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# Fish Spoilage In The Tropics: A Review

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ABSTRACT

Fish is a perishable commodity, spoilage begins immediately after harvest by autolytic bacteria especially, in the tropics, hence the objectives of the review paper were to highlight the causes of fish spoilage and identify the possible ways of reducing the spoilage. As fish spoils, its nutritional value decreases, the bacteria causing the spoilage degrade the fish protien, bacteria action produces nitrogenous compounds with obnoxious odour and the affected fish become unattractive to the consumer. Spoilage in fresh fish can produce toxins which cause food poisoning; histamine contamination is prevalent among pelagic fish such as Mackerel and Sardine. Pathogenic bacteria contamination of fresh fish caused by poor handling and washing the fish in polluted water can also cause food poisoning. Fish spoilage results from three basic mechanisms: Enzymatic autolysis, oxidation, microbial growth. There is need to address these problems so as to minimize spoilage.

## INTRODUCTION

They are three modes of fish spoilage: Chemical, Enzymatic and Microbial spoilage. One-fourth of the world's fish supply and 30% of landed fish are lost through microbial activity alone. With the a growing world population and the need to store and transport the food from one place to another, fish preservation becomes necessary in order to increase its storage time sand maintain its nutritional value, texture and flavor Ayuba et al., 2015. Historically salting, drying, smoking, fermentation and canning were the methods to prevent fish spoilage and extend its shelf life. In response to consumer demand for texture, appearance and taste, new methods were developed including: Cooling, freezing and chemical preservation. Low temperature storage and chemical techniques for controlling water activity, enzymatic, oxidative and microbial spoilage are the most common methods use in the industry today. Hansen et al., (1996) stated that autolytic enzymes reduced textural quality during early stages ofdeterioration but did not produce the characteristic spoilage off-odors and off-flavors. This indicates that autolytic degradation can limit shelf-life and product quality even with relatively low levels of spoilage organisms. (FAO, 2005). Most of the impact is on textural quality along with the production of hypoxanthine and formaldehyde. The digestive enzymes cause extensive autolysis which results in meat softening, rupture of the belly wall and drain out of the blood water which contains both protein and oil (FAO, 2005). A number of proteolytic enzymes are found in muscle and viscera of the fish after catch. These enzymes contribute to post mortem degradation in fish muscle and fish products during storage and processing. There is a sensorial or product associated alteration that can be contributed by proteolytic enzymes (Engvang and Nielsen, 2001). During improper storage of whole fish, proteolysis is responsible for degradation of proteins and is followed by a process of solubilization (Lin and Park, 1996). On the other hand, peptides and free amino acids can be produced as a result of autolysis of fish muscle proteins, which lead towards the spoilage of fish meat as an outcome of microbial growth and production of biogenic amines (Fraser and Sumar, 1998). Belly bursting is caused by leakage of proteolytic enzymes from pyloric caeca and intestine to the ventral muscle. The proteases have optimal pH in the alkaline to neutral range. Martinez and Gildberg (1988) reported that the rate of degradation by proteolytic enzymes was reduced when the fish was kept at 0°C and a pH of 5.

### Characteristics of spoiled fish

- The flesh is soft to touch. When the flesh is pressed it leaves a permanent indentation.
- The skin looks dull and has slime on the surface.
- The gills look brownish.
- It gives a bad smell.

### Ways of reducing spoilage in fresh fish

The following are ways of reducing spoilage in fresh fish:

- Avoid physical damage.
- Removal of internal parts (gutting).
- Cooling of fish (icing or freezing).
- Application of salt.
- Sun drying

### How to prevent physical damage of fish

- Remove fish carefully from nets, traps etc.
- Place fish gently in a container.
- Do not place fish on the ground.
- Keep fish away from flies, birds and animals
- Do not step on the fish.

### How to remove the internal parts of the fish

- Cut fish open in the stomach area with clean knife.
- Remove all the intestines
- Remove the gills.
- Use clean water to wash the cut area and the whole fish well.

## Oxidative spoilage

Lipid oxidation is a major cause ofdeterioration and spoilage for the pelagic fish speciessuch as mackerel and herring with high oil/fat contentstored fat in their flesh (Fraser and Sumar, 1998). Lipidoxidation involves a three stage free radicalmechanism: initiation, propagation and termination(Frankel, 1985; Khayat and Schwall, 1983). Initiationinvolves the formation of lipid free radicals throughcatalysts such as heat, metal ions and irradiation. Thesefree radicals which react with oxygen to form peroxylradicals. During propagation, the peroxyl radicalsreacting with other lipid molecules to formhydroperoxides and a new free radical (Fraser andSumar, 1998; Hultin, 1994). Termination occurs when abuildup of these free radicals interact to form nonradicalproducts. Oxidation typically involves thereaction of oxygen with the double bonds of fatty acids.Therefore, fish lipids which consist of polyunsaturatedfatty acids are highly susceptible to oxidation.Molecular oxygen needs to be activated in order toallow oxidation to occur. Transition metals are primaryactivators of molecular oxygen (Hultin, 1994).In fish, lipid oxidation can occur enzymatically ornon-enzymatically. The enzymatic hydrolysis of fats bylipases is termed lipolysis (fat deterioration). During this process, lipases split the glycerides forming free fatty acids which are responsible for:Common off flavour, frequently referred to as rancidity andreducing the oil quality (Huis in't Veld, 1996).The lipolytic enzymes could either be endogenous of the food product (such as milk) or derived from psychrotrophic microorganisms Undeland et al., (2005). The enzymes involved are the lipases present in the skin, blood and tissue. The main enzymes in fish lipid hydrolysis are triacyl lipase, phospholipase A2 and phospholipase B Non-enzymatic oxidation is caused by hematin compounds (hemoglobin, myoglobin and cytochrome) catalysis producing hydroperoxides (Fraser and Sumar, 1998). The fatty acids formed during hydrolysis of fish lipids interact with sarcoplasmic and myofibrillar proteins causing denaturation. Undeland et al., (2005) reported that lipid oxidation can occur in fish muscle due to the highly pro-oxidative Hemoglobin (Hb), specifically if it is deoxygenated and/or oxidized. They found that the addition of acids, which lower the pH, can accelerate lipid oxidation through deoxygenated Hb.

### Chemical rancidity

This is distinguishable from hydrolytsic (enzymic) rancidity, which is caused by the hydrolysis of triglyceride molecules to glycerol and fatty acids, and it is brought about by the presence of moisture in oils. Lipid oxidation is a major cause of deterioration and spoilage for the pelagic fish species such as mackerel and herring with high fat content stored fat in their flesh (Fraser and Sumar, 1998). Lipid oxidation involves a three stage free radical mechanism: initiation, propagation and termination (Frankel, 1985; Khayat and Schwall, 1983). Initiation involves the formation of lipid free radicals through catalysts such as heat, metal ions and irradiation. This free radical which react with oxygen to form peroxyl radical. During propagation, the peroxyl radicals reacting with other lipid molecules to form hydroperoxides and a new free radical (Fraser and Sumar, 1998; Hultin, 1994). Termination occurs when a buildup of these free radicals interact to form non radical products. Oxidation typically involves the reaction of oxygen with the double bonds of fatty acids.Conell (1995) reported that in chemical rancidity, there are two pathways.Radical pathway or autoxidation or thermal way, which is affected by phonolic antioxidant and is divided into three parts.

**Initiation**

This is the formation of the first free radical. At the initiation stage, hydrogen is abstracted from an unsaturated triglyceride to yield a free radical. The initiation step has a high energy of activation and the action of enzymes and the presences of metals, light and amino acids reduce this high energy requirement.

**Propagation**

This is the step of constant or increasing radical concentration. Once a free radical has been formed it will combine with oxygen to form a peroxy-free radical. The peroxy-free radical then abstracts hydrogen from another triglyceride to yield peroxide and a new free radical. The peroxide radical breaks up into aldehydes and ketones, which are responsible for the off-odour and flavours.

**Termination**

The reaction at the propagation stage leading to the production of a free radical may continue until all the oxygen or oils has been used up.Photocatalytic pathway (non-radical pathway), which is not affected by phenolic antioxidant. It is distinct from the UV catalysis of the degradation of saturated hydroperoxides of the radical pathway. This pathway has a definite requirement for a photosynthesis. e.g. chlorophyll in plants, but in animals, the haeme pigments, haemoglobin and myoglobin take over this function.

### Microbial spoilage

Composition of the micro flora on newly caught fish depends on the microbial contents of the water in which the fish live. Fish micro flora includes bacterial species such as Pseudomonas, Alcaligenes, Vibrio, Serratia and Micrococcus (Gram and Huss, 2000) Microbial growth and metabolism is a major cause of fish spoilage which produce amines, biogenic amines such as putrescine, histamine and cadaverine, organic acids, sulphides, alcohols, aldehydes and ketones with unpleasant and unacceptable off-flavors (Dalgaard et al., 2006; Emborg et al., 2005; Gram and Dalgaard, 2002). For unpreserved fish, spoilage is a result of Gram-negative, fermentative bacteria (such as *Vibrionaceae*), whereas psychrotolerant Gram-negative bacteria (such as *Pseudomonas* spp. and *Shewanella* spp.) tend to spoil chilled fish (Gram and Huss, 2000). It is, therefore, important to distinguish non spoilage micro flora from spoilage bacteria as many of the bacteria present do not actually contribute to spoilage (Huss, 1995). Trimethyl amine (TMA) levels are used universally to determine microbial deterioration leading to fish spoilage. Fish use Trimethylamine Oxide (TMAO) as an osmoregulant to avoid dehydration in marine environments and tissue waterlogging in fresh water. Bacteria such as *Shewanella putrifaciens, Aeromonas spp., psychrotolerant Enterobacteriacceae, P.phosphoreum* and *Vibrio* spp. can obtain energy by reducing TMAO to TMA creating the ammonia-like off flavors (Gram and Dalgaard, 2002). Table 2 lists spoilage bacteria in descending order of spoilage activity. Pseudomonas putrifaciens, fluorescent pseudomonads and other spoilage bacteria increase rapidly during the initial stages of spoilage, producing many proteolytic and hydrolytic enzymes. Composition of the micro flora on newly caught fish depends on the microbial contents of the water in which the fish live. Fish micro flora includes bacterial species such as *Pseudomonas, Alcaligenes, Vibrio, Serratia* and *Micrococcus* (Gram and Huss, 2000) Microbial growth and metabolism is a major cause of fish spoilage which produce amines, biogenic amines such as putrescine, histamine and cadaverine, organic acids, sulphides, alcohols, aldehydes and ketones with unpleasant and unacceptable off-flavors (Dalgaard et al., 2006; Emborg et al., 2005; Gram and Dalgaard, 2002). For unpreserved fish, spoilage is a result of Gram-negative, fermentative bacteria (such as Vibrionaceae), whereas psychrotolerant Gram-negative bacteria (such as Pseudomonas spp. and Shewanella spp.) tend to spoil chilled fish (Gram and Huss, 2000). It is, therefore, important to distinguish non spoilage microflora from spoilage bacteria as many of the bacteria present do not actually contribute to spoilage (Huss, 1995).

### Factors affecting bacterial growth

Eyo (2001) reported that increase in the population of micro-organisms by geometric progression is theoretically possible; its practical implication is limited by the environmental factors prevailing. These factors are temperature, water contents, osmotic pressure, pH of the medium, redox potential, and the nutrient composition of the environment.

### Temperature

This is an extremely important factor influencing growth of micro-organisms. When temperature is below minimum required by micro-organisms, they either remain in a lag phase or dies slowly. High tropical ambient temperature actually favours the growth of micro-organisms. Exposure of fish to direct sunlight should be avoided. In artisanal fishery, in

**Table 1:** Summary of changes in chilled or frozen fish.

| Enzyme(s) | Substrate | Effect | Prevention |
|---|---|---|---|
| Glycolytic enzymes | Glycogen | Lactic acid production resulting in pH drop. | Avoid pre-rigor stress |
| Autolytic enzymes involved in nucleotide break down | ATO,ADP, AMP,IMP. | Gradual production of Hypoxanthine | Avoid pre-rigor stress and improved handling. |
| Cathepsins | Protein, peptides | Softening of tissue | Avoid rough handling during storage. |
| Chymotrypsin,trypsin, carboxy-peptidases | Protein, peptides | Belly-bursting | Problem increased with freezing/ thawing or long-term chill storage |
| Calpain | Myofibrillar proteins | Softening | Removal of calcium |
| Collagenases | Connective tissue | Softening and gaping of tissue | Time and temperature of chilled Storage |
| Trimethylamine Oxide (TMAO) demethylase | TMAO | Formaldehyde | Storage temperature less than -30°C, physical abuse, freeze/thawing. |

the absences of ice, fish should be kept in clean containers and shaded. Most tropical lean fish will remain in good condition for three weeks to four weeks in ice provided the insulated boxes have provision for the exit of melt water to avoid recontamination of the fish (FAO, 1995).

Temperature affects growth of micro-organisms in many ways. At low temperature the chemical reactions in the organism are slowed down leading to suspend growth. Too high a temperature causes the destruction of heat labile components of the organism such as nucleic acid and protein resulting in death. Although the overall limit for bacterial growth is between -24oc to 90oc, not all bacteria can survive at the extremes of this temperature.

### Water content

Water is essential for life and bacteria cell contain 90% moisture. Moisture requirement for bacteria is expressed as water activity (AW). The water activity is defined as the ratio between the water vapour pressure of a substance and the vapour pressure of water at the same temperature. Micro- organisms can grow over a wide range of water activity (0.60-0.99) depending on the species of fish. A reduction in water activity of the flesh will limit the chances of bacteria growing in the fish. Dehydration or evaporation, presences of solutes such as sugar or ionic material like salts and formation of crystals during freezing can cause such a reduction (Eyo, 2001).

### Acidity or alkalinity (pH)

Fish spoilage bacteria grow well over a wide range of hydrogen ion concentration ranging from 4 to 9. The optimum pH for growth for most bacteria lies between pH 6.5-7.5, although some bacteria are capable of growing at the extremes of the pH ranges. Bacterial growth and toxin production are inhibited if the condition becomes too acidic or too alkaline. In general acids conditions are more lethal to micro-organisms than alkaline (Eyo, 2001).

### Redox potential

The redox potential is the ability of an organism to gain or lose an electron. When an organism gains an electron, it is reduced and when it loses an electron it is oxidized .The electron transferring system is called oxidation-reduction. Anaerobic organisms require a negative potential for growth whereas the aerobic ones requires a positive potential for growth (Eyo, 2001).

### Nutrient composition

Bacteria are living organisms and like other living things such as plants and animals, they require a source of energy to survive. Such energy can be obtain from sunlight or by the breakdown of nutrients mainly carbohydrates, proteins, fats and oils, vitamins and other growth factors. The process of attack of carbohydrate is called fermentation. During microbial fermentation, acid is produced which leads to a change in pH. The accumulation of acids retards fermentation and increases putrefaction (Eyo, 2001).

Some bacteria can also breakdown fats to produce obnoxious odour, unsaturated fatty acids are usually given priority over saturated fatty acids. In addition, moist fats arebroken down much more rapidly than dry fats. Vitamins are growth factors, and many bacteria have a requirement for the B vitamins. Nutrients that are relatively deficient in the B vitamins are in most cases not affected by micro- organisms e.g. fruits. If these factor are well managed, spoilage can be reduced.

### Control of microbial spoilage

#### Proper hygiene

The surface of all material coming in contact with fish should be kept clean. These include filleting knives, boards and benches, filleting machines, containers, hold of vessels etc. Adequate hygiene will improve the keeping quality of the fish. In the study of shrimps and crabs, the number of bacteria fell during washing, cooking, and freezing and rose during handling, peeling, breading and packaging (Burt et. al., 1991 and Johnson et. al., 1994).

#### Gutting of the fish

This involves the removal of the viscera, which harbour spoilage bacteria, and spoilage enzymes that attack the flesh of the fish after death. While the enzymes are involved in the digestion and the general enzymatic activities of the living fish, the bacteria proliferation is inhibited by the general metabolic reactions in the fish. Gutting should be done immediately the fish is hauled. Removal of the viscera not only eliminate the gut enzymes, it also prevent infestation by intestinal micro-organisms and eliminate the gall bladder which harbours bile, an alkaline greenish liquid which gives rise to the condition known as “belly burn” – a visible discolouration of the belly cavity (Gorga and Ronsivalli, 1988). The bile imparts an undesirable bitter flavour to fish when consumed.

#### Rigor mortis

Rigor mortis means the stiffening of the muscles of an animal shortly after death. Immediately after death the muscles of an animal are soft and limp, and can easily be flexed; at this time the flesh is said to be in the pre-rigor condition, and it is possible to make the muscles contract by stimulation, for example by means of an electric shock (FAO,2005).

#### Salting

Salt will remove water from fish tissues by osmosis thereby render water unavailable for microbial growth. The cell of micro-organisms is also plasmolysed from salt uptake (Eyo, 1998).

