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acta SATECH 12 (1): 52 – 65 (2020)

Journal of Life &Physical Sciences

Pathogenic contaminants of fresh and processed fish: a review

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Abstract

Fish is an essential and a major protein source in the diet of people in sub-Sahara Africa which supplies amino acids, poly-unsaturated fatty acids and other nutrients to the consumer. However, fish is a highly perishable food commodity and begins to spoil once dead. Researches have shown that the spoilage that starts immediately on dead fish can be due to autolytic breakdown of the nutrient components, contamination through handling and exposure to pathogenic organisms such as bacteria, fungi, virus and parasites in the air, soil and water. These spoilage organisms or contaminants are present on fresh and processed fish that are not hygienically handled and properly preserved. Contaminated fish and seafood are bad and has potential effect on the health of consumers and also cause economic loss to the farmers and traders. Therefore, the focus of this paper is to review some of these microorganisms and parasitic contaminants on fresh and processed fish with suggested procedures for ensuring safe fish and seafood products, among which is proper cooking before consumption.

Keywords: Contamination, fish, microbes, parasites

Introduction

A fish is a limbless cold-blooded vertebrate animal with gills and fins, living wholly in water. According to Onyia *et al*, (2014), fish is a major source of animal protein and an essential food item in the diet of Nigerians because it is relatively cheaper than meat. It also contains most of the important essential amino acids, particularly, lysine, methionine and tryptophan that are lacking in plant proteins and important source of vitamins and minerals which are important for good living (Abolagba and Melle, 2008). In addition, fishes are known for their high nutritional quality, they are relatively low in saturated fat, cholesterol and high in polyunsaturated fatty acids, protein and minerals such as calcium,

phosphorus, sodium, potassium and magnesium (Carruthers, 1986).

Generally, food and nutrition (especially protein) play an important role in the life of man and a nation. In Nigeria, fish is eaten fresh, preserved or processed (Adebayo–Tayo *et al*., 2008). Fish processing and preservation is carried out to slow down deterioration to maintain the fish flesh (Carruthers, 1986).

Fish is an extremely perishable food which begins to spoil as soon as it is caught perhaps even before it is taken out of the water. This is reason why fish become soft and the smell becomes more noticeable (Carruthers, 1986). Spoilage of food products can be due to chemical, enzymatic or microbial activities (Ghaly *et. al*., 2010). Also, physical damage, dehydration and contamination are the other causes of quality loss in fish. In tropical countries, spoilage of fish is rapid due to the high temperature and lack of required facilities to preserve like refrigeration, irradiation, chilling, canning, etc. Meanwhile, the quality of fresh seafood depends on the condition of the fish after it has been caught, as well as factors such as hygiene and handling during pre and post processing (from catch to onshore processing).

Contaminant is a substance, artificially or naturally produced, that is found in a place where it should not be or in amount greater than it should be. On the other hand, microbial food spoilage is an area of global concern as it has been estimated that as much as 25% of all food produced is lost through microbial activities (Baird-Parker, 2002). Microbial spoilage could predispose consumers to health hazards resulting from food poisoning (Gram *et al*., 2000). Therefore, an improved science-based understanding of the growth and activity of spoilage micro-organisms in seafood and other foods is crucial for the development of preservation techniques and subsequent reduction of losses due to spoilage (Gram and Dalgaard, 2002). It is also important to look into the area of pre-cooling and choice of packaging with respect to temperature control during transport, processing and storage.

Overview of finfish, shellfish and contamination

Fish and shellfish are very important proteinous portion of the human diet worldwide. They come in extremely varied food products with numerous fish species, from marine and freshwater, from cold temperate and warm tropical waters, farmed or wild and processed or preserved in different ways. The above variations affect the microbiology of the fish, shelf life and safety.

Proper handling of fish between capture and delivery to the consumer is a crucial element in assuring final product quality. Also the standards of sanitation, method of handling, the time and temperature of

holding fish are all significant quality factors. With a few exceptions, freshly caught fish are considered free of pathogenic bacteria of public health significance. The presence of bacteria harmful to man generally indicates poor sanitation in handling, processing and the contamination is almost always of human or animal origin.

