Chemical composition of fish

The main components of fish are 66%−81% water, 16%−21% protein, 1.2%−1.5% mineral, 0.2%−25%fat and 0%−0.5% carbohydrate.

1-Moisture:

Water contributes the major portion of the body of all organisms, including fishes and acts as a medium through which the transport of various nutrients, transfer of chemical energy and several cytoplasmic reactions takes place. In the case of majority of fish species, the value of **moisture generally ranged between 60% and 80%**

The moisture amount of muscles changed inversely with the content of fat. With an increase in age, there occurred an increase in fat content and a decline in water content in fish flesh. Such variation in the proximate composition of fish with age might be because of spawning and migration.

2-Proteins:

Fish protein, in comparison with mammalian protein, is very rich in amino acids such as **lysine, methionine, but low in tryptophan.**

TABLE 1 Composition of fish divided into five categories

Category	Types	Oil content	Protein content
A	Low oil–high protein	Less than 5%	15%–20%
B	Medium oil–high protein	5%–15%	15%–20%
C	High oil–low protein	More than 15%	Less than 15%
D	Low oil–very high protein	Less than 5%	More than 20%
E	Low oil–low protein	Less than 5%	Lower than 15%

The major constituent of fish flesh is water, which accounts for about 70–80% of the weight of the fillet. The crude protein content of seafood ranges from 17 to 22%.

There is an **inverse relationship between water and lipid content in fish.** During different seasons, with an increase in fat content, there is a decrease in water content. The moisture content is also known to generally decrease with age.

The **myoglobin content of muscle** increases with **age, and during the migration season.**

The **ease of digestion of fish** is due to **the low connective tissue content and the shortness of the muscle fibres.**

Fish and shellfish muscle proteins are classified, based on solubility in salt solutions, into three main groups: such as sarcoplasmic, myofibrillar and stromal proteins.

2.1-Sarcoplasmic proteins:

Sarcoplasmic proteins, which can be **soluble in water and dilute salt solutions,** comprise about **15–30%** of the total protein in fish muscle.

These proteins consist of **hundreds of enzymes, pigmented proteins such as myoglobin and haemogobin, and other albumins**. Unlike land animals, **fish contain more Ca2+ binding proteins**.

- The **red muscle of fish** has a darker appearance, due to **high concentration of myoglobin**. Red muscle contains **more mitochondria** and **less sarcoplasmic reticulum** than white fibers, which are required for prolonged aerobic metabolism of energy reserves.
- The content of **sarcoplasmic protein is higher in pelagic fish** than in **demersal fish**. The myoglobin content of muscle increases with age, and during the migration season.

The **content and composition of the sarcoplasmic proteins can vary between species**, so sarcoplasmic protein can be utilized as **fingerprints to identify fish species.**

- **The myoglobin content of muscle increases with age, and during the migration season. Oxymyoglobin and oxyhaemoglobin** are responsible for the colour characteristics of fish muscle. Some molluscs, crustaceans and certain colourless blood Antarctic fish species, for instance, contain no haemoglobin. Shellfish have copper-containing proteins called **haemocyanins.**

2.2-Myofibrillar proteins:

Myofibrillar proteins are structural proteins that compose **65–70% of** the fish muscle protein. They are **soluble in high salt solutions**.

Myosin and actin are responsible in muscle contraction–relaxation cycle. In post-mortem muscle, myosin and actin exist as an actomyosin complex.

Myosin, ranging from **50 to 60%,** forms the thick myofilaments, whereas **actin,** accounts for **15–20%,** is the principal component of the thin filaments. The other regulatory proteins are tropomyosin, troponin, actinin proteins. Troponin and tropomyosin are also responsible for prevention of actomyosin formation during relaxation.

2.3- Stroma proteins (connective tissue proteins):

They consist predominantly of collagen, with the remainder being elastin and gelatin. Stroma proteins are located in the extracellular matrix, accounting for **3% of the total muscle protein**. However, elasmobranch fish such as shark and ray can contain **up to 10% stroma proteins**. This low content of collagen gives the soft texture to fish meat. **The collagen** present in fish muscle is **rich in essential amino acids** and is **more thermolabile and contains fewer, but more labile, cross-links than collagen from warm-blooded vertebrates.**

2.4-Non-protein nitrogen compounds:

In addition to proteins, **other nitrogenous compounds are present** in fish muscle. **They are categorized as non-protein nitrogen**, including chemical compounds such as **amino acids, small peptides, creatine, creatine phosphate, creatinine, amine oxides, guanidine compounds, quaternary ammonium compounds, nucleosides, and nucleotides** (including ATP). These compounds are responsible **for not only sensorial characteristics but also contribute to the spoilage of fishery products**.

