Fisheries and Aquaculture Journal
ISSN: 2150-3508

Getu et al., Fish Aquac J 2015, 6:4
http://dx.doi.org/10.4172/2150-3508.1000154

Review Artilce Open Access

Post-harvesting and Major Related Problems of Fish Production

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Abstract

Fish is an important source of animal protein in the especial cases of African countries, where the combine forces of high cost, disease, low genetic potentials of indigenous species among other factors have raised the cost of livestock almost beyond the reach of the low income groups. Fish becomes readily accessible source of animal protein but this alternative is also threatened by poor post-harvest techniques in African countries, which have resulted in massive losses. This paper discusses about the most important type of post-harvest fish lose. It also describes the cause of these loses, the factors that affect or facilitate such problems. It also briefly describes the mechanisms of problems or conditions that resulted in fish lose. The losses can be physical lose, quality lose, economical or nutritional lose, and also the most important cause of lose is spoilage. Fish lose due to spoilage is estimated to be 10 to 12 million tons per year which accounts 10% of total production of fish. In general post-harvest fish lose results in low income of the society, low quality (unhygienic) fish and available fish products are very low. It also results in low diet or low nutritional value which gives in unhealthy and poor population.

Keywords: Loses; Nutritional value; Post-harvest; Quality.

Introduction

Food security exists when all people at all the times have both physical and economic access to the basic food they need. Fisheries make an important contribution to the animal protein supplies of many communities in both the industrialized and developing world [1]. It is, however, in Low Income Food Deficit Countries (LIFDC's), that some communities are dependent on fish, not only for animal protein, but also as a source of micronutrients, minerals and essential fatty acids [2]. But these fisheries dependent communities encounter Post-harvest fish losses. For example spoilage accounts a loss of 10 to 12 million tons per year and 20 million tons of fish in a year are discarded at sea [3]. Post-harvest losses of fish occur in various forms. The physical losses of material, quality lose, discarding of by catch, Economic losses, nutritional loss and loose due to spoilage. In addition the lowering of large quantities of fish catches into animal feeds can be considered under certain conditions as a loss for human food security [2]. Spoilage is the degradation of food such that the food becomes unfit for human consumption. Food can be spoiled by a number of means, autolytic enzymatic spoilage, oxidative spoilage, microbial spoilage which results in numerous undesirable metabolites being produced in the food that cause unwanted flavors and odors [4]. The rate of spoilage is influenced to a large extent by high ambient temperature. Consumers generally demand and pay more for good quality fish. Poor quality fish constitutes an economic loss to fishermen and fish traders [5]. Objectives of this paper to identify the type of post-harvest fish lose and know different factors that affect post-harvest fish lose.

Post-harvest fish lose

What are post-harvest fish losses?: Post-harvest fish lose (PHFL) refers to fish that is either discarded or sold at a relatively low price because of quality deterioration. This means that fish operators (fishers, processors, traders, and other stakeholders involved in fisheries) lose potential income. It also means that less fish is available to consumers, or consumers are supplied with low quality fish and fish products [6]. Fish is a very perishable commodity and hence susceptible to high post-harvest losses. Both physical (material) and quality losses are high in fisheries sector. And these translate into losses in nutritional contribution of fish to the total diet and health's of populations [7]. Very high levels of post-harvest loss occur during pre-processing, processing, storage and transportation of fishery products [8]. Post-harvest fish lose are commonly caused by: discarding of bycatch at sea because fish is too small or not valuable enough to land for sale; poor processing techniques damaging fish; animal predation and insect infestation; inadequate packaging and storage practices leading to damage of the end Product [6].

Factors that affect post-harvest fish lose: A high ambient temperature is the most important factor that contributes to the production of biogenic amines during post-harvest handling. Both the postmortem formation of amino acids and their rapid decarboxylation biochemically or microbiologically are temperature dependent that leads to spoilage [9]. Long and unreliable transport with Lack of/ inadequate preservation and Lack of markets due to imbalance between Supply/demand also site as factors for the loss. In addation to this, Species of fish, Gears used and the storage time affect Post-harvest fish lose [10].