On the other hand, food is considered to be microbiologically unsafe owing to the presence of microorganisms which may invade human body (e.g *Salmonella, Escherichia coli, Listeria monocytogenes,* etc) and also those that produce toxins ingested with a food such as *Staphylococcus aureus, Clostridium botulinum* and *Bacilus cereus* (Ofred, 2009). A number of microbiological tests of fish and fish products are used by authorities to check that the microbiological status is satisfactory. The purpose of these tests is to detect pathogenic bacteria or indicator organisms of faecal pollution such as *Escherichia coli* or other types of general contamination or poor handling practises (coliform bacteria, faecal streptococci, total viable count). However, microbiological testing can be costly and time consuming.

The microbiology of fish and fish products is complex and covers a wide range of both quality and safety related issues. Microorganisms are found on all of the outer surfaces and within the intestine of live fish. It is noteworthy that microbes on the skin of fish may be in the range of 10^2-10^6 per cm^2. The bacterial load on freshly caught fish tends to reflect the environment from which it was caught, rather than the fish species and those from cold clean waters carry lower load than those from warm waters.

When fish are alive, the muscle tissue is considered to be sterile, but after death, the barriers to microbiological invasion begin to break down and bacteria are able to grow more freely, although will be rarely found within deep muscle tissue. After the fish is caught and dead, the microflora may begin to change due to the varying environmental conditions. Usually, fishes are stored on ice which will clearly reduce the temperature but will also reduce the salt concentration surrounding marine fish. These changes will affect the ability of microorganisms to grow and will start to change the microflora of the fish. At this point, the difference in microbiology between fin fish and shellfish should be noted. Molluscs are filter feeders usually found in coastal waters near human habitation and contaminants in surrounding waters will be concentrated within the animal through feeding. Hence, molluscs may contain human pathogens as are often eaten raw and can constitute risk to human health.

The monitoring of microorganisms has been suggested as a measure of fish quality. In the fish

processing chain, managing the risks should be based of scientific knowledge of the microbiological hazards and the understanding of the primary production, processing, manufacturing technologies and handling during food preparation, transport, storage, retail and catering (Reilly, 2006).

Meanwhile, the term fish processing refers to the processes associated with fish and fish products between the time fish are caught or harvested and the final product delivered to the customer. The central concern of fish processing is to prevent fish from deteriorating and this should remain the underlying factor. Fish processing can be subdivided into fish handling-which is the preliminary processing of raw fish and the manufacture of fish products. Another natural subdivision is the primary processing level involved in the filleting and freezing of fresh fish for onward distribution of fresh fish and the secondary processing that produces chilled, frozen and canned products for the retail and catering outlets. Canned fish are fish which have been processed, sealed in an airtight container such as a sealed tin can and subjected to heat. Fish products are preserved using almost every food processing technique that has ever been developed (drying, smoking, freezing, canning, fermenting, high pressure processing) and of course, there is the increasing trend towards the consumption of high quality raw fish in the form of sushi.

Contamination in seafoods

The contamination of seafood can occur naturally from the environment where fish are harvested, during harvesting, processing or during food preparation. Cross contamination may occur during food processing or preparation where bacteria are transferred from raw fish, contaminated surfaces and from utensils or combination of any of these to hygienically safe seafood.

During processing, contaminated water may also introduce microorganisms including pathogens into the food. In some cases, the levels of pathogen present in the food may not be critical as to pose a health hazard to consumers. Improper methods of handling, such as, poor general or personal hygiene and distribution-time or temperature abuse may provide ideal conditions for the pathogens to proliferate and reach infective levels.

A number of pathogens belonging to different microbial taxa are predominant in marine environments and find their way into seafood. These include *Aeromonas*, *Plesiomonas*, *Clostridium botulinum*, *Listeria monocytogenes* and *Vibrio species* (Wekell *et al*., 1994). Also, microbial activity has been reported to be responsible for spoilage of most fresh and several lightly preserved seafoods (Lund *et al.*, 2000).

Pathogens in temperate water fish

The microflora of wild fish is mainly gram negative rod-shaped bacteria belonging to genera such as: *Psuedomonas, Moraxella, Acinetobacter, Alcaligenes, Shewanella, Flavobacterium, Vibrio* and *Aeromonas*. Some gram positive bacteria (*Bacillus, Micrococcus*, and *Clostridium*) can also be found although lactic acid bacteria are rare. It should be noted that *Clostridium botulinum* is found in the aquatic environment and this should be kept in mind when further processing of fish is carried out. The microflora of farmed fish from temperate waters is similar to that of wild fish, as farm environments are usually closer to human waste sources where higher contamination with microorganisms such as *Listeria* can occur.