2.4.1-Free amino acids:

The **main constituents of flavour compounds in fisheries are amino acids, nucleotides, guanidine compounds and quarternery ammonium compounds.** The individual amino acids (such as glycine, valine, alanine, and glutamic acid) are known to contribute to taste, together with the degradation components of nucleotides such as inosine.

The **sweet taste of fresh shrimp and crab** is due to their **free glycine content.**

Shrimp, lobster, crab, squid and other shellfish generally contain larger amounts of amino acids, including **arginine, glutamic acid, glycine, and alanine**, than finfish. The higher contents of these amino acids during the winter season make squids more palatable, as compared with those harvested in summer.

Some unique non-protein amino acids such as **taurine, β-alanine, methyl histidine and proline dominate in most fish. Mollusca such as mussel and scallops** are rich in taurine, meanwhile **crabs** and some fish species contain less taurine.

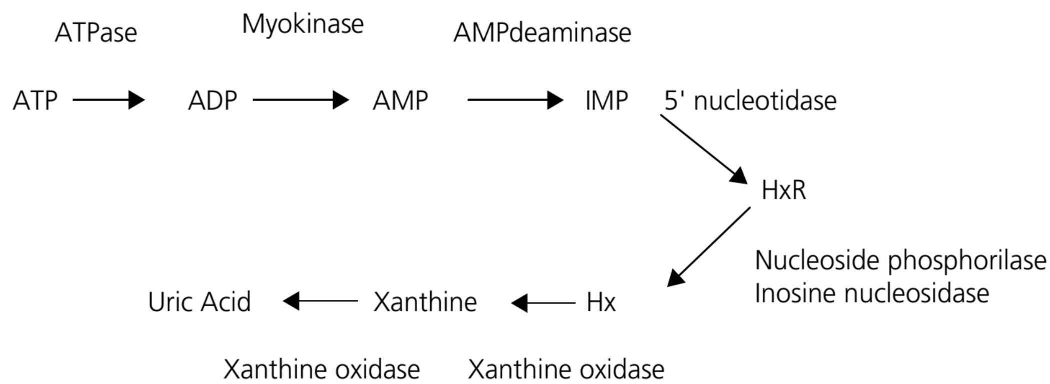
Fish seems to be unique among meat-producing animals in having free histidine in its muscle. **Red muscles** tend to contain **more histidine** than white muscles. **The tissues of scombroid fish, such as tuna and mackerel contain high levels of free histidine**, which may be converted into histamine by associated microorganisms. The levels of free amino acids usually increase in fishery products during storage due to action of endogenous and exogenous proteases.

2.4.2-Peptides:

Three basic dipeptides are characterized in fish muscle: **carnosine** (β-alanyl histidine), **anserine** (β-alanyl-1-methyl histidine) and **balenine** (β-alanyl-3-methyl histidine). **Dark muscles** tend to contain these compounds **more than white muscles**. The **ratio of carnosine to anserine is higher in freshwater than marine fish**. Anserine, as well as carnosine, was reported to have strong ability to eliminate hydroxyl radicals and single oxygens.

2.4.3-Nucleotides:

Most of the nucleotides present in fish muscle are formed by ATP degradation products. In living organisms, muscle contraction is powded by the release of energy during the breakdown of ATP. When the oxygen level is insufficient after death, the muscle tends to shift to anaerobic metabolism.



ATP is gradually depleted by membrane and contractile ATPase enzymes and microbial metabolism also contributes to degradation. A series of reactions results in the conversion of ATP through several compounds; ATP is sequentially degraded to adenosine diphosphate (ADP), adenosine monophosphate (AMP), inosine monophosphate (IMP), inosine (HxR), and hypoxanthine (Hx) by autolytic enzymes.

2. 4.4- Guanidine compounds:

The **phosphorylated form of creatine** plays an important role in fish muscle, acting as an energy reservoir. The creatine content of fish muscle varies depending **on species ranging from 160 to 720 mg/100 g**. **White muscle** tends to **contain higher amounts of guanidine compounds than dark muscles**. **Invertebrates contain less creatine than finfish.**

2.4.5-Trimethylamine oxide (TMAO):

Trimethylamine oxide is a characteristic non-protein nitrogen compound in **marine species.** The **amount of TMAO** in the muscle varies according to **species, age, size, season and environmental salinity**. **Demersal fish generally contain larger quantities of TMAO than pelagic fish, and the contents vary from 19 to 190 mg%.**

There is a direct relationship between TMAO content and salinity of the habitat. TMAO seems to play a role **in regulation of osmotic pressure in fish tissue and also protect the denaturation of protein**. This compound is negligible in most freshwater fish however, some species like the Nile perch and tilapia contain TMAO.

