SPOILAGE MECHANISM AND QUALITY CHANGES IN SEAFOOD

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Fish is an important food item for mankind in view of its high protein content, vitamins and poly unsaturated fatty acids. However, the seafood quality is unique and compared to terrestrial meat, seafood deteriorates rapidly post-mortem as a consequence of various biochemical, autolytic and microbial breakdown mechanisms.The high ambient temperature of our country favours the rapid growth of micro-organisms. With higher ambient temperatures, fish quality deteriorates very rapidly. Spoilage of fishoccurs concurrently and independently, their relative importance varying with species of fish, environmental conditions, method of slaughter and post-mortem handling, storage procedures and processing conditions.

Post-mortem changes in fish

After the fish dies, the supply of oxygen to fish muscle ceases and thus the synthesis of adenosine tri phosphate (ATP) stops. The glycogen reserves in the body convert to lactic acid anaerobically instead of CO_2 and water, leading to a reduction in muscle pH. At this stage, the breakdown of Adinosine Tri Phosphate (ATP) begins. As pH decreases, muscle proteins approach their iso-electric point and denaturation begins. The decline in pH affects the quality of fish muscle in that the flesh becomes firmer and the tendency to drip is enhanced (Connel, 1975). Anaerobic catabolic activity continues till the ATP level reduces up to 5% in the muscle. Drop in ATP level initiates a combination of actin and myosin leading to the formation of actomyosin. This results in a rigid condition of the muscle, called rigor mortis. Within hours, depending upon species, condition and temperature, the muscles begin to contract and the fish enter into the stage of stiffening or rigor mortis.

The development of rigor is closely related to temperature. The length of time between death and onset of rigor is determined by the relative activities of enzyme systems responsible for ATP degradation. This in turn is controlled by the relative concentrations of ATP, creatine phosphate and glycogen in the muscle tissue at the time of death.

The ATP is broken down to adenosine diphosphate (ADP), adenosine monophospahte (AMP), inosine (IMP) and then hypoxanthine (Hx). The initial sweet, meaty and species characteristic flavours of fresh fish reflect the combination of IMP and free amino acids present in the flesh, as well as some sugars and sugar phosphates (Jones, 1961).

Spoilage of fish

Spoilage of fish begins as soon as the fish dies. In tropical countries, spoilage begins rapidly within few houres of landing, if the fish is not properly cooled. In raw fish, spoilage takes place mainly due to 3 reasons ie., enzymatic, microbial and chemical action.

1. Enzymatic spoilage

After death, anaerobic glycolysis takes palce and glycogen will converted to lactic acid. The accumulation of lactic acid in the muscle brings down the pH to 6.2-6.5. The decline in pH accompanied by natural post mortem stiffening is called rigor-mortis. After rigor mortis, the muscle enzymes begins hydrolysing nucleotides, protein and lipids in the fish muscle. Enzymatic hydrolysis result in the development of compounds with undesirable flavour and odour. In heavly fed fishes, autolysis leads to belly bursting due to higher rate of hydrolysis by muscle enzymes in the belly area.

2. Microbial spoilage

Enzymatic hydrolysis degrades the protein into peptides, peptones and aminoacids, which together with vitamins, minerals and nucleotides constitute an ideal medium for microbial proliferation. Fish spoils mainly due to the action of bacteria. The saprophytic bacteria (Psedomonas, Flavobacterium, Acinetobacter, Aeromonas etc.) present on the slime, gill, skin, intestine etc. invade in to the tissue and start decomposing protein, lipid etc. Microbial action in fish leads to the production of compounds like Tri Methyl Amine(TMA), ammonia, histamine, indole,hydrogen sulphide, methyl mercaptan etc. All these compounds together gives undesirable offodour and off flavour to the fish and hence the fish become unacceptable for consumption.

3. Chemical spoilage

The most important chemical spoilage takes place in fish is the fat oxidation. Fish lipid have high concentration of poly unsaturated fatty acids and hence undergoes oxidative changes. Fat oxidation give rise to problems such as rancid odour and flavour as well as discoloration. The lipid oxidation is initiated and accelarated by oxygen, heat, light, presence of metallic ions like Cu^{2+} and Fe^{2+} etc. The products of fat oxidation like carbonyls, aldehydes etc. further reacts with proteins and aminoacids and reduces its solubility.Fattyacid is oxidised to hydroperoxides initailly and the peroxides further get oxidised to aldehydes and ketones with typical rancid odour.