In temperate water fish, bacteria may begin to grow as soon as the fish dies, as the microflora is well adapted to the chill temperatures used for storage. It has been reported that the time taken for the number of bacteria to double under these conditions may be 24 hours. The microflora need time to adapt to chill storage conditions in temperate water fish and there is reported to be a lag phase of up to two weeks before growth begins. The fish microflora will change during storage and reports suggest that Pseudomonas and Shewanella spp. make up the majority of the population during aerobic iced storage of either temperate or tropical fish. If storage conditions are altered, for example, by vacuum packing or storage under carbon dioxide, then the flora will change. Pseudomonas sp. being inhibited by the lack of oxygen, whilst Shewanella sp. can grow anaerobically and *Photobacterium phosphoreum* is able to grow in the presence of higher levels of carbon-dioxide.

In chilled fish products, the only barrier to microbial growth is low temperature. Reducing storage temperature reduces the number and types of micro-organisms able to grow and should reduce the growth rate of those that are able to grow. However, even at very low chill temperature (for example, less than 3°C), some microrganisms will still be able to grow and this means that chilled products will always have a short shelf life that must be determined by the manufacturer before placing the product onto the market. Manufacturers of such products must be aware of the risk and employ suitable control measures to prevent growth and toxin formation by these microorganisms.

Gastro-intestinal illnesses caused by members of the genus Vibrio are often reported as viral illnesses. It is interesting that one of the largest outbreaks of food poisoning ever recorded affected nearly 300,000 people in Shanghai and was linked to under cooked mussels contaminated with Hepatitis A. The

microbiology of fish can change fairly rapidly after catching and killing, as the application of chilled temperatures, together in some cases with mild preservatives such as low levels of salt, change the types of flora able to grow on the product.

Pathogens in tropical water fish

Gram positive organisms such as *Bacillus* and *Micrococcus* tend to be found on fish caught in tropical waters. Beside these, the flora will tend to be the same as that found on temperate water fish. There are several human pathogens in tropical waters. For example, *Vibrio parahaemolyticus, Vibrio cholera*, and *Vibrio vulnificus*, the potential presence of these microorganisms should be noted when handling fish from these waters. The microflora of farmed fish from tropical water does not differ significantly from that of wild fish. However, as farms tend to be near areas of human habitation, the water may be contaminated with higher than normal levels of human and animal wastes. This brings concerns of contamination with enteric organisms such as Salmonella and *Escherichia coli.* Such microorganisms do not survive in colder nutrient deprived temperate waters, but do persist and may even grow in more nutrient rich tropical environments.

Bacteria which tend to be confined to the surface of the dead fish and this is where growth will occur and spoilage begins.

Fish are processed in many different ways in different parts of the world. Heavy salting, freezing, drying, hot smoking, canning and pasteurisation are all recognised methods of fish preservation. All affect the microorganisms on the fish in different ways and will result in a different type of microflora and different risks from spoilage organisms and pathogens. However, traditionally processed fish products (TFPs) are reported to carry high potential risk for human health for halophilic pathogenic bacteria, histamine and parasites (Köse, 2010)

The key to any preservation system is for the producer to understand how the process works and what needs to be controlled to get a safe stable product. For example, a correctly processed canned fish will be commercially sterile and can be stored at ambient temperatures for long periods without spoilage or risk to consumer safety. Once the can is opened, the contents become open to contamination and as there is usually no preservative within the product and the contaminating microorganisms will be able to grow. Therefore, canned fish products should be consumed shortly after opening. In dried or frozen fish, the microflora is prevented from growing

by the storage conditions used and the product may have a long shelf life in the preserved state.

