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Common *Aeromonas* Infections in Ornamental Fishes: A review

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ABSTRACT: In fishes majority of the pathogenic agent of disease are bacteria, fungi, viruses, and parasites. Generally, the primary causes of contagion are gram-negative bacteria, which have been identified often from diseased fish, resulting in increased mobility and death rates. Bacterial illness can become evident as acute, chronic, or peracute symptoms, but the challenge is that when signs emerged and the disease was recognized, it's too late to cure. Aeromonas are most devastating among all the bacteria and cause significant losses in all cultures, including the ornamental fish culture. It is eminently found in water and is constantly present. An extrinsic agent such as overpopulated, sloppy handling, deteriorating water which leads to degrading quality, contaminated food, and inadequate diet, might incline fish towards *Aeromonas* infection. Motile species of *Aeromonas* are recognised as the etiological agents of motile *Aeromonad* septicemia infections in ornamental fish, which cause significant mortality and economic loss in the ornamental fish business. It can be detected by colonization and adherence in the epidermis, gills filaments, gastrointestinal lining, and lesions or ulcers. Also, it is essential to note that finding the disease in ornamental fish is not easy. The main challenge is that these fishes are too costly and have emotional attachments with their owners, so sampling is difficult for the researcher. After going through so many recent studies and records, we found that the Aeromonas is one of the potential bacteria with so many virulent factors which may become responsible for considerable losses in ornamental fishes. For the avoidance of these losses, it is necessary to suggest a solution. It is critical to emphasize that prevention is preferable to therapy; thus, good management practices and a stress-free environment are essential. If an ailment develops, it is vital to treat it using approved medications and procedures. Ornamental fishes propose various opportunities over food fishes used in aquaculture, including the capacity to treat chemicals and treatments that food fishes are not permitted to get.

Keywords: Aeromonas, Ornamental, Pathogenicity, Therapy, Medication, Prevention.

INTRODUCTION

Non-food fisheries include ornamental fish cultivation. It is well known significant source of revenue and employment (Whittington and Chong, 2007). The ornamental fish industry is composed of colorful fishes collected from various species from multiple sources and countries like Singapore, India, Hong Kong, Brazil, Colombia, Indonesia, Malaysia, Nigeria, Peru, Sri Lanka, and Thailand. These fishes also are the result of crossbreeding and selective breeding between different species belonging to distinct areas and habitats. They are also contributors to employment in developing countries when exported to developed countries (Yue, 2019; Raja *et al*., 2019). With the increase of hobbyists, the hobby of petting ornamental fishes also increases, in an estimated 5000 fresh water and 1450 marine water fish species are accepted as a pet. The majority of the ornamental fish trade (90 percent) comes from farm-bred freshwater species, whereas marine species are primarily taken in the wild (Whittington and Chong, 2007). Beautiful fish businesses turn out to be expected in recent years, and ornamental fish aquaria may now be seen in homes, restaurants, businesses, hospitals, and more public places. Transport, high stocking density, poor water quality, sloppy handling, and contaminated feed are causes of the stresses that ornamental fish face, resulting in a high prevalence of illnesses (Yue, 2019*;* Raja *et al.*, 2019).

Bacteria, fungi, viruses, and parasites are coursing the disease in fish. Bacterial infections, primarily caused by Gram-negative bacteria, have been identified often from diseased fish, resulting in increased illness and deaths. (Yukgehnaish *et al*., 2000). Bacterial illness can manifest as acute, chronic, or peracute symptoms. The most sensitive regions of the fish for bacterial colonization and adherence are the exterior of skin, gills, the gastrointestinal lining of the gut tract, and seen in the form of lesions or ulcers (Noga, 2010).