Changes in fish due to spoilage

Flavour changes

During spoilage many undesirable compounds are produced in the fish. Nucleotide degradation result in the production of hypoxanthene which is bitter in taste. Moreover, the accumulation of ammonia, and other voltile bases like Tri methyl Amine (TMA), formaldehyde etc. brings about definite changes in the inherent flavour of the fish.

Color changes

Color is an important factor in sea food quality. Color of the fish is changed due to enzymatic oxidation or nonenzymatic fat oxidation and pigment oxidation. The importanrt discoloration in seafood is described below.

Blue or black discoloration in shrimp and lobster

The development of black spot in shrimp and lobster is due to the presence of an enzyme polyphenol oxidase. Black spot is formed by the oxidative action of this enzyme, particularly tyrosinase on the aminoacid tyrosin, thus melanin is formed. The pigment is formed on the shell surface initially and in advanced stages, on the underlying meat. This makes the shrimp unattractive for marketing. Discoloration at the butt of the tail, black spot between the segments are pronounced in moribund lobster. In crab, in addition to black discoloration, blue discoloration also occures which is induced by the oxidation of haemocyanin pigment in the blood and is non enzymatic.

Yellowing of fish flesh

During chilled or frozen storage, some fishes developes an yellow color on the surface. This is due to the oxidation of fat as well as carotenoids. Freezing or other process desrupt chromatophores and release carotenoids and their migration to subcutaneous fat layer causes.

Brown discoloration

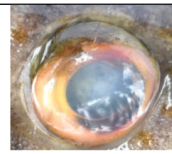
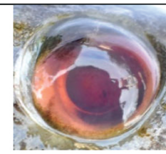
This type of discoloration is more pronounced in dark fleshed fishes such as tuna and mackerel. Myoglobin in the blood get oxidised to metmyoglobin and color of muscle changes to brown. Reaction between protein or aminoacid with the product of lipid oxidation also lead to brown discoloration.

Changes in texture

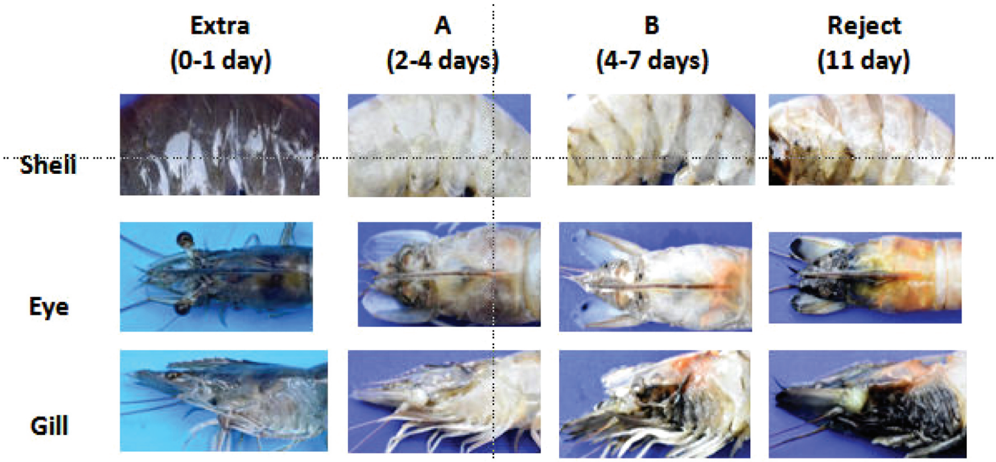
The collagen fibrils attaching the muscle bundlesmaintain the toughness and integrity of fish muscle. The action of microbial as well as autolytic enzymes on fish flesh brings about undesirable changes in the texture. The enzymes degrades muscle proteins and breake down the connective tissue in muscle. As a result, the texture of fish muscle become soft. Degradation of myofibrillar proteins also contributes to softenss of muscle during storage. These undesirable changesare due to the activity of autolytic enzymes (e.g. collagenase,ATPase) degrading different proteins and breaking down theconnective tissue in muscle meanwhile the spoilage microorganisms multiply rapidly and promote the progress of spoilage.The fish muscle loses its stiffness, elasticity, springines and chewiness after spoilage.

