Review Article

BASJVETRES

BASRAH JOURNAL OF VETERINARY RESEARCH, 2024, 23(4):265-277.
https://bjvr.uobasrah.edu.iq/

The Dual Threat of *Aeromonas* Species: Aquatic Pathogens and Emerging Human Health Concerns

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DOI: https://doi.org/10.23975/bjvr.2024.152038.1118

Received: 20 July 2024 Accepted: 8 September 2024.

Abstract

Aeromonas species are facultatively anaerobic, Gram-negative, rod-shaped, non-spore-forming, oxidase-positive bacteria. They are divided into the non-motile psychrophilic aeromonads and the motile mesophilic aeromonads. Due to the possibility that phenotypic identification techniques may not correctly identify some of the species, the taxonomy of this genus is complicated. Most Aeromonas strains are fish infections that cause hemorrhagic septicemia, which frequently increases mortality and causes large financial losses in aquaculture. *A. caviae, A. hydrophila, A. sobria, A. salmonicida,* and *A. veronii* are often linked to fish disease and mortality. These bacteria are commonly found in freshwater, soil, and agricultural produce. The genus Aeromonas belongs to the Aeromonadaceae family. It comprises a group of these bacteria widely distributed in aquatic environments, with some species able to cause disease in fish, other aquatic animals, and humans. However, bacteria of this genus are isolated from many other habitats, environments, and food products, which have been recognized as an important pathogenic species in aquaculture that causes motile Aeromonas septicemia, red spot diseases, infectious dropsy and Furunculosis. However, vaccination is the ideal strategy to avoid infectious diseases. Gastroenteritis, bacteremia, and wound infections have dominated since aeromonads were first linked to human disease. Based on current information about the ecology, epidemiology, and pathogenicity of the genus Aeromonas, we should assume that these bacteria produce a significant health problem in the future. The objectives of this review are to ascertain how Aeromonas affects aquaculture and human health and how to prevent it.

Keywords: Aquaculture, *Aeromonas* species, Bacterial infections, Human health disorder.

Introduction

Aquaculture is commonly referred to as fish farming, production, leisure activities, methodical cultivation, and rearing aquatic plants, animals, and other living organisms (1). Fish cultivation and distribution are common concerns of aquaculture and fisheries, with very little distinction between them (2). In many nations, fish constitute a significant source of food and money, as their economy depends partly on fishing and aquaculture (3). The aquaculture industry has seen increased demand and has benefited from this by rising to prominence within the development of the industry; this has made a great ability to satisfy the rising global demand for seafood and caused aquaculture to grow rapidly (4). Epidemics are one of the primary problems in aquaculture and have environmental, social, and economic repercussions. Bacterial infection outbreaks such as Aeromonas zoonosis increase mortality in fish farms (5).

The *Aeromonas* genus belongs to the family *Aeromonas* and contains a diverse group of Gram-negative bacteria that act as opportunities-seeking pathogens. These microorganisms are naturally distributed in a variety of water-based systems that can be easily isolated from shellfish and fish, allowing them to be discovered through several sources such as plants, soil, reptiles, and amphibians. they can be harmful to fish, people, and other aquatic animals. The disease process usually occurs in people with weakened immunity and in fish and other marine species when they are under stress (6, 7).

In association with growth conditions and biochemical characteristics, the Aeromonas genus is divided, into two main subgroups: motile, mesophilic species (*A. hydrophila, A. caviae, and A. sobria*), which grow well at 35–37 °C and non-motile, psycnrophilic species (*A. salmonicida*) with good growth between 22 and 25 °C (8). The classification of Aeromonas has changed significantly, with more new species added since 1992. Determining the species-level of a strain can be difficult due to the diverse behavior of the strain, which has led to too much confusion and misunderstanding (9).

Different strains of Aeromonas are primarily fish pathogens. They cause hemorrhagic septicemia, which often results in increased mortality and significant economic losses in aquaculture. *Aeromonas caviae, Aeromonas hydrophila, Aeromonas sobria, Aeromonas salmonicida* and *Aeromonas veronii* are commonly implicated in fish disease and mortality. *A. salmonicida* is also considered an important pathogen among a variety of fish, causing furunculosis in salmonids (10, 11).

Aeromonas hydrophila is found in all inland waters, bottom sediments, and aquatic organisms. It dominates the microflora of water-based fish, especially in the digestive system and skin mucous. This poses a common threat to fish welfare, especially in high-density aquaculture's intense feeding systems. Direct contact with diseased fish is the common way to spread the infection or environmental pollution and poses health ris ks during food processing (12). In humans,

mesophilic Aeromonads are well known as agents for causing various systemic and extra intestinal infections, including gastroenteritis, peritonitis, septicemia and diarrhea (13, 14). Th are to ascertain how Aeromonas affects aquaculture and human health and how to prevent it.

Challenges and Advances in Aeromonas Taxonomy and Identification

The taxonomy of a genus can become complicated with phenotypic identification because closely related species may exhibit convergent evolution, where they develop similar traits independently, leading to potential misidentification based on phenotype alone (15). However, molecular techniques, including employing concatenated housekeeping gene sequences, have been shown to be quite reliable. Since 1992, several species have been classified as belonging to the genus Aeromonas, indicating that it has always remained flexible (7). The first classification within the genus Aeromonas based on development characteristics and biochemical testing was established by *Aeromonas* in the late 1950s and early 1960s. In particular, Aeromonas was formally classified in 1958 by W. L. B. Phillips, who used phenotypic characteristics and biochemical testing to identify and differentiate species within the genus (16). Nevertheless, due to phenotypic heterogeneity and the increasing number of known species, it is so difficult to identify many strains of Aeromonas based on these species-level traits (17). Before the end of 1970, scientists used the physiological traits and host range of Aeromonas to divide them into two major categories. Adaptable Aeromonads and those anticipated to cause human illnesses was identified as being *A. hydrophila* and non-motile Aeromonad which infects fish called *Aeromonas salmonicida* (18). There are at least eight pathogenic motile Aeromonas species that are known to be found in aquaculture: *A. hydrophila, A. veronii, A. jandaei, A. caviae, A. sobria, A. bestiarum, A. dhakensis, and A. schubertii.* Some of these species have been known to cause up to 100% mortality during disease outbreaks (19).

Virulence and Epidemiology of Aeromonas: Implications for Health and Safety

Some species possess virulence factors, such as flagella, elastase, hemolysins, aerolysins, adhesins, enterotoxins, phospholipases, and lipases, which result in pathogenic activities and allow them to penetrate, colonize, and damage host cells. It can result in a variety of health issues, including hemorrhagic septicemia, ulcers, enteric infections, and gastrointestinal issues (20). Numerous sources, such as drinking water and ready-to-eat foods (fish, meat, fresh vegetables, dairy products, and others), have been found to contain Aeromonas (21). The Aeromonas is widely distributed through many biomes and taken from the surface as well as from a number of clinical samples (22). In aquatic habitats, during the warmer months of the year, ' 'fairly safe to assume that higher concentrations of aeromonads increase the possibility of exposure to these bacteria and elevate the risk of infection (23). Direct contact with diseased fish is the common

way to spread the infection or environmental pollution and poses health risks during food processing (12).

These emerging bacteria can infect people with strong and weak immune systems (24). Based on pathogenicity, epidemiology, and other factors of Aeromonas, we should anticipate that these bacteria's infections will continue to be a significant health problem. This issue will be worsened by the proliferation of these bacteria and the rising older density for which these bacteria are an adversarial infection (7).

Aeromonas hydrophila: A Growing Threat to Aquaculture

Infectious diseases are a major burden in aquaculture end a significant yield-limiting factor in production that is costly to manage. They are also a potential vector for zoonoses (25). The most common aquatic pathogenic bacteria are Aeromonas (26). The importance of Aeromonas spp., an opportunistic fish pathogen frequently found in estuary, freshwater, and saltwater environments, is growing for the aquaculture sector (27). There are at least eight pathogenic motile Aeromonas species that are known to be found in aquaculture: *A. hydrophila, A. veronii, A. jandaei, A. caviae, A. sobria, A. bestiarum, A. dhakensis, and A. schubertii*. Some species have been known to cause up to 100% mortality during disease outbreaks (19). *Aeromonas hydrophilia* causes freshwater fish diseases, impacting global food supply and aquaculture finances. Symptoms include edema, motile Aeromonas septicemia, bacterial hemorrhagic enteritis, bacterial hemorrhagic septicemia (28, 29). The outbreaks of sickness occur when the water is above 21 °C, due to the extremely hemolytic nature of the infection (30). Affected fish typically exhibit advanced illness symptoms such as lethargy, loss of appetite, and an icteric look (31).

