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About food safety, viruses and fish

Alejandro De Jesús Cortés-Sánchez

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

E-mail: alecortes_1@hotmail.com; ORCID ID: 0000-0002-1254-8941

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ABSTRACT: Fish is considered an essential food in the human diet due to its nutritional qualities and is widely consumed around the world. The source of fish destined for human use and consumption is through capture fisheries and aquaculture activities. Although fish is a food of nutritional quality, it is also a food susceptible to deterioration and microbiological contamination, putting the health of consumers at risk. The different viruses are considered hazards of biological origin in food that cause various outbreaks of diseases through the consumption of fish, and products derived from their contamination in distinct phases of the food chain, through contaminated water and food handlers. Therefore, this document aims to provide an overview of foodborne diseases and causative agents, especially viruses, through a bibliographic review. In the production and commercialization of foods such as fish and products, it is considered that actions to control and prevent viral diseases, sanitary regulation and microbiological analysis tests should be involved, all in favor of the promotion and safeguarding of public health through the availability and consumption of safe food and water.

Keywords: Aquaculture; Fishing; Food pathogens; Gastroenteritis; Water quality.

1. INTRODUCTION

Foodborne Diseases (FD) are those that are caused by ingesting food or beverages contaminated with chemicals or pathogenic microorganisms that affect consumer health either individually or collectively. The common symptoms are abdominal pain, fever, diarrhea, and vomiting, although others may also present such as headaches, double vision, up to severe complications, such as sepsis, meningitis, abortions, Reiter's syndrome, Guillan Barré syndrome or death [1-3].

FD is considered a major public health challenge due to their morbidity and mortality rates, negative effects on the economy, trade in food products, and inflated costs of health services [4-6]. According to estimates by the World Health Organization (WHO), six hundred million people in the world fall ill due to the consumption of contaminated food, where more than 400,000 die from this cause [7]. Food safety is considered a basic characteristic in food, along with nutritional, organoleptic, and commercial characteristics, constituting the total quality of food. Therefore, safe food is one that does not cause harm or disease to the person who consumes it [8].

Food can be subjected to contamination throughout the food chain (from primary production to final consumption) from sources such as air, water, soil, animals, raw materials, utensils, human beings, transportation, storage, processing, and distribution, leading to foodborne diseases [4]. 250 FD have been identified [6]. Among the different causal agents are those of a physical, chemical and biological nature [3,5,8,9], being bacteria, prions, viruses and parasites mostly related to outbreaks, and where most of the causal agents of the disease are considered zoonotic [3,9,10].

FD whose causative agents are of biological origin (pathogenic microorganisms) are classified into two main groups: a) foodborne infections that, in turn, are divided into invasive infections produced by parasites, viruses and bacteria (*Salmonella* spp., *Aeromonas* spp., *Shigella* sp., *Vibrio parahaemolyticus, Yersinia* sp.) that invade host organs and tissues; toxic-infections produced by bacteria such as *Vibrio cholerae, Bacillus cereus* (diarrheal-type), *C. perfringens, E. coli* O157:H7, among others, that are not invasive but colonize the human intestinal tract produce and excrete toxins, and b) food poisoning produced by the consumption of toxins formed during microbial growth in food. Among the producing bacteria are *C. botulinum, B. cereus* (emetic-type) and *Staphylococcus aureus* [11-13].

In recent years, the incidence of food-borne diseases has increased due to factors such as new trends in food processing technologies, market globalization, increased personal travel and food transportation, changes in eating habits, climate change, the appearance of new forms of transmission, increased life expectancy, vulnerable population groups, and increased microbial resistance [1,4,6,14,15].

Foods related to diseases are those that are consumed raw or were subjected to inadequate cooking conditions, such as meats, eggs, dairy products, fish, shellfish, and vegetables [9]. FD can occur anywhere, in those places where poor hygienic or sanitary habits are practiced and where crowded conditions are visible [4]. The main population groups at risk of these diseases are babies, children, pregnant women, the elderly, and the immunocompromised [5,9].

Multiple challenges are present to achieve food safety, controlling and preventing diseases; they involve the management and actions by the different members of the food chain such as producers (agricultural, livestock, aquaculture, and fisheries), government, academy, food industry to handlers and finally consumers.

