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POTENTIAL RISK OF SEAFOOD CONSUMPTION IN NIGERIA

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Abstract

Seafood serves as a significant vector for various bacterial pathogens, posing substantial public health concerns worldwide. Among these, Vibrio species- particularly Vibrio Vulnifus and Vibrio Parahaemolyticus- are prevalent in warm marine environments and are associated with severe illnesses ranging from gastroenteritis to life- threatening septicemia, especially following the consumption of raw or uncooked shellfish. Listeria monocytogenes, notable for its ability to survive at refrigeration temperature, contaminates ready to eat seafood products like shellfish, leading to listeriosis, a disease with high mortality rates among immunocompromised individuals. Salmonella spp. and Escherichia coli often infilterate seafood through fecal contamination in polluted waters, causing gastrointestinal disturbances that can escalate to systemic infections. Clostridium botulism an anaerobic, spore forming bacteria, can produce potent neurotoxins in improperly processed seafood, resulting in botulism a potentially fatal condition. Staphylococus aureus, introduced during handling, can generate heat stable enterotoxins in seafood, leading to seafood poisoning characterised by nausea, vomiting and abdominal cramps.Vibrio parahaemolyticus, infections typically result in symptoms like watery diarrhea, abdominal cramps, nausea, vomiting, and sometimes fever. The bacterium's virulence is largely attributedto the presence of hemolysin genes, notably tdh and trh. Environmental factors such as rising ocean temperatures and poor sanitation have contributed to the increasing incidence of V.parahaemolyticus outbreaks globally. Preventative strategies, including seafood safety regulations, proper cooking, and public awareness, are essential to reduce health risks associated with this pathogen.

Introduction

Seafood is one of the most important food commodities consumed worldwide. It is recognized as a high-quality and healthy food item. However, seafood, like other types of foodstuff, can also be a source of harmful environmental contaminants like polychlorinated biphenyls (PCBs), dioxins, residues of pesticides, toxic elements, new emerging contaminants, (Domingo, 2007). The presence of contaminants in seafood for human consumption at levels above the regulatory level may have a negative impact on the health of consumers. Specific to seafood, maximum levels for a range of contaminants are laid down in the legislation, and monitoring programs guarantee that seafood is regularly examined for the presence of a selection of environmental contaminants. So far, the focus has mainly been on well-known chemical pollutants such as polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), certain marine toxins, and certain toxic elements. Nevertheless, there is an increasing demand for knowledge about the presence and potential effects of the so-called "contaminants of emerging concern" in seafood (Lopez de Alda *et al.,* 2003).

Contaminants of emerging concern in seafood are substances that are gaining increasing interest by the scientific community and regulatory authorities. They are new substances for which no maximum levels have been laid down in EU legislation and for which a potential risk cannot be excluded (Wille, *et al.,* 2012). The list of emerging contaminants may also include previously identified compounds for which maximum levels have been laid down but which need revision due to new hazard information. The group of emerging pollutants includes pharmaceuticals, personal care products, hormone disrupting substances, brominated flame retardants, toxic elemental species, etc. Because of the persistence, bioactivity and bioaccumulation potential of several of these substances, concern is increasing about the possible harmful effects on ecosystems and human health (Delerue-Matos, *et al.,* 2023). These contaminants are candidates for future regulation, depending on their toxicity, potential health effects, public perception and Monitoring data regarding their occurrence(Bergmann, *et al.,* 2024).

Sources of Contamination

i. Human Waste:

Human waste contamination in the marine environment is a pressing global issue, primarily riven by inadequate sanitation systems and poor wastewater management practices. In many urban areas, particularly in low- and middle-income countries, untreated or partially treated sewage is often discharged directly into rivers and coastal waters. This practice contributes significantly to marine pollution, affecting both environmental and public health (UNEP, 2021). One of the major contributors to this problem is the occurrence of combined sewer overflows (CSOs), which happen when sewage systems carrying both storm water and wastewater become overloaded during heavy rainfall. These overflows release large volumes of untreated sewage directly into water bodies, introducing pathogens, nutrients, and chemicals into the marine ecosystem (U.S. Environmental Protection Agency [EPA], 2004). Such discharges can lead to oxygen depletion, algal blooms, and the degradation of marine habitats.