- **TMAO** is degraded to **trimethylamine (TMA)** by bacterial spoilage and enzymatic, TMAO-reductase, activity. The species belonging to the family Enterobacteriaceae and some bacteria such as ***Alteromonas, Photobacterium and Vibrioare*** able to reduce TMAO.
- **Formation of TMA depends primarily on the content of TMAO in the fish** and gives the characteristic 'fishy' odour. The formation of **dimethylamine (DMA) and formaldehyde from TMAO** is due to the action of the indigenous enzyme TMAO demethylase. **Generation of DMA and formaldehyde are correlated with textural change during frozen state**. TMAO-breakdown products are measured to provide an indicator of fish freshness.

2.4.6-Urea

Fresh water elasmobranchs **retain and synthesize less urea** than **marine fish**. A **high content of urea** in fish muscle is characteristic for elasmobranchs such as sharks and rays. They are reported to **produce, and retain, within their bodies large amounts of urea, a compound readily degraded to ammonia, leading to a rise in pH and total volatile basic nitrogen (TVB-N) during storage.**

The **urea** is broken down by the activity of **bacterial urease with the formation of ammonia and carbon dioxide.**

3-Lipids:

Lipids are the third major constituent in fish muscle after water and protein.In fish muscle the lipids are triacylglycerol and phosphoglycerides, both containing long-chain fatty acids.

The lipid content of fish species varies, even within the organs of species. These differences depend on many factors, such as the type of muscle and its location, age, sex and sexual maturation.

Fish are often classified based on their fat contents into

1. **Lean fish (fat less than 5%)**
2. **fat fish (fat 5–10%)**
3. **fatty fish (fat more than 10%)**

N.B:

Red muscles also contain two to five times **more lipid, B-vitamins, glycogen and nucleic acids** than **white muscles.**

The **lipid content** is affected by external factors such as **seasonal fluctuations in the environmental conditions and availability of phytoplankton**. In many pelagic fish, lipid contents ranging from 12 to 20% are found during winter compared with 3–5% during summer.

Cholesterol is the main sterol in marine fish like haddock, pollock, salmon, and crustaceans like shrimp and lobster. It has been reported that fish muscle is low in cholesterol, **whereas shrimps, prawns; squid and octopus are high in cholesterol. Freshwater fish muscle contains more cholesterol than marine fish**.

Depending on the nature of the hydrocarbonated chain, fish lipids are composed of saturated fatty acids (SFA), monounsaturated fatty acids (MUFA), and poly-unsaturated fatty acids (PUFA), whose proportions and amounts vary from one species to another.

<u>Saturated fatty acids (SFA):</u>

SFA are long-chain carboxylic acids **with no double bonds**. Among SFA, **palmitic and stearic acids** are the most important ones for marine- derived organisms.

<u>Mono-unsaturated fatty acids (MUFA):</u>

MUFA contains one carbon **double bond** along the length of the hydrocarbon chain of the related fatty acid, while the other carbon atoms are linked with a single bond. **<u>palmitoleic and oleic acids</u>** are the major constituents. **Oleic acid is the dominating monounsaturated fatty acid in many freshwater fish.**

<u>Poly-unsaturated fatty acids (PUFA)</u>

Approximately 50% of fatty acids in lean fish and 25% of fatty acids in fatty fish are PUFA. **The group of PUFAs** termed as **omega-3 (n-3) and omega-6 (n-6) fatty acids have double bonds starting at three and six carbons from the methyl end of the fatty acid chain, respectively.** The major varieties of PUFAs are **n-3 PUFAs**, such as **docosahexaenoic acid (DHA,**

C22:6n-3) and eicosapentaenoic acid (EPA, C20:5n-3), and n-6 PUFAs such as arachidonic acid (AA, C20:4n-6).

The composition of fish lipids is different from that of other lipids because they are composed **of mainly two types of fatty acids, EPA and DHA. These two main omega-3 fatty acids are typically found in marine fish and originate from the phytoplankton and seaweed that are part of their food chain.**

PUFA are highly susceptible to **oxidation on exposure to air, even at ambient temperature, leading to oxidative rancidity**.The other type of problem is the development of **hydrolytic rancidity** leading to the formation **of free fatty acids**. These free fatty acids react with proteins causing protein denaturation. **Lipid hydrolysis is more in ungutted than in gutted fish, probably due to the involvement of lipases present in digestive enzymes.**

4-Carbohydrates:

Carbohydrates occur in glycogen and as part of the chemical constituents of nucleotides in fish muscle. The amount of glycogen content is associated with the ultimate pH value of the flesh. The content of carbohydrates is influenced by conditions before and during capture, which may lead to depletion of glycogen stores. The amount of lactic acid produced is related to the amount of stored glycogen in the living tissue. In general, fish muscle contains low level of glycogen compared to mammals; therefore, less lactic acid is generated after death. The fish exposed to various forms of long-term stress before death, which depletes its glycogen reserves consequently on the ultimate post- mortem pH.

5-Minerals:

Minerals are divided into two groups: **macro- and microelements. Macroelements** are those present in amounts greater than 5 g in the human body and include **calcium, phosphorus, potassium, sulphur, sodium, chloride and magnesium.** Microelements are present in **microgram** levels per 1 g of food. They are both essential for human health.

The mineral content varies depending on season, biological characteristics (species, age, size, gender, sexual maturity), food sources, environmental factors (temperature and salinity of the surrounding water, presence of planktons, contaminants).

In general**, shellfish tend to be richer sources of minerals than fish.**

5.1-Macroelements

Calcium and phosphorus are the most abundant minerals in fish. **Oysters, clams and shrimp contain more calcium.** The sodium content is 60mg/100 g in freshwater and marine fish, and 120–140 mg/100 g in shellfish. Also, crabs are rich in terms of mineral content, especially sodium, potassium, calcium and phosphorus.

5.2-Microelements

Consumption of an average portion of fish and marine invertebrates meets the daily needs in terms of essential microelements.

Dark muscles of fish tend to contain **more iron than white muscles**. **However, it is** reported that the **iron content of beef muscle is approximately three times higher than fish muscle.**

Oysters are the richest zinc source of animal origin, whereas the **lowest concentration of zinc is present in fish and mammals, among marine organisms.**

Molluscs and crustaceans are good sources of zinc and copper, as well as iodine.

Fish muscle contains as much **copper as land animals**. The accumulation of copper in fish is affected by season, temperature, salinity and the presence of other metals such as manganese and iron in water.

Molluscs and crustaceans contain **significantly higher levels of manganese than fish.**

The iodine content of freshwater fish is lower than marine fish.

Fish and shellfish contain **much higher concentrations of selenium than other meats.**

6-Vitamins

Vitamins are organic compounds that are essential for metabolic reactions in the body. They function as cofactors or coenzymes in biochemical reactions. Vitamins are present and are effective in minute amounts; most of them cannot be synthesized by the organism and their absence from the diet causes specific deficiencies. Therefore, they are essential nutrient elements that shoud be supplied in the diet. **Vitamins are divided into two groups** basing on their solubility in **fat (A, D, E, K) and water (B complex and C).** Both water-soluble and fat-soluble vitamins are present in fish.

The amount of **vitamins and minerals is species specific** and can vary with many factors such as **season, age, feeding and environmental factors**. Vitamins are found in the body or liver depending on whether the fish is lean or fat.

Fatty species supply reasonable amounts of **vitamins A and D, which are found especially in fish liver oils**. These **vitamins continue to accumulate in the liver with increasing age.** Some mobilization of vitamins from muscle to other tissues may occur during sexual maturity. Water-soluble vitamin composition of wild fish may alterate during migration, maturation, and in when food is scarce.

<u>6.1-Fat-soluble vitamins:</u>

Fat-soluble vitamins **A, D and E** are present in seafood in varying amounts, often in concentrations higher than those in other meats.

Vitamin A (retinol) is abundant in some marine derived foods, whereas **carotenoids are responsible for the colour of fish and shellfish**. The **human body converts β-carotene in the diet into vitamin A.** Carotenoids are highly concentrated in **fish liver oils**, but small amounts are found in fish muscles or fillets. The concentration of vitamin A in the liver depends on the species and other factors such as fish size, spawning cycle, season and feeding.

Fish liver oils are the richest sources of vitamin D but seafood provides small amounts of vitamin E. Fish cannot synthesize vitamin E, and hence, the concentration of this vitamin is related to feed. **The dark muscle of fish has more vitamin E than white muscle,** and shellfish has little vitamin E content.