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Review
Derleme

Diseases, Economic Losses and Treatment Methods in Trout (*Oncorhynchus mykiss*) Farming

Alabalık (*Oncorhynchus mykiss*) Yetiştiriciliğinde Görülen Hastalıklar, Ekonomik Kayıplar ve Tedavi Yöntemleri

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Abstract: Trout farming is important in aquaculture production worldwide and appeals to a wide range of consumers due to its high protein content and nutritional value. However, various diseases seen in trout negatively affect production processes and food safety, and can cause environmental problems and behavioral disorders by affecting the welfare of the fish due to the use of chemicals (formaldehyde, copper sulfate, etc.) used for treatment. In this article, some of the diseases that are frequently encountered in trout and cause economic losses are examined and the effects of these diseases on trout farming are discussed. Diseases seen in trout are generally caused by bacterial, viral, parasitic and fungal pathogens. While these factors seriously threaten the health of trout, they also cause economic losses to producers such as high treatment costs and production losses. In addition, measures taken to prevent the spread of diseases generally require improving water quality, increasing hygienic measures and applying chemical treatment methods. Moreover, problems such as excessive use of drugs and the development of antibiotic resistance complicate this process. As a result, disease prevention, early intervention and the development of effective treatment methods are critical for sustainable production in the sector for trout producers. This article aims to provide important information on disease management and control strategies in the trout farming industry.

Keywords
- Trout
- Diseases
- Production
- Economic losses
- Treatment

Özet: Alabalık yetiştiriciliği, dünya genelinde su ürünleri üretimi içerisinde önemli bir yere sahip olup, yüksek protein içeriği ve besleyici değeri nedeniyle geniş bir tüketici kitlesine hitap etmektedir. Ancak, alabalıklarda görülen çeşitli hastalıklar, üretim süreçlerini, gıda güvenliğini olumsuz etkilemekle birlikte, tedavi için kullanılan kimyasallar (formaldehit, bakır sülfat vb.) kullanımından dolayı çevresel sorunlara, balıkların refahını etkileyerek davranış bozukluklarına neden olabilmektedir. Bu makalede, alabalıklarda sıkça karşılaşılan ve ekonomik kayıplara neden olan hastalıklardan bazıları incelenmiş, bu hastalıkların alabalık yetiştiriciliği üzerindeki etkileri ele alınmıştır. Alabalıklarda görülen hastalıklar, genellikle bakteriyel, viral, parazitik ve mantar kökenli patojenlerden kaynaklanmaktadır. Bu etmenler, alabalıkların sağlık durumunu ciddi şekilde tehdit ederken, üreticilere yüksek tedavi maliyetleri ve üretim kayıpları gibi ekonomik zarara uğratmaktadır. Ayrıca, hastalıkların yayılmasını önlemek amacıyla alınan tedbirler, genellikle su kalitesinin iyileştirilmesi, hijyenik önlemlerin artırılması ve kimyasal tedavi yöntemlerinin uygulanması gerekliliğini ortaya koymaktadır. Diğer yandan, aşırı ilaç kullanımı ve antibiyotik direncinin gelişmesi gibi sorunlar da bu süreci karmaşıklaştırmaktadır. Sonuç olarak, alabalık üreticileri için hastalıkların önlenmesi, erken müdahale ve etkili tedavi yöntemlerinin geliştirilmesi, sektörde sürdürülebilir bir üretim için kritik öneme sahiptir. Bu makale, alabalık yetiştiriciliği sektöründeki hastalık yönetimi ve kontrol stratejileri hakkında önemli bilgiler sunmayı amaçlamaktadır.

Anahtar kelimeler
- Alabalık
- Hastalıklar
- Üretim
- Ekonomik kayıp
- Tedavi

1. INTRODUCTION

Trout (*Oncorhynchus mykiss*) is one of the most cultivated freshwater fish species worldwide. These fish, cultivated specifically for freshwater resources, reach a large consumer base, especially due to the growing trend of healthy eating. Trout is a food source with high nutritional value, low-fat content, and rich in protein. These characteristics make trout popular among health-conscious individuals. This increasing demand has elevated the economic importance of trout production, which constitutes a significant part of the aquaculture sector in many countries (FAO, 2020). Trout farming serves as a major source of income for many countries, both for local consumption and export (Arslan & Yıldız, 2021). Trout production is one of the fastest growing parts of the aquaculture industry in Europe, North America and some parts of Asia (Başçınar, 2004). For example, countries such as Norway and Chile have a significant share of global trout production, while Türkiye, China and Japan are also important trout producers (FAO, 2020). However, trout production faces many environmental, biological and economic challenges.

