Review Article

Incidence of Foodborne Bacteria that cause Serious Health Hazards in Fish: A Review

Eman A Beyari, Magda M Aly* and Samyah D Jastaniah

Department of Biology, King Abdulaziz University, Jeddah, Saudi Arabia

Corresponding author:
Magda M Aly,
Department of Biology,
King Abdulaziz University,
Jeddah, Saudi Arabia;
E-mail: magdammali@hotmail.com

Abstract

The issue of food security is a complex one in both developed and developing countries, where proteins source from animals such as fish and fish products are generally regarded as high risk and unwholesome commodities with respect to pathogen contents, availability of natural toxins and other possible contaminants, especially when raw or undercooked fish and fish products are consumed, also the use of adulterants reduction in economic growth. Fish deterioration by microbial spoilage during the harvesting, transportation, storage, and poor hygienic maintenance is a global problem regarding food safety and economic impact and it is a major concern for seafood consumers. The possible sources of these contaminants are due to the unhygienic manner of handling fish or from marine pollution that could contaminate fish. This implies that these fish are viable sources of various diseases. Some of these diseases could spread and acquire epidemic status which could pose and even death, especially in children. There is a need to educate for good production practices among food processors and food vendors. It is expedient that good hygienic practices should be observed at the market. Also, prevention of marine water pollution which could pollute fish and marine animals must be applied.

Keywords: Consumption; Fish; Pollution; Microbial; Contaminants

Introduction

In the recent years, world consumption of fish has increased clearly and it is estimated that more than 30% of fish for human consumption comes from aquaculture. Fish and fish products are the most important source of protein, minerals such as calcium, phosphorus, sodium, potassium, magnesium and selenium, vitamins especially vitamin D and long chain poly unsaturated fatty acids. [1-3] Fishes are known for their exceptional health benefits, particularly against cardiovascular diseases due to their long-chain polyunsaturated fatty acids content. The American Heart Association recommended eating fish at least twice per week to reach the daily intake of omega-3 fatty acids. [4] Fish intake has also been linked to a lower risk of stroke, depression, and mental decline with age. For pregnant women, mothers who are breastfeeding, and women of childbearing age, fish intake is important because it supplies DHA (Docosa Hexaenoic Acid), a specific omega-3 fatty acid that is beneficial for the brain development of infants. [3] About 88% of the global fish production is for direct human consumption, 44% of them are in live, fresh, or chilled statuses, forms that are most preferred and highly priced in many markets. The rest of production is processed, with 35% frozen, 11% in prepared and preserved forms, and 10% dried, salted, smoked, or otherwise cured.

Fish Composition

Efforts over the past century to establish the proximate composition of fish have been only partially successful, as many gaps in our knowledge still exist. Large variations occur in proximate composition, both from species to species and from fish to fish of the same species. [4,5] In addition, large variations occur in composition of different parts of the fish. The protein content of fish, although averaging about 19%, may vary from 6% to 28%. Oil content may vary from 0.2% to 64%, ash from 0.4% to 1.5%, and moisture from 28% to 90%. Most species fall into the category of low oil and high protein content. The cause of variation in the proximate composition of fish often ascribed to such factors as geographical area or season relates primarily to the feed ingested, to the metabolic rate, and to the mobility of the fish. The content of minerals and fat soluble vitamins in sea foods is slightly higher than those in terrestrial animals. The flavour of sea foods depends on the species, the fat content, and the presence as well as the type of non-protein nitrogenous compounds. [6]

Fish Contamination

Fish is one of the most perishable foods. The muscle tissue of fish undergoes faster spoilage than mammalian muscles. The high water and free amino acid content, and the lower content of connective tissue as compared to other flesh foods lead to the more rapid spoilage of fish. [7] Fish could be contaminated with microorganisms [8] and /or chemicals compounds which include heavy metals, organochlorine contaminants for example Polychlorinated Biphenyls (PCBs), Dichloro-Diphenyl-Trichloroethane (DDT), dieldrin, chlordane, and dioxins [5] Artificial origin radionuclides or radioactive substances and oily petroleum spillage accidents. [9-11]

How to cite this article: Beyari EA, et al. Incidence of Foodborne Bacteria that cause Serious Health Hazards in Fish: A Review. Ann Med Health Sci Res. 2021;11:60-66.