Belly bursting

Enzymatic spoilage causes belly bursting especially during a period of heavy food intake. Heavly fed fish have a high content of digestive enzyme in the intestinal tract. In such fish, autolysis begins rapidly and in the dissolved gut component, bacteria proliferates and produces gases such as carbon dioxide and hydrogen sulphide. This gas production lead to belly bursting after short storage period.

Days	**0 day**	**5^{th} day**	**15^{th} day**
Eye			
	Convex with transparent cornea, black pupil, bright yellow sclera	Convex, slightly opaque cornea, black but dull pupil, Reddish sclera with yellow tinge.	Concave eye , red cornea, opaque and red pupil, ingression of blood, red sclera
Gills			
	Bright blood red gills covered with thin layer of transparent mucous	Dull red color with bleaching from the dorsal gill rays	Pale brown color, all gill rays bleached

Changes in grouper during iced storage



Changes in *Penaeus vannamei* (Pacific white shrimp) iced storage

Factors affecting spoilage of fish

Temperature

It is well known that both enzymatic and microbiological activity is greatly influenced by temperature. However, in the temperature range from 0 to 25°C, microbiological activity is relatively more important, and temperature changes have a greater impact on microbiological growth than on enzymatic activity. In general, an increase of 5^{0}C temperature will double the rate of spoilage. Many bacteria are unable to grow at temperatures below 10°C and even psychrotrophic organisms grow very slowly, and sometimes with extended lag phases, when temperatures approach 0°C. The shelf life of fish products, therefore, is markedly extended when products are stored at low temperatures. High temperatures are partly responsible for the speed of the oxidation processes. In addition, direct sunlight, wind, heat, light (especially UV-light) and several organic and inorganic substances may also accelerate oxidative processes. It is often critical to reach the desired short-term storage temperature rapidly to maintain the highest visual quality, flavour, texture, and nutritional content of fresh fish.

Intrinsic factors

The spoilage rate of fish is affected by many parameters like species, pH, fishing ground, season etc. and the fish spoil at different rates depending on these factors. In general it can be stated that larger fish spoil more slowly than small fish, flat fish keep better than round fish, lean fish keep longer than fatty fish under aerobic storage and bony fish are edible longer than cartilaginous fish. Several factors probably contribute to these differences and whereas some are clear, many are still on the level of hypotheses.

Factors affecting spoilage rate	**Relative spoilage rate**	
	Fast	**Slow**
Size	Small fish	Larger fish
post mortem pH	High pH	Low pH
Fat content	Fatty species	Lean species
Skin properties	Thin skin	Thick skin

Handling

Rough handling will result in a faster spoilage rate. This is due to the physical damage to the fish, resulting in easy access for enzymes and spoilage bacteria. Physical mishandling in the net, such as very large catches, fishermen stepping on fish or throwing boxes, containers and other items on fish catch, may cause bruises and rupture of blood vessels that can accelerate the rate of spoilage. When fish is in rigormortis, rough handling can cause gaping. Apart from the microorganisms that fishes have at the time of capture, more is added via unhygienic practices and contaminated equipments, utensils and storage containers.

Initial bacterial load

The microflora on tropical fish often carries a slightly higher load of Gram-positives and enteric bacteria but otherwise is similar to the flora on temperate-water fish. Basically, bacteria populations on temperate fish are predominantly psychrotrophic reflecting water temperatures of about 10^0C while fish from the tropics have largely mesophilic bacteria.

Methods of capture

The fishing gear and method employed determines the time taken between capture and death. Fish caught in gillnets struggle much to escape and hence, they are bruised by the net which increases exposure to microbial growth and subsequent deterioration. Fish caught by hook and line methods, on the other hand, die relatively quickly and therefore bruises and stresses are likely to be minimal. Physical mishandling in the net due to long trawling nets and very large catches accelerates spoilage. The large catches in the net are compacted against each other resulting in the fish getting bruised and crushed (especially small sized fish) by the heavy trawl net.

Suggested readings

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