Trout farming is directly affected not only by environmental factors and water conditions, but also by various diseases seen in trout. As an organism living in aquatic environments, trout can encounter many pathogens. Trout are susceptible to bacterial, viral, parasitic and fungal diseases, and the rapid spread of these diseases can threaten fish health and lead to high economic losses. For example, in the case of viral diseases such as Infectious Pancreatic Necrosis (IPN) and Viral Hemorrhagic Septicemia (VHS), losses are seen at a rate of 70-80%, while this rate can be seen as 5-20% in bacterial and fungal diseases (Georgiadis et al., 2001; Lafferty et al., 2015).

Diseases are one of the biggest threats to trout production. Many of these diseases weaken the immune system of the fish and can cause high mortality rates (Georgiades et al., 2016; Behringer et al., 2020). Particularly, diseases with high mortality rates pose a great economic threat to producers (Perera et al., 2005). Bacterial infections can spread rapidly, especially in cases of poor water quality, while viral diseases are another significant threat to trout producers. Additionally, parasitic and fungal diseases can spread rapidly in polluted waters or areas where fish are intensively farmed (Nguyen, 2024).

Trout are especially vulnerable to diseases when they are young and sensitive individuals. It has been observed that diseases spread more rapidly and mortality rates are higher in juvenile trout (Yilmaz et al., 2011; Griffin et al., 2013). In addition, when trout are raised in intensive farming conditions, stress levels increase, facilitating the rapid spread of diseases. These diseases encountered in trout farming not only threaten the health of the fish, but also threaten the jobs of fish producers. Epidemic diseases caused by pathogens such as IPN, VHS, Bacterial Cold Water Disease (BCWD) can lead to high mortality rates such as 70-80%, especially in young fish (0.3-15 g), resulting in production losses, increased treatment costs and potential market losses (Meyer, 1991; Lieke et al., 2020). Combating these various diseases in trout farming can lead to significant economic challenges. Diseases can seriously reduce efficiency of trout production and disrupt the financial balance in the sector. The removal of infected fish, their treatment, and rehabilitation lead to increased costs. In addition, fish mortalities due to diseases cause losses to producers (Bauer et al., 2023).

The economic impact of diseases is not limited to direct production losses. They can also cause problems in the marketing of fish. The introduction of infected fish to the market can cause reputation damage to trout producers and reduce consumer confidence. Especially in this period of increasing global competition, the spread of diseases can directly affect a producer's commercial success (Bondad-Reantaso et al., 2005). Additionally, the use of chemicals such as antibiotics, medications, and disinfectants to treat certain diseases adds to production costs and damages profitability (Waagbø & Remø, 2020; Bauer et al., 2021).

The economic impact of diseases is especially pronounced for small-scale enterprises. Since small businesses operate with less capital compared to large-scale producers, losses caused by diseases can quickly weaken them financially (Blanco et al., 2000). Furthermore, the additional infrastructure and technological solutions required to prevent the spread of diseases come at a high cost, making it difficult for producers to maintain sustainable operations, which negatively affects the competitive structure of the sector (Opiyo et al., 2018).

Prevention and treatment of diseases in trout farming is of critical importance for producers. In

order to prevent the spread of diseases, it is necessary to ensure the hygiene of production areas, regulate water quality and implement strategies that strengthen the immune system of fish. In addition, it is important to balance biological, environmental and management factors for healthy trout farming (Ferreira, 2007; Maldonado-Miranda, 2022). Therefore, protection should be provided with immersion vaccination when the fish reach 2-3 grams of weight and injection vaccination after 20 grams of weight, and attention should be paid to stock density, feeding and size.