Bacterial contaminants of fish and seafood

The most common cases of food poisoning which involve fish and seafood usually occur as a result of eating contaminated prawns or other shellfish. Oysters is a good example of seafood which some people enjoy consuming whilst raw, but these often contain bacteria which are likely to cause food poisoning and other similar conditions. These shellfish filter seaweed and algae from the surrounding water but bacteria which live in this water get to enter the oyster during the filtration process. Consequently, these bacteria then take root inside the fish. Usually, it is easy to think of food poisoning as an issue associated with contaminated chicken, beef or pork but unfortunately, fish is included. For example, *Escherichia coli* is a bacterium that is present in nearly all types of shellfish as a result of contact with water contaminated by raw sewage. Five bacterial species namely: *Staphylococcus aureus, klebsiella* sp. *Salmonella* sp., *Escherichia coli* and *Pseudomonas* sp. are the major bacterial pathogens associated with post-harvest fish spoilage. According to the findings by Gram and Huss (2001), who reported that these microorganisms were the major causes of microbial spoilage of fresh fish after capture and the microbial count on different media suggests contamination. The total bacterial count on fish rarely indicate the quality of the fish but it gives an indication of the risk of spoilage induced since each of these microorganisms had different ways of affecting health conditions of consumers of such contaminated fish (Gram *et al.*, 2000). Conversely, Miller *et al*., (1973) observed that not all bacteria present on fresh fish are spoilers but there are certain active spoilers which are the major pathogens associated with fish spoilage.

The presence of *Klebsiella* and *Salmonella* spp. in the fresh fish samples is an indication that the water used for processing was faecally contaminated. The presence of *Staphylococcus aureus*, a normal flora of skin and mucous membrane of humans can be attributed to human contact during handling and processing (Dalgaard *et al*., 2006). *Staphylococcus aureus* produces a variety of extra cellular enzymes and toxins that have been found to be responsible for food poisoning and can rapidly develop resistance to many antimicrobial agents and pose health risk with therapeutic problems (Thrower, 2000 and Abolagba *et al*, 2011). However, *Clostridium botulinum*, the bacterium causes botulism, is considered as the most harmful of these bacteria (Long, 2009).

Fungal contaminants of fish

Dried fish has a storage life of several years and thus gives fungi a greater opportunity to contaminate it. Fungi are omnipresent in the environment, being found wherever water, suitable organic nutrients and an appropriate temperature occur. They secrete enzymes outside their body structure and absorb the digested foods (Prescott *et al*., 1999). The growth of filamentous fungi in foods and food products results in waste and is costly as well as sometimes hazardous. Mycotoxins are secondary metabolites produced by moulds that are capable of causing disease and death in humans and animals (Bennett and Klich, 2003). Drying to moisture content below 15% prevents the growth of many spoilage microorganisms while mould growth is only suppressed at 10% moisture content (Buere, 2005).

Fafioye *et al.* (2002) studied the fungal infestation of five traditionally smoked dried freshwater fish in Ago-Iwoye, Nigeria and isolated and identified eleven different fungal species of which *Aspergillus flavus* was the most frequently encountered fungi on the fish species. Also, in a study of mycoflora of smoke-dried fishes sold in Uyo, Eastern Nigeria by Adebayo-Tayo *et al*. (2008), twelve different fungi specie were found to be associated with the smoke-dried fish samples. The associated fungi were *Aspergillus flavus, Aspergillus tereus, Aspergillus fumigatus, Absidia sp, Rhizopus sp, Aspergillus niger, Mucor sp, Cladosporium Sp, Penicillin italiculum, P. viridatus, Candida tropicalis and Fusarium moniliformis.* Similarly, Junaid *et al* (2010) in a study aimed at isolating and identifying the fungi associated with stockfish, showed that seven different fungi species were found. However, moulds may be present without producing any toxin (Bennett and Klich, 2003), but the presence of toxigenic fungi increases the risk for mycotoxin production (Jacobsen *et al.*, 2008). The reason being that even though the fungus is no longer alive, while it was growing, it can produce mycotoxin which can poison the food (Wong, 2007). Mycotoxins greatly resist decomposition or being broken down in digestion so they remain in the food chain and even temperature treatments such as cooking and freezing, therefore, do not destroy the mycotoxins.

