food. Even high fat fish will add fewer calories to the diet than an equal amount of most red meat [37] Conventional finfish and seafood potentially provide 199–200 cal per 100 g, which is mainly attributed to the protein and fat contents of fish. Cooked low-fat white fish contains about80–90 cal per 100 g raw edible portion, medium-fat fish about 100 cal, and high-fat [4].

Fish contains between 150 and 225 cal per 100 g. canned herring, salmon, and tuna have 208, 203, and 197 cal per 100 g, respectively. Chinook salmon may contribute as much as 222 cal, pink salmon can provide 119 cal, and mackerel as much as 191 cal/100 g. Surimi-based shrimp analog has an energy content of116 cal, while cooked oyster has a value of only 76 cal/100 g [38]. Table 4 presents calorie and fat contents of some fish preparations.

Vitamins

Fish oils are rich sources of vitamins A, D, and E. Vitamin A is concentrated mostly in fish liver oils. Halibut and cod liver oils are rich sources of vitamin A and D. Sardine contain 100–4500 IU vitamin A and up to 500 IU vitamin D per 100 g meat, with an average of 125 μg/g oil.

Herring, mackerel, salmon, and lake trout contain varying amounts of vitamin D in their tissues [39]. OZ of salmon provides 90% of daily need of vitamin D Fish cannot synthesize vitamin E, and hence, the concentration of this vitamin, mainly α-tocopherol, is related to feed. Seafood provides moderate amounts of thiamin. However, much of thiamin is destroyed by heat and oxygen or is lost in cooking water or when exposed to ionizing radiation.

The average content of thiamin in 155 fish species is between 6 and 434 mg/100 g meats. Fish also contain modest amounts of biotin, folic acid, niacin, and pantothenic acid. The best sources of pyridoxine (vitamin B6) are salmon and tuna, and to some extent, shellfish. Modest amounts of riboflavin are present particularly in the dark flesh of some species like canned herring, mackerel, and pilchard. Pyridoxin is present in fish and shellfish in reasonable amounts, with tuna and salmon being rich in this vitamin. Fish and shellfish, particularly anchovies, clams, herring, oysters, pilchard, and sardines, are rich sources of vitamin B12, containing 25–40 μg/100 g meat [39, 40].

Minerals

Seafood items are rich in important minerals and trace elements such as selenium and iodine, as compared with red meat. Shellfish contain nearly twice the amount as finfish. The total content of minerals such sodium, potassium, calcium, magnesium and phosphorus, and microelements such as selenium, fluorine, iodine, cobalt, manganese, and molybdenum in raw marine fish muscle and invertebrates are roughly in the range of 0.6 to 1.5% wet weight.

Most fresh marine fish may be considered moderately low-sodium foods delivering approximately 140 mg sodium per serving. The higher contents are the result of conventional onboard handling and processing treatments such as brining, storage in refrigerated seawater, etc. Battered and frozen seafood contain an average of 400 mg sodium per 100 g. The sodium content of fresh fish fillets ranges from 39 to 90 mg/100 g [41].

Selenium provides protection against mercury and cadmium toxicity. Seafood, especially tuna, is an important source of this nutrient. In general, shellfish tend to be richer sources than finfish [40]. Seafood is also a source of calcium, its contents varying from 6 to 120 mg/100 g depending upon the species [41].

The calcium content in 100 g muscle may be as low as 15 mg in the case of mackerel, 15–50 mg in catfish, haddock, and oysters and above 100 mg in pollock, salmon, and trout [18, 41]. Tuna bones were in use as a source of calcium in Japan in the mid-1980s in institutional feeding programs for elderly and in school meal programs. A fish processing company in Tokyo has successfully processed scales of sardine into an easily absorbable, edible food supplement containing calcium and collagen [29].

Fresh fish are a good source of potassium containing 250–320 mg of the element per 100 g. Shellfish (clams, oysters, scallops) and fish having dark-colored flesh such as bluefish, herring, mackerel, sardines, and smelt are reasonably good sources of iron, supplying 1–2 mg/100 g muscle. The iron content in 100 g meat may vary as 0.9 mg in cod, Oysters and clams provide between 45 and 60% of the daily requirement of the mineral. An average serve of fish or marine invertebrate can satisfy the total human requirements for essential microelements [38, 39].

Adverse array of bioactive compounds such as anticancer agents are present in marine organisms, particularly, jellyfish, corals, shark cartilage, shellfish, as well as in marine microorganisms [42].

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