Main types of post-harvest fish losses

Lose in nutritional value: Fish that has decomposed to such a degree that it is unfit or unsafe for human consumption can be considered a nutritive loss. Likewise, fish that is discarded at sea due to its low economic value or lack of marketing schemes are regarded as a nutritive loss [11]. Fresh fish is extremely perishable and is subject to bacterial spoilage. As fish spoils, its nutritional value decreases, as the bacteria causing the spoilage degrade the protein which is intended for human consumption. However, bacterial action produces nitrogenous compounds with noxious odours and the affected fish will become highly unattractive because there is too much nutritional damage [3].

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Received October 23, 2015; **Accepted** December 14, 2015; **Published** December 20, 2015

Citation: Getu A, Misganaw K, Bazezew M (2015) Post-harvesting and Major Related Problems of Fish Production. Fish Aquac J 6: 154. doi:10.4172/2150-3508.1000154

Bacterial spoilage in fresh fish can produce toxins which cause food poisoning; histamine contamination is prevalent among pelagic fish such as mackerel and sardine. Pathogenic bacterial contamination of fresh fish caused by poor handling and washing the fish in polluted water can also cause food poisoning [12]. The major factors that affect the nutritive value of fish products are related to how fish is handled, processed or preserved and stored. Traditional practices such as exposing fish for long periods to weather elements coupled with traditional methods of preservation (hot smoking, sun-drying, and deep frying) and poor storage are subjecting fish to different kinds of degradation [11].

High temperatures of about 50°C as are encountered in smoking especially in Africa where hot smoking is preferred, affect the availability of lysine, one of the amino acids found in fish protein. Loss of available lysine and other essential monoacids could also occur at much lower temperatures, such as 0°C [3]. This raises the possibility that nutritional losses can occur when fish is sun dried. Other nutrients present in fish muscle which can be affected by the heat used in traditional processing methods include methionine and other sculpture amino acids and vitamins K. Oxidation continues during storage of fish, leading to the development of a bright yellow/orange color and distinctive and unpleasant pointy odor. The product will become very unattractive to consumers and may be completely rejected [12].

Physical loss: Physical fish loss refers to fish that, after capture or landing, is not used. It is either thrown away accidentally, voluntary or as authorized [13,14]. Physical losses of fish after harvest can be regarded in two distinct ways; First, there is what might be termed complete physical loss. Quantities of fish may spoil completely and become inedible. The by-catch from shrimp trawling is thrown overboard. Related to these losses is the under-utilization of resources when small fish are converted into fish meal instead of being used for human food. Also there are many less popular fish which are seldom used for human consumption [3]. The second type of physical loss, which can be regarded as a loss of material, is a result of poor handling and processing of both fresh and cured fish. The physical loss of material is caused by, poor handling and preservation or the discarding of by catch. Physical loss can be also caused by theft, by insects eating the fish, or by bird or animal predation. Poor packaging and rough handling can also be a direct cause of physical loss [12]. Fish have spent many hours caught in the fishing gear. The fish have been dead in the water and have begun to spoil. By the time the fishing gear is hauled into the canoe, the fish have become too spoiled to fetch a good price and market and are not worth landing, and therefore, they are thrown away at sea [6].

Quality loss: Quality loss refers to fish that has undergone changes owing to spoilage or physical damage and has suffered quality deterioration. Such fish is sold for a lower price than that which would have been achieved if the fish were of "best quality". This is the most common PHFL in many areas [6]. It is the difference between the potential value of fish/fish product (best quality) and actual value of the fish after it has undergone changes due to spoilage (lower quality) and sold at a lower price. Examples of quality loss include damaged dried fish sold at a reduced price, fresh fish sold several hours after catch without preservation, rejected fish sold for another purpose (animal feeds). High ambient temperatures Poor transport Long period's storage inadequate market information reduces Quality and leads to low selling prices [10].

Economic loss: The losses of material will inevitably involve a loss in value, as the fisherman, processor, or distributor has less weight of material to sell [3]. Furthermore, the material may command a relatively lower price. Dried fish which has been attacked and partly eaten by insects will be less attractive to consumers than undamaged fish and its price per kilogram will usually be lower. Not only is there less to sell, but what can be sold is worth relatively less. Here, we have a material loss and a bigger financial loss, as someone in the chain has lost the value of the weight of fish eaten by insects and a drop in value of the remainder [15].