Bacterial hemorrhagic septicemia and fin- or tail-rot

Aeromonas hydrophilia is considered one of the best hazardous producing mortality outbreaks in several species of cultured fish linked to enormous loss of economic resources in numerous nations (32). Both wild and cultivated fish are frequently affected by Aeromonas spp., particularly *Aeromonas hydrophilia,* which is known to induce hemorrhagic septicemia with indications of ulceration, epizootic ulcerative syndrome (Fig.1) (33), and tail or fin erosion (34), as shown in (Fig.2). (35).

Fish stopped eating and exhibited abnormal swimming behavior, in the aquarium at the bottom remaining, protruding scales, edema within scale pockets being absorbed, and exophthalmia (36). There seems to be hemorrhage at the operculum and in the mouth; bases of the fins, with a bloated abdomen and hemorrhagic protrusions from the anal region, were similarly noticed. In addition to lighter or darker skin and have developed or not developed ulcers (37). Internally, the fish displayed pale gills, a high level of intestinal fluid buildup, pale gonads, an enlarged liver, gall bladder, and spleen, as well as empty or partially empty

bowels and stomach, along with a darkened and expanded posterior kidney. Also, fish displayed an increase in white blood cells, which may indicate that they are migrating from the spleen to the bloodstream and causing leukocytosis (36, 37). A significant bacterial infection with Aeromonas is often isolated from sick fish worldwide, which histologically causes alterations in the fish's kidneys, liver, and intestines (38).

A virulent strain of *Aeromonas hydrophila, A. veronii, A. dhakensis, A. jandaei, A. sobria, and A. caviae* led to severe illness and a significant mortality rate (5,39). Acute hemorrhagic septicemia and chronic ulcerative syndrome were described as the two types of the illness (40). In addition, severe hemorrhagic dermatitis, abdominal hyperemia, moderate ascites, pan ophthalmitis, and orbital cellulitis that result in ocular rupture are motile Aeromonas septicemia instances (41).

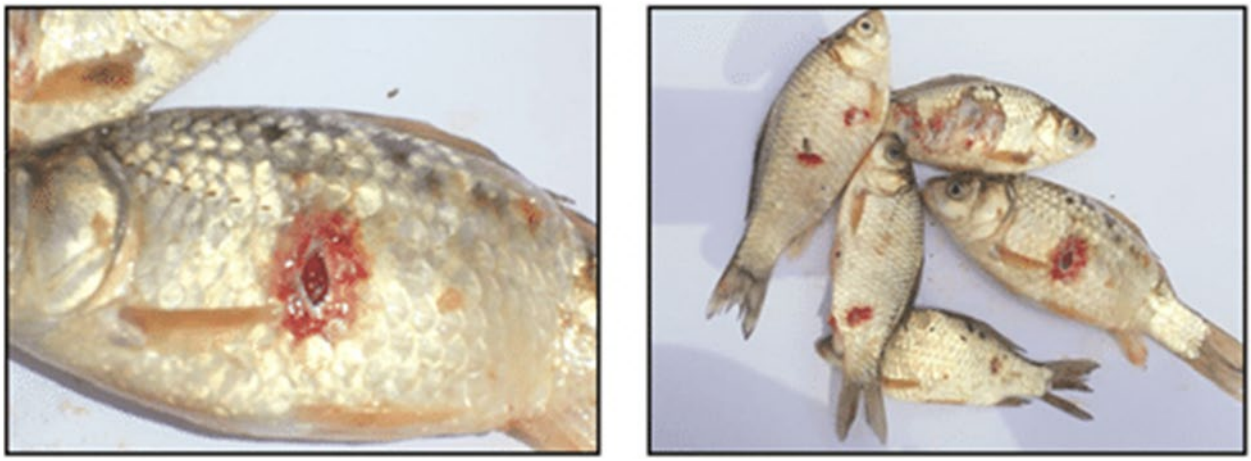

Figure 1: Fish infected with *Aeromonas hydrophila* (33).