Therefore, this document aims to provide a general description of food-borne diseases and specific causative agents, specifically viruses (Figure 1), through a bibliographic review. Foods, such as fish, are specifically considered to encompass actions for the control and prevention of viral diseases, sanitary regulation, and detection in food, all in favor of the promotion and safeguarding of public health through the availability and consumption of safe foods of water origin.

2. VIRUSES AND FOOD

Viruses are considered non-cellular microscopic biological entities since they lack distinctive characteristics of cellular ones, including not being open dynamic systems that take nutrients and discharge substances to the outside [16,17]. Viruses are considered infectious agents of various forms of life (bacteria, archaea, and eukaryotes) being obligate intracellular parasites [18]; they depend on the biosynthetic capacity of the cell they infect to replicate, synthesize, or obtain structural components, causing damage to the cell [16,17].

Viruses are made up of genetic material (RNA or DNA but not both) that are arranged in the form of spiral filaments in one (single-stranded) or two (double-stranded) chains, enclosed by a layer of antigenic protein known as a capsid; in some viruses, there is a lipid membrane that surrounds the lipid capsid of the host cell's cytoplasmic membrane [16-19].

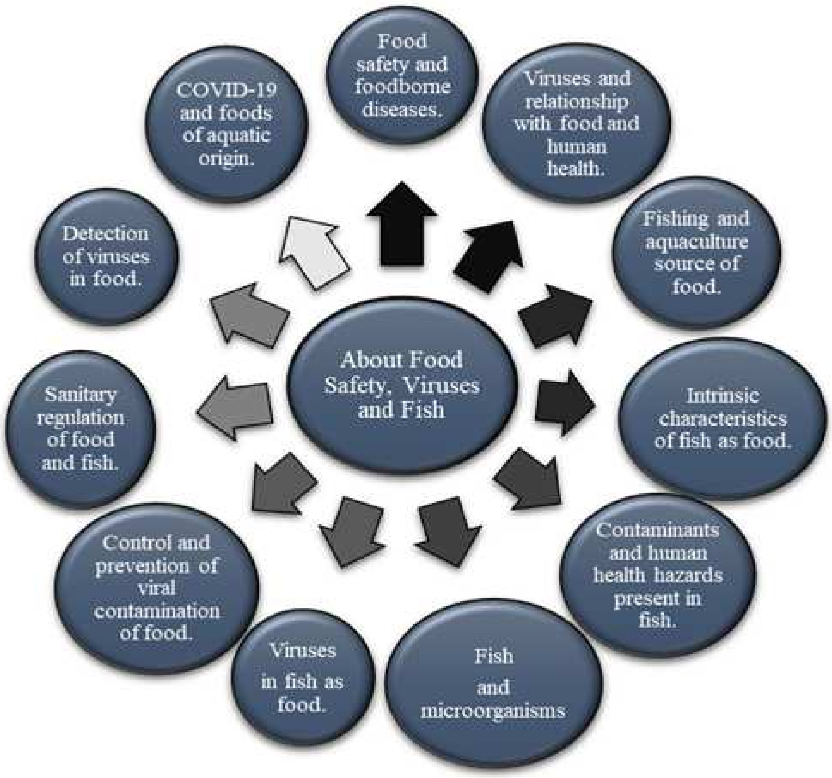

Figure 1. Scheme of contents of this article.

Viruses can be classified by different ways either by their morphology, type of nucleic acid, mode of replication, host, and type of disease they cause [20]. Currently, there are 2 main types of classifications: a) the International Committee on Taxonomy of Viruses (ICTV) that incorporates orders, families, subfamilies, genera and species, and b) Baltimore classification where viruses are divided into 7 groups according to their DNA or RNA genome, sense (or polarity) of molecules, being positive or negative, type of chain, either single or double, and the mRNA production mechanism [20,21]. The Baltimore classification is practical but not taxonomic, although the taxonomic categories described by the International Committee on Taxonomy of Viruses (ICTV) as Families, can be included in these seven groups [20,21].

Viruses can cause various human pathologies such as myocarditis, meningitis or aseptic encephalitis, liver failure, gastroenteritis, and hepatitis, even causing death [14,22,23]. In general, virus affectations are classified into two groups: a) gastroenteritis and b) viral hepatitis, either acute or chronic [24]. Viruses are among the main causes of infectious diarrheal diseases transmitted by water and food and are also known as enteric viruses. Some of these are hepatitis A and E viruses, rotavirus, Norwalk virus, poliovirus, adenovirus, coxsackieviruses, caliciviruses, echoviruses, Sapporo-like viruses (SLVs), parvoviruses and astroviruses that are considered among the main health hazards related to food consumption, affecting food safety [9,10,14,17,22-26].