Market force lose: Market force losses are due to inadequacy between demand and supply leading to changes in price of fish. If the price of fish falls because of oversupply, the seller may incur a market force loss. Market force loss is difficult to measure accurately, because it usually sets the ground for quality and physical losses [10]. The relationship between oversupply of fish physical lose and quality lose are shown below in diagram (Figure 1).

Losses due to traditional processing: Traditionally processed fish is a nutritionally and economically important commodity in many tropical developing countries. However, the major losses that occur are due to traditional processing methods, particularly the dried products that are processed by sun drying, salting and smoking. Salting is often used to enhance the quality and acceptability of naturally dried fish. In the case of oily fish, prolonged drying leads to bruising and rancidity [16]. The smoking process has a minimal effect on muscle lipids, triglycerides and phospholipids and no significant changes were detected in the overall fatty acid composition. Salt can encourage oxidation of lipids in smoked. The antioxidant effects of some smoke compounds protect fat-soluble vitamins. However, in thick bodied fish, smoking can result in some loss of thiamine (2-25%), niacin and riboflavin. Thus it affects the nutritional value of the fish, mainly by reducing the biological availability of proteins [17]. Overheating in some of the traditional ovens may reduce the availability of lysine during the initial stages of smoking with fire. With dehydration the lipid content was noted to increase by smoking. Therefore, it is essential to use a low temperature in the initial stages (pre-drying) to avoid nutritional losses [16]. The typical smoked flavor results from a number of chemicals found in the smoke, mostly phenols. The use of high temperatures (70-80°C) may lead to the formation of 3, 4, benzopyrene (Indicator of carcinogenicity). Furthermore, higher levels of polynuclear aromatic hydrocarbons (PAH) were detected in hot smoked fish [15].

Losses during distribution and storage: Further losses result from

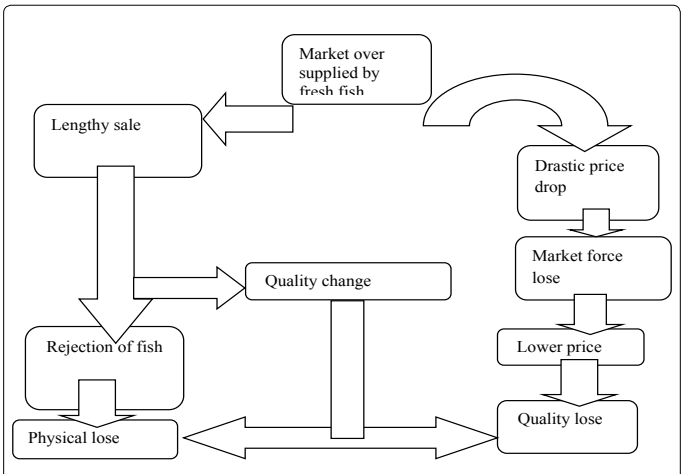

Figure 1: Market force loss resulting in quality and physical loss. Source: [10].

storage and distribution. Careless handling of fish during distribution can result in the fragmentation of the fish, which might make the fish to become unsalable. Sometimes, there may be transport problems; the road could be impassable due to poor engineering/design, which often leads to flooding, collapsing of structures like bridges and all these will simply prevent the fish from getting to the market or when it does, in a bad state that would not attract good price [17]. Common constraints identified in wet fish distribution were lack of technical knowledge, recurrence of natural disaster, low catch of fish, lack of ice box, unavailability of ice, high price of ice, money lending at high rate, fluctuation of fish price, limited opportunity of alternative income generating activities (AIGA) [16]. In addition in shrimp value chain were huge unskilled workers involved in each stage, high price of ice, lack of regular monitoring and advise from GO/NGOs, dominance of Account Holder in shrimp/ prawn business, selling price controlled by processing plant syndicate through Account Holder, declining trend of shrimp/ prawn culture and negative role of media and other environment groups on shrimp farming [15].