Figure 2: Photograph of *Cyprinus carpio* with skin infection and Fin rot with *A. sobria* and *A. hydrophila* (35).

Red spot disease and Furunculosis

The term "red spot disease," which refers to a condition characterized by hemorrhagic lesions, reddening, and skin ulceration, is used to describe a disease caused by *Aeromonas hydrophila* and *A. sobria* that has been responsible for high morbidity and mortality in populations of farmed fish for about 20 years (42). While Aeromonas salmonicida is among a primary organism causing surunculosis in wild and cultivated salmonids (Fig.3) (43), it also causes fish to develop bacterial septicemia (44). Because it cannot develop at 37 degrees Celsius, *Aeromonas salmonicida* is only considered a main bacterium not in humans but in fish. However, numerous investigations have shown that it may infect humans and cause septicemia and endocarditis (45).

Figure 3: Photograph of gross lesion of Furunculosis in Atlantic salmon showing a furuncle (boil like lesion) on lateral side (43).

Diverse Sources and Human Health Implications of Aeromonas Species

Most Aeromonas infections in people are contracted through exposure to freshwater or through the consumption of uncooked seafood (46). Consequently, it is not difficult to establish contact between these bacteria and humans (47). More than thirty naturally occurring Gram-negative bacterial species found in aquatic habitats make up the genus Aeromonas. These microbes, typically considered fish and other animal infections, have become more well-known in medical research because of their capacity to colonize and infect humans (Fig.4) (48).

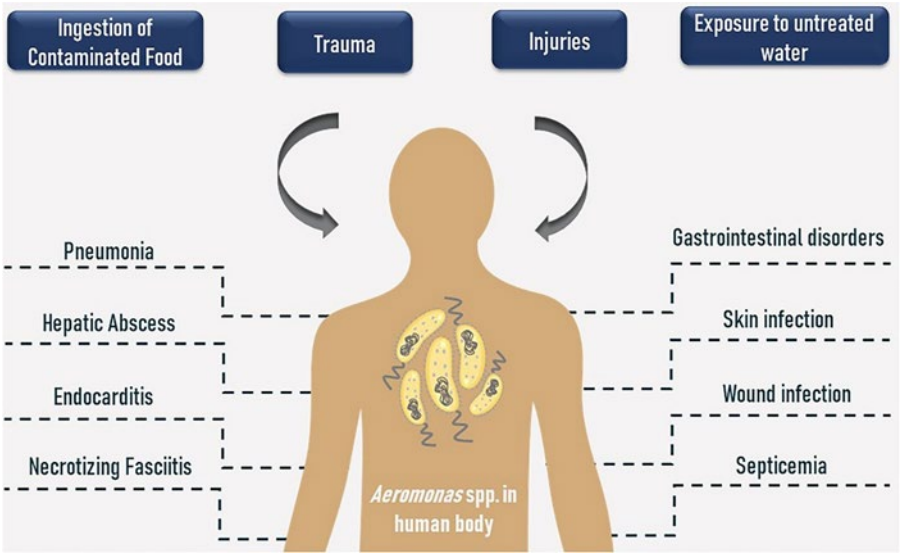

Figure 4: Contamination routes and human health disorders caused by Aeromonas species (48).

Challenges and Advances in the Identification and Detection of Aeromonas Species in Aquatic Environments

Aeromonads are known as significant fish diseases. Aeromonas selective agar was used to isolate it (49). Conventional phenotypic recognition of Aeromonas species is difficult (50). Notably, one of the unique traits of the Aeromonas genus is its unreliability when identified phenotypically using traditional biochemical tests or commercial systems like Vitek, API20, and Microscan, which are frequently utilized in day-to-day operations in the majority of laboratories (51). The species *A. hydrophila, A. caviae and A. veronii* were identified using polymerase chain reaction (52). The immunoassay shows promise as a useful screening technique for monitoring Aeromonas species in food and environmental samples (53). The kidney is typically recommended for internal sampling, followed by the spleen and liver, and then skin ulcers, if present, for external sampling (54).