#### Smoking

Smoking as a method of preservation of perishable foods dates back to civilization. Fish and fishery products are one of the most perishable of all staple commodities. They are, therefore, suitable media for the growth and proliferation of micro-organisms. To prolong the shelf life of fish, fish is preserved by smoking. Smoke is generated from wood and other appropriate combustive material (such as saw dust, Agricultural by-product offal) by burning. Smoke has bacteriostatic, bactericidal and antioxidant functions while heat generated from the wood has dehydrating effect on the fish. The combination of these processes gives fish dry effect.

#### Antibiotics

Antibiotics such as oxytetracycline, choltetracycline, tetramycine and auromycine during ice manufacture have been found to extend the shelf-life of chilled fish. However, antibiotics used for medical purposes are not allowed to be included in fish hence they have been withdrawn. The use of nisin and/or tylosin to suppress bacteria has been suggested (Eyo, 2001).

#### Carbon dioxide

This is known as modified gas atmosphere (MAP). In this process, fish are packed in sealed transparent containers including an atmosphere rich in carbon dioxide. The bacterial growth is retarded at an average of 20% depending on species (Clucas, 1981).

### Reduction Of Fish Spoilage

(1) **Properhandling of fresh fish**.
•Avoid exposing the fish to sunlight. Keep them in a shaded area.
•Ice the fish immediately after they are caught to lower their temperature.
•Remove the gills and internal organs.
•Avoid soaking the fish too long in the water after death as this easily spoils the fish.
•Use mechanical refrigeration if there are facilities.
•

**(2) Improvement of landing facilities and distribution**

Very often, whenever unexpectedly large catches are taken, landing facilities and the distribution system cannot handle the surplus of fish. Thus, a long period of time may elapse before the fish can be processed. Consequently, a high percentage of the fish may become unsuitable for processing. It is therefore important to expand cold storage facilities in proximity of the catch areas whenever sufficient and/or adequate transport facilities (e.g. trucks equipped with a refrigeration system) are not available. Alternatively, processing plants may be located near the catch areas in order to avoid the need for extensive transport facilities.

**(3) Maintaining the fish at low temperatures**

To minimise spoilage, fish should be kept as cool as possible immediately after catching until processing starts. If tropical fish are chilled with ice, they may be kept in an edible condition for an increased period. The actual length of time depends very much on the type of fish, but may be as long as three weeks. However, in many areas far away from major towns, ice may not be available in sufficient quantities. Fish may then be kept relatively cool by other means, including the following:Keeping the fish in the shade out of direct sun, placing damp sacking over the fish. This helps reduce the temperature as the water evaporates. The sacking must be kept wet and the fish must be well ventilated.Pixing the fish with wet grass or water weeds in an open-sided box so that the water can evaporate and cool the fish. In this method, the fish should be kept continuously wet.

**(4) Maintaining a hygienic environment**

Fish which have been handled cleanly and carefully will be in a better condition than fish which have been handled carelessly; they can, therefore, be worth more money.

Before processing starts, attention must be given to the following:
I Keeping the fish as clean as possible. Washing with clean water will remove any of the bacteria present on the fish skin, especially in the presence of mud.
ii. Keeping the fish cool, chilled in ice or chilled water, if possible, at all stages before processing starts. Fish spoilage is a continuing process: once a particular stage of spoilage has been reached no amount of good practice or processing can reverse it.
iii. Avoid damaging fish by careless handling. If the skin is broken this will allow bacteria to enter the flesh more quickly and spoilage will be more rapid. This sort of damage can be caused by walking on fish and by the use of a shovel. If the guts can be removed and the gut cavity washed carefully, this will reduce the number of spoilage bacteria present; however, in some areas, the purchaser requires whole fish so that this practice may lower the value of the catch (Dalgaard et al., 2006).

## CONCLUSION

The spoilage of fish and fish products depends on a number of factors. These factors as well as the spoilage mechanism must be thoroughly understand before developing proper handling and pre-treatment methods and preservation techniques. To stop the rapid spoilage of fish, it is essential to store the fish at 0°C after catching during harvesting. However, theseoperation is only a temporary method for preservation whereas, this can decrease microbial and enzymatic spoilage but cannot prevent oxidative spoilage.With the annual drop in fish production as against an ever increasing human population, it is necessary to improve better fish handling, processing and preservation techniques in the artisanal and commercial fisheries. This will ensure sufficient availability of fish for the teeming population with minimal wastage and increase food security.

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