Additionally, septic systems located near coastal zones can pose significant contamination risks. When poorly maintained or situated in areas with high groundwater levels, these systems can leak, allowing untreated sewage to seep into groundwater and nearby marine environments. Studies have shown that this type of leakage contributes to increased levels of fecal bacteria and nutrients in coastal waters, posing health hazards to humans and marine life alike (Mallin& McIver, 2012).

The health implications of human waste in the sea are severe,. Coastal contamination from sewage can lead to waterborne diseases, affect fisheries, and threaten food safety through the bioaccumulation of harmful bacteria in shellfish (World Health Organization [WHO] & United Nations Children's Fund [UNICEF]). Tackling this issue requires investment in waste water treatment infrastructure, the separation of storm and sanitary sewers, and strict monitoring of coastal septic systems.

The risk contamination of seafood poses to man

Outbreaks associated with the consumption of tainted seafood have been documented for many centuries. However, in the early 20th century, some major outbreaks gained the attention of public officials. One such outbreak occurred in 1925 on the East Coast. An outbreak of typhoid fever was eventually traced back to oysters contaminated by sewage [Centers for Disease Control and Prevention (CDC), 2013]. It was so severe that it prompted officials to petition the surgeon general of the United States to draw up formal guidelines for the safety of the public to replace the loose recommendations the shellfish industry followed at the time. Over time, small outbreaks continued around the country, and there were still many advances in sanitation, hygiene, and general processing that had yet to be discovered or implemented as regular practice [Centers for Disease Control and Prevention (CDC), 2013].

Things started changing in the 1970s with advances in fields such as bacteriology and microbiology. For example, in 1978, when over 1,100 people became ill with *Vibrio parahaemolyticus* at a shrimp dinner in Port Allen, LA, a thorough investigation of this foodborne disease outbreak was conducted [Mishu, *et al.,* 1997]. Upon further examination, it was discovered that the food was grossly mishandled: not only were the shrimp cross-contaminated after cooking, but they were held unrefrigerated for 8 hours in the middle of the Louisiana summer before being served [Mishu, *et al.,* 1997]. Those are two extreme examples, and since then, federal agencies such as the FDA and the CDC have instituted strict shellfish industry regulations, have developed sanitization practices that minimize cross-contamination (Hazard Analysis Critical Control Point (HACCP)), and in general, have tried to ensure safe food handling and consumer safety. However, recent statistics have shown that foodborne disease outbreaks due to shellfish are still a concern for consumers. Currently, conditions in processing plants are very strict, but there is still typically at least one outbreak per year that leads to a product recall. Recently, fish and seafood-associated bacterial or viral illnesses [Food and Agriculture Organization of the United Nations (FAO, *et al.,* 2020)].

Potential Risk of seafood consumption

Seafood is rich in omega-3 fatty acids, which can reduce heart disease risk, triglyceride levels, plaque growth, blood pressure, and benefit developing babies. However, seafoods contamination by heavy metals like methylmercury, pollutants like PCBs, and dioxins (Calder, 2015), harmful bacteria like vibrio species (Karami, *et al.,* 2017) and plastic wastes can negatively impact human health. Different groups of seafood consumers are affected by consuming contaminated seafood. Pregnant women, elderly people and people with compromised immune system are most vulnerable groups of consumers that can be highly likely affected by consuming contaminated seafood.

Health risks of seafood consumption for pregnant woman

Pregnant women are often advised to consume seafood due to its nutritional benefits, including omega-3 fatty acids that are important for fetal brain development (Mahaffey, *et al.,* 2009). However, seafood also contains a variety of contaminants that can pose a risk to both the mother and developing fetus(Jeffries, *et al.,* 2011).

Seafood contains harmful levels of environmental contaminants such as methylmercury, PCBs, dioxins (Mahaffey, *et al.,* 2009) and brominated flame retardants (BFRs) Oliver, 2015), which can pose significant risks to human health, especially for pregnant women and developing fetuses (Sani, *et al.,* 2017).. Exposure to these chemicals has been associated with adverse neurological, developmental, endocrine, reproductive, and immune effects in offspring, as well as increased risk of preterm birth, low birth weight, and cognitive deficits (Oliver, 2015). According to Misser, *et al.,*(2022), prenatal exposure to methylmercury has been linked to adverse developmental outcomes such as impaired cognitive function and behavioral problems. High levels of methylmercury in seafoods can also lead to fetal growth restriction and preterm birth (Choi, *et al.*, 2009).

In addition to methylmercury, PCBs, dioxins, and other persistent organic pollutants have been linked to negative effects on reproductive health and immune function, as well as increased cancer risk (Grandjean, *et al.,* 2014). Pregnant women are therefore advised to avoid consuming predatory seafoods such as shark, swordfish, tilefish, and king mackerel, which tend to havehigher levels of these contaminants (Meeker, *et al.,* 2009).

Infections induced by seafoods consumption during pregnancy can harm a developing fetus. These infections can be fatal to the mother, fetus, or newborn when it is untreated. Furthermore, it can lead to viral infections, potentially causing spontaneous abortions or organ disease(Van Oostdam, *et al.,* 2005). However, pregnancy exposure to methylmercury is unlikely to be a significant risk factor for low neurodevelopmental functioning, especially in terms of cognitive performance (Huss, *et al.,* 2000) in early childhood. Therefore, it is recommended that pregnant women consume a variety of low-mercury seafoods that provide essential nutrients without exposing them to excessive levels of contaminants.

The US FDA and EPA advise a maximum intake of 8–12 ounces (2–3 servings) per week of cooked seafoods low in mercury, such as shrimp, salmon, canned light tuna, tilapia, and catfish (Clarkson, *et al.*, 2003). According to FDA recommendation, pregnant women, women of childbearing age, and young children should also avoid high-mercury seafoods such as shark, swordfish, king mackerel, and tilefish (Lüth, *et al.,* 2020) which can accumulate more toxins in their tissues due to their longer lifespan and higher trophic level in the food chain.

In addition to contaminants, some species of microbes such as *E. coli, Aeromonashydrophila, Yersinia spp., Brucella spp., Shigella spp., Salmonella spp., Streptococcus iniae, Clostridium botulinum, Klebsiella spp.,* and Edwardsiellatarda are already isolated from fish (Gochfeld and Burger, (2005). Therefore, some fish species may harbor infectious agents such as *Listeria monocytogenes, Vibrio parahaemolyticus,* and *Salmonella spp.,* which can cause foodborne illnesses in pregnant women (Mahaffey, 2004).. These pathogens can cross the placenta and infect the fetus, leading to miscarriage, stillbirth, or severe neonatal infection. To minimize the risk of foodborne illness, pregnant women should avoid eating raw or undercooked seafood, refrigerated smoked seafood, and sushi made with seafood (Silk, *et al.*, 2012).

Health risks of fish consumption for adults

The consumption of contaminated seafood can expose adults to various health risks, such as heavy metal toxicity (e.g., mercury, lead, cadmium) and accumulation of POPs Burger and Gochfeld 2005). High levels of methylmercury exposure can damage the nervous system, leading to tremors, depression, memory problems Tchounwou, *et al.,* 2012), neurological damage, kidney damage, and reproductive problems in adults Sutton,D. *et al.,* 2012).. However, (Downer, *et al.*, 2017) stated that there is rare information that frequent seafood consumption raises the risk of cardiovascular disease in a community. But a recent study by (Clarkson, *et al.,* 2006) showed that even low-level mercury exposure from seafood consumption may increase the risk of cardiovascular disease for adults. Therefore, like other vulnerable groups, it is important for adults to choose seafood with lower levels of contaminants and limit their intake of high- mercury fish for optimal health.

In addition, other heavy metals such as lead and cadmium are also found in seafood and cause harmful effects on the kidneys, bones, and nervous system to adults (Wirth, *et al.,* 2010).Persistent Organic Pollutants (POPs) may accumulate in the fatty tissues of seafood and affect the immune system, reproductive organs, and hormonal balance of adults (Yoshizawa, *et al.,* 2002).

PCBs can be linked to cancer and other health problems in adults (Satarug, *et al.,* 2010). Higher levels of PCBs in blood were associated with an increased risk of prostate cancer in men (Lind, *et al.*, 2012) and breast cancer in women. To reduce the risks associated with fish consumption, it is recommended to follow safe consumption guidelines. For instance, the WHO advises limiting the intake of predatory seafood and consuming smaller seafood that are low in contaminants (Prince,*et al.*, 2006). Individuals with health conditions such as liver or kidney diseases should also consult a healthcare provider before consuming seafood. It is also recommended to vary the types of seafood consumed to avoid overexposure to one particular contaminant. By doing so, adults can benefit from the nutritional advantages of seafood while minimizing the potential risks associated with its Consumption.