Viruses can potentially be present in food that has suffered direct contamination with fecal matter or through contaminated water [17,22]. The main viral pathogens acquired through food consumption are norovirus, rotavirus, hepatitis A and E virus [9,22]. Most viruses in the environment and food are stable and are transmitted by the fecal-oral route, where infected humans can excrete considerable amounts of pathogenic viruses, as well as animal, and where plant material can carry high viral loads [14,27,28].

The main sources of viral contamination of water and food can be through: a) wastewater, feces, vomit or aerosols of animal or human origin; b) symptomatic or asymptomatic infected food handlers, and c) food from infected animals [14,23,25,27-30].

Viruses do not multiply in food or water. Therefore, when food is contaminated, they will not growth during processing, transport or storage, and the contaminated product will display a normal appearance, smell, and taste [29]. Foods generally associated with viral infections are those minimally processed, raw, undercooked, bivalve mollusks (oysters, mussels, clams and cockles), meats, vegetables, salads, fruits, drinking water, ice, as well as prepared and ready-to-eat foods that have been contaminated by improper handling in preparation or after cooking [10,14,16,22-24,28,31].

3. FISH

Fish are those foods extracted from oceanic or continental waters (sweet or brackish) intended for human and animal nutrition, generically involving fish, crustaceans, mollusks, and algae [32]. Fish is also indicated as a nutritious and healthy food in the human diet as it is the main source of protein with high biological value and digestibility, content of polyunsaturated lipids, vitamins and minerals [32] and it is considered an alternative to beef, pork and poultry, for consumers who demand meat with lower fat content for a healthy lifestyle [33].

Through capture fisheries and aquaculture activities, the production of food for human consumption is carried out, having a joint production of 178.5 million tons and a per capita consumption of 20.5 kg globally [34], being the fish products in live, fresh, refrigerated or frozen state the most preferred and quoted forms in the market [35]. On the other hand, and despite its nutritional value, fish is highly susceptible to deterioration, due to its pH close to neutrality, high water activity in tissues, high proportion of nutrients assimilated by microorganisms, lipid content (oxidation) and autolysis by enzymes present in tissues and organs [32,36].

Through the food chain, from capture or cultivation through handling, processing and marketing, fish is subjected to physicochemical, sensory and microbiological changes, being factors such as the methods of capture or harvest, fishing area, composition, type of fish, cooling, processing, commercialization, among others, that influence the degree of conservation and freshness that can lead to rejection or devaluation [32,33,36].

In the growing demand for fish, safety is an important factor to consider, since these animals can be vehicles for transmission of various contaminants of biological origin, being the most common *Campylobacter jejuni, Escherichia coli* O157H7*, Listeria monocytogenes, Salmonella enteritidis, Vibrio cholerae, V. vulnificus, Yersinia enterocolitica,* Hepatitis A and E viruses, Norovirus, Rotavirus, *Cryptosporidium parvum, Giardia lamblia*, among others, giving rise to outbreaks of food-borne diseases representing a major public health problem (see Table 1) [14,32,33,36,38,39].

4. FISH AND MICROORGANISMS

The microbiota of fish is related to its deterioration and safety as food. This microbiota in fish and other organisms have a microbial population based on that one present in the aquatic environment where they live or are captured [45,46].

Table 1. Contaminants in fishery and aquaculture products [35,40-44].

