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Review
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FUNGAL DISEASES IN FISH

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Abstract: Fungal diseases of fish have become increasingly important, over the past 20 years. The traditional "fungi" are comprised of members from several different taxonomic kingdoms. An increasing number of other environmental fungi are being reported from diseased fish, further testament to the opportunistic nature of many fungi. Active fungal agents living in waters cause infections in juvenile and adult individuals in fish populations, leading to decay in eggs and larvae. Fungal infections that are generally observed as a secondary infection in fish populations become established in lesions caused as a result of mechanical injury by bacterial, viral, and parasitic primary agents, consequently causing a change in the prognosis of the disease. Fungi, however, can cause disease under a variety of other circumstances. Some may be more aggressive and play a more primary role. Fungi can be external or internal, and systemic. Fungi can cause problems during reproduction, for example, by infecting fertilized eggs in spawns. Certain species of fungi can grow in poorly stored feeds and produce mycotoxins. Fungal diseases, in general, are very difficult to control or treat once they have taken hold. Prevention is, as always, the best medicine. Increased knowledge of basic biology will help guide treatment and control methods. This review study sought to provide insights into the fungal diseases of wild or farmed fish introduced onto the market.

Keywords: Fish, Fungi, Mycotic diseases

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1. Introduction

The ever-increasing world population has led to increasing demand for protein, a condition that has generated a growing interest in fish meat as a source of rich protein. Fish farming is of great importance in meeting a particular part of the need for fish meat. Data published by FAO in 2020 indicate that the total aquaculture production in the world has reached an amount of approximately 178.5 million tonnes (FAO, 2020). The aquaculture production in Turkey, on the other hand, amounts to 314.537 tonnes, with the rainbow trout (*Oncorhynchus mykiss*) produced in inland waters having the greatest quota in the production with 103.192 tonnes (TUİK, 2018). The total global production of this species, on the other hand, amounts to 848 thousand tonnes. Rainbow trout production represents circa 50% of the total fish production in Turkey (TUİK, 2019). The problems producers experience in aquaculture production also lead to economic losses, inflicting financial and moral damages on enterprises (Yilmaz et al., 2011). It is a fact that diseases account for most of the burden arising from monetary losses. Fungal infections represent an essential part of fish diseases. There is a considerable amount of literature on fungal diseases in fish (Silphaduang et al., 2000; Rand et al., 2000; Blaylock et al., 2001). It is of prime importance to define and isolate the related agent to understand the biological characteristics of fungal disease and diagnose and treat it. The present review study sought to provide insights into the fungal infections that afflict fish populations.

2. Saprolegniasis

Saprolegniasis is the most frequently seen and economically most significant disease caused by fungi. It is also called winter fungus or winter kill syndrome (Durborow et al. 2003). It is known that *Saprolegnia* has approximately 14 genera and between 126 and 146 species, among which *S. parasitica* and *S. invaderis* are the most common. It is the fungal disease most frequently seen in freshwater and marine fish populations (Yarsan, 2020). The Saprolegnia genus members belonging to the Oomycete family cause a disease called Saprolegniasis (Beakers et al., 1994; Roberts, 1989). Most of the fungal infections that affect fish are categorized as opportunistic invasive infections. Adverse environmental conditions and stress lead to suppression in the immune system. With excessive mucus secretion, fungi begin to settle secondary to bacterial and viral infections (Khoo, 2000). However, it has been observed that some Saprolegnia species cause fatal and primary diseases, especially in catfish. Saprolegnia is ubiquitous in freshwater ecosystems. It damages the epidermal tissues in fish and can spread to

the whole body, starting from the head and fins (Kutama et al., 2013). Among the Saprolegnia species, *S. parasitica* is a highly virulent species that cause extensive fish kills and decay in eggs in salmon and trout farming (Jiang et al., 2013). The disease's lesions manifest themselves in the skin, gills, and especially in fish eggs in the form of a cotton wool puff (Figure 1).