Bacterial Fish Contamination

Microorganisms in the marine environment have both beneficial and harmful functions. They execute biogeochemical cycles that are a critical process in marine environments. [12] Microbial contaminants mainly consist of pathogenic groups of bacteria, viruses, and parasites. The presence of different bacteria species including human pathogenic bacteria in fish can be linked to direct contact with a contaminated water environment and ingestion of bacteria from sediments or contaminated feed. Thus, bacteria detected in fish reflect the condition and safety of aquatic environments. [13] Bacteria represent most pathogens in fish that can cause food borne diseases in humans. Bacterial abundance in fish species generally varies based on environmental and biological factors. Some fishes are inherently more prone to contamination depending on the species, feeding pattern, age, size, harvest season, habitat characteristics, and geographical location. [14]

Various factors including the season, part of the digestive tract of fish, and feeding type can affect the number of microorganisms detected. The minimum and maximum findings for specific bacteria were related to the changes of water temperature and were observed during winter and summer seasons. [15]

Fish is one of the most perishable foods by bacteria due to presence of unsaturated fish oils which seem to be more susceptible to oxidative deterioration than other animal fats. Also, fish flesh is more perishable due to rapid autolysis by fish enzymes and pH of fish has an important influence on it's perish ability in addition to availability of nutrients for the growth of microorganisms, ambient temperature and high moisture content. [16]

The microbiology of fish skin and gastrointestinal tract has been subjected to many researches. Fish can spoil from both outer surface and inner surfaces as fish stomach contain digested and partially digested food which can pass into the intestine. Fish microorganisms present on the external surfaces including slime, gills, and the gut of the fish. These microorganisms are kept away from invading the sterile flesh by the normal defense mechanism of fish when they are alive. After fish is being caught and dying the immune system collapses and the enzymes secreted by microorganisms make them to invade or diffuse and proliferate freely into the flesh, stomach and skin surface, where they react with complex mixture of natural substances present resulting in a well-defined sequence of changes in odoriferous and flavours compounds. [2]

Microflora of Fish and Fish Environments

Fish from natural environments are known to harbor various bacterial species. Bacterial colonization can be observed on fish skin and gills due to constant exposure to contaminated water, while the digestive tract may be affected through contaminated feed or water. Contamination of fish muscles is also possible when immunological resistance is compromised. [17] It is generally accepted that bacteria found on fish skin are the same as those found in the contaminated water, including such genera and species as *Aeromonas spp.* (*Aeromonas hydrophila, A. bestiarum, A. caviae, A. jandaei, A. schubertii, A. veronii*), *Flexibacter spp., Proteus spp., Providencia spp., Psychrobacter spp., Moraxella spp., Pseudomonas fluorescens, Acinetobacter johnsonii, Alcaligen espiechaudii, Enterobacter aerogenes, Escherichia coli*, *Micrococcus luteus*, and *Vibrio fluvialis.* [13] Usually, the muscles and internal organs of healthy fish are sterile. However, some studies reported the presence of bacteria (*Pseudomonas spp. and Vibrio spp., including V. fischeri, V. harveyi, V. pelagius, V. splendidus*) in the liver and kidneys of turbot (*Scophthalmus maximus*). [18,19] The highest bacterial loads were observed in the gills and digestive tract of fish and can reach 106 CFU/g and 108 CFU/g, respectively. [13]

Foodborne Diseases

Bacterial gastrointestinal infections continue to cause illness and death and contribute to economic loss in most parts of the world, including high-income generating countries that have developed surveillance and control programs. [20] In the developing world, foodborne infection leads to the death of many children, as well as resulting in diarrheal disease which can have long-term effects on children's growth as well as on their physical and noes is development and it also heavily affects the healthcare systems. Consumption of fish may cause diseases due to infection or intoxication. Many microbial species are pathogenic to humans. They are known to produce toxins that cause lethal diseases. [21-23]

According to Clarence et al. food borne diseases are diseases resulting from ingestion of bacteria or toxins produced by micro-organisms present in food. The intensity of the signs and symptoms may vary with the amount of contaminated food ingested and susceptibility of the individuals to the toxin. [24] Pathogens such as *Campylobacter, Salmonella, Yersinia, E. coli*, and *Listeria monocytogenes* are responsible for major foodborne outbreaks worldwide. [25]

Epidemic and pandemic cholera is associated with toxigenic strains of *Vibrio cholerae* O1 and O139. The toxin is produced in the intestine during multiplication and causes marked loss of fluid into the intestine, resulting in extremely watery diarrhea which leads to extreme dehydration and, if not treated, to death. Contamination of seafood is usually either by fecal contamination of the marine environment or by contact with fecal contaminated fresh water during preparation of the food. *Vibrio cholerae* serotypes other than O1 and O139 may be pathogenic. Some may be able to produce cholera toxin but lack the ability to produce epidemics and pandemics. Although *Vibrio cholerae* O1 and O139 infections are potentially severe, and the public health consequences of epidemics may be grave, infections due to other *Vibrio cholerae* serotypes are much more commonly associated with seafood and, in general, cause a much higher level of morbidity and mortality from this source. *Vibrio cholerae* O1 outbreaks have also been reported in association with raw shellfish consumption or raw seafood or cooked crab. [26] Whereas contamination with other *vibrios* arises from bacteria naturally present in the marine environment that with *Vibrio cholerae*, serovar O1, may be associated with fecal contamination. *Vibrio cholerae* non-O1 serotypes have also been reported from the marine environment in the UK, France, and Italy. [27,28]