Contaminant	Agent/Hazard	Example
Biological	Bacteria	*Salmonella* spp., *Shigella* spp., *Vibrio* spp., *Helicobacter pylori, Plesiomonas shigelloides, Edwardsiella tarda, Listeria monocytogenes, Streptococcus iniae, Staphylococcus aureus, Escherichia coli, Clostridium botulinum, C. perfringens, Bacillus cereus, Campylobacter jejuni, Aeromonas hydrophila, Yersinia enterocolitica, Legionella pneumophila, Mycobacterium* sp., *Erysipelothrix rhusiopathiae*
	Viruses	Hepatitis A, hepatitis E, adenovirus, norovirus, astrovirus, rotavirus, enterovirus
	Fungi	*Fusarium* spp., *Aspergillus* spp., *Penicillium* spp.
	Parasites	*Anisakis* sp., *Gnathostoma* sp., *Pseudoterranova* sp., *Phocanema* spp., *Angiostrongylus* sp., *Contracaecum* sp., *Diphyllobothrium* sp., *Phagicola* sp., *Clonorchis* sp., *Paragonimus* sp., *Heterophyes* sp., *Cryptosporidium* sp.
Chemical	Biotoxins	Tetrodotoxin, ciguatera (ciguatoxin, scaritoxin, maitotoxin, palytoxin, and okadaic acid), gempilotoxin, and mycotoxins
	Heavy metal	Lead, cadmium, copper, mercury
	Organic compounds	Polycyclic aromatic hydrocarbons, polychlorinated biphenyls, polybrominated diphenyl ethers, dioxins, pesticides, microplastics, antibiotics, and hormones
	Nitrogen compounds biogenic amines	Histamine, putrescine, and cadaverine by the decarboxylation of histidine, ornithine, and lysine, respectively, in activities mediated by bacterial metabolism
Physical	Object present in the food and that should not be found in it, being capable of causing harm or illness to the consumer	Bone, thorns, crystals, porcelain, pieces of wood and metal, watches, rings or jewelry, packaging, or packaging materials

This microbiota is very varied, being located on all external surfaces such as skin, gills, and intestines of both live and recently caught fish, estimating a normal range of bacteria of 10^2-10^7 CFU/cm^2 on the surface of the skin, while in gills and intestines between 10^3 and 10^9 CFU/g [47]. Members of the microbiota such as bacteria in freshly caught fish depend, qualitatively and quantitatively, on the aquatic environment they are caught, which can naturally contain pathogenic microorganisms (temperature is a selective factor) or reaching them through contaminated water [38,47].

Among the human pathogenic microorganisms present in fish, bacteria such as *Clostridium botulinum, Vibrio* sp., *Plesiomonas shigelloides,* and *Aeromonas hydrophila* are reported, which are found autochthonous, and are widely distributed, in aquatic environments around the world. On the other hand, there are non-autochthonous microorganisms, such as different *Enterobacteriaceae*, including: *Citrobacter* sp., *Serratia* sp., *Salmonella* sp., *Shigella* sp., *E. coli, Enterobacter cloacae*, and Gram-positive ones such as *Staphylococcus aureus, S. epidermidis, Enterococcus faecalis, E. faecium*, among others, whose presence in fish results from fecal contamination (human or animal) of aquatic environments or through direct contamination of products during processes of elaboration, conservation, storage, transport and distribution [35,38,40,46,47].

The presence of viruses in fish and other products of aquatic origin is simply the result of contamination from infected food handlers or contaminated water where they live in, with different viruses such as Norwalk virus, enteroviruses (Polio, Coxsackie, Echo, Hepatitis A, among others), adenovirus and reovirus [45,47]. For bivalve mollusks that feed through filtration processes, these tend to concentrate the viruses in the water in which they grow (up to 1,500 L/day/oyster), being the viral concentration in the mollusk even higher than in the surrounding water (see Figure 2) [47].