Fungi colonies consist of heavily branched filaments called hyphae. Many hyphae form a fungus network called mycelium (Yarsan, 2020). As the mycelium is the vegetative part through which a fungus absorbs nutrients, lesions in diseases can be of different colours due to mycelia. Since mycelia feed on algae, they may appear red and brown. First attacking the gill, *Saprolegnia* moves on to infect the eye, brain, liver, spleen, kidney, and swim bladder (Neish and Hughes 1980; Ferguson, 1989). Research has reported limited success in treatment. Water quality, particularly water temperature, is vital in dealing with the disease. Environmental conditions should be improved, and egg and pond disinfection should be performed.

Figure 1. Saprolegnia infections (Chesser, 2020).

3. Aphanomycosis (Epizootic Ulcerative Syndrome)

Aphanomyces was first described by Bary in 1860 and was included in the Leptoleniaceae family by Dick et al. (1999) due to its morphological similarity to this family. It includes about 45 zoopathogenic species found in freshwaters and marine environments. The most reported species are *Aphanomyces invidans* infecting fish populations, and *Aphanomyces astaci* that are mainly observed in arthropods. *Aphanomyces invidans* that is the causal agent of Epizootic Ulcerative Syndrome (EUS) causes mortality up to 100% in aquaculture (Figure 2). It was first defined in Japan in 1971 (İberahim et al., 2018). Research reports that 87 fish species have so far been affected by EUS (Kamilya and Baruah 2014). It is seen more frequently in juvenile individuals than in adult fish (Pagrut et al., 2017). Normally, the skin of fish has the function of a defense system. But changes in environmental factors that lead to lower pH and lower oxygen content influence the defense system, leading to the suppression of the immune system and consequently to EUS epidemic in some cases (Kiryu et al., 2005). Infections begin with the attachment of motile zoospores to damaged areas. The hyphae, composed of zoospores, deeply invade the lower tissues, causing excessive ulceration and destruction in the tissue. The occurrence of skin lesions varies depending on the fish species. Mildly infected fish show only minor inflammation without external lesions, but also petechial haemorrhages in the body, mouth, as well as on the anal fin and exophthalmos (İberahim et al., 2018). Ulcers appear as white areas on the fish's skin, which turn entirely red with a reddish center and later cause external factors. As the disease progresses, the eyes protrude, the body decays, and in some cases the head is eroded, resulting in the death of the fish depending on the severity of the disease (Podeti and Benarjee 2017). Although *Aphanomyces invidans* is the causal agent of EUS, it can be isolated from fish infected with other pathogenic viruses (mostly rhabdovirus), bacteria (mainly *Aeromonas hydrophila*), or parasitic protozoans with *A. invadans* (Huchzermeyer et al., 2012). These infections cause stress in fish and can render them more vulnerable to diseases. Malachite green is important in treatment. It has, however, been prohibited worldwide as it affects the environment and people working in the enterprises in the sector. It is a disease difficult to treat; it is, therefore, important to provide proper nutrition, ideal stock ratio, and optimum water quality conditions (İberahim et al., 2018).

Figure 2. Ulcers on the lateral and fins due to EUS effect (FAO, 2020; Huchzermeyer et al., 2012).