Viral contaminants of fish

Numerous viruses of human or animal origin are found in the environment and infect people via water and food: bivalve molluscs, vegetables and prepared foods are classified by the World Health Organization as priority hazards. Hepatitis A virus (HAV), genogroup GI, GII, and GIV norovirus (NoV), enterovirus (EV), rotavirus (RoV), hepatitis E

virus (HEV), adenovirus (AdV), and bocavirus (BoV) have been detected in food (especially shellfish), water samples and surface swabs by nested (RT) PCR, real-time PCR and sequence analysis (Purpari, *et al*., 2019).

Viruses are tiny capsules, much smaller than bacteria that contain genetic material. Viruses cause infections that can lead to sicknesses and people can pass viruses to each other. Also, viruses are present in the stool or vomit of infected people. It may contaminate food and drinks, especially if infected persons do not wash their hands thoroughly after using the toilet. Acute viral gastroenteritis is an important and often unappreciated cause of morbidity and mortality worldwide (Lee *et al*., 2013).

Common sources of foodborne viruses include:

- Food prepared by a person infected with a virus
- Shellfish from contaminated water
- Produce irrigated with contaminated water

Common foodborne viruses include:

- Norovirus, which cause inflammation of the stomach and intestines.
- Hepatitis A, which cause inflammation of the liver

Norovirus

Ingestion of raw or insufficiently steamed clams and oysters also poses a high risk for infection from Norovirus, a cause of viral gastroenteritis or the stomach "bug". Food other than shellfish are contaminated by the Norwalk virus by ill food handlers.

It is estimated that Norwalk viruses are responsible for about one-third of the cases of viral gastroenteritis, not involving the 6 to 24 months age group. Approximately 181,000 cases occur annually, with no known associated deaths (Schmutz *et al*., 2020). Norovirus has been associated with outbreaks on cruise ships, in communities, camps, schools, institutions and families. Foods such as raw oysters, cake frosting, salads, as well as drinking water, have been implicated as a common source of viral infection in several outbreaks (Lee *et al*., 2013).

A mild and brief illness usually develops 24 to 48 hours after contaminated food or water is consumed and lasts for 24 to 60 hours (FDA/CFSAN, 2019). Norwalk virus infection symptoms include nausea, vomiting, diarrhea, and abdominal cramps. Symptoms experienced less often include headache, fever, chills and muscle pain. Fluid replacement is the common therapy.

Parasitic contaminants of fish

Fish parasites, mainly nematodes otherwise known as round worms, are a normal part of the ecosystem and are found in the majority of waters, both sea and

fresh. Consumers are unlikely to come across parasites due to the measures put in place in commercial fishing and processing to remove or minimise their presence. Most living things, including fish, have parasites that are usually harmless. Controls in place mean it is unlikely the consumer will find any in the fish they purchase. Any parasite found can be removed and fish preparation continued as normal. In homes, any parasites present in fish will be killed by normal cooking (the centre of the fish fillet needs to reach a temperature of 70^{o} for two minutes) or freezing for a minimum of four days in a domestic freezer (commercial freezers will need less time). If they have been killed by freezing or cooking they are not harmful if eaten. If eaten in their live state, they can cause inflammation of the stomach or the small intestine, an example is Anisakis. Illness in the UK is very rare as most fish is cooked prior to consumption. However, there is a possible risk when fish is consumed raw.

Procedures for ensuring fish and seafood safety

The same rules about food safety and preparation apply to fish as with any other food products. If fish is left out on a work surface for any period of time, then it will decay or "go off" very quickly. Raw and cooked fish must not come into contact with each other due to the risk of cross contamination. This means using separate utensils and chopping boards for raw and cooked fish and wiping them down after use. Fish needs to be cooked thoroughly and at the correct temperature. One exception to this is sushi. The sushi is a popular Japanese dish which consists of raw fish, e.g. salmon, rolled in rice and seaweed. It is available in restaurants and as ready prepared packs in supermarkets. Generally, this is safe to eat as long as the fish used has been cooked or if raw, has been frozen beforehand in order to kill off any parasites.

Despite the wide range of canned fishery products that are available, there are relatively few operations which are unique. The correct pre-process handling techniques and refrigerated storage conditions of all fish for canning have much in common (in fact, there is very little difference in the handling methods of fresh fish and processed fish). Similarly, with the seaming, with retort operating procedures and post-process handling of containers, the methods adopted are independent of the type of the product. The purpose of retorting-that is to achieve a shelf-stable and safe product by the application of lethal heat remains the same for all canned fishery products. It is understandable that there are common guidelines which discourage manual handling of all processed wet containers and recommend that all retort cooling water be chlorinated.