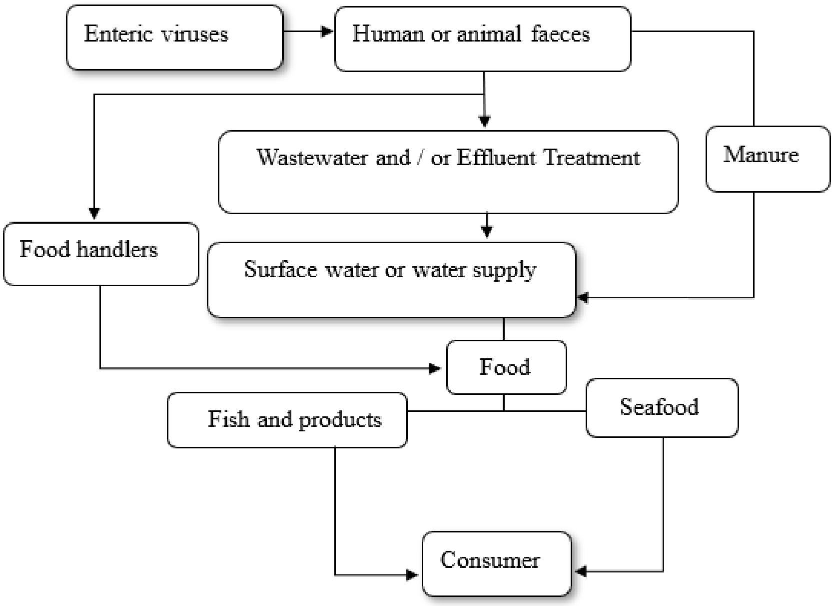

Figure 2. Routes of contamination of food, fish, and shellfish by viruses [14,28].

Different viruses associated with diseases derived from the consumption of fish products have been reported, which the type-A Hepatitis virus (HAV), type-E Hepatitis (HEV), Norwalk virus, Rotavirus, Calicivirus and Astrovirus stand out [38,39,47].

Around the world, health systems and epidemiological surveillance have pointed out the importance of pathogenic viruses, and their relationship with fish and products in the transmission of diseases. In European countries such as France, during the period 2006-2015, 11,807 outbreaks of food poisoning were reported, where 4% of the main responsible agents identified correspond to norovirus, and 34% of the foods involved were fish and bivalve mollusks, where consumption of raw or undercooked fish and shellfish, untreated drinking water, inadequate hygiene practices in preparation, infected handlers, and food preservation are identified as risk factors for infection by norovirus, type A hepatitis virus, and type-E hepatitis virus [48].

In Spain, Espinosa et al. [49] indicated that in the period 2008-2011 there was a total of 2342 outbreaks with 30219 cases, which 69% were associated with a specific causal agent, being the viruses responsible in 10.1% the norovirus, rotavirus, and type-A hepatitis virus. Meanwhile, food involved in outbreaks, 6% corresponded to fish and 7% shellfish, and among the main factors contributing to disease are cross contamination, inadequate storage temperature, contaminated food, inadequate cooling, and heating, as well as infected handlers.

Alerte et al. [5] pointed out that between the period 2005-2010 the reported outbreaks of diseases transmitted by food and water in the Metropolitan Region of Chile were 2806, which 2472 were analyzed, finding that 2.5% of the total were viral enteritis, and the mainly suspected foods of the outbreaks were fish and shellfish with 15.45 and 15.1%, respectively, being related causes of loss of food safety handling, raw material, inadequate storage, transportation and processing. Finally, the surveillance system for food-borne disease outbreaks in the United States of America and Puerto Rico, between the years 2009-2015, reported 1,870 disease outbreaks, where the main causative agents were rotavirus, astrovirus, sapovirus, type-A hepatitis virus, and Norovirus. Likewise, the category of foods of aquatic origin (fish, crustaceans, mollusks, among others) were one of the most linked to disease outbreaks [50].

5. CONTROL AND PREVENTION OF FOOD CONTAMINATION

The appearance of diseases through food is an indicator of its hygienic-sanitary quality, and it has been shown that its contamination can occur during any phase of its production, including the use of contaminated raw material [1].

The transmission of viruses can occur through the fecal-oral route by the consumption of food contaminated with sewage. On the other hand, viruses cannot always be effectively eliminated by wastewater treatment methods, and consequently cause viral contamination of the environment from treated and untreated wastewater, as well as indirectly through contamination by manure runoffs used in agriculture [14,27]. Direct fecal contamination of the aquatic and terrestrial environment by humans and animals, and the resulting viral contamination of the sea, coastal waters, rivers and other surface waters, groundwater, irrigated vegetables, and fruits, are associated with subsequent risks of reintroduction of the viral pathogens in human and animal populations [14].

It has been reported that the application of null or deficient sanitation practices in the different phases of the production chain, along with weak control of water contamination (feces) for agricultural and aquaculture activities, insufficient regulatory systems, weak food safety laws, time and temperature inadequate during food preservation, inadequate financial resources in spending for equipment, and inadequate education in handling, storage and preparation, are related to foodborne diseases, with different microorganisms as causative agents, including viruses [10,26,51].