Losses due to insect infestation: Infestation of sun-dried fish by the blowfly and beetle larvae caused up to 30% loss of the products [18]. Dried fish contaminated by both insects and harmful insecticides comprises about 80% of the total dried products that is considered unfit for human consumption. Salted ilish, *Tenualosa ilisha* and smoked *Metapenaeus* had suffered from qualitative (nutritional loss) and quantitative losses (eaten out by insects, moisture loss and fragmentation) as the raw materials were not adequately handled and the products were preserved and marketed through open baskets [8]. Insect related losses of cured fish up to 25% are thought to be common and in some cases may reach 90% if no preventive measures are used. Inadequate protection of fish during storage may lead to insect infestation. Blowfly infestation of traditionally processed fish in some developing countries is a serious problem that results in significant physical and economic losses. This is coupled by the unregulated use of inappropriate and hazardous insecticides by fish processors [16]. Some processors have responded to the problem by applying toxic household and agricultural insecticides directly to their fish, hence, endangering their own health and the health of other fish consumers [19].

Throughout processing and early storage fish are exposed to infestation by blowflies. The wet fish are attacked by blowflies which lay their eggs on them and later form intensive infestation by maggots (larval stages) that penetrate the fish bodies. This cause's significant postharvest loss in the traditional fish processing industry related such infestations to the basic, unhygienic conditions under which much of the fish is processed particularly at the small-scale level [19]. House fly larvae (maggots) and beetles are the major pests that degrade smoked and dried fish products. Flies lay their eggs on fish at different levels along the market chain. The smell, especially from off-flavours resulting from microbial processes, attracts flies to the fish products. Other practices that increase exposure to flies are the absence of containers to keep fish covered during transport and storage. In addition, the nature of the fish products, especially the by-products, also induce flies to breed on fish [16]. Flies try to protect their eggs by laying them in depressions such as incisions in the flesh of fish or in orifices such as gills and mouth; hence by-products such as heads and skeletons are ideal breeding ground for flies. So fish does not only result in physical losses of nutrients in exudates but also gives opportunity for flies to infest fish products. Fish dried on the ground also easily gets infected with fly larvae that stay in the soil [7] (Table 1).

Stage	Cause	Lose Type
During fishing	Use of destructive/harmful methods of fishing.	Physical, quality
	Falling from the net or discarded as by catch	Physical
	Setting fishing gear for long periods, causing fish to spoil.	Physical, quality
Holding fish on board	Delay returning to landing after fishing and exposure of fish to high T at sea.	Quality, physical
	Failure to gut (when practically feasible), wash and chill the fish on board	Quality
	Stepping on fish, causing physical damage	Quality
During unloading	Poor hygienic practices causing contamination	Quality
	Fish falling from the pan/crate/basket on to the shore	physical
	Theft at the landing site during offloading of fish	physical
Fresh fish marketing	Inadequate application of ice, and no insulated container used	Quality, physical
	No access to or lack of marketing information, with oversupply of market.	Market, quality
	Deliberate delay in purchasing the fish by traders	Quality
During processing and packaging	Processing of already spoiled/poor-quality fish	Quality, physical
	Processing fish under unhygienic conditions, allowing blowfly infestation	Physical, quality
	Drying fish unsupervised, on ground, rocks or herbs	Physical, quality
	Breakage or damage owing to inadequate packaging method and materials.	Quality, physical
	Oxidation of fatty fish leading to rancidity	Quality
During storage	Growth of mould causes spoilage and makes the fish damp	Quality
	Insects consume fish during storage	Physical, quality
	Discoloration owing to chemical changes	Quality
	Inadequate storage facilities	Quality, physical
	Damage to fish during transportation	physical
During marketing	Delays in selling	Quality
	Inadequate cold-storage facilities and warehouses and lack of ice	Quality, physical
	Supplying the market at the "wrong time"	Market
	Poor purchasing power of buyers/consumers	Market

Source: [10].

Table 1: Summary on causes of post-harvest fish losses.

Spoilage

Spoilage of fish begins as soon as the fish dies. In tropical countries fish spoil quite rapidly within a few hours of landing, if not properly cooled. Fish losses caused by spoilage are estimated at 10 to 12 million tons per year, accounting for around 10 percent of the total production from capture fisheries and aquaculture [2]. Chemical deterioration and microbial spoilage are responsible for loss of 25% of gross primary agricultural and fishery products every year [20]. Fresh fish spoilage can be very rapid after it is caught. The spoilage process (Rigor mortis) will start within 12 h of their catch in the high ambient temperatures of the tropics [21].

Rigor mortis is the process through which fish loses its flexibility due to stiffening of fish mussels after few hour of its death [22]. Most fish species degrade as a result of digestive enzymes and lipases, microbial spoilage from surface bacteria and oxidation. During fish spoilage, there is a breakdown of various components and the formation of new compounds. These new compounds are responsible for the changes in odour, flavour and texture of the fish meat. These changes during fish spoilage are the result of lipid oxidation and protein degradation as well as the loss of other valuable molecules. This represents a major concern of the freshness of saleable products and the breakdown of proteins and lipids [20].

Causative factors of spoilage

Spoilage and freshness are the two qualities that have to be clearly defined. A fresh product is defined as the one whose original characters remain unchanged. Spoilage therefore is the indicative of Post-harvest change. This change may be graded as the change from absolute freshness to limits of acceptability to unacceptability [23]. Spoilage is usually accompanied by change in physical characteristics. Change in colour, odour, texture, colour of eyes, color of gills and softness of the muscle are some of the characteristics observed in spoiled fish. Spoilage is caused by the action of enzymes, bacteria and chemicals present in the fish. In addition, the following factors contribute to spoilage of fish. This includes; High moisture content, high fat content, high protein content, weak muscle tissue, ambient temperature, unhygienic handling and time [23].

Fish spoilage mechanisms

The spoilage of fish is a complicated process brought about by actions of enzymes, bacteria and chemical constituents. The spoilage process starts immediately after the death of fish. The process involves three stages: Enzymatic autolysis, Oxidation, Microbial growth [23].

Autolytic enzymatic spoilage

Shortly after capture, chemical and biological changes take place in dead fish due to enzymatic breakdown of major fish molecules [13,14]. Autolytic enzymes reduced textural quality during early stages of deterioration 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 [24]. The autolytic change that occur in chilled/frozen fish are summarized in (Table 2). 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.

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 product associated alteration that can be contributed by proteolytic enzymes [25]. During improper storage of whole fish, proteolysis is responsible for degradation of proteins and is followed by a process of solubilization [26]. 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. Belly bursting is caused by leakage of proteolytic enzymes from pyloric caeca and intestine to the ventral muscle [27].

Oxidative spoilage

Lipid oxidation is a major cause of deterioration and spoilage for the pelagic fish species such as mackerel and herring with high oil/fat content stored fat in their flesh. Lipid oxidation involves a three stage free radical mechanism: initiation, propagation and termination [27].

a) Initiation involves the formation of lipid free radicals through catalysts such as heat, metal ions and irradiation. These free radicals which react with oxygen to form peroxyl radicals.

b) During propagation, the peroxyl radicals reacting with other lipid molecules to form hydroperoxides and a new free radical [27].

c) Termination occurs when a buildup of these free radicals interact to form nonradical products. Oxidation typically involves the reaction of oxygen with the double bonds of fatty acids. Therefore, fish lipids which consist of polyunsaturated fatty acids are highly susceptible to oxidation. In fish, lipid oxidation can occur enzymatically or non-enzymatically. The enzymatic hydrolysis of fats by lipases is termed lipolysis (fat deterioration). During this process, lipases split the glycerides forming free fatty acids which are responsible for:

i. Common offlavour, frequently referred to as rancidity and

ii. Reducing the oil quality [27].

The lipolytic enzymes could either be endogenous of the food product or derived from psychrotrophic microorganisms [24]. The enzymes involved are the lipases present in the skin, blood and

Enzyme(S)	Substrate	Effect
Glycolytic enzymes	Glycogen	Lactic acid production resulting in pH drop
Autolytic enzymes involved in nucleotide break down	ADP, AMP, IMP	Gradual Production of Hypoxanthine
Cathepsins	Proteins, peptides	Softening of tissue
Chymotrypsin,trypsin, carboxy-peptidases	Proteins, peptides	Belly-bursting
Calpain	Myofibrillar proteins	Softening
Collagenases	Connective tissue	Softening and gaping of tissue
TrimethylamineOxide (TMAO) demethylase	TMAO	Formaldehyde

Source: [13,14].

Table 2: Summary of changes in chilled or frozen fish.