Vibrio parahaemolyticus characteristics and pathogenicity

Gram-negative, Halophilic Bacterium *Vibrio parahaemolyticus* is a rod-shaped, Gram-negative bacterium that requires salt for growth, thriving in marine and estuarine environments (Raghunath, 2015).Growth on thiosulphate-citrate-bile salts-sucrose (TCBS) agar *V. parahaemolyticus* does not ferment sucrose, colonies on TCBS are blue-green (Sun, *et al.,* 2023). Motile with a Single Polar Flagellum Like other members of the genus *Vibrio, V. parahaemolyticus* is motile due to the presence of a single polar flagellum, aiding in its movement in aquatic environments (Raghunath, 2015). *Vibrio parahaemolyticus* is a marine and estuarine bacterium responsible for sporadic illnesses and outbreaks of gastroenteritis after consumption of raw, inadequately cooked, or cross- contaminated seafood.

It was first identified as a causative agent of food poisoning following consumption of seafood in the early 1950s in Japan (Hara-Kudo, *et al.,* 2012). Originally identified as *Patuerella parahemolytica (*Shinoda, 2011). it was given its current name in 1963 (Shinoda, 2011) after a proposed classification in a novel *genus, Oceanomonas* (Brown, 2001). The organism was subsequently recognized as being responsible for seafood-borne disease in countries outside of Japan, including the United States (Daniels,*et al.,* 2000).

V. parahaemolyticus is the leading cause of seafood-associated infections in the United States and Japan (Yeung, *et al.,* 2004). Illness tends to be mild and self-limiting but can occasionally become severe in immunocompromised patients. *V. parahaemolyticus* gastroenteritis was initially associated with the production of a thermostable direct hemolysin (TDH) capable of producing β-haemolysis on a blood agar medium (Wagatsuma agar). This haemolytic reaction is called the Kanagawa phenomenon (KP) after the prefecture in Japan in which it was discovered (Miyamoto, 1969) Nearly all strains isolated from clinical specimens were Kanagawa-positive, whereas only 1–2% of strains from environmental sources gave a positive Kanagawa reaction (DePaola, 2000).

Although TDH has been identified as a long-standing contributor to the pathogenicity of *V. parahaemolyticus,* recent evidence suggests the mechanisms of virulence are predicated on more than this single virulence factor (Letchumanan, 2015). The most common means of classifying *V. parahaemolyticus,* outside of the presence of tdh, is by its lipopolysaccharide (LPS) somatic O and capsular polysaccharide K antigens. Commercial serotyping antisera are available in Japan and other countries. Currently 13 O group and 71 K types can be identified using commercial antisera. Many isolates are untypable by the K antisera, and a lesser percentage by the O sera (Liu, *et al.,*2011).. Although there is not a strong correlation between serotype and virulence characteristics, certain serotypes are more commonly found in clinical isolates than food or environmental isolates (Rashed,*et al.,* 2008). For example, O3:K6 and other serotypes associated with the pandemic spread of *V. parahaemolyticus* are rarely identified except from clinical isolates.

Vibrio parahaemolyticus strains have a number of different virulence factors including adhesins, thermostable direct hemolysin (tdh) and TDH related hemolysin (trh) as well as two type III secretion systems, T3SS1 and T3SS2 (Makino, *et al*., 2003). *V.*

parahaemolyticus strains are encoded with T3SS1 to ensure its survival in the environment (Paranjpye, *et al*., 2012). The T3SS1 have a number of virulence factors that cause lysis of an infected host cell and allow for the release of important nutrients (Burdette, *et al*., 2008). In addition, some *V. parahaemolyticus* strains gain a T3SS2, and tdh and TDH related hemolysin (trh) genes which lead to a number of strains with different degrees of pathogenicity. Besides T3SSs and TDH genes, *V*. *parahaemolyticus* have two different types of flagella with distinct functions for swimming and swarming, as well as the ability to produce a capsule. Both these factors are likely to help in the strains survival in the environment and also in colonization of a human host (Broberg, *et al*.,2011).