4. Branchiomycosis (Gill Rot Disease)

Branchiomycosis is a much-feared fungal disease in fish farms (mainly in carp farms) and is in the gill epithelium and capillaries. This fungal disease, called gill rot, generally causes high fish mortality, being acute in some freshwater fish (Judy, 2010) It is usually seen in regions with a hot climate (Ramaiah, 2006) Water temperature, the amount of organic matter, and the high amount of ammonia in the ponds fertilized with organic fertilizers are the critical factors that fundamentally influence the prognosis of the disease. Branchiomycosis is an acute infection of the gills that can cause high mortality and respiratory distress in Koi, eel, perch, and many freshwater fish species. It is also called gangrenous bronchitis. Cases have been reported in Europe, Taiwan, and the USA. There are two agents isolated from this disease (Noga, 2010).). While *Branchiomyces sanguinis* and *B. demigrans*. *B. sanguinis* affect carp and tench populations, *B. demigrans* mainly affects the populations of pike, sea bass, and tench (Riad et al., 2015). The two species have significant distinguishing features. *B. demigrans* can multiply and spread outside the blood vessel. It differs from *B. sanguinis* in that it has thicker hypha walls and larger spores (Patel et al., 2018). Both species are seen in fish in environments with low dissolved oxygen and low pH (5.8-6.5) as well as in those being under stress. Respiratory distress, loss of appetite, weakening of movements, and lack of feed are observed in infected fish. This disease, which manifests itself with the necrosis of the gills in fish, causes respiratory distress in the infected gills and is characterized by high mortality due to fungal spores falling from necrosed gills (Figure 3) (Adeshina et al., 2019). There is no cure for branchiomycosis. Dead fish must be removed from ponds and disposed of. Surviving fish are carriers of the infection and should never meet with intact fish in any way (Lio-Po and Lim 2002, Chalmers, 2003). Poor environmental conditions do constitute a vital stress factor for Branchiomycosis induction in infected fish. Water quality parameters, predominantly temperature, dissolved oxygen, and nitrogenous wastes, should be kept at optimum values (Ali, 2005).

5. Ichtyosporidis (Swinging Diseases)

It is a chronic, systemic granulomatosis internal fungal disease, which is endemic in both freshwater and marine fish and is mainly seen in trout. The causal agent of the disease is *Ichthyophonus hoferi* (Choudhury et al., 2014). The disease was first described by Hofer in 1893 in brown trout. Cases have been reported in more than eighty fish species (Zadeh et al., 2014). The agent develops in low water temperatures. The optimum water temperature likely to favor the development of the disease has been reported as 10 °C. The spread of the disease occurs through dead and infected fish, fungal cysts in the feces and cysts free in the water, and foods containing fungi. Internal nodules arise primarily in the skin and tail region (Figure 4) (Govind et al., 2012). An emery-paper-like appearance is particularly noticeable on the fungi granulomas due to epithelial loss. Besides, it affects the central nervous system, particularly in salmonids, as a result of which neurological symptoms such as swimming and balance disorder, swaying movement are observed in fish (Hodneland et al., 1997). The disease mainly attacks the liver. Apart from the liver, the spleen, heart, kidney, gonads, brain, gills, muscles, and nerve tissues behind the eyes are severely affected. Spinal curvature has been observed in some fish (Govind et al., 2012). The prognosis of the disease varies according to the host involved and environmental conditions (Kocan et al., 2009). There is no cure for the disease. The contaminated feed should be avoided, and factors causing stress should be eliminated (Choudhury et al., 2014).

Figure 3. Pale, necrotized, and obstructed gills caused by branchiomycosis (Khalid Subhi, 2011; Riad et al., 2015).

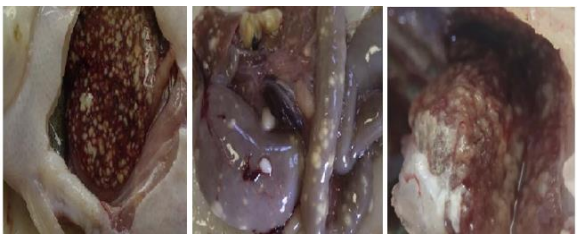

Figure 4. Granulomas formed in the liver and intestine as a result of Ichtyosporidis (Huntsberger et al., 2017).

6. Conclusion

Fungal infections represent an essential part of fish diseases. There is a considerable amount of literature on fungal diseases in fish controlling fungal diseases is necessary to ensure continued growth in the aquaculture industry. It is important to continue studying the underlying molecular processes of fungal – host fish interactions.

Author Contributions

All authors had equal contribution and all authors reviewed and approved the manuscript.

Conflict of Interest

The authors declare that there is no conflict of interest.

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