Food is subjected to different processing and preservation treatments (physical and chemical) that are widely used in the food industry to increase its shelf life and guarantee its safety [17,22,26,52]. Heat treatment is effective in inactivating foodborne pathogens such as viruses. However, the differences between the variety of viruses and resistance to these treatments must be considered, since they are a function of the intrinsic characteristics of the food matrix, presence of organic matter, initial viral load, and time-temperature relationship [16,22,26,52]. For minced fish, an internal viral inactivation temperature of 62.8 °C has been established, as well as a 3-minute cooking time [16].

Many of the food-borne viruses can persist for a long time in food products or the environment. Due to the strictly intracellular parasitic nature of viruses, they cannot multiply in food, are generally more resistant than bacteria to stressful environmental conditions and different commonly used preservation and inactivation technologies such as refrigeration, freezing, pH, drying, ultraviolet radiation, heat, pressure, and disinfection [16,17,22,26,30,52]. The use of bioactive natural compounds such as polyphenols, essential oils, proteins, polysaccharides, alkaloids, and sulfurized organic compounds, has recently been proposed, although further research is still required [26].

Among the various actions for disease prevention and safe food production are the implementation of procedures such as good aquaculture and fishing practices, good agricultural practices, good manufacturing practices, Sanitation Standard Operating Procedures (SSOP), and traceability [6,29,31,36,53], as well as the implementation of sanitary surveillance and information systems in the food chain (from the farm to the consumers), such as the Hazard Analysis and Critical Control Points (HACCP) system [9,29,31,33]. Also, to achieve food safety, it is required to apply health education in personal hygiene, hygienic food handling, sanitation of the premises and kitchen, in addition to regular medical examination of food handlers [5,9,16,29]. On the other hand, some preventive measures for viral infections in the general population have been set, like the use of vaccines, especially in children, against viruses transmitted by food such as type-A hepatitis virus, rotavirus and picornavirus that causes poliomyelitis [54-56].

5.1. Sanitary regulation in food and fish

Due to the incidence of food-borne diseases, their negative repercussions on health and the economy, as well as the knowledge of conditions that favor them and the identification of causal agents, various sanitary regulations for food intended for human consumption have been developed, promoted, and implemented around the world. In regards of food safety affected by viruses, codes, guidelines, and recommendations have been developed and promoted by different international organizations such as FAO through the Codex Alimentarius to guarantee food safety [22]. Such is the case of the general principles of food hygiene (CXC 1-1969) [57] that involve guidance for the implementation of good hygiene practices and HACCP systems throughout the entire food chain to obtain safe and suitable food for consumption. Meanwhile, for the case of fish and products, there is the code of practice for fish and fishery products (CXC 52-2003) [58]. On the other hand, in the European Union, regulations have been established to obtain safe food for consumption, including Regulation (EC) No. 178/2002 [59], which establishes the principles and general requirements of food legislation, the creation of the European Authority Food Safety (EFSA) and setting procedures regarding food safety; Regulation (EC) No. 852/2004 on the hygiene of food products [60]; Regulation (EC) No. 853/2004 establishing specific hygiene standards of foods of animal origin including fish [61]; Regulation (EC) No. 854/2004 which establishes specific rules for the organization of official controls of products of animal origin, including fish intended for human consumption [62], and Regulation (EC) No. 2073/2005 on microbiological criteria for foodstuffs where the latter does not refer to specific criteria for viruses in fish and products [63]. Through the European Food Safety Authority (EFSA) and its scientific panel on biological hazards, it has generated the recommendation to focus on preventive measures to avoid viral contamination above actions aimed at eliminating or inactivating the viruses present in food. and the introduction of microbiological criteria for viruses in fishery products such as bivalve mollusks [37].

In the United States of America, the Food and Drugs Administration (FDA) regulates seafood products, including fish (except Siluriform) and shellfish. Domestic production and all imports of siluriform, fish, and fishery products are regulated by the USDA's Food Safety Inspection Service (FSIS) under the Federal Meat Inspection Act [35].

The FDA has established the implementation of good manufacturing and packaging practices for food for human consumption (21 CFR 110) [64]. Likewise, the FDA issued the Code of Federal Regulations Title 21 section 123 (21 CFR 123) to guarantee the safety and health in the processing of fish and fishery products, which includes good manufacturing practices, Sanitation Standard Operating Procedures (SSOP) and HACCP plan, as well as Communicable Disease Control (21 CFR 1240) [35,65].