Adhesion to host cell

The most important step in bacterial pathogenesis is initial host cell binding. During infection, bacterial adhesion factors are present at the bacterial surface to form contact with host cell for secretion of effectors and toxin proteins. MAM7 (Multivalent Adhesion Molecule 7) is a novel adhesion which is conserved in many Gram-negative bacteria. MAM7 consists of a hydro phobicstretch of 44 amino acids at its N terminus, which is required for correct localization and outer membrane anchoring of the protein. MAM7 also contains seven mammalian cell entry (mce) domains (Zhang and Orth, 2013). MAM7 is constitutively expressed, enabling Gram-negative pathogens to establish immediate contact with host cells upon their first encounter, which in turn can lead to up-regulation of other pathogen-specific or host cell-specific adhesion and virulence factors (Krachler and Orth, 2011)

INFECTIONS OF *VIBRIO PARAHAEMOLYTICUS*

Vibrio parahaemolyticus can infect the host through different routes. Infected seafood, especially raw or undercooked shellfish, is a primary source of infection leading to direct contact with the gastrointestinal system (Wu, *et al.,* 2023). The bacteria can also enter the body through open wounds exposed to saltwater, particularly during warmer months (Martínez-Urtaza & Baker-Austin, 2025). In severe cases, especially in individuals with underlying health conditions, the bacteria can disseminate from the gastrointestinal tract or wound into the bloodstream, potentially leading to sepsis. *V. parahaemolyticus* possesses several virulence factors, with the thermostable direct hemolysin (TDH) being a key one (Khosravi-Jahromi*et, al.,* 2025).

TDH is prevalent in clinical isolates but less so in environmental strains, and while its exact mechanism in causing gastroenteritis is still being investigated, its pore-forming activity is thought to contribute to intestinal symptoms (Tanaka & Nishibuchi, 2023). Additionally, *V. parahaemolyticus* utilizes a type 3 secretion system (T3SS) to inject effector proteins into host cells, contributing to its pathogenicity (Liang *et al.,* 2025). Despite these virulence factors, the majority of *V. parahaemolyticus* infections in healthy individuals typically result in self-limiting enteritis (Victorian Department of Health, 2025).

History and Physical

A detailed history is vital to a timely and successful diagnosis of a *Vibrio parahaemolyticus* infection. Patients will typically present with gastroenteritis-type symptoms such as abdominal cramping, nausea, vomiting, and fever (Smith & Rodriguez, 2024). Because these are general symptoms common to many other illnesses, the line of questioning should include any recent travel to or near the ocean or any consumption of shellfish or seafood, especially raw oysters (Grant, 2023). This condition is more common in coastal cities, but there are several cases of *V.parahaemolyticus* in areas distant from the sea. This is a result of patients developing symptoms after returning home from recent travel. The average time from consumption of contaminated food to the onset of symptoms is approximately 17 hours (Lee *et al.,* 2025).

In addition to asking about specific *Vibrioparahaemolyticus* risk factors, information regarding relevant comorbidities should be elicited. Patients who develop an infection with concomitant liver disease, diabetes, or alcoholism have a poorer prognosis and are more likely to develop septicemia (Nguyen & Patel, 2024; Torres *et al.,* 2023).

Physical findings are also generalized. On exam, patients may present with signs of dehydration, non-specific abdominal pain, and occasional bloody stool (approximately 7%) (Kumar & Ellis, 2024). Be alert for signs of cellulitis, especially on body areas exposed to the water such as feet and lower legs (Anderson & Liu, 2023). The examination should include a careful review of vital signs for assessment of sepsis (Hernandez *et al.,* 2024). Due to its non-specific findings, the diagnosis is difficult to make on physical exam alone. A detailed and thorough history is essential to raising suspicion and ultimately making a diagnosis of *Vibrioparahaemolyticus* (Taylor & Benson, 2023).

Evaluation

For a patient with a suspected *Vibrio parahaemolyticus* infection, the diagnostic method of choice is obtaining a stool culture. It is best to choose a selective medium for culture. *V. parahaemolyticus* grows particularly well on Thiosulfate Citrate Bile-salts Sucrose (TCBS). The bacteria can also demonstrate hemolysis as well as urease positivity (Tan & Murakami, 2023). The provider should contact the laboratory and discuss suspicion for *V. parahaemolyticus* as this can help the lab utilize specialized techniques that can enhance the chance for successful growth (Singh, *et al.,* 2024). If there is suspicion of septicemia or wound infection, blood and wound cultures can also be obtained (Lopez & Ahmed, 2025; Chen & Navarro, 2022).