Invasive *Listeriosis* is a severe disease mainly associated with a specific risk group of people. It causes meningitis, encephalitis, bacteremia, and febrile gastroenteritis. Most disease occurs in immunosuppressed individuals. The organism occurs widely in the environment. Although there is a large concentration on testing of seafood products for *Listeria monocytogenes*, and some other *Listeria spp*., the level of risk associated with this organism from seafood consumption is probably small. The United States of America risk assessment on *Listeria monocytogenes* only identified four seafood associated outbreaks worldwide in the period 1970-2000, one associated with raw seafood, one with smoked seafood and two with smoked mussels. [29]

Bacterial Contamination Sources

Fish may be a vehicle for pathogenic bacteria naturally occurring in aquatic environments, referred to as indigenous or derived from polluted waters and/or from post capture contamination. [30] The indigenous bacteria that occur naturally in the marine environment which, when consumed in seafood in large enough numbers, will cause illness in humans. This primarily relates to the *vibrios*. Some species of the genus *Aeromonas* are considered to some to possibly cause gastro-enteritis in humans, and these may also be present naturally in the marine or more especially, the estuarine environment. Spores of type *F Clostridium botulinum* are found widely in marine sediments and the intestinal tract of fish and shellfish and, if seafood is stored under conditions (principally in the absence of oxygen) that allows the spores to germinate and the bacteria to multiply, toxin may be formed in the seafood and then cause botulism in humans when the food is consumed. [28]

Globally, the sea has been used as a dumping ground for sewage and other waste products. Sewage water contains microorganisms and several human-made-chemical compounds. The possible sources of fish bacteria are likely to come from the skin of the animal from which the fish was obtained. This may arise from contamination with human feces from sewage discharges, boats, and ships or, in some countries, direct defecation into the marine environment or rivers and streams flowing into it. Some bacteria may also arise from the contamination of the marine environment by animal feces. Again, this may arise from discharges from animal keep lots or slurry pits, or direct defecation into the marine environment or rivers or streams flowing into it. [28] The presence of indicator-microorganism in water is evident that the water is polluted with fecal material from humans or other warm-blooded animals. This kind of pollution means that any normal flora and pathogenic microorganisms that occur in the intestinal tract of these animals may also be found. The indicator-microorganisms are coliform bacteria that are divided into fecal coliform and non fecal coliform. The fecal type is *Escherichia coli*, which is normal flora found in the human intestinal tract and other warm-blooded animals. The nonfecal type includes *Enterobacter aerogenes* which is commonly distributed in nature and occasionally found in the intestinal tract of warm-blooded organisms. [31] The walls of fish intestines do break down sufficiently for bacteria to move into the flesh through the muscle fiber. It has been suggested that intestinal microflora is the causative agent for fish spoilage. Fecal coliform in fish demonstrates the level of pollution in their environment because coliform are not named flora of bacteria in fish. [32] Some bacteria, such as *Salmonella typhi* and *Vibrio cholerae*, are principally associated with human fecal contamination while non-typhi *Salmonella* and *Campylobacter*, may arise from either source. Seafood harvested from such environments may constitute a risk if the bacteria are initially present in sufficient numbers that exceed the infectious dose or the seafood is stored under conditions that allow a lower initial concentration to multiply to the point where the bacteria exceed the infectious dose and, if any control measures are applied, they are not sufficient to reduce to, or maintain the bacterial concentration, at a low enough level.

The outlined and discussed the hazards and challenges associated with handling fish during farming, capture and the environmental contaminants in seafood that may pose a risk to human health. [33] Potential sources of microbial contaminations are the equipment and items used for each operation that is performed until the final product is eaten. Boats, fish boxes, fishermen and workers clothing and hands, knives, cutting boards, display tables, ice, and the physical facilities themselves are all implicated. Retail cut could also result in greater microbial load because of the large amount of exposed surface area, more readily available water, nutrient, and greater oxygen penetration available. Hence retail cuts displayed are conducive for microbial growth and proliferation which leads to spoilage of the fish. [34] Lengthy food supply procedures, mass catering complex associated with increased international movement, changes in eating habits and poor hygiene practices are major contributing factors for fish contamination. [35] The issue of temperature control following harvesting is particularly important. In the USA, it has been shown that the cooling time and subsequent time and temperature of transport and storage are significant risk factors. [36]

Antibiotic Resistance

By considering the food safety as well as the public health significance, an important attention has to be arisen on the drugs resistance trait of pathogens proliferated in fish and fish product, which may create serious problem in course of diseases medication. [37] In developing countries, the problem of resistance may arise from the extensive misuse of antibiotics and for the use of antibiotics during fish harvesting and processing which may decrease the effectiveness of drugs eliminating bacterial infections. [38,39] Therefore, determination of the complete profile of pathogenic load and their antibiotic resistance in sea fish is necessary to estimate the associated public health risk as well as the preventive strategy to eliminate pathogens should also be evaluated. [40]