In Latin American countries like Mexico, the sanitary regulation in fishery products is made up of different norms, including NOM-242-SSA1-2009, which establishes the sanitary requirements for bivalve mollusk capture areas, establishments that process fishery products either fresh, refrigerated, frozen and/or processed, including fishing, and harvesting vessels, as well as the sanitary specifications that such products must present [66]. However, this does not yet present microbiological specifications regarding viruses. The NOM-128-SSA1-1994 establishes the application of a Hazard Analysis and Critical Control Points (HACCP) system in industrial plants that process fish products [67]. The NOM-251-SSA1-2009 sets the minimum requirements of good hygiene practices and guidelines for the application of a Hazard Analysis and Critical

Control Points (HACCP) system that they must have in food processing and its raw materials to avoid contamination throughout the process [68]. Finally, the NMX-F-605-NORMEX-2016 focused on hygienic handling in the service of prepared foods and obtaining the "H" distinctive [69].

5.2. Detection of viruses in food

An important part in the process of controlling disease-causing microorganisms through food is related to the analytical method used for their detection [1]. Viral contamination of food can occur at any stage of the food chain, and food analysis is complex, enlisting a variety of methods [37]. To evaluate food for virus transmission, it is essential to generate standardized and / or comparable effective methods for its application [70]. Virus detection is commonly through two principles: 1) detection by propagation in cell culture based on the formation of cytopathic effects, and 2) subsequent quantification by plaque assay, most probable number, Tissue Culture Infectious Dose 50 (TCID50), and detection of viral genomes by molecular techniques such as PCR or RT-PCR [70].

Detection of enteric viruses in food is especially complex since most of these pathogens do not easily replicate in cell cultures, its viral contamination is not uniform, they can be internalized in food and are found in very low concentrations [22,31,70]. Ingestion of 10 to 100 viral particles has been reported to be sufficient to cause disease [31], where, for instance, the infectious dose for type-A hepatitis viruses and norovirus is 10 to 100 infectious particles [22,70]. Therefore, it is estimated that, to guarantee or consider a safe food with respect to human enteric viruses, these should not be more than one hundred viruses [31]. Therefore, the factors to consider for the analysis of food are the type of sampling, which must be representative of the sample lot, sensitivity, and specificity of the method since the level of contamination may be low [31,37,70]. The methods used involve extraction phases using buffer or chemicals and concentration through filtration, centrifugation, or precipitation processes for the detection of viruses [25,37,70].

In recent years, methods based on molecular techniques such as PCR and its different variants, have acquired relevance for the detection of viruses in water and food due to their speed, sensitivity, reproducibility, and minimization of contamination [25,70]. These methods may involve phases of separation of the viruses from the food matrix, concentration, and purification to reduce the sample volume, extraction of genetic material, retro transcription (cDNA) and detection by PCR [22,27,28,37,39,70].

One of the limitations the methods that involve concentration phases have shown is the loss of virus particles during manipulations and / or addition of chemical agents to eliminate the food matrix, which avoids the presence of inhibitors and concentrate viral particles for RT-PCR [31]. Furthermore, a key point in the use of molecular techniques based on the detection of genetic material of viruses is the correlation between the infectivity of the virus with the genetic material detected (RNA). The presence of viral RNA is an indication that there was contact between viruses and food, which results in a potential danger to human health [31].

Among the standardized methods that have been developed for the detection and quantification of viruses in food and food surfaces are those for type-A hepatitis viruses and Norovirus such as ISO/TS 15216-2:2013 and ISO 15216-1:2017, respectively. These methods include a process of releasing virus from the sample, extraction of viral genetic material and use of the real time Reverse-Transcriptase Polymerase Chain Reaction (RT-PCR) [22].

Other methods of detection of enteric viruses are immune-chemicals through the detection of viral antigens such as the enzymatic immunoassay, radioimmunoassay, or Enzyme-Linked Immunosorbent Assay (ELISA) [14,25,27,37]. These methods are, unlike PCR, of greater simplicity, speed in obtaining results and do not require such specialized equipment [27,37]. But its analytical sensitivity is low for diverse types of samples, such as environmental ones [14].

Other viral detection options have also been reported, including the combination of detection methods between cell culture, immunological methods, or molecular biology, where, for instance, the combination of cell culture and RT-PCR detection can reduce incubation periods and allows the detection of viruses that grow without causing cytopathic effects [14].

