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Food-Borne Bacteria Associated with Seafoods: A Brief Review

A. Ali [1], A. Parisi [2], M.C. Conversano [3], A. Iannacci [4], F. D'Emilio [4], V. Mercurio [5], G. Normanno [1*]

1. Department of Science of Agriculture, Food and Environment (SAFE), University of Foggia, Via Napoli 25 71122, Foggia, Italy
2. Zooprofilactic Institute of Apulia and Basilicata, Via Manfredonia 20, 71121, Foggia, Italy
3. Veterinary Doctor, Quality Assurance Expert in Fishery Products, Vico Tasselli 21, 70010 Valenzano (BA), Italy
4. Local Health Authority Foggia (ASL-FG), Via Michele Protano 13, 71121, Foggia, Italy
5. Veterinary Doctor, Specialist in Food Inspection, Via F. La Guardia, 6, 71121, Foggia, Italy

HIGHLIGHTS

- This paper briefly reviews the most important bacterial seafood-borne diseases.
- *Vibrio*, *Salmonella*, *Listeria monocytogenes*, *Staphylococcus aureus*, *Clostridium botulinum*, *Shigella*, and *Aeromonas* are considered as microbiological hazards for seafoods.
- Food-borne intoxications can be controlled by the proper refrigeration of seafoods and monitoring of the chill chain.

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Acronyms and abbreviations
RTE=Ready-To-Eat

ABSTRACT

Consumption of contaminated seafoods is a major cause of death and hospitalization particularly in poor and developing countries. As with other food types, seafoods are also not free of food-borne pathogens and several risk factors are associated with its consumption. Regarding seafoods, there are regulatory hygienic alerts in importing countries. This paper briefly reviews the occurrence of seafood-borne diseases and describes the most important bacterial causes of these infections. Also, major bacterial threats, the route of infection, and food safety concerns associated with seafoods consumption are explained. Several bacterial pathogens, like *Vibrio* spp., *Salmonella* spp., *Listeria monocytogenes*, *Staphylococcus aureus*, *Clostridium botulinum*, *Shigella* spp., and *Aeromonas* spp. are considered as microbiological hazards for seafoods. These bacteria can contaminate seafood products anytime from farm to table. Some effective methods should be adopted for control and prevention of bacterial hazards in fish industry. Maintaining the microbiological water quality of domestic capture, post-harvest care, proper hygiene, etc. can minimize the bacterial hazards. Food-borne intoxications can be controlled by the proper refrigeration of seafoods and the continuous monitoring of the chill chain during the entire production process right up to consumption. Other ways to prevent food-borne outbreaks due to consumptions of seafoods are training of the consumers about correct handling of food, proper preparation, and storage of seafoods.

Introduction

Seafoods are considered healthy choice of animal proteins compared to another protein sources. They have additional health benefits as they are also rich source of omega-3 fatty acids, vitamin D, selenium, and iodine

* Corresponding author (G. Normanno)
E-mail: giovanni.normanno@unifg.it
ORCID ID: https://orcid.org/0000-0001-7212-4457

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(Mahaffey et al., 2008). It has been proved that seafoods are beneficial in prevention of cardiovascular diseases as well as providing health benefits in neural, visual, and cognitive development during gestation and infancy (Emmett et al., 2013).

Ready-To-Eat (RTE) foods are now an increasing global trend, because many people have less time for preparing and cooking food. Seafoods and fishery products (like surimi, salads, smoked fish, carpaccio, etc.) are some of the most popular RTE seafood choices, although they are not always free from microbial risk. Seafoods comprise different kinds of finfish, mollusks, crustaceans, and fish eggs (Iwamoto et al., 2010). The varieties and health benefits of seafoods cause their heavy demand and importation in various parts of the world. There is continuous growth in demand and consumption of seafoods across the world. For instance, the gross supply of seafood products in the USA increased to more than 70% since 1980 to 2.2 billion kg in 2009 (Wang et al., 2011).

The fishery industry is a source of income for a large number of people across the world. It is estimated that fishery and aquaculture farming provides a source of income for many people across the globe. The continent with the highest percentage of the population involved in this industry is Asia (around 84%), with around 10% in Africa and 4% in America and the Caribbean, while the average is 2% in the rest of the world (Elbashir et al., 2018).

Safety of seafoods is one of the most important public health issues directly linked to farming and food production steps. Consumption of contaminated seafoods is a major cause of death and hospitalization particularly in poor and developing countries. As with other food types, seafoods are also not free of food-borne pathogens and several risk factors are associated with its consumption. Regarding seafoods, there are regulatory hygienic alerts in importing countries (Abdollahzadeh et al., 2016; Novoslavskij et al., 2016).

So, this paper briefly reviews the occurrence of seafood-borne diseases and describes the most important bacterial causes of these infections. In addition, major bacterial threats, the route of infection, and food safety concerns associated with consumption of seafoods are explained.

Risk factors for seafood-borne diseases

Growing demand and consumption of seafoods in various countries makes seafoods more vulnerable to bacterial and viral contamination. Consumption of seafoods may be occurred during primary production, handling, transferring, preparing, etc. The disease burden associated with contaminated seafoods has increased tremendously in last decade (Kim et al., 2017); however, with the increasing threat, the general awareness of seafood-borne diseases has also been increased worldwide. The seafood-borne outbreaks may be occurred because of parasites, bacteria, and viruses; and the symptoms can vary from mild gastroenteritis to life threatening infections (Barrett et al., 2017; Butt et al., 2004; Elbashir et al., 2018; Iwamoto et al., 2010; Pekala-Safinska, 2018).

Shellfish becomes contaminated by viruses (such as norovirus, hepatitis A virus), bacteria (*Vibrio* spp., *Shigella* spp., *Salmonella* spp.), and protozoan (*Toxoplasma gondii*, *Cyclospora* spp., *Cryptosporidium* spp.) (Tedde et al., 2019). Also, freshwater and marine finfish and cephalopods can carry a number of zoonotic pathogens. Several incidents of *Vibrio* spp. infection have been observed due to the consumption of contaminated shellfish including oysters (Velazquez-Roman et al., 2014). *Salmonella* outbreaks are often connected to the consumption of sushi, while contamination of smoked mussel, salmon, and other fish has been associated with *Listeria* spp. outbreaks. *Vibrio* spp. is also responsible for several food-borne outbreaks. Direct transfer of disease can occur through zoonotic bacteria (e.g. *Salmonella*), as these have the ability to induce disease in both aquatic species as well as humans (Gauthier, 2015; Haenen et al., 2013).

The risk of contaminated seafoods causing illness can be categorized as high or low, although some authors may not agree with this classification. According to Huss et al. (2000), high risk food products include mollusks and shellfish, raw and lightly processed fish products, and fish products processed at low temperature. Low risk seafoods include smoked dried fish, semi-preserved fish, fresh/frozen fish and crustaceans, and heat treated (canned) fish. Consumption of dry and heavily salted fish poses hardly any threat to any type of infection or pathogens.

Although, the Hazard Analysis Critical Control Point (HACCP) has been implemented to reduce the incidence of seafood-borne diseases, contaminated seafood is still a major cause of food-borne infections in the USA. Interestingly, the seafood-borne outbreaks were more often linked to intoxication rather than any infection which is due to the large number of cases of histamine food poisoning reported (Guergue-Diaz de Cerio et al., 2016). Environmental contamination (sea water and sediment) due to naturally occurring pathogens (e.g. *Vibrio* spp. and *Aeromonas* spp.) can be an important risk factor for intake of seafoods by the consumers. There is also the possibility of inter cross-contamination between operations.

Seafoods associated bacterial pathogens

- Vibrio spp.

Several *Vibrio* species have been found to be causative agents in food-borne diseases. The genus *Vibrio* include Gram-negative, rod shaped, curved, non-spore forming, motile, and facultative anaerobic bacteria. They are more prevalent in estuarine and coastal areas, where they live freely in water, sediments, plankton, and nearly all flora and fauna found in coastal environment (Normanno et al., 2006; Parisi et al., 2004; Scharer et al., 2011). The pathogenic species which are most likely to infect human are *V. parahaemolyticus, V. vulnificus*, and *V. cholerae*. These are major human health microbial hazards risks causing seafood-borne diseases in the people who consume raw or undercooked contaminated seafoods (Scallan et al., 2011).

In 2015, Canada had suffered the largest outbreak linked to the consumption of raw oysters harvested from British Columbia coastal water. The causative organism was found to be *V. parahaemolyticus* (Taylor et al., 2018). There are several incidents of the occurrence of *V. parahaemolyticus* in seafoods in US (Jones et al., 2014; Klein and Lovell, 2017; Konrad et al., 2017; Yang et al., 2017).

Consumption of contaminated seafoods can also lead to human infection of *V. vulnificus* which is responsible for 1% of all food-related deaths in the world. The multiple virulence factors of *V. vulnificus* include the ability to acquire iron, capsule, proteins, the hemolysin encoded by the *vvh* gene, and transmembrane regulatory protein (Giltner et al., 2012; Miyoshi, 2006). Two hundred and seventy-four incidences of illness due to consumption of undercooked seafoods were observed in the U.S. during 1990s (Oliver, 2005). This bacterium was responsible for approximately 96 illnesses, 91 cases of hospitalization and around 35 deaths annually in US (Scallan et al., 2011).

V. mimicus, a close relate organism of *V. cholerae*, is also found in fresh and brackish water. Infection by *V. mimicus* is characterized by profuse diarrhea, dehydration, and electrolytic imbalance. The pathogenicity factor associated with *V. cholerae* is cholera toxin and toxin co-regulated pilus (Hill et al., 2011; Rivera et al., 2001).

- Salmonella spp.

Salmonella are rod shaped, and facultative anaerobic Gram-negative bacteria. These are usually motile having peritrichous flagella and they are oxidase-negative, catalase-positive, and a non-lactose fermenter (Elbashir et al., 2018). They cause moderate to severe enteric inflammation and diarrhea; and the symptoms start 12-72 h after eating contaminated food. *Salmonella* spp. are terrestrial bacterium that could be found in the intestine of animals such as poultry, cattle, reptiles, etc.; however, consumption of raw, and undercooked finfish, mollusks, and crustaceans can cause salmonellosis. Environmental factors such as water quality play a very important role in the occurrence of *Salmonella* in fish and pose a great risk for those consuming fish caught in contaminated waters without sanitary control (Amagliani et al., 2012; Thompson et al., 2017).

Salmonellosis is a global health threat and is recognized as a principle source of seafoods associated outbreaks across the globe. It is the second leading cause of food-borne disease in U.S. (McCoy et al., 2011; Scallan et al., 2011). There were 18 outbreaks of *Salmonella* between 1973 and 2006 due to seafoods consumption resulting in 374 reported illness and 28 hospitalizations in U.S. (Iwamoto et al., 2010). Contamination of seafoods with *Salmonella* has been considered the most critical public health hazard in seafoods trade (Heinitz et al., 2000). Another *Salmonella* outbreak due to sushi consumption occurred in Western Sydney, Australia in 2015 (Thompson et al., 2017). High prevalence of *Salmonella* spp. has been also observed in the Asian countries particularly in tropical regions. *Salmonella* spp. contamination has been found in 24.5% of shrimp samples in Vietnam and it was major threat for seafood products like shrimp and prawns (Phan et al., 2005).

- Listeria monocytogenes

Several outbreaks are also reported to be linked with the consumption of contaminated seafoods by *L. monocytogenes*. Since 1981, listeriosis is considered as a food-borne disease of increasing public health and food safety concern. Out of all bacteria, *L. monocytogenes* is responsible for product detention in 4% of cases worldwide (Gudmundsdottir et al., 2006; Huss et al., 2000; Miettinen and Wirtanen, 2006); contamination by this bacterium causes product recalls leading to heavy financial losses to traders (Wan Norhana et al., 2010). *L. monocytogenes* is one of the most important causes of death from food-borne infections in developed countries (Jami et al., 2014; Latorre et al., 2007; Wan Norhana et al., 2010). The bacterium can grow and multiply during refrigeration, and is also able to survive at relatively low water activity (Ghanbari et al., 2013; Vongkamjan et al., 2015).

Last two decades has noticed several seafood-borne listeriosis outbreaks across several countries, including U.S, Australia, New Zeeland, and European countries. The major risk factors associated with *L. monocytogenes* are refrigerated RTE products which has a long shelf life and food items which are eaten with little or no prior heating (Cartwright et al., 2013; Rocourt et al., 2003).

There has been found to be an increased incidence of listeriosis in Scandinavian countries compared with other European countries because of higher RTE-fish consumption rate in these Scandavian countries (Lambertz et al., 2012, 2013). Listeriosis outbreaks have been associated with the consumption of mussels and smoked mussels, smoked cod roe, and undercooked fish (Barrett et al., 2017; Brett et al., 1998). Miya et al. (2010) isolated several serotypes of *L. monocytogenes* strains from minced tuna, salmon roe, and cod roe. Cases of listeriosis due to 4 serotypes of *L. monocytogenes* has also been revealed in Italy (Gambarin et al., 2012). Significant *L. monocytogenes* contamination was observed in fresh fish, including salmon and tilapia imported to US from other countries (Wang et al., 2011). Another study reported a prevalence of 6.1% of *L. monocytogenes* in RTE crabmeat samples collected monthly from some processing plants during the plant operating season in the U.S. (Pagadala et al., 2011, 2012).

- *Staphylococcus aureus*

Human beings are the main source of enterotoxigenic *S. aureus* and seafoods become contaminated during handling under poor hygienic conditions. Staphylococcal enterotoxins produced by this bacterium are the cause of its pathogenicity and virulence with reference to food safety. These enterotoxins can cause gastroenteritis characterized mostly by vomiting in the patients (Argudin et al., 2010; Fisher et al., 2018). In addition to cases of food poisoning due to *S. aureus*, a problem linked to the presence of methicillin-resistant strains of *S. aureus* in food also is rising continuously (Albuquerque et al., 2007; Sergelidis and Angelidis, 2017).

- *Clostridium botulinum*

The neurotoxin produced by *C. botulinum* is responsible for food-borne botulism which causes illness mostly by the consumption of unhygienic processed seafoods. The bacterium produces several serologically classified toxins of which A, B, E, and F cause human food-borne botulism (Iwamoto et al., 2010). Temperature abuse, inadequate preservation process, and the absence of oxygen during storage (e.g. vacuum packaging, canning) are the major causes of food-borne illness in consumers of seafood products (Elbashir et al., 2018; Walton et al., 2014).

Botulism outbreaks were mostly associated to ingestion of ethnic food, home-canned, salt-cured, fermented whole fish, and other seafood. A variety of fish dish like white fish, flounder, smoked fish, cod, rock fish, etc. have been found to be contaminated by *C. botulinum* type E spore and toxins (Iwamoto et al., 2010). It is worth noting that *C. botulinum* type E, the most frequently type associated with the aquatic environment, is able to multiply and release the neurotoxin at refrigeration temperatures as low as 3.3 °C (Horowitz, 2010; Leclair et al., 2017; Walton et al., 2014).

- *Shigella spp.*

There are few cases of shigellosis caused by the consumption of seafood products. Wang et al. (2011) reported that 32% of seafood samples (shrimps, salmon, tilapia) tested by PCR were positive for *Shigella* spp., but none of them isolated through culture methods. In India, *S. dysenteriae* was isolated from two edible fishes, namely *Megalaspis cordyla* and *Priacanthus hamrur* (Sujatha et al., 2011). The same bacterial species was also isolated from Nile tilapia in Kenya (David et al., 2009).

- *Aeromonas spp.*

Some minor seafood-borne outbreaks have also been observed in *Aeromonas* spp**.** in India and Bangladesh. *Aeromonas* spp. are responsible for Epizootic Ulcerative Syndrome (EUS) in different fish, resulting in significant damage to quality of seafood products. The contamination of seafoods may be due to the colonization of gut by this bacterium in marine environment (Aberoum and Jooyandeh, 2010). *A. hydrophila* HG2 and HG3, which are suspected of causing outbreaks in Finland have been isolated from frozen shrimp (Hanninen et al., 1997).

Conclusion

Several bacterial pathogens, like *Vibrio* spp., *Salmonella* spp., *L. monocytogenes*, *S. aureus*, *C. botulinum*, *Shigella* spp., and *Aeromonas* spp. are considered as microbiological hazards for seafoods. These bacteria can contaminate seafood products anytime from farm to table. Some effective methods should be adopted for control and prevention of bacterial hazards in fish industry. Maintaining the microbiological water quality of domestic capture, post-harvest care, proper hygiene, following Good Manufacturing Practices (GMP), Good Hygienic Practices (GHP), and HACCP protocols can minimize the bacterial hazards. Food-borne intoxications can be controlled by the proper refrigeration of seafoods and the continuous monitoring of the chill chain during the entire production process right up to consumption. Other ways to prevent food-borne outbreaks due to consumption of seafoods are training of the consumers about correct handling of food, proper preparation, and storage of seafoods. Regular surveillance is important for assessing the effectiveness of current as well as future prevention strategies.

Author contributions

G.N. guided and edited the whole manuscript; A.A. wrote the manuscript; A.P., M.C.C., F.D., V.M., and A.I. edited the manuscript. All the authors revised and approved the final manuscript.

Conflicts of interest

The authors declared that there was no conflict of interest.

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