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 [27]. The fatty acids formed during hydrolysis of fish lipids interact with sarcoplasmic and myofibrillar proteins causing denaturation. Most 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 p^H, can accelerate lipid oxidation through deoxygenated HB [28].

Microbial spoilage

Composition of the microflora on newly caught fish depends on the microbial contents of the water in which the fish live. Fish microflora includes bacterial species such as *Pseudomonas*, *Alcaligenes*, *Vibrio*, *Serratia* and *Micrococcus* [29]. 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 [30]. For unpreserved fish, spoilage is a result of Gram-negative, fermentative bacteria (such as *Vibrionaceae*), psychrotolerant Gram-negative bacteria (such as *Pseudomonas* spp. and *Shewanella* spp.) tend to spoil chilled fish [29] (Gram and Huss, 2000). But all bacteria that are found in fish do not tend to spoil fish. Trimethylamine (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*, and *Vibrio* spp. can obtain energy by reducing TMAO to TMA creating the ammonia-like off-flavors [29]. (Table 3) shows spoilage bacteria and spoilage compounds.

Conclusions and Recommendations

Post-harvest fish lose is the discard of fish after harvest and causes the loss of potential income. It is because of poor processing techniques, animal predation and insect infestation, inadequate packaging and storage and discarding of the fish at sea e.t.c. Many factors affect this loss. Among these factors are: long transport, lack of preservation, high ambient temperature, species of fish, lack of market and long storage time. These factors determine the occurrence of many types of Post-harvest fish lose. These lose are classified as; lose in nutritional value, physical lose, quality lose, market force lose, lose due to traditional processing, lose during distribution and storage, and lose due to insect infestation.

Fish that is decomposed to such a degree that it is unfit or unsafe for human consumption is a nutritional loses. Physical fish lose refers to fish that is after capture or landing is not used. It is either complete physical lose or partial lose in materials. Quality lose refers to fish that are undergone changes owing to spoilage or physical damage which gives lower price than best quality fish. Technological and infrastructure problems are often cited as cause of Post-harvest quality lose. Market force lose is due to inadequacy between demand and supply leading to lower in price. Traditional processing methods of fish results in loss of materials; prolonged drying leads bruising and rancidity; smoking results in loss of thiamine, niacin and riboflavin; and overheating reduces the availability of lysine. Further loses result from storage and distribution. This occur due to careless handling, transport problems like long distance poor road flooding etc. long time storage also associated with the loss of materials. Insect infestation by house fly, blowfly and beetle fly larvae cause up to 30% loss of the product.

Specific spoilage bacteria	Spoilage compounds
Shewanella putrifaciens	TMA, H2S, CH3SH, (CH3)2S, HX
Photobacterium phosphoreum	TMA, HX
Pseudomonas spp.	Ketones, aldehydes, esters, non -H2S
Vibrionacaea	TMA, H2S
Aerobic spoilers	NH_3, acetic, butyric and propionic acid

TMA: Trimethylamine; H2S: Hydrogen sulphide; CH3SH: Methylmercarptan; (CH3)2S: Dimethylsulphide; HX = Hypoxanthine NH_3: Ammonia. Source: [23].

Table 3: Spoilage bacteria and spoilage compounds.

Fish losses caused by spoilage are estimated at 10 to 12 million tons per year, accounting for around 10 percent of the total production from capture fisheries and aquaculture. Chemical deterioration and microbial spoilage are responsible for loss of 25% of gross primary agricultural and fishery products every year. Spoilage is affected by many factors; high moisture, high fat and protein content, high ambient temperature, unhygienic handling and time. These factors contribute to the occurrence of spoilage which is caused by three mechanisms: autolytic enzymatic spoilage, oxidative spoilage and microbial spoilage. During these mechanisms many compounds are produced which is responsible for spoilage. Recommendations are suggested to reduce Post-harvest fish lose like appropriate use of fish curing, icing, freezing and canning, avoid microorganisms contaminates, hygiene practices, preventing fragmentation, careful packaging with suitable plastic materials can prevent insect infestation of cured fish, Use of ice for fresh fish handling, distribution and marketing.

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Citation: Getu A, Misganaw K, Bazezew M (2015) Post-harvesting and Major Related Problems of Fish Production. Fish Aquac J 6: 154. doi:10.4172/2150-3508.1000154