Aeromonas sp. is associated with the Aeromonadaceae family (Martin-Carnahan, 2005). This family made up of 6 genera, *Aeromonas, Pseudaromonas, Oceanimonas, Tolumonas, Oceanisphaera,* and *Zobellella*. Aeromonas are gram-negative bacilli, catalase and oxidase-positive, glucose fermenters, nitrate degraders, and 2, 4-Diamino-6,7-di-isopropylpteridine phosphate (vibriostatic factor, O/129) resistant. A whole of 36 *Aeromonas* species had been identified, with two separate morphological groupings (Fernández-Bravo and Figueras, 2020). *Aeromonas* species are psychrophilic (grow best around 22–28°C) or nonmotile associated with the first category. This nonmotile *A. salmonicida* is the pathogenic agent of furunculosis disease in salmonid fishes and affects non-salmonid fishes like koi and goldfishes. It also has the potential to infect human beings, but more studies required to establish this fact. (Austin *et al*., 1998, Hoole *et al.*, 2001). Another big category includes *Aeromonas* species that are mesophilic (grow best at 35–37°C) or motile (Zhong *et al.*, 2021).

Similar to other bacteria, *Aeromonas* sp. also include multifactorial and multifunctional virulence factors, such as lipopolysaccharide (LPS), outer membrane proteins (OMPs), extracellular factors hemolysins (Hly), toxins (Alt, Ast, and Ast), secretion systems i.e. type III secretion system (T3SS), type VI secretion system (T6SS), and quorum sensing (QS) mechanisms, iron acquisition system (IAS), quorum sensing (QS) mechanisms, flagella, fimbriae, lipases (Lip), and proteases (Ser), (Chopra *et al*., 1999; Hossain *et al.*, 2021). Previous research has linked pathogen identification, cell signaling, and apoptosis to the expression of immune-related genes that actively contribute to hosting adherence, colonization, and infection (Hoel, *et al.*, 2017; McCoy 2010; Srivastava 2017).

Ornamental fish industry: Ornamental fishes are classified into three categories first is freshwater ornamental fish, second is marine and then comes brackish water ornamental fishes. Among these, freshwater fishes are liked mainly by hobbyists. (Raja *et al.* 2019) estimate that 2 billion ornamental fish are traded globally. That is categorized under freshwater and marine-water ornamental fishes, in which freshwater accounts for 4500 and marine reserve for 1450 species (Walczak *et al.*, 2017). This commerce is worth 2.2 billion USD globally, accounting for 15 percent of the entire total, i.e., retail market, which includes other connected items (water pumps, aquaria, gravels or stones, and so on (Hossain *et al.*, 2021). Fish species that account for 90–96% of the worldwide trade are freshwater species (Livengood and Chapman, 2007). Primary exporters of these fishes are Asian countries. In 2014, the entire export worth was 197.7 million US dollars and Singapore is the exporter (USD 42.97 million in export value), accounting for 12.7 percent of total exports. The largest exporting regions for ornamental fish are Europe, the Middle East, North America, Africa, and Oceania. The ornamental fish trade is dominated by Goldfish (*Carassius auratus*), neon tetra (*Paracheirodon innesi*), zebra danio (*Danio rerio*), angelfish (*Pterophyllum* sp.), guppy (*Poecilia reticulata*), and discus (*Symphysodon* sp.). Guppy and zebra danio both account for above 14% of all traded fish. Furthermore, koi fish (*Carrasius auratus*) account for 10% of world commerce, with more significant exports from Japan (Hossain and Heo, 2021).

Aeromonas infections in ornamental fishes

Ulcer disease: Non-salmonids (mostly Goldfish and Koi carp) are usually infected with *A. salmonicida*, though salmonids are equally susceptible. Unlike Furunculosis, ulcer disease is typically limited to the skin and only becomes systemic later. Skin infection with atypical *A. salmonicida* causes carp erythrodermatitis (CE), a typical illness in European farmed carp (Roberts, 2012). The infected dropsy of carp (IDC) complex contains this illness. IDC is a disease that affects cultured carp produces by *Rhabdovirus carpio* in the acute form and atypical *Aeromonas salmonicida* in the chronic form**.** From white discolorations to superficial hemorrhagic ulcers to profound lesions that reveal underlying muscle or bone, skin lesions come in different shapes and sizes (Erkinharju *et al.*, 2021). Water molds, protozoa, and other microorganisms frequently infect lesions as a result of their chronicity. The fish's body and base may have bleeding (Roberts, 2012).