There is a direct and unavoidable relationship linking raw material quality and end product quality and this holds as much for the production of canned fish as it does for fish which is bought fresh and prepared at home. Because handling conditions immediately after catching are responsible for rapid loss of the "fresh" quality, the quality of canned fish suffers whenever the raw material is temperature abused or physically damaged between catching and thermal processing. This means that the quality criteria considered desirable by cannery management when they assess their raw materials ought to be the same as those chosen by consumers when they purchase fresh fish. Fish for canning can be trimmed to remove bruises and other localised flesh defects. As the quality of fish deteriorates from the moment of death, all that can be hoped for by good handling is to retard the rate at which undesirable, quality degrading, changes occur.

All of the pre-treatments ought to be carried out under conditions of good manufacturing practise, which means that the rudimentary steps of process hygiene should be implemented. Satisfactory control of contamination from operating surfaces and raw materials is achievable with regular cleaning (i.e., by washing the product, cleaning the line and ancillary equipment) and limiting the duration of exposure at temperatures suitable for growth of spoilage microorganisms.

In summary, seafood safety tips involve carefully buying from a reputable seller, keep seafood cold and live shellfish alive, refrigerate live shellfish properly, do not cross-contaminate and cook seafood thoroughly (Schmutz *et al*., 2020).

Conclusion

Parasites, contaminated water and careless handling of fish increases microbial contamination. Very low temperature or high temperature techniques i.e canning and other methods of fish preservation, such as, drying which reduces the moisture content will reduce microbial growth or eliminate them. Fresh and processed fish in the markets have been reported to be either contaminated with bacteria or fungal toxins. Contamination occurs by invasion of toxigenic strains ubiquitously found before and during harvesting or processing or by improper storage, thus the prevention of contamination is not an easy task. Therefore, there is the high need for good hygiene or sanitary conditions coupled with proper cooking before consumption.

References

Abolagba, O.J. and Melle O.O. (2008): Chemical composition and keeping qualities of a scaly fish tilapia (*Oreochromis niloticus*) smoked with two energy sources. *African J. Gen. Agric.,* 4(2): 113-117.

Abolagba, O.J., Adekunle, A.T, Dede A.P.O and Omoigui, G.O. (2011): Microbial assessment of smoked fish (Clarias Spp) in Benin metropolis, Edo State, Nigeria. *Nig. J. of Agric. Food and Environ.*, 7(3): 55-58.

Adebayo-Tayo, B.C., Onilude, A.A. and Patrick U.G. (2008): Mycofloral of smoke-dried fishes sold in Uyo, Eastern Nigeria, *World J. Agric. Sci.,* 4(3): 346-350.

Baird-Parker, T.C. (2002): The production of microbiologically safe and stable foods in: the microbiological safety and quality of food. Lund BM, Baird-Parker, T.C. and Gould, G.W. (eds). Gaithersburg: Aspen Publishers, Inc.; 3-18.

Bennett, J.W. and Klich, M. (2003): Mycotoxins. *Microbiol. Rev.* 16(3): 497-516.

Buere, C.R. (2005): Fish processing technologies http:www.geocities.com/fish processing/

Carruthers, R.T. (1986): Understanding fish preservation and processing. Technical paper #44.

Celeste Philbrick and Ira j. Somerset (Technical reviewers). Volunteers in technical Assistance.

Dalgaard, P., Samieia, N. and Emborg, J. (2006): Biogenic amine formation and microbial spoilage in chilled garfish (Belone belone)– effect of modified atmosphere packaging and previous frozen storage. *J. of Appl. Micro.,* 101: 80-95

Fafioye, 0.0., Efuntoye, M.O. and Osho, A. (2002): Studies on the infestation of five traditionally smoked-dried fresh-water fish in Ago-Iwoye, Nigeria. *Mycopathologia*, 154: 177-179.

FDA/CFSAN, U.S. (2019): The Norwalk Virus Family [WWW document. URL http://vm.cfsan.fda.gov/~mow/chap34.html

Ghaly, A.E., Dave, D., Budge, S. and Brooks, M.S. (2010): Fish Spoilage Mechanisms and Preservation Techniques: Review. *Ame. J. of Appl. Sc.* 7(7): 859-877.