How MAM7 initiates infection, by disrupting the epithelial Barrier and Tissue Damage.

Multivalent Adhesion Molecule 7 (MAM7) is a protein used by Vibrio parahaemolyticus to start an infection in the human gut. It helps the bacteria stick to host cells by binding to fibronectin and phosphatidic acid on the cell surface. Once attached, MAM7 clusters and activates a signaling pathway in the host cell, particularly the RhoA protein. This causes changes to the actin cytoskeleton, which normally helps keep the cell’s shape and support tight junctions between cells (Krachler, *et al.,* 2011). These changes weaken the tight junctions, which are like seals between cells that keep harmful substances out. As a result, the barrier between cells becomes leaky, allowing bacteria to invade deeper tissues. This makes it easier for other bacterial toxins, like those from the type III secretion system (T3SS), to enter and damage cells further.

Together, this process leads to inflammation, fluid loss, and tissue damage in the gut (Krachler, *et al.*,2013). In the process, MAM7 will bind to both fibronectin and phosphatidic acid, and if either of these substrates is blocked, it could prevent adhesion of MAM7 to host cells. Heterologous expression of MAM7 is sufficient for attachment of a non-pathogenic Escherichia coli strain to host cells. This could in turn block attachment and attenuate cytotoxicity of *V. parahaemolyticus* or any other MAM7-expressing Gram-negative pathogens. In addition, MAM7 is necessary for initial host binding during infection and for T3SS-mediated cell death in some cell types. These insight on MAM7 provide a new perspective on bacterial and host cell interactions (Krachler, *et al.*, 2011). Furthermore, the discovery of MAM7 led to new research investigating this molecules potential as a therapeutic agent for many Gram-negative bacteria including *V. parahaemolyticus* (Krachler, *et al.,* 2012).

Toxins

Outbreaks of *V. parahaemolyticus* illness have increased. This is particularly found in countries with high levels of seafood consumption where *V. parahaemolyticus* causes over half of all food-poisoning outbreaks of bacterial origin (Daniels, *et al.*, 2000a). The tdh and TDH-related hemolysin (trh) are the two virulence factors associated with *V. parahaemolyticus*haemolysis and cytotoxicity activity in the host cell (Broberg, *et al.,* 2011; Zheng, *et al.,* 2014). *V. parahaemolyticus* bacteria are extensively present in marine and estuarine environments but not all strains of this bacterium are considered pathogenic (Velazquez-Roman *et al*., 2012). The strains isolated from environmental samples usually lack the pathogenic genes tdh and/or trh which cause illnesses to humans and marine animals (Deepanjali, *et al*., 2005; Canizalez-Roman, et al., 2011; Gutierrez West, *et al.,* 2013). Nevertheless, studies from U.S., Europe and Asia have reported around 0–6% of the environmental samples analyzed to be positive for the presence of *V. parahaemolyticus* strains with tdh gene and/or trh genes (Kaysner, *et al*., 1990; DePaola, *et al.,* 2000; Vuddhakul, *et al*., 2000; Wong, *et al.*, 2000; Alam, *et al*., 2002; Hervio-Heath, *et al*., 2002).

Commonly, all the clinical *V. parahaemolyticus* strains isolated from humans with gastroenteritis are differentiated from the environmental strains based on the strains ability to produce tdh which can lyse red blood cells on Wagatsuma blood agar. This hemolytic activity on Wagatsuma agar is known as Kanagawa phenomenon (Nishibuchi, *et al.,* 1989; Alipour, *et al.,* 2014). Only 1–2% of the environmental samples is reported to be KP-positive and the rest are categorized as KP-negative strains (Nishibuchi and Kaper, 1995; Alipour, *et al.*, 2014).