Integrated Strategies for Managing Aeromonas Infections in Aquaculture: From Prevention to Treatment

Limiting the amount of Aeromonas species that enter the system through good treatment and maintenance is the most effective method for reducing Aeromonas growth. Management in the aquaculture environment includes getting rid of sick animals, decreasing disease prevalence by maintaining excellent water quality, regulating temperature, cleaning equipment, and reducing stress (55). Cooking the items to reduce the risk of pathogen transmission, but this strategy has not always worked well because if the pond products are consumed raw, there is no health benefit. Waters must

be monitored constantly to detect water-borne diseases and lower aeromonads' health risks (56).

Antibiotics and vaccinations are a few of aquaculture management techniques and methods to avoid disease. Vaccination is regarded as essential as one of the primary methods for disease prevention and control in aquaculture (57). Phage therapy can provide fish with overall protection and treat diseases in aquaculture (58). Although it is ideal for preventing infections in aquaculture, it is not always feasible due to the difficulty in providing the best conditions and nutrition. Natural products like algae and barely cancan improve fish performance and contribute to strong immunity, making fish more resilient to both outbreaks of infectious diseases and unfavorable environmental circumstances (59). Additionally, its success might require efficient bio-control methods to lower infections (60).

Conclusion

Aquaculture is a vital industry that provides significant economic benefits and is a substantial source of protein and other essential nutrients for human populations worldwide. However, the health of aquaculture systems is frequently challenged by bacterial infections, particularly those caused by Aeromonas species. These bacteria are widespread in aquatic environments and can lead to severe fish diseases such as hemorrhagic septicemia, red spot disease, and Furunculosis, resulting in high mortality rates and substantial economic losses for fish farmers. Aeromonas species are a concern for aquatic animals and pose significant health risks to humans. They are emerging as important pathogens capable of causing a range of infections, including gastroenteritis, septicemia, and wound infections. These bacteria can spread through direct contact with contaminated water or fish, consumption of undercooked seafood, and exposure to contaminated food products. The potential for antibiotic resistance among Aeromonas strains further complicates treatment efforts, posing a growing public health challenge.

Conflicts of interest

The authors declare that there is no conflict of interest**.**

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التهديد المزدوج لأنواع الأيروموناس: مسببات امراض البيئة المائية والمخاوف الناشئة على صحة الإنسان

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الخلاصة

أنواع الأيروموناس هي بكتيريا لا هوائية اختيارية، سالبة الجرام، عصوية الشكل وغير مكونة للأبواغ، وتنقسم إلى مجموعتين: الهوائية غير المتحركة المحبة للبرودة، والهوائية المتوسطة الحركة. يتميز تصنيف هذا الجنس بالتعقيد بسبب صعوبة تحديد بعض الأنواع بدقة باستخدام تقنيات النمط الظاهري. تعتبر معظم سلالات الأيروموناس ممرضة للأسماك وتسبب تسمم الدم النزفي، مما يؤدي إلى زيادة الوفيات وخسائر مالية كبيرة في تربية الأحياء المائية. تنتشر هذه البكتيريا في المياه العذبة، التربة، والمنتجات الزراعية، وغالبًا ما ترتبط بأمراض مثل سمّية الأيروموناس المتحركة، أمراض البقع الحمراء، الاستسقاء المعدي، وداء الدمامل. على الرغم من أهمية التطعيم كاستراتيجية مثلى للوقاية، فإن الأيروموناس لا تزال مرتبطة بشكل كبير بالتهابات المعدة والأمعاء، تجرثم الدم، والتهابات الجروح لدى البشر. مع الأخذ في الاعتبار البيئة وعلم الأوبئة والقدرة المرضية لجنس الأيروموناس، فإن هذه البكتيريا تشكل تهديدًا متزايدًا على صحة الإنسان وتربية الأحياء المائية، مما يتطلب جهودًا مكثفة في الوقاية والسيطرة عليها.

الكلمات المفتاحية: تربية الأحياء المائية، أنواع الأيروموناس، الالتهابات البكتيرية، الاضطرابات الصحية للإنسان.