On the other hand, methods focused on the detection of viruses in food are usually laborious and expensive, so they are not carried out in a common way [16,31,71]. Many times, in practice, it is difficult, or not possible at all, to determine all the pathogenic microorganisms present in water or food due to their variable diversity and low concentration, increasing the difficulty of detection [45]. To this, microbiological indicators such as bacteria or bacteriophages have been sought and proposed to determine viral contamination in food [16,31,45,71].

Several of these microbial indicators have been useful to determine food safety and are also incorporated as microbiological criteria that are used for validation and verification of HACCP processes, as well as other hygiene control measures, checking the quality and food safety [37,38]. These indicators are related to organisms of intestinal origin, like common total coliform bacteria, fecal, *E. coli*, enterobacteria, Pseudomonas and fecal streptococci [38,45]. However, as previously mentioned, viruses present greater stability in the environment than the bacterial indicators commonly used to evaluate fecal contamination, so the absence of viruses in drinking water, surface water, seawater or bivalve mollusks that meet bacterial microbiological index standards, cannot be guaranteed [27,37]. Given this, the use of *E. coli,* in substitution of fecal coliforms, has been recommended as an indicator of fecal contamination in shellfish collection areas when applying bacterial indicators [37].

6. COVID-19 AND FOODS OF AQUATIC ORIGIN

Members of the coronavirus family (enveloped RNA viruses) have been identified as being pathogenic and as respiratory diseases, diarrhea, and gastroenteritis producers in humans [23,72-75]. Currently due to the COVID-19 pandemic whose causative agent is the coronavirus (SARS-CoV-2), has been analyzed by various researchers beyond the transmission from person to person the possible transmission through food, including those of aquatic origin [23,76-78].

The detection of SARS-CoV-2 in feces, wastewater and surface waters has been considered common [78,79]. And it is known about the ability of bivalves to filter volumes of seawater, thus being related to studies of human fecal contamination in waters where these organisms live. Therefore, Polo et al. [78] carried out a study for the detection of RNA SARS-CoV-2 in aquatic environments, products such as bivalve mollusks and coastal water-sediment indicating the detection of RNA SARS-CoV-2 and an extremely low risk of acquiring SARS-CoV-2 from shellfish consumption. However, other researchers have pointed out that a direct link between a SARS-CoV-2 infection and food consumption cannot be pinpointed as it still requires further research and documentation [23,76-78].

On the other hand, it has been reported that this virus can contaminate surfaces, food handled by an infected person, or those in contact with contaminated material. SARS-CoV-2 has low stability in fomites between 21 °C and 23 °C, and it has been indicated that the virus can survive at temperatures of 4 °C, -20 °C, and -80 °C for up to 21 days in meat, fish and animal skin, being those conditions associated with transport and storage actions for the commercialization of food [23,77], thus showing a possible unusual transmission mechanism that requires the development and implementation of protocols for the trade in aquatic products [23]. In addition, it has been necessary to establish preventive actions in the transmission from person to person and the possible contamination of food in fish producing farms and processors with procedures that involve physical distancing, contact tracing and tests, hygiene improvement. respiratory and hands, frequent disinfection of high contact surfaces, isolation of infected workers and contacts [23].

7. CONCLUSIONS

Food-borne diseases constitute a major health problem worldwide due to their incidence and repercussions on health and the economy. Viruses are entities of biological origin capable of contaminating food, constituting a significant hazard to human health.

Fish and products are nutritious foods and widely consumed in different presentations around the world. However, fish is also very susceptible to deterioration and contamination by a variety of microorganisms, including viruses in the distinct phases of the food chain, with numerous cases and outbreaks of diseases due to consumption of contaminated food.

The microbiological conditions of the aquatic environment from which the fish is extracted, as well as the hygiene conditions in processing and handling, constitute part of the main sources of viral contamination of fish and products. The production and availability of safe food must be the responsibility of all members of the food chain. The implementation of good aquaculture and fishing practices, good manufacturing practices, HACCP systems, food hygiene education programs for end handlers, legislation, sanitary surveillance by regulatory authorities, as well as the development and standardization of methods for detecting viruses in food, are part of the requirements for quality and safety in food.

Conflict of Interest: The author declares no conflict of interest.

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