Antibiotics and vaccines are frequently used in the treatment of bacterial diseases, while vaccines have been developed abroad for the treatment of viral diseases, but they are not yet used in our country. In addition, immunostimulants are used to help strengthen the immune system of fish. However, excessive use of antibiotics for treatment can lead to new health problems such as antibiotic resistance in fish, which can complicate future treatment processes (Kan & Kubilay, 2024). Instead, studies on alternative solutions such as biological control methods, vaccines and genetic selection have an important place in the fight against diseases. In addition, it is possible to prevent the spread of diseases with early detection of diseases, rapid intervention and effective management strategies (Glover et al., 2017; Robinson et al., 2023).

2. DISEASES IN TROUT

2.1. Bacterial Diseases

Bacterial diseases are important common infections in trout and pose a significant threat to fish health. Bacterial pathogens weaken the immune system of fish and cause diseases to spread rapidly (Radosavljević et al., 2022; Duman et al., 2023). Bacterial diseases are more common in environments with poor water quality, high stress, and inadequate hygiene (Brunt et al., 2007; Chapela et al., 2018).

2.1.a *Aeromonas salmonicida*

Aeromonas species are frequently encountered pathogens in trout, especially in fish production facilities, and can cause serious diseases. In addition to the most common pathogen, *Aeromonas hydrophila*, species such as *Aeromonas sobria* and *Aeromonas caviae* can also cause infections in trout. These bacteria lead to serious clinical symptoms such as septicemia (blood infections), skin lesions, ulcers and bleeding in fish. In addition, they can cause digestive system infections with symptoms such as diarrhea, bloating and weight loss (Cao et al., 2020). Aeromonas infections are usually more common due to factors such as stress, poor water quality, overcrowding and lack of hygiene. Although antibiotics can be used to treat infections, the treatment process can be difficult, especially due to the resistance developed by *A. hydrophila* to antibiotics. Therefore, monitoring water quality, minimizing stress factors and providing proper care are critical for disease in prevention (Yang et al., 2021).

2.1.b Columnaris

Columnaris is a bacterial infection that affects fish, including trout, and is caused by *Flavobacterium columnare*. This bacterium becomes more active at high temperatures and in conditions such as poor water quality and stress. Columnaris disease spreads rapidly in fish and can cause significant economic losses. The disease typically presents as skin lesions and wounds (Austin & Austin, 2016). In more advanced stages, fish may show symptoms such as respiratory distress, swelling, digestive problems and bleeding. Columnaris weaken the immune system and multiplies rapidly in the body, especially under stressful and intensive farming conditions. Antibiotics and appropriate water conditions play a crucial role in treating the disease, but resistance developed by *Flavobacterium columnare* to some antibiotics can complicate treatment. Regular monitoring of water temperature, pH and oxygen levels is necessary for early intervention and to prevent the spread of the disease (Evenhuis et al., 2015).

2.1.c *Vibrio anguillarum*

Vibrio species are significant pathogens in trout and other aquatic organisms. Species such as *Vibrio anguillarum*, *Vibrio ordalii* and *Vibrio harveyi*, cause vibriosis in fish. Vibrio infections are generally more common in warmer waters (above 14 degrees) and are characterized by symptoms such as skin lesions, ulcers and bleeding in fish. (Lieke et al., 2020; Mondal & Thomas, 2022). *V. anguillarum* is the most prevalent agent and can cause septicemic infections and inflammation in trout, seriously affecting their overall health (Yang et al., 2021; LaFrentz et al., 2022). *Vibrio* species are easily transmitted to fish due to factors such as weak immune systems, stress, poor water quality, and high-density. In advanced stages of infections, fish may show clinical signs such as decreased appetite, severe respiratory distress, and death.

Although antibiotics can be used to treat these infections, *Vibrio* species often develop antibiotic resistance, making treatment more difficult. Therefore, improving water quality, managing stress factors, and ensuring hygienic conditions are essential for preventing infections (Evenhuis et al., 2015; Urku et al., 2024).

2.1.d *Yersinia ruckeri*

Yersinia species, particularly *Yersinia ruckeri* and *Yersinia pseudotuberculosis*, are known pathogens in fish and can cause a disease called yersiniosis (Pajdak-Czaus et al., 2019). These bacteria can cause serious health problems, especially in freshwater fish such as trout. *Y. