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Review paper

Viruses in shellfish — food safety risks

Mirjana Dimitrijević[a], Nevena Grković[a], Ivana Milošević[b] and Nedjeljko Karabasil[a]*

[a] University of Belgrade, Faculty of Veterinary Medicine, Department of Food Hygiene and Technology Bulevar Oslobođenja 18, Belgrade, Serbia

[b] University of Belgrade, Clinic for Infectious and Tropical Diseases, Clinical Centre of Serbia Faculty of Medicine, Bulevar Oslobođenja 16, Belgrade, Serbia

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ABSTRACT

Shellfish production in the EU has declined in recent decades, which is not the case with global aquaculture production of shellfish. The trend towards a healthy lifestyle and diet is becoming increasingly topical and often involves the consumption of uncooked shellfish. Unfortunately, shellfish can often be contaminated with various pathogens, especially viruses, which can endanger human health. Among the outbreaks of shellfish-borne viruses, the most notable are those caused by Norovirus (NoV) and hepatitis A virus (HAV). However, other viruses belonging to the *Herpeviridae, Picornaviridae, Adenoviridae, Astroviridae,* and *Reoviridae* can mainly cause intestinal disease in humans after consumption of contaminated shellfish. The listed viruses have been detected in shellfish worldwide and they are mostly the consequence of sewage-contaminated water. Numerous preventive and control measures are recommended to solve this problem.

1. Introduction

The search for high-quality proteins in people's diets and the provision of sufficient quantities, i.e. by another 1 million tons in 2020 compared to 2018, means that 90 million tons (51%) of the supply came from capture fisheries, whereas 88 million tonnes came from aquaculture (49 percent) (*FAO*, 2022). In Europe, Denmark produced the most mussels in 2021 (23,500 tons), but Europe is expected to increase aquaculture production. Data from the FAO indicates that worldwide production of aquaculture will decrease the supply of mussels the most by 2026, with a predicted annual growth of 0.4% (*European Mussel Trends*, 2022). Even if the production of mussels in our neighbour Montenegro is constantly rising, the capacity is still less than anticipated (*Dimitrijevic et al.*, 2022). The Serbian market is supplied with shellfish from imports, which in recent times has been about 620 tons annually of chilled or frozen shellfish. Unfortunately, shellfish can frequently contain a variety of pathogens, including viruses, that can be harmful to human health. According to *Richards* (2016), shellfish bioconcentrate pollutants, such as enteric viruses, within their edible tissues. Raw or undercooked shellfish (oysters, clams, mussels and cockles) is one of the most notable foods that may contain enteric viruses. Among the outbreaks of shellfish-borne viruses, the most notable are those caused by norovirus (NoV) and hepatitis a virus (HAV). However, shellfish can commonly become contaminated with additional viruses from the *Herpeviridae, Picornaviridae, Adenoviridae, Astroviridae* and *Reoviridae*.

***Corresponding author:** Mirjana Dimitrijević, mirjana@vet.bg.ac.rs

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2. Foodborne viruses in shellfish

Shellfish are most frequently contaminated with enteric viruses that can cause intestinal diseases in humans, (with diarrhoea, vomiting, nausea, abdominal cramps, fever, chills, body ache), but HAV and hepatitis E virus (HEV) may lead to further consequences. Although extreme dehydration can occasionally cause death, enteric viruses rarely cause mortal outcomes. However, this is especially true in places where rehydration medication is difficult to access (*Richards*, 2016). These viruses are all spread by the faecal-oral route and are the main viral infections to watch out for in outbreaks that are foodborne and waterborne, including those that include shellfish eating. There have been numerous reports about enteric virus contamination of shellfish products globally (*Fouillet et al.*, 2020; *Meghnath et al.*, 2019; *Miranda & Schaffner*, 2019). Lack of clean water, globalization of the supply chain, and changes in eating habits, especially an increase in the intake of food that is often eaten raw, are all factors that contribute to the growth and spread of viral foodborne disease. Effective management plans for virus monitoring in shellfish harvesting regions are usually inadequate in underdeveloped nations. Although developed nations have achieved significant progress by modernizing their sewage systems, which has decreased the viral loads in sewage, it is challenging to assess the relevance of these improvements due to the absence of regulations in place that define the acceptable limits for viruses (*Shuping, Human, Lues & Paulse*, 2023).

2.1. Norovirus — NoV

Among the outbreaks of shellfish-borne viruses, the most notable are those caused by NoV, which belonging to the family *Caliciviridae* (*De Graaf et al.*, 2016). The genogroups GI and GII, with GII.4 and GII.17, are mostly responsible for human infection, which often manifests as gastroenteritis, though some populations (young, old and immunosuppressed) can experience additional complications (*Mans, Armah, Steele & Taylor*, 2016; *Zhou et al.*, 2019). According to *Hall et al.* (2012), NoV account for an estimated 5.5 million cases of acute foodborne gastroenteritis each year in the United States, making them the most common cause of this illness. NoV outbreaks linked to shellfish have occurred in many countries (*Richards*, 2016). *Sufferdini* et al. (2020) found that in bivalve shellfish marketed in Hanoi, Vietnam, NoV was the most frequently observed virus (81.8% of samples), with NoV GI and NoV GII detected in 50.4% and 79.3% of samples respectively. In samples collected in the Gulf of Naples, Italy, NoVGII was confirmed in 39.7% of shellfish samples (*Fusco et al.*, 2019). The first comprehensive analysis of the prevalence of NoV in mussels from harvesting sites around the Adriatic Sea coast of Montenegro reveals that 43% of the samples tested positive for the virus, with a greater prevalence of genogroup GII (74.2%) (*Ilić et al.,* 2017). The Centres for Disease Control and Prevention (CDC), the US Food and Drug Administration (FDA), the Texas Department of State Health Services, and other public health partners, are investigating a multistate outbreak of norovirus illnesses linked to raw oysters from Texas and found that 298 illnesses have been reported as of December 20, 2022. At the beginning of this year, US FDA advised restaurants, retailers and consumers to avoid raw oysters from Deep Bay, British Columbia, Canada, that were gathered between January 16, 2023, and February 17, 2023, and distributed in 13 US states, as the shellfish were potentially contaminated with NoV, were not safe and should be thrown away (*FDA*, 2023).

2.2. Viruses — Hepatitis A (HAV) and Aichivirus (AiV)

HAV and AiV are enterically transmitted viruses with clinical importance that are members of the *Picornaviridae* family (*Wells & Coyne*, 2019). Depending on the virus and the susceptibility of the affected people, HAV can cause a variety of symptoms of illness. It is frequently an asymptomatic infection in healthy people with spontaneous remission but can cause liver damage and acute liver failure, which may be fatal. WHO estimated that in 2016, 7134 people died from HAV worldwide (*Randazzo & Sanchez*, 2020). The largest outbreak of HAV occurred in 1988 in and around Shanghai, China, after the consumption of harvested clams, where over 293,000 people became ill, and 47 deaths were reported (*Cooksley*, 2020). According to a prior epidemiological analysis completed by the Korea Disease Control and Prevention Agency in September 2019, salted shellfish, primarily bivalves, were identified as a source of the 2019 HAV epidemic in two South Korean locations (*Hyun, Yoon & Lee*, 2022). The ingestion of raw or undercooked shellfish has been linked to the majority of outbreaks of HAV in shellfish (*Boxman et al.*, 2016). *Boussettine et al.* (2023) have detected HAV in 15.38% of samples from shellfish harvesting areas in Morocco. *Bazir et al.* recently discovered HAV in 46.15% of the mussel samples in Morocco *Bazir et al.,* 2022 and *Fusco et al.* (2019) found HAV in 8.9% of shellfish samples in Italy. The previous authors also found the presence of AiV in 5.6% of the samples in Gulf of Naples, Italy. AiV is currently thought to be an emerging human enteric pathogen that can cause gastroenteritis via contaminated shellfish, even though, the prevalence of AiV in cases of gastroenteritis is modest, ranging from 0.4–6.5% globally (*Macaluso et al.*, 2021).

2.3. Hepatitis E Virus (HEV)

HEV is a member of the family *Hepeviridae* within the genus *Orthopevirus*, which has five human-infecting genotypes (HEV 1, 2, 3, 4 and 7), and according to the World Health Organization (WHO), it can affect nearly 20 million people each year, resulting in roughly 3.3 million acute liver injuries, 56,600 fatalities, and significant subsequent healthcare-related economic losses (*WHO*, 2022). Also, it is considered as an emerging foodborne pathogen. Hepatitis E epidemics commonly occur in Asia and other regions of the world and only a few cases have been reported in the US, even though it can be a devastating condition (*Richards,* 2016). According to reports, the incubation period for hepatitis E is between 2 and 8 weeks, and early symptoms may include nausea, fatigue, anorexia, and low-grade fever before possibly progressing to spleen enlargement and pain in the upper right quadrant, both of which are indicative of liver involvement. *Mast & Krawczynski* (1996) indicate that clinical symptoms often go away in 4–8 weeks, except for pregnant women, who have a mortality risk of 15–25%. Virus transmission involving shellfish has occasionally been observed, but recently, *Rivadulla et al.* (2019) detected HEV in 24.4% of samples in shellfish harvesting areas from Galicia, Spain. Results of *Macaluso et al.* (2021) show that 5.56% of shellfish samples were contaminated with at least one NoV, HAV and/or HEV along the production and distribution chain in Sicily, Italy.

2.4. Astrovirus (AstV), Adenovirus (AdV) and Rotavirus (RV)

Astrovirus, Adenovirus and Rotavirus (they belong, respectively, to the family *Astroviridae, Adenoviridae* and *Reoviridae*) can also be transmitted by shellfish and often result in mild and self-limiting illness. The sudden rise in occurrences, however it is not typically linked to outbreaks. Typically, these viruses affect young infants who have not yet established immunity and symptoms include loss of appetite, occasional vomiting, abdominal pain, diarrhoea and fever (*Richards*, 2016). The incubation period is short (1–3 days) and the illness lasts up to 4 days. Even though there have been few outbreaks reported, these viruses have not been often detected in mussels or oysters (*Upfold, Luke & Knox*, 2021), but *Suffredini et al*. (2020) reported that they can be occur in high concentrations in sewage waters and provide a potential risk for contaminating shellfish. Also, this group showed an alarmingly high level of AstT, 12.4%, in samples of shellfish produced in Vietnam.

3. Conclusion

Since shellfish can be the main vector for transmission of different viruses, it is necessary to reduce viral infections through improving surveillance at all phases of shellfish production, harvesting, distribution and processing. The industry and consumers must enhance their hygiene procedures and reduce pollution. To stop the spread of foodborne viral infections, outbreaks must be better reported and epidemiologically followed up on. Also, better analytical methods for enteric virus detection in shellfish would increase shellfish safety and provide improved consumer and business protection. Recent improvements in analytical methods are projected to improve food and water monitoring capacity and lower the frequency of enteric virus infection among shellfish consumers.

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