Motile aeromonad septicemia (MAS): Motile aeromonad septicemia is a kind of septicemia that affects fish. It's also recognized as hemorrhagic septicemia, red sore disease, and motile aeromonad infection and aeromonads caused it (Schäperclaus, 1992). According to (Hossain *et al.*, 2021), *A. caviae* (previously known as *A. punctata*) is responsible for infectious abdominal dropsy in the wild and farmed common carp (*C. carpio*). Motile Aeromonads induce ulcers in different organs in fish, including the gastrointestinal system, muscle, kidney, and spleen. They may be found in a heterogeneity of freshwater fish species, including fishes of our interest, along with in marine creatures that live on a rare basis (Lewbart, 2001). Motile Aeromonads are a kind of opportunistic bacterium seen in immune-compromised fish. Environmental variables that may influence ornamental fish to motile Aeromonad septicemia include overcrowding, poor nutrition, excessive temperature fluctuations, and improper handling (Sarder, 2017).

Furunculosis: In 1894, Furunculosis has been initially discovered in *Salmo trutta*. (Hossain *et al.*, 2021) Furunculosis is a septicemic infection commonly detected in salmonids, and psychrophilic *A. salmonicida* is the pathogenic agent of Furunculosis (Dallaire-Dufresne *et al.,* 2014). Furunculosis, commonly acknowledged as koi ulcer disease or ornamental fish ulcer disease is a disease that affects koi carp (Cyprinus carpio) and Goldfish (Carassius auratus) (Lewbart, 2001). The body of the infected fish generally has superficial deep sores, exophthalmia, a bloated belly, and ecchymosis are the symptoms (Bruno *et al*., 2013). (Mazumder *et al*., 2021) found that diseased fish with exposed wounds transmitted the illness to other fish.

Virulence factors in Aeromonas: Understanding interplay involving the host and pathogenic microorganisms at both the cellular and molecular levels is aided by discovering virulence factors. A diverseness of these factors enable microorganisms to infiltrate, proliferate, and harm host organs (Hossain and heo. 2020, Yu *et al*., 2007). Due to extreme multifunctional and multifactorial activities of these virulence determinants in Aeromonas, pathogenicity has various paths. To detect pathogenic potentials, virulence determinants must be determined (Hossain *et al*., 2018). Extracellular toxins and enzymes, secretion systems, quorum sensing, iron acquisition mechanisms, structural components, and biofilm are several of the virulence factors associated with *Aeromonas* pathogenicity that are implicated in fish disorders. *Aeromonas* sp. virulence factors in ornamental fish have received little attention in research (Tomás, 2012). However, extracellular poisons, biofilms, flagellar systems, secretion systems, and extracellular enzymes have been extensively researched in ornamental fish (Hossain *et al*., 2021).

Exotoxins: *Aeromonas* sp., like other bacteria, may produce a diversity of exotoxins. *Aeromonas* sp. have three forms of exotoxins: cytotoxic enterotoxin, aerolysin, and cytotonic enterotoxin. These toxins are crucial in forming infections in *Aeromonas* spp (Soler *et al*., 2004; Sha *et al*., 2002). They cause liquid buildup in animal intestinal loops, cell enlargement, Y1 tumor cell turning, and a rise in cAMP levels (Chopra and Houston 1999), as well as cytotoxic, enterotoxin, aerolytic, and hemolytic effects (Chopra and Houston 1999). The most imperative virulence identifier is the act gene, however, it is linked to enterotoxin, cytotoxic, and hemolytic effects. The cytotonic enterotoxin-related ast and alt genes, on the other hand, are mostly related to diarrhoea, which allows animals' intestines to secrete fluid (Nawaz *et al.*, 2010).

Sreedharan *et al*., (2012) isolated *A. veronii, A. biovar, A. sobria, A. caviae*, and *A. jandaei.* After scanning the gene, they found that act gene was available in 58% of the isolates. Furthermore, motile aeromonads, which were segregated from ornamental fish also shown to have ast and alt genes. *Aeromonas* species generate hemolysins lacking enterotoxin characteristics, such as β-hemolysin and α-hemolysin. The cytotoxic effects of α-hemolysin are reversible, and incomplete erythrocytes are lysed. In most cases, β-hemolysin is created during the ascending development phase. This toxin forms a pore that induces erythrocyte osmotic lysis and destruction (Mendoza-Barberá *et al*., 2021). 73.3% of motile *Aeromonas,* which is isolated from the ornamental fishes, are showing hemolytic activity. Motile Aeromonas isolated from zebrafish and guppy was show the high abundance of hemolysin A gene called hlyA (83% in zebrafish and 80% in guppy)

Extracellular enzymes: Extracellular enzymes produced by *Aeromonas* include nucleases proteases, lipases, gelatinases, amylases, chitinases, and gelatinases, others for establishing pathogenicity. The extracellular enzyme of Aeromonas is mainly generated by the secretion system (type II) called the general secretory route. *(Tomás. 2012).* In phenotypic pathogenicity testing, all motile *Aeromonas* isolates displayed gelatinase and DNase activity (Shameena *et al.,* 2020). However, earlier research has discovered DNAse activity in motile *Aeromonas* isolated from ornamental fish, but no other isolates had the exu gene (Hossain *et al.,* 2020). Other extracellular enzyme genes found in motile aeromonads from guppy, Goldfish, and zebrafish included elastase (ahyB), glycerophospholipid-cholesterol acyltransferase (gcat), and lipase (lip) (Hossain *et al.,* 2021). Shreedharan *et al*., (2012) also discovered that the gcat gene was available in all *Aeromonas* isolates.

Secretion systems: Gram-negative bacteria contain Types II (T2SS), III (T3SS), IV (T4SS), and VI (T6SS) secretion systems. Aerolysin, DNases, Amylases, and Proteases are all transported by T2SS which are the injection of effector proteins directly to the cytosol of fish cells are connected with the Type III secretion system (Soto-Rodriguez *et al.*, 2018). The type IV secretion system is working for the achievement of the antibiotic resistance gene. Also, it functions as the transporter of virulence factor, which helps the bacteria form disease in the fish. Also, provide a mechanism to decimate the therapeutic for safeguarding the bacteria (Rangrez *et al.,* 2006). Type III secretion system and T3SS related genes, in particular aexT, ascV, and ascF-ascG, which is generally seen in the Aeromonas, and asc V gene is well documented in zebrafish (52%), Goldfish (67%), and guppy (58%) (Hossain *et al*., 2021).

Other virulence factors: Chemotaxis, penetration, and adhesion of host tissues are all biotic functions of bacterial flagellar motility promoted by lateral or polar flagella (Yang *et al.,* 2016). Outer membrane proteins are involved in bacterial adhesion to host epithelial cells and shield bacteria from host defense systems (Khushiramani *et al.,* 2012). They are in charge of boosting the immune system of the host and contributing to the plasma membrane mechanism (Austin *et al.,* 2012). *A. hydrophila* isolated from ill Goldfish was an exhibit to have the outer membrane protein (OMP-TS) (Viji *et al*., 2012). Biofilms are bacterial defence systems that enable them to withstand antimicrobial agents (Lynch *et al.,* 2002). According to (Lazado and Zilberg, 2018), motile *Aeromonas* sp. Isolated from guppy show several regulatory mechanisms for biofilm formation that will be closely connected to virulence factor synthesis. The fla gene involved in flagellar motility was found in all motile aeromonads isolated from ornamental fish (Shreedharan *et al*., 2012). More than half of motile *Aeromonas* isolates from zebrafish, Goldfish and guppy amplified the fla gene (Hossain *et al.*, 2021).

Disease prevention and Treatment: Nonetheless, with careful care, most infections may be prevented. In fish rearing and culture, it is critical to monitor the health condition of the fish daily. Several small factors should be considered to facilitate the daily observation of fish welfare to minimise the stress, such as color, ventilation rate, swimming pattern and abnormal habits like food intake(less or more the normal), growth rate, and presence of morphological abnormalities such as reproductive performance and injury (Noga, 2010). These markers should be incorporated in the usual problem-solving workup and daily monitoring of the fish population.

Deteriorating water quality, overstocking, transportation, and inadequate feeding are all factors that might lead to bacterial illness in ornamental fish (Musa *et al*., 2008). In the ornamental fish sector, ornamental fish health and nutrition are significant. Maintaining acceptable water quality decreases the many stresses that fish are exposed to, minimizing the risk of infections, and keeps the fish in good health. The water quality and other parameters must be checked regularly and recorded to analyze potential threats and solutions.

Ornamental fishes are continuously exposed to chemicals for exporting and sale to keep them alive and minimize the stress and contamination during transportation. Clinoptilolite and methylene blue are often used during the packaging process to eliminate ammonia(from feces) and suppress bacterially (mainly Aeromonas due to rapid growth in normal condition) development, respectively, during fish transit (Ng, 2016).

Aquaculture of all types including food-fish and ornamental fishes employs a variety of chemicals to maintain the health of its fish. antimicrobials or Antibiotics, disinfectants, chemotherapeutic agents, hormones, piscicides, and anesthetics are numerous chemicals used in aquaculture (Anjur *et al*., 2021). Chemotherapeutic medicines, vaccines, probiotics, probiotics, yeast extracts, and disinfectants can all be used to control bacterial illnesses like MAS in fish. Chemotherapeutics are generally utilised in fish with MAS, according to experience (Stratev and Odeyemi, 2017). Antibiotics such as oxytetracycline (OTC), sulfadimethoxine, and ormetoprim are commonly practiced to treat. *A. hydrophila* infections (Agnew and Barnes, 2007). Because *A. hydrophila* is an opportunistic infection, the best way for disease control and inhibitors is to minimise variables that predispose to the disease and follow standard sanitation practices on fish farms (Amal *et al*., 2018).

Chemical therapy is commonly used since pharmacological and medical supplies are more readily available. Disinfectants, herbicides, insecticides, spawning aids, and preventive disease vaccinations are all possible uses for these medications and substances. Aquaculturists, contrarily, need access to safe and effective regulated and controlled chemicals and must use them following their proposed use, best management practices, and applicable system and regulations (Anjur *et al*., 2021), because these drugs arrive finally in local drainage system and eventually pollute rivers (Ng, 2016). Chemotherapy medications are being utilised more often to prevent and control bacterial infections. Topical disinfectants, antimicrobials, and probiotics are the three most frequent types of chemotherapeutics. Topical disinfectants are used by aquafarmers in a variety of ways. The more conventional chemicals include formalin, benzalkonium chloride, acriflavine, malachite green, hypochlorite, and polyvinylpyrrolidone. Acriflavine and malachite green are used only in hatcheries, whereas the rest are employed in ponds and hatcheries (Mohamed *et al.*, 2000).

Polyvinylpyrrolidone, acriflavine, and malachite green have not been known to be used as of yet. All nations, including India, have prohibited malachite green as an aquaculture disinfectant, but some relaxation is given to non-food fishes like ornamental fishes (Anjur *et al*., 2021).

CONCLUSION

Aeromonas can be found in ornamental fish environments such as fish tanks, culture systems, and transport begs within fish. But it requires a trigger to activate, such as poor water quality, excess food, or stress. It can treat three disorders in particular: Ulcer disease, MAS, and Furunculosis, and it is suggested that more research is required for the identification of new conditions related to Aeromonas infection because it is among the commercially significant pathogenic bacteria. *Aeromonas* is both virulent and avirulent. It has virulence due to the occurrence of several essential virulent factors such as secretion systems, extracellular enzymes, and exotoxins. It also contains certain virulent factors, although they are not as crucial. Finally, disease prevention and management are critical. It is crucial to mention in this section that preclusion is better than Treatment; thus it is crucial to adopt sound management practices and create a stress-free environment. If a disease occurs, it must be treated by approved chemicals and medications. Ornamental fishes have various benefits over food fishes employed in aquaculture, such as curing with chemicals and treatments that don't apply to food fishes.

FUTURE SCOPE

The aquarium fish industry constitutes a large segment of the pet animal industry in aquaculture, having a global marketing network. Alike in any aquaculture practice, the intensification of the ornamental fish culture has led to the emergence of diseases and mortality with varied manifestations. However, the present study provided details on the prevalence of Aeromonas infections in Ornamental fishes. Considerable research works are required to fill plentiful breaks of knowledge. Determination of virulent genes of the pathogenesis of *Aeromonas* sp. and identification of secreted enzymes and toxins contribute to the organism's pathogenicity. Recognition of *Aeromonas* sp. And there, a different pattern and symptoms will be more helpful for identifying and recognition diseases caused by this bacteria. There is also mass scope for developing new treatment methods and medications without ignoring the sustainable goal and environment.

Conflict of Interest. Nil.

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