Gram, L. and Dalgaard, P. (2002): Fish spoilage bacteria – problems and solutions. *Curr. Opin. in Biotechno.,* 13: 262-266.

Gram, L. and Huss, H.H. (2001): Microbiological spoilage of fish and fish products. *Int. J. of Food*

Micro., 33: 121 – 137.

Gram, L., Oundo, J.O. and Bon, J. (2000): Shelf life of fish depends on storage temperature and initial bacteria load. *Trop. Sc.*, 25: 28-30.

Jacobsen, B.J., Coppock, R.W. and Mostrom, M. (2008): Aflatoxins and Aflatoxicosis

http:wiki.bugwood.org/Aflatoxins_and_Aflatoxicosis .

Köse S. (2010): Evaluation of seafood safety health hazards for traditional fish products: preventive measures and monitoring issues. *Turk. J. of Fish. and Aqua. Sc.* 10: 139-160.

Junaid, S.A., Olarubofin, F. and Olabode, A.O. (2010): Mycotic contamination of stockfish sold in Jos, Nigeria. *J. of Yeast and Fungal Res.* 1(7): 136-141.

Lee, R.M., Lessler, J., Lee, R.A., Rudolph, K.E., Reich, N.G., Perl, T.M. and Cummings, D.A.T (2013): Incubation periods of viral gastroenteritis: a systematic review. *BMC Infectious Diseases*. 13:446.

Long, K. (2009): Reviewer: Smoking fish at home. Cooperative Extension Service, University of Alaska Fairbanks. Original article by Chuck Crapo1989.

Lund, B.M., Baird-Parker, A.C. and Gould, G.W. (2000): The Microbiological Safety and Quality of Foods. Aspen Publishers, Inc. Maryland, USA, 1885 pp.

Miller, A., Scanlan, R.A., Lee, J.S. and Libbey, L.M. (1973): Volatile compounds produced in sterile fish muscle (*Sabastes melanops*) by *Pseudomonas putrefaciens, Pseudomonas fluorescens* and Achromobacter species. *Appl. Micro.*, 26: 18-21.

Ofred, J.M.M. (2009): Microbiology and Spoilage Trail in Nile Perch (*Lates niloticus*), Lake Victoria, Tanzania. A Thesis submitted for a partial fulfilment of the requirement for the degree of Masters of Science in Food Science (Seafood Processing) Faculty of Food Science and Nutrition, School of Health Sciences University of Iceland Reykjavik, Iceland. 94pp.

Onyia, L.U., Adebayo, E.F., Adewuyi, K.O., Ekwunife, E.G. and Ochokwu, I.J. (2014): Comparative economics of fresh and smoked fish marketing in some local government areas in Adamawa State, Nigeria. IIFET, 2014 Australia Conference Proceedings.

Prescott, L.M., Harley, J.P., Klein, D.N. (1999): The fungi (Eumycota), slime moulds and water mould in: Microbiology 4th edition. WCB/McGraw–Hill. USA; 522-539pp.

Purpari, G., Macalusoa, G., Di Bellaa, S., Gucciardia, F., Miraa, F., Di Marcoa, P., Lastraa, A.

Petersenb,E. La Rosac, G. and Guercioa, A. (2019): Molecular characterization of human

enteric viruses in food, water samples, and surface swabs in Sicily. *Int. J. of Inf. Dis.* 80:

66-72.

Reilly, A. (2006): Managing microbiological risk in the fish processing chain in: FAO-

EUROFISH workshop on seafood safety; 13th-15th Dec, Copenhagen.

Schmutz, P., Hoyle E.H. and Hoover, A. (2020): Foodborne illness related to seafood. Factsheet,

HGIC 3660, Food Safety Unit, Clemson University. Published: January 30.

https://hgic.clemson.edu/factsheet/foodborne-illness-related-to-seafood/

Thrower, S.J. (2000): Handling practices on onshore fishing vessels. Effects on the quality of

finfish products. *Food Res.*, 47: 50-55.

Wong, G.J. (2007): Mycotoxins: magical mushrooms and mystical moulds

http://www.botany.hawaii.edu/faculty/wong/BOT135/Lect11