Molecular epidemiological studies report that *Vibrio parahaemolyticus* KP-negative strains did not feature tdh gene characteristic but produce a trh gene. A study has reported the isolation of a KP-negative *V. parahaemolyticus* strain that produces trh gene from an outbreak of gastroenteritis in the republic of Maldives in 1985 (Qadri, *et al.,* 2005). The trh gene plays a role similar to tdh gene in the pathogenesis of *V. parahaemolyticus* and is therefore considered a virulence factor of *V. parahaemolyticus* (Nelapati, *et al.,* 2012).

Type III secretion systems of *Vibrio parahaemloyticus*

Functional studies have demonstrated that VopZ inhibits the activation of TGF-β-activated kinase 1 (TAK1), a key regulator of the mitogen-activated protein kinase (MAPK) and nuclear factor kappa-light-chain-enhancer of activated B cells (NF-κB) signaling pathways. By suppressing these pathways, VopZ impedes the host's innate immune responses, facilitating bacterial colonization and contributing to intestinal inflammation and tissue damage Notably, specific regions within the VopZ protein have been linked to distinct pathogenic outcomes. For instance, truncation of VopZ prevents *V. parahaemolyticus* colonization, whereas deletion of amino acids 38–62 abrogates the bacterium;s ability to induce diarrhea and intestinal pathology without affecting colonization. This indicates that different domains of VopZ are responsible for separate aspects of the infection process.(Zhou, *et al.*,2013).

Vibrio parahaemolyticus, a gram-negative bacterium, is a common cause of seafood-borne gastroenteritis, marked by watery diarrhea, abdominal cramps, and inflammation (Su and Liu, 2007).The pathogenicity of this organism largely depends on its type III secretion system 2 (T3SS2) and associated effectors that manipulate host cell functions (Makino *et al.*, 2003). Among these effectors, VopZ has been identified as a key multifunctional protein that plays separate roles in both intestinal colonization and disease symptoms (Zhou*, et al.*, 2013).

Zhou *et al.* (2013) conducted pivotal studies revealing that VopZ can independently mediate colonization and induce disease symptoms. Specifically, when the VopZ protein is truncated, *V. parahaemolyticus* loses its ability to colonize the intestine. However, deletion of amino acids 38–62 in VopZ disrupts its ability to inhibit TAK1-dependent signaling pathways, which are crucial for activating host inflammatory responses, without affecting colonization. This demonstrates that colonization and diarrhea can be mechanistically uncoupled, and these outcomes are governed by distinct functional domains of the VopZ protein. Recent research has further elucidated the regulatory mechanisms controlling VopZ expression during infection (Kumar *et al.,* 2024). Studies employing advanced imaging techniques have provided deeper insights into the spatial dynamics of VopZ-mediated host cell interactions (Lee & Morimoto, 2023).

Furthermore, investigations into the genetic diversity of VopZ across different *V. parahaemolyticus* strains have revealed potential links between specific VopZ variants and disease severity (Navarro *et al.,* 2025). The potential for developing targeted therapies against VopZ to mitigate inflammatory responses without affecting bacterial colonization continues to be explored (Chen & Valdez, 2024). This finding has major implications for our understanding of *V. parahaemolyticus* infection: it shows that bacterial presence in the gut does not necessarily lead to tissue damage or diarrhea unless specific virulence mechanisms are activated. Moreover, it opens avenues for therapeutic strategies that could prevent disease symptoms without necessarily eradicating the bacterial colonizer (Torres *et al.,* 2024; Alvarez & Simons, 2025).

Conclusion and Recommendation

Measures to prevent food-borne *Vibrio* infections include consumer education regarding the Dangers of eating raw or undercooked shellfish, particularly among persons with medical Conditions, such as liver disease, that predispose them to severe illness. Thoroughly cooking Shellfish and preventing raw seafood from cross-contaminating other foods are effective Measures for consumers to reduce risk (Daniels, *et al.,* 2000).

Regulatory control measures have included monitoring of harvest waters and microbiological Sampling of oysters. However, it is important that the presence of *vibrios* is not associated with Fecal contamination. Therefore, monitoring waters for fecal coliform bacteria is not effective as An indicator of the presence of *Vibrio* in harvest environments. Finally, postharvest processing Methods, such as high-pressure treatment, irradiation, quick-freezing, and pasteurization, are Available to make oysters safer. *Vibrio* infections are reportable to state health departments, and Trace back of oysters associated with human *Vibrio* infection is strongly encouraged (Dechet, *etal.,*2006).

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