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Review Article

Food, Fish and Diseases Transmitted to the Consumer

Alejandro De Jesús Cortés-Sánchez

Consejo Nacional de Ciencia y Tecnología (CONACYT). Unidad Nayarit del Centro de Investigaciones Biológicas del Noroeste (UNCIBNOR+). Calle Dos, No. 23. Cd. del Conocimiento. Cd. Industrial. C.P. 63173. Av. Emilio M. González, Tepic, Nayarit, México.

Abstract: Foodborne Diseases (FD) are currently considered a clear challenge for public health, mainly in developing countries, due to its incidence, mortality, sequelae, as well as for the detriment in the economic, productive and health sectors. Fish is considered one of the most widely produced, marketed and consumed foods around the world, and it is also a highly nutritious food, being a main source of protein, lipids, vitamins and minerals. However, it is also a food highly susceptible to deterioration and contamination by various agents of chemical or biological origin throughout the food chain (from the farm to the consumer's table), putting health at risk. The objective of this review document is to give the reader an overview of foodborne diseases, causative agents, control and prevention measures, including different regulations around the world focused on production, processing, consumption of fish and protection of public health.

Keywords: Food safety, Food pathogens, Fish-borne, Aquaculture.

1. Introduction

Food safety is the quality of not causing harm or disease to the person who consumes it; therefore, along with the nutritional, sensory and commercial qualities, they are constituents of the total quality of food (De la Fuente and Corona, 2010).

Foodborne Diseases (FD) are those conditions caused by the ingestion of water and food contaminated by chemical or biological agents, in amounts that affect the consumer's health (Espinosa *et al*., 2014; Soto *et al*., 2016; WHO, 2020).

FD is considered a public health challenge around the world, due to its incidence, mortality and negative repercussions on the economy (Alerte *et al*., 2012; Rodríguez-Torrens *et al*., 2015), being the elderly, children and immunocompromised the most susceptible population groups, and mainly related to high levels of poverty and social unhealthiness (Olea *et al*., 2012; Alerte *et al*., 2012; Rodríguez-Torrens *et al*., 2015).

The World Health Organization (WHO) estimates that 600 million people become ill each year from eating contaminated food and that 420,000 dies from these causes (WHO, 2019). The incidence of FD around the world is due to different causes such as globalization in the food supply, microbial adaptation, changes in food production systems, climate change and changes in the demographic behavior, and lifestyle of the human population (Olea *et al*., 2012; Rodríguez-Torrens *et al*., 2015).

On the other hand, another challenge related to FD is added, and that is the growing demand for food and the market price in relation to the sustained increase in the world population. Due to the fact that the population growth rate is not parallel with an increase in food production, it is estimated that, by 2050, it will be necessary to feed almost 10 billion people globally, this may lead to an imbalance between demand and supply, placing the provision of food at risk (Miralles, 2013).

For the world's population, the route that provides food is the three fundamental factors: enough quantities, safety and nutritional quality are vital for the preservation of life and the promotion of health. Currently, the food supply travels and crosses barriers around the world, so cooperation between different social entities such as public administration, academy, industry, and consumers contributes to guaranteeing food safety (Miralles, 2013; WHO, 2019).

The objective of this review document is to give the reader an overview of foodborne diseases, causative agents, control and prevention measures, including different regulations around the world focused on production, processing, consumption of fish and protection of public health.

*Corresponding Author: Alejandro De Jesús Cortés-Sánchez 0000-0002-1254-8941
E-mail: alecortes_1@hotmail.com
Phone No.:

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2. Causal agents of FD

The causative agents of Foodborne Diseases (FD) can be physical (glass, wood, metal, among others), chemical (heavy metals, pesticides, additives, antimicrobials, natural toxins, among others), and biological (viruses, parasites, bacteria, fungi, and prions). Approximately, 250 etiological agents are described, where those of biological origin are generally related to cases and outbreaks, having bacteria as the producing agent, thus giving rise to food poisoning (De la Fuente and Corona, 2010; Olea *et al*., 2012; Espinosa *et al*., 2014; Alerte *et al*., 2012; Rodríguez-Torrens *et al*., 2015).