Antibiotic resistant bacteria from commercially marketed fish in Adana, Turkey were investigated. A total of 126 antibiotic resistant bacteria were isolated from gill and intestinal contents of five types of retail fish samples. Viable counts of antibiotic resistant bacteria isolated from gill and intestinal content samples showed high frequencies of resistance to tetracycline, ampicillin, streptomycin, while the proportion of chloramphenicol resistance was rather low. A high incidence of resistance to tetracycline, ampicillin and cephalothin as well as almost an absence of resistance to amikacin and gentamicin was

found among selected isolates which represented the resistant bacterial population. These strains were predominantly resistant to 3 and 4 antibacterial. Isolates from gill exhibited resistance to as many as 7 antibiotics, whereas those from intestinal content were resistant to 5 or fewer antibiotics. These results indicate that retail fish studied were either contaminated with handling or commercial fishes residing in waters near the disposals of urban sewage, might play a role as carriers of antibiotic resistant bacteria, prompting a health risk to public health for fish consumers. [41]

Fish Preservation Methods

Considering the popularity, nutritional and economic importance, it is necessary to maintain the microbiological quality of the sea fish as well as to establish the preventive mechanism, which can eliminate the microbial growth and hence may ensure the public health safety. Traditionally, fish preservation rely on the ice storage, rapid chilling, freezing, salting, drying, [42,43] smoking, heating, organic acids, use of antimicrobial antioxidants, edible coating and modified atmosphere packaging which can inhibit or eliminate microbial growth but the chance of cross contamination is left. [44-47] However, the application of ionizing radiation was afterwards found to effectively eliminate spoiling microorganisms in fresh and frozen sea foods. [48] Bacterial contamination is of paramount importance to the safety and shelf life of processed food. To optimize the microbiological quality of food, it is important to implement acceptable good manufacturing practices through adequate temperature control and training of personnel. Recommended training includes personal hygiene and the use of clean and hygienically controlled equipment, utensils and materials including water used during processing. [49]

Bacterial Species Isolated from Fishes

Fish contamination has been extensively investigated along the Saudi coasts, but studies pertaining to bacterial pathogens are dismayed. Alikunhi et al. conducted qualitative assessment and molecular identification of culture-dependent bacteria in 13 fish species from three coastal sites and a local fish market in Jeddah, Saudi Arabia. Bacterial counts of gills, skin, gut, and muscle were examined on different media. Bacterial counts significantly differed between species, sources and feeding habits of examined fishes. Fishes from Area I had higher bacterial loads, coinciding with those in seawater and sediment from the same site, indicating direct association between habitat conditions and the levels of bacterial contamination. By feeding habit, detritivorous fish harbored higher counts than herbivorous and carnivorous species. Bacterial counts of skin were higher in fish from market than field sites, and positively correlated with other body parts indicating the relation of surface bacterial load on the overall quality of fish. *Rahnella aquatilis* and *Photobacterium damselae* were among the dominant species from fish muscle based on 16S rRNA sequencing. These species are known human pathogens capable of causing foodborne illness with severe antibiotic resistance. Also, *Vibrio harveyi*, *Aeromonas salmonicida*, *Psychrobacter faecalis*, *Aeromonas sp*. were isolated. Opportunistic pathogens, e.g. *Hafnia sp*. and Pseudomonas *stutzeri* were also identified. [4]

The bacterial flora occurring in brackish pond water, sediment, gills, and intestine of healthy tilapia cultured in Saudi Arabia, Al Qassim region, were estimated both quantitatively and qualitatively, and the isolates were identified to genus or species level. In total, 19 bacterial species were identified. The bacteria were predominantly Gram-negative rods (87%). Pond water and sediment bacteria influenced the bacterial composition of gills and intestine of tilapia. In contrast to gill bacteria, more diversification was observed in intestinal bacteria. The predominant bacterial species were *Vibrio parahaemolyticus*, *Vibrio carchariae*, *Vibrio alginolyticus*, *Chryseomonas sp*., *Vibrio vulnificus*, and *Streptococcus sp*. in all the populations except for the sediment population where Streptococcus sp. was replaced by *Shewanella putrefaciens*. *Vibrio spp*. (58% of the total isolates) dominated the total bacterial population. [50]

Rani et al. conducted a study to evaluate the hygienic quality and freshness of fish Indo-pacific King Mackerel "*Scomberomorus guttatus*" in Maduri district, Tamil Nadu, India through the investigation of the occurrence of bacteria which is an indicator for fish quality. Skin surface of the fish was examined. *Escherichia coli, Proteus vulgaris, Bacillus subtilis, Klebsiella pneumonia, Pseudomonas aeruginosa* and *Staphylococcus aureus* were identified by Biochemical tests: Indole, Methyl red, Voges-Proskauer, and Citrate tests (IMViC Tests). Among the six bacterial species *E. coli* and *K. pneumonia* were found in all the collected samples whereas other bacterial species were not found. Apart from the enteric- organisms, S. *aureus* encountered in this study are known enterotoxin producing agent and a microorganism which is poisonous. The result of this study revealed that raw fish sold in Madurai fish market has high contamination so the presence of the bacterial species has strongly suggested the urgent need to improve the quality control systems in Madurai fish market. [2]

In Iraq, there were isolating and identifying *Vibrios* bacteria that taken from multi-kinds of fresh and frozen fish from different fish markets. Kinds of fish isolated such as Suoboor tenualosailisha, silver carp (*Hypophthalmichthys molitrix*), beni (*Barbus sharpey*) and shanak (*Spondyliosoma cantharus*). About 210 fish were collected from Basrah market (big market in Basrah, Al-Ashar, Al- Tanoma and Khmsameel), while 150 fish were collected from silver carp, beni and shanak from Nasiriyah market (big market and Harj market), this collecting process of samples taken a period from 2-June to 30- November 2013. 30 positive samples from *Vibrios* were identified, such as, *Vibrio cholera* and *Vibrio fluvialis*. The study confirmed that fresh fish including these bacteria more than frozen fish Results. [51]

Antwi-Agyei and Maalekuu evaluated the level of microbial contamination of meat and fish products that are sold in two major markets in the Kumasi metropolis of the Ashanti Region in Ghana. Ten samples of different meat portions and fish samples each were selected from the two markets. By using different biochemical test, Pathogens like *Escherichia coli, Salmonella, Staphylococcus aureus, Pseudomonas spp.* and *Bacillus spp*. were isolated from both the meat and fish products. The study suggested that most of the meat and fish products that are sold are commonly contaminated with pathogenic microorganisms.

[34] A study was undertaken to find out the total microbiological load and the presence of pathogenic microorganisms on food contact surfaces in seafood retail markets in the Sultanate of Oman. Microbiological and sanitary conditions on food contact surfaces in four retail fish markets were studied. Escherichia coli were obtained from samples collected from most food contact surfaces. Similarly, significant numbers of pathogenic bacteria such as *Salmonella sp., Staphylococcus aureus* and *Clostridium perfringens* were observed in microbiological samples from all fish markets. This study reveals the presence of contaminating and pathogenic bacteria in seafood retail outlets and the urgent need to improve the hygiene status of retail fish markets in the Sultanate of Oman. [52]

A study was conducted to determine the prevalence of *Listeria spp*. in fish obtained from Urmia fish markets, Iran. A number of 194 fish comprising *Oncorhynchus mykiss, Sander lucioperca, Cyprinus carpio, Hypophthalmiachthys molitrix, Abramis brama, Astacus leptodactylus* and *Silurus glanis* were obtained from different fish markets of Urmia from June 2009 to February 2010. *Listeria* isolation was performed in two stages including enrichment in cold and selective plating. After colony formation, to confirming the genus of the Listeria, a fragment of Prs gene using *Listeria* genus specific primers was amplified from isolated bacteria using Polymerase Chain Reaction (PCR). Results revealed that Listeria was isolated from 24 fish (12.37%). The highest prevalence of Listeria was observed in both A. *brama* and A. *leptodactylus* with 25%, while the lowest prevalence of Listeria was seen in S. *lucioperca* (9.7%). From the total of 24 Listeria isolates, five isolates (21%) were confirmed to be L. *monocytogenes*; seven isolates were L. *ivonoi* (29%) while L. *Seeligeri* was not isolated from any examined fish. The study showed that L. *monocytogenes* and other *Listeria* species are common contaminant of fish obtained from Urmia fish markets, and this may pose serious public health implications. [53]

A total of 78 raw retail fish samples from 30 freshwater and 48 marine fish were examined for the presence of Listeria, *Aeromonas*, and *Vibrio* species in Turkey. The overall incidence of *Listeria spp*. was 30% in freshwater samples and 10.4% in marine fish samples. *Listeria monocytogenes* (44.5%) was the most isolated species in freshwater fish, and *Listeria murrayi* (83.5%) was the most isolated species in marine fish samples. Motile *Aeromonas* were more common in marine fish samples (93.7%) than in freshwater fish samples (10%). *Vibrio alginolyticus*, *Vibrio fluvialis*, and *Vibrio damsela* were isolated only in marine fish samples, representing 40.9%, 38.6%, and 36.3% of *Vibrio* isolates, respectively. In freshwater and marine fish, the highest incidences of *Listeria* and *Aeromonas* were found in skin samples; the highest incidence of *Vibrio* in marine fish was found in gill samples. The location of *Listeria spp*. and *Listeria monocytogenes* in a fish was significantly different among freshwater fish. A high incidence of these bacterial pathogens was found in the brown trout (*Salmotrutta*) and horse mackerel (*Trachurus trachurus*). Handling of contaminated fish, cross-contamination, or eating raw fish might pose a health hazard, especially in immunosuppressed individuals, elderly people, and children. This study highlights the importance of bacterial pathogens in fish intended for human consumption, but more study is needed. [54]

The incidence of *Listeria spp*. in the salt-water edible fishes and in the environment of fish markets in Thessaloniki, Northern Greece was studied. One hundred and twenty raw/fresh fish bought at the fish markets of Thessaloniki (Northern Greece), were sampled, and tested for presence of *Listeria* species using a two-step enrichment procedure, followed by plating on two selective agars and subsequent biochemical identification of the isolates. Five fish samples were positive for *Listeria spp*. and in only one sample *Listeria monocytogenes* was detected. Also, 100 samples of knives, hands, boxes etc. were sampled and 18 samples were positive for *Listeria spp.* and five for *Listeria monocytogenes*. *Listeria innocua* was more common being detected in four fish samples and 13 environmental samples. *Listeria seeligeri* was detected only in one environmental sample. Study findings indicate that only a few fish were contaminated with *Listeria spp*., while the level of contamination of the environment of fish markets was higher. [55-58]

Conclusion

A survey of 50 different samples of fresh marine fish in Spain (conger, swordfish, sole, grouper and whiting) was conducted over a period of 5 months. Trays of fillets and steaks were obtained at retail level and tested for foodborne bacterial pathogens. *Vibrio cholerae* and Salmonella were not detected. Two samples (4%) yielded *Vibrio strains* carrying a DNA fragment specific for *Vibrioparahaemolyticus*. *Aeromonas* were found in 31 (62%) samples. All fish portions were positive for the *Aeromonas* hlyA gene and 38 for both aerA and hlyA genes, which may contribute to diarrhea-related virulence. The incidence of *Listeria monocytogenes* was 10%. Levels of Staphylococcus aureus lower were found in 15 (30%) samples. Numbers of presumptive *Clostridium* perfringens were detected in 42 (84%) samples. Edwardsiella tarda was detected in two samples of grouper fillets. Displayed portions of raw fish carried bacteria that can cause foodborne disease. The risk posed by fresh fish when properly cooked is low, but high when destined to be consumed raw, undercooked or very lightly processed.

The microbiological quality of six varieties of retail market traditionally cured fish in Morogoro, Tanzania was investigated over a five month period. The fish were contaminated with fecal coliforms, fecal streptococci, *Staphylococcus aureus*. Of fecal coliform, 45% of the isolates were Escherichia coli. About 25% of the S*taphylococcus aureus* isolates were coagulase positive. The results of this preliminary study emphasize the importance of proper processing and handling of fish in the tropics in order to safeguard public health.

References

1. Shamery GMRE. Studies on contamination and quality of fresh fish meats during storage. Egypt Acad J Biol Sci. 2010;2:65-74.
2. Rani MK, Chelladurai G, Jayanthi, G. Isolation and identification of bacteria from marine market fish *Scomberomorus guttatus* (Bloch and Schneider, 1801) from Madurai district, Tamil Nadu, India. J Parasit Dis. 2016;40:1062-1065.
3. Torpy JM, Lynm C, Glass R. Eating fish: Health benefits and risks. JAMA. 2006;296:1926.