Foodborne Diseases, whose causative agents are biological in nature, are classified as I. Food infections – They occur when a pathogen is present in the food that establishes and multiplies itself in the consumer. In turn, these infections have two varieties: a) Invasive infections, where the microorganism colonizes consumer tissues and organs, and b) Toxi-infections, caused by non-invasive microorganisms, capable of colonizing and multiplying in the intestinal tract of the host, producing and releasing toxins (Rodríguez-Torrens *et al*., 2015); and II) Food poisoning - Derived from toxins produced by microorganisms that have presented a certain growth in food (Caballero, 2008; Rodríguez-Torrens *et al*., 2015).

Symptoms related to foodborne diseases are gastrointestinal such as diarrhea, nausea, vomiting, and abdominal pain; however, neurological, gynecological, immunological symptoms and, in severe cases, disability and mortality can occur as well (Soto *et al*., 2016; WHO, 2020).

Food contamination can happen at any stage of the food chain, from primary production, processing, preservation, distribution, to consumption (from the farm to the consumer's table) (Espinosa *et al*., 2014; WHO, 2020). In places where there are inadequate or no hygiene practices, pathogens can be incorporated into the food surface from various sources such as soil, water, humans and insects, causing health risks to consumers. Therefore, it is a good means of transportation for various biological health hazards, due to its composition and favorable conditions for microbial growth in short periods of time, especially in hot temperatures (Barbosa-Cánovas & Bermúdez-Aguirre, 2010).

3. Fish

The total production of fish is through fishing and aquaculture activities; as of 2016, it reported approximately 171 million tons worldwide, of which the 88% was destined for direct human consumption, registering a consumption of 20.3 kg per capita (FAO, 2018). Currently, fish is indicated and demanded as a substitute for beef, pork and poultry, due to the consumer's demand for low-fat meat, aimed at fulfilling a healthy lifestyle (Fernandes *et al*., 2018). The outlook for the United Nations Food and Agriculture Organization (FAO) for fish production is 195 million tons by 2025, and consumption of 21.8 kg per capita per year worldwide (Fernandes *et al*., 2018). Therefore, fish is considered a food source of nutrition, food security and economic development for humans (FAO, 2018).

Fish is defined as that vertebrate animal extracted from aquatic sources, whether oceanic or continental, destined for food. It is considered as a very nutritious food for its content of proteins of high biological value, lipids (omega-3), vitamins, minerals and low proportion of carbohydrates; however, it is also a food that is also highly susceptible to deterioration and contamination by various chemical or biological hazards throughout the food chain (Arias & Buelga, 2005; Soares and Gonçalves, 2012).

The deterioration of fish is due to a set of factors such as its chemical composition, enzyme activity (autolysis), microbial activity, and chemical activity (lipid oxidation) (Huss, 1997; Soares and Gonçalves, 2012). Visible elements of the deterioration include strange odors and flavors, exudate formation, gas production, color loss, and texture changes (Huss, 1997). Fish handling conditions, ranging from capture or production to processing, preservation and marketing, are essential to guarantee its freshness, quality and safety (Soares and Gonçalves, 2012).

4. Diseases transmitted by fish as food

Supplying a growing demand for fish by the population involves safety as a relevant factor since these animals obtained from fishing or aquaculture can be vehicles for the spread of different causal agents that can put human health at risk (Table 1) (Quijada *et al*., 2005; Fernandes *et al*., 2018).

The European Food Safety Authority (EFSA), in 2015, reported that bacterial pathogens such as *Campylobacter* spp., *Salmonella* spp., *Yersinia* spp., *E. coli* and *Listeria monocytogenes* are the main culprits related to outbreaks of foodborne illness globally (Novoslavskij *et al*., 2015). In addition, EFSA reported that the foods that caused the most diseases in 2016 in Europe were chicken (9%), cheese (8%) and fish (7%) (Fernandes *et al*., 2018). Meanwhile, in a particular case in countries such as Spain from 2008 to 2011, it registered a total of 2342 outbreaks of diseases, with the causal agents being identified mainly as bacteria, followed by viruses, toxic substances and parasites, while the related foods were mainly eggs and dairy products, meat, fish and seafood (Espinosa *et al*., 2014). In South America, in countries such as Chile, during the period from 2005 to 2010, 2806 outbreaks of foodborne illness were registered, where 15.4% of the outbreaks corresponded to mollusks, and 15.1% to fish, being the causal agents mainly bacteria related (Alerte *et al*., 2012). Diseases transmitted to humans through the consumption of fish caused by biological agents such as bacteria, viruses and parasites are called ichthyozoonoses (Quijada *et al*., 2005; Maniscalchi *et al*., 2015). Fish that come from natural environments can present several microbial species, colonization by bacteria that occurs in the skin and gills derived from constant exposure to contaminated water, while the digestive tract can be affected by contaminated feed or water; muscle contamination is possible when immune resistance is compromised or due to inadequate hygiene processing and preservation (Novoslavskij *et al*., 2015).

Fish-borne pathogens of bacterial origin are classified into two groups: those whose natural habitat is water and where temperature has a selective effect, where some of these microorganisms are *Vibrio parahaemolyticus, Vibrio cholerae, Clostridium botulinum, Plesiomonas shigelloides, Edwardsiella tarda, Bacillus* sp., *Pseudomonas* sp., *Aeromonas* sp., among others; and those in which bacteria are present in the water due to fecal contamination and/or associated with processing and handling (*Salmonella* spp., *Shigella* spp., *E. coli, Listeria monocytogenes, Staphylococcus aureus*) (Huss, 1997; Arias & Buelga, 2005; Romero *et al*., 2016).

5. Control and prevention of diseases transmitted by fish for consumption

Surveillance and monitoring of foodborne diseases are essential for the implementation of control and prevention actions, which will be different according to the food or water involved in the cases or outbreaks (Espinosa *et al*., 2014).

Table 1: Hazards producers of diseases by consume of food, water and fish (Huss, 1997; Arias & Buelga, 2005; Bofill-Mas *et al*., 2005; Quijada *et al*., 2005; Caballero, 2008; Field *et al*., 2008; Pis *et al*., 2008; Lima dos Santos, 2010; Kaskhedikar and Chhabra, 2010; Dos Santos and Howgate, 2011; Domenech-Sánchez *et al*., 2011; Martinez *et al*., 2012; Soares and Gonçalves, 2012; Chelós *et al*., 2013; Barba *et al*., 2013; Ortega, 2014; Raimann *et al*., 2014; Conde *et al*., 2015; Romero *et al*., 2016; Novoslavskij *et al*., 2015; Soto *et al*., 2016; FDA, 2018).

Epidemiological Agents		Causal Agents	Food
Parasites	Nematodes	*Gnathostoma spinegerum, Pseudoterranova decipiens, Anisakis* spp., *Phocanema* spp., *Angiostrongylus* sp., *Contracaecum* sp.	Consumption of freshwater and sea fish in the raw state, subject to poor hygiene, cooking and conservation practices.
	Cestodes	*Diphyllobothrium latum, Diphyllobothrium pacificum, Diphyllobothrium dentriticum*	
	Trematodes	*Phagicola, Clonorchis sinensis, Paragonimus* sp., *Heterophyes* sp.	
	Protozoan	*Cryptosporidium parvum*	
Microorganisms	Bacteria	*Vibrio parahaemolyticus, Vibrio cholerae, Vibrio vulnificus, Plesiomonas shigelloides, Edwardsiella tarda, Salmonella* spp., *Listeria monocytogenes, Staphylococcus aureus, Escherichia coli, Clostridium botulinum, Clostridium perfringens, Bacillus cereus, Shigella* sp., *Campylobacter jejuni, Yersinia enterocolitica, Aeromonas hydrophila*	Consumption of raw, salted, smoked, canned, poorly cooked fish, subjected to poor hygiene, cooking and conservation practices.
	Fungi	*Fusarium* spp., *Aspergillus* spp. and *Penicillium* spp., (Producing genera of mycotoxins in fish feed in aquaculture)	Fish consumption in any presentation derived from bioaccumulation of mycotoxins
	Virus	Hepatitis A, Hepatitis E, Adenovirus, Norovirus, Astrovirus, Enterovirus	Consumption of raw fish, subjected to poor hygiene, cooking and conservation practices.
Nitrogenous Compounds	Biogenic amines	Histamine, putrescine and cadaverine by decarboxylation of histidine, ornithine, and lysine respectively, mediated by bacteria (*Morganella morganii, Klebsiella pneumoniae, Klebsiella oxytoca, Hafnia alvei*, *Vibrio* sp., *Clostridium perfringens, Aeromonas hydrophila, Enterobacter aerogenes, Proteus mirabilis, Clostridium perfringens, Bacillus* spp., *Pseudomonas putrefaciens*, among others).	Consumption of fish subjected to poor hygiene and conservation practices.
Chemical substances	Biotoxins	Tetrodotoxin, Ciguatera (ciguatoxin, scaritoxin, maitotoxin, palytoxin and okadaic acid) gempilotoxin. The latter developed by consumption of certain dinoflagellates and algae by fish.	Fish consumption derived from bioaccumulation
	Heavy Metals	Lead, cadmium, copper, mercury	
	Organic Compounds	Polychlorinated biphenyls, dioxins and pesticides	
		Antibiotics and hormones	Antibiotics due to improper use have an impact on the increase in AMR* of food pathogens.

*AMR: Antimicrobial resistance

The control and prevention of diseases because of fish consumption is in avoiding the habit of preparing and consuming it raw or in minimally processed products (ceviche or sushi), in preventing the consumption of fish subjected to poor hygiene practices (cross-contamination), in cooking and conservation, as well as that fish which do not receive cooking treatments prior to consumption such as those smoked or salted (Quijada *et al*., 2005; Alerte *et al*., 2012; de Araújo Sousa Santiago *et al*., 2013).

It has been established that the implementation of various plans and systems such as good hygiene practices, animal health, and Hazard Analysis and Critical Control Points (HACCP) throughout the food chain, going from primary activities such as fishing and aquaculture, through processing, conservation, distribution, and marketing up to prior consumption, reduces the risk of being contaminated by various hazards and guarantees fresh, nutritious and safe food (Huss, 1998; Quijada *et al*., 2005; Balbuena, 2011; dos Santos and Howgate, 2011; Ledezma *et al*., 2013).

Regulations regarding hygiene conditions, analysis and microbiological criteria that fish must meet for its commercialization have been established around the world to guarantee the supply of safe food to the population. In the European Union, there are different regulations such as Regulation (EC) No. 178/2002 (EUR-Lex-32002R0178), which establishes the principles and general requirements of food legislation; it created the European Food Safety Authority (EFSA) and also establishes procedures relating to food security. Subsequently, it is the Regulation (EC) No. 2073/2005 (EUR-Lex-32005R2073) regarding the microbiological and histamine criteria applicable to food products, including fish, and microbiological laboratory analysis methods. The Regulation (EC) No. 853/2004 (EUR-Lex-32004R0853) establishes specific hygiene rules for food of animal origin, while Regulation (EC) No. 854/2004 (EUR-Lex-32004R0854) makes reference to specific rules for the organization of official controls on products of animal origin intended for human consumption, just to name a few in regards of foods like fish.

Meanwhile, non-governmental organizations like FAO, and through the Codex Alimentarius, have issued different codes and guidelines to guarantee the safety of these foods, such as the general principles of food hygiene (CAC / RCP 1-1969), while specifically developed the code of practice for fish and products (CAC / RCP 52-2003) that incorporates the Hazard Analysis and Critical Control Points (HACCP) for fishery and aquaculture products.

In primary production aspects (aquaculture) for hygiene and safety, the five keys to greater safety of aquaculture products have been developed by the World Health Organization (WHO) in order to protect public health, covering quality aspects water and hygienic handling (WHO, 2016). Moreover, the Codex Alimentarius developed the code of practice on good animal feeding (CAC / RCP 54-2004) and the code of practice to prevent and reduce contamination of cereals by mycotoxins have been developed, which are used as food or feed in aquaculture activities (CAC / RCP 51-2003). Along with those codes, the code of practice for the prevention and reduction of dioxins, dioxin-like PCBs and non-dioxin-like PCBs in food and feed (CXC 62-2006) and the code of practice to minimize and contain antimicrobial resistance (CAC / RCP 61-2005) that incorporates the use and regulation of antimicrobials in veterinary medicine. Likewise, for the collection of samples prior to the analysis of fish microbiological parameters in order to determine their sanitary quality and safety, there are general guidelines on sampling (CAC / GL 50-2004). Even the World Health Organization (WHO) itself has made guidelines and recommendations focused on the general population as food handlers and final consumers and have contributed to food safety through the manual on the five keys to food safety (WHO, 2007).

On the other hand, different quality and safety certification schemes for products of aquatic origin have been established, in where aquaculture production activities are included so that the products are marketed in different regions of the world. Some examples of those certifications are ISO 22000, Global GAP, Safe Quality Food (SQF), Accredited Fish Farm Scheme, Bio Suisse, Global Aquaculture Alliance (GAA), Aquaculture Certification Council (ACC), KRAV (CECOPESCA, 2012).

In Latin American countries such as Mexico, the sanitary regulation of fish and food products is through Official Mexican Standard NOM-242-SSA1-2009 for fresh, refrigerated, frozen and processed fishery products that include sanitary specifications and analysis methods. The NOM-128-SSA1-1994 establishes the application of a Hazard Analysis and Critical Control Points system (HACCP) in the industrial plant that processes fishery products, while the NOM-251-SSA1-2009 regulates practices of hygiene for the process of food, drinks or food supplements. Meanwhile, and regards to aquaculture production activities, Manuals of Good Practices have been established by the National Service of Health, Safety and Agro-Food Quality (acronym SENASICA) in order to guarantee the health and safety of the products marketed and protect public health (SENASICA, 2019).

6. Microbiological analysis of food and fish

The control and prevention of microorganisms related to FD involve the microbiological analysis of food by health authorities and the food industry, and it is based on the analytical methods for its detection (Flores and Herrera, 2005). For fish, the analysis is generally using traditional microbiological techniques, many of them through methods standardized and approved by government organizations such as the U.S. Food and Drugs Administration (FDA) and its Bacteriological

Analytical Manual (BAM). Microbiology Laboratory Guidebook (MLG) published by the United States Department of Agriculture and Food Safety and Inspection Service (USDA-FSIS). Standard methods published by Public Health England (PHE) and the UK's national reference laboratory (NRL) for food microbiology. Ministry of health and family welfare of India and food safety and standards authority of India (FSSAI) and its manual of methods of microbiological analysis of foods. the National Administration of Medicines, Food and Medical Technology of Argentina (ANMAT) and its official analytical methodology for pathogenic microorganisms in food and finally Secretary of Health of Mexico through the Official Mexican Standard NOM-210-SSA1-2014, where the microbiological methods for determination of indicator microorganisms and pathogens in food are specified. On the other hand, there are those methods developed or approved by non-governmental entities such as the International Organization for Standardization (ISO) and the Association of Official Analytical Chemists (AOAC) for different pathogenic microorganisms and microbiological indicators. Most of the methods require study phases that involve the sample collection, preparation, dilution, inoculation and incubation in different culture media (differential, selective and enrichment), identification, and confirmation through biochemical and serological tests.

Also, and as another option, is it the alternative microbiological analysis methods which are fast, sensitive, specific, and capable to process large amounts of samples through molecular biology as is the Polymerase Chain Reaction (PCR) for the detection, quantification and typing of different pathogens in foods such as *S. aureus, Listeria monocytogenes, Clostridium perfringens, E. coli, Salmonella* spp.*, Bacillus cereus, Vibrio cholerae*, among others, including those microorganisms that cannot be analyzed by conventional techniques as they cannot be grown on artificial substrates (Flores and Herrera, 2005; Herrera & Flores, 2006; Austin, 2006; Carrillo-Inungaray *et al*., 2011; Palomino and Gonzalez, 2014; Law *et al*., 2015; Huertas *et al.*, 2019).

7. Conclusions

Foodborne Diseases are a major, manifested challenge to public health today around the world due to its incidence, mortality, sequelae and detriment in the economic, productive and health sectors, with the population of developing countries being the main affected.

Fish is considered one of the most widely produced and marketed foods around the world, and it is also highly nutritious due to its protein, vitamin, mineral and lipid content. However, its chemical composition makes it, in parallel, one of the most susceptible to deterioration and contamination due to various hazards, mainly of biological origin, throughout the food chain (from farm to table).

Currently, and due to various factors such as globalization in the production and marketing of food, changes in lifestyle, eating habits, and even climate change, the population has been at risk of acquiring various health hazards through water and food derived from the urgent need to feed; therefore, physical and chemical analysis methods, criteria, good production hygiene practices, systems, schemes and food certification standards have been developed and implemented around the world in order to guarantee food safety to a constantly growing population.

The actions to control and prevention of the various causal agents of food-borne diseases is a comprehensive and joint effort between the different social entities ranging from governments, academy, the food industry and consumers in such a way as to guarantee the safety of food in the entire food chain.

Conflicts of Interest

The author declares no conflict of interest.

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