4. Alikunhi NM, Batang ZB, AlJahdali H, Aziz MA, AlSuwailem AM. Culture-dependent bacteria in commercial fishes: Qualitative assessment and molecular identification using 16S rRNA gene sequencing. Saudi J Biol Sci. 2017;24:1105-1116.
5. Acharjee M, Ahmed E, Munshi SK, Noor R. Validation of γ-irradiation in controlling microorganisms in fish. Nutr Food Sci. 2014;44:258-266.
6. Venugopal V, Shahidi F. Structure and composition of fish muscle. Food Rev Int. 1996;12:175-197.
7. Masniyom P. Deterioration and shelf-life extension of fish and fishery products by modified atmosphere packaging. Songklanakarin J Sci Technol. 2011;33:181-192.
8. Greenfield BK, Jay AD, Russell F, Cassandra R, David C, Gary I. Seasonal, interannual, and long-term variation in sport fish contamination, San Francisco Bay. Sci Total Environ. 2005;336:25-43.
9. Law RJ Hellou J. Contamination of fish and shellfish following oil spill incidents. Environ Geol. 1999;6:90-98.
10. Yoshimura M, YokodukaT. Radioactive contamination of fishes in lake and streams impacted by the Fukushima nuclear power plant accident. Sci Total Environ. 2014;482:184-192.
11. Hubanova N, Anna H, Roman N, Valentyna S, Oksana K, Nataliia G, et al. Accumulation of radionuclides in Dnipro reservoir fish. Ukr J Ecol. 2019;9:227-231.
12. Hewson I, Meyers MEJ, Fuhrman JA. Diversity and biogeography of bacterial assemblages in surface sediments across the San Pedro Basin, Southern California Borderlands. Environ Microbiol. 2007;9:923-933.
13. Novoslavskij A, Terentjeva M, Eizenberga E, Valciņa O, Bartkevičs V, Berziņs A. Major food borne pathogens in fish and fish products: A review. Ann Microbiol. 2016;66:1-15.
14. Novotny L, Dvorska L, Lorencova A, Beran V, Pavlik I. Fish: A potential source of bacterial pathogens for human beings: A review. Vet Med. 2004;49:343-358.
15. Diler O, Diler A. Quantitative and qualitative changes of the gastrointestinal microflora of pike-perch (*Stizostedion Lucioperca* L. 1758) in Egirdir Lake. Turkish J Vet Anim Sci. 1998;22:325-328.
16. Erkmen O, Bozoglu TF. Food microbiology principles into practice. 2016.
17. Guzman MC, Bistoni M, Tamagnini LM, Gonzalez RD. Recovery of Escherichia coli in freshwater fish, *Jenynsia multidentata* and *Bryconamericus iheringi*. Water Res. 2004;38: 2368-2374.
18. Apun K, Yusof AM, Jugang K. Distribution of bacteria in tropical freshwater fish and ponds. Int J Environ Health Res. 1999;9:285-292.
19. Toranzo AE, Novoa B, Romalde JL, Nunez S, Devesa S, Marino E, et al. Microflora associated with healthy and diseased turbot (*Scophthalmus maximus*) from three farms in northwest Spain. Aquaculture. 1993;114:189-202.
20. Ternhag A, Torner A, Svensson A, Ekdahl K, Giesecke J. Short-and long-term effects of bacterial gastrointestinal infections. Emerg Infect Dis. 2008;14:143-148.
21. Bienfang PK, DeFelice SV, Laws EA, Brand LE, Bidigare RR, Christensen S, et al. Prominent human health impacts from several marine microbes: History, ecology, and public health implications. Int J Microbiol. 2011:1-15.
22. Garthwaite I. Keeping shellfish safe to eat: A brief review of shellfish toxins, and methods for their detection. Trends Food Sci Technol. 2000;11:235-244.
23. Watkins SM, Reich A, Fleming LE, Hammond R. Neurotoxic shellfish poisoning. Mar Drugs. 2008;6:431-455.
24. Clarence SY, Obinna CN, Shalom NC. Assessment of bacteriological quality of ready to eat food (Meat pie) in Benin City metropolis, Nigeria. Afr J Microbiol Res. 2009;3:390-395.
25. European centre for disease prevention and control. The European Union summary report on trends and sources of zoonoses, zoonotic agents and food-borne outbreaks in 2013. EFSA J. 2015;13:3991.
26. Weber JT, Mintz ED, Canizares R, Semiglia A, Gomez I, Sempertegui R, et al. Epidemic cholera in Ecuador: Multidrug-resistance and transmission by water and seafood. Epidemiol Infect. 1994;112:1-11.
27. Hervio DH, Colwell RR, Derrien A, Pillot AR, Fournier JM, Pommepuy M. Occurrence of pathogenic vibrios in coastal areas of France. J Appl Microbiol. 2002;92:1123-1135.
28. Lee RJ, Rangdale RE, Croci L, Dominique HH, Solen L. Bacterial pathogens in seafood. In improving seafood products for the consumer 2008.
29. Crum NF. Update on Listeria monocytogenes infection. Curr Gastroenterol Rep. 2002;4:287-296.
30. Herrera FC, Santos JA, Otero A, Lopez MLG. Occurrence of foodborne pathogenic bacteria in retail prepackaged portions of marine fish in Spain. J Appl Microbiol. 2006;100:527-536.
31. Bahry SNA, Mahmoud IY, Belushi KA, Elshafie AE, Harthy AA, Bakheit CK. Coastal sewage discharge and its impact on fish with reference to antibiotic resistant enteric bacteria and enteric pathogens as bio-indicators of pollution. Chemosphere. 2009;77:1534-1539.
32. Emikpe BO, Adebisi T, Adedeji OB. Bacteria load on the skin and stomach of *Clarias gariepinus* and *Oreochromis niloticus* from Ibadan, Southwest Nigeria: Public health implications. J Microbiol Biotechnol. 2011;1:52-59.
33. Yagoub SO. Isolation of *Entero bacteriaceae* and *Pseudomonas* spp. From raw fish sold in fish market in Khartoum state. J Bacteriol Res. 2009;1:85-88.
34. Agyei PA, Maalekuu B. Determination of microbial contamination in meat and fish products sold in the Kumasi metropolis (A case study of Kumasi central market and the Bantama market). MRJASSS. 2014;2:38-46.
35. Hedberg CW, Levine WC, White KE, Carlson RH, Winsor DK, Cameron DN, et al. An international foodborne outbreak of shigellosis associated with a commercial airline. J Med Appli. 1992;268:3208-3212.
36. https://www.fda.gov/food/cfsan-risk-safety-assessments/quantitative-risk-assessment-public-health-impact-pathogenic-vibrio-parahaemolyticus-raw-oysters.
37. Tenover FC. Mechanisms of antimicrobial resistance in bacteria. Am J Med. 2006;119:3-10.
38. Dutta S, Hassan MR, Rahman F, Jilani MSA, Noor R. Study

of antimicrobial susceptibility of clinically significant microorganisms isolated from selected areas of Dhaka, Bangladesh. Bangladesh J Medical Sci. 2013;12:34-42.

39. Noor R, Acharjee M, Ahmed T, Das KK, Paul L, Munshi S, et al. Microbiological study of major sea fish available in local markets of Dhaka city, Bangladesh. J Microbiol, Biotechnol Food Sci. 2020;2:2420-2430.
40. Mathew AG, Cissell R, Liamthong S. Antibiotic resistance in bacteria associated with food animals: A United States perspective of livestock production. Foodborne Pathog Dis. 2007;4:115-133.
41. Matyar F, Dincer S, Kaya A, Colak O. Prevalence and resistance to antibiotics in gram negative bacteria isolated from retail fish in Turkey. Ann Microbiol. 2004;54:151-160.
42. Gelman A, Glatman L, Drabkin V, Harpaz S. Effects of storage temperature and preservative treatment on shelf life of the pond-raised freshwater fish, silver perch (*Bidyanus bidyanus*). J Food Prot. 2001;64:1584-1591.
43. Haghparast S, Kashiri H, Shabanpour B, Pahlavani MH. Antioxidant properties of sodium acetate, sodium citrate and sodium lactate on lipid oxidation in rainbow trout (*Onchorhynchus mykiss*) sticks during refrigerated storage (4°C). Iran J Fish Sci. 2010;9:73-86.
44. Himelbloom BH, Crapo C, Brown EK, Babbit J, Reppond K. Pink salmon (*Oncorhynchus gorbuscha*) quality during ice and chilled seawater storage. J Food Qual. 1994;17:197-210.
45. Horner WFA. Preservation of fish by curing (drying, salting, and smoking). Fish Processing Technology. 1997;32-73.
46. Masniyom P, Benjakul S, Visessanguan W. Shelf-life extension of refrigerated sea bass slices under modified atmosphere packaging. J Sci Food Agric. 2002;82:873-880.
47. Motalebi AA, Hasanzati RA, Khanipour AA Soltani M. Impacts of whey protein edible coating on chemical and microbial factors of gutted kilka during frozen storage. Iran J Fish Sci. 2010;9:255-264.
48. Savvaidis IN, Skandamis P, Riganakos KA, Panagiotakis N, Kontominas MG. Control of natural microbial flora and Listeria monocytogenes in vacuum-packaged trout at 4 and 10 C using irradiation. J Food Prot. 2002;65:515-522.
49. Shikongo-Nambabi M, Shoolongela A, Schneider MB. Control of bacterial contamination during marine fish processing. J Bio Life Sci. 2011;3:112-123.
50. Harbi AHA, Uddin N. Bacterial diversity of tilapia (*Oreochromis niloticus*) cultured in brackish water in Saudi Arabia. Aquaculture. 2005;250:566-672.
51. Hussainy KSA, Algboory AO, Altememy MS. Used PCR technology (real time) for discovering about the responsible genetic to gen hly and vfhly for isolation and diagnosis *Vibrio cholerae* and *Vibrio fluvialis* bacteria from fish. J Agric Res. 2015;4:182-201.
52. Sudheesh PS, Al-Ghabshi A, Al-Aboudi N, Al-Gharabi S, Al-Khadhuri H. Evaluation of food contact surface contamination and the presence of pathogenic bacteria in seafood retail outlets in the sultanate of Oman. Adv J Food Sci Technol. 2013;5:77-83.
53. Modaresi R, Mardani K, Tukmechi A, Ownagh A. Prevalence of Listeria spp: In fish obtained from Urmia fish markets. Afr J Microbiol Res. 2011;5:5398-5401.
54. Yucel N, Balci S. Prevalence of Listeria, Aeromonas, and Vibrio species in fish used for human consumption in Turkey. J Food Prot. 2010;73:380-384.
55. Soultos N, Abrahim A, Papageorgiou K, Steris V. Incidence of Listeria spp. in fish and environment of fish markets in Northern Greece. Food Control. 2007;18:554-557.
56. Mugula JK, Lyimo MH. Microbiological quality of traditional market cured fish in Tanzania. J Food Saf. 1992;13:33-41.
57. http://www.fao.org/state-of-fisheries-aquaculture.
58. https://www.fda.gov/food/cfsan-risk-safety-assessments/quantitative-assessment-relative-risk-public-health-foodborne-listeria-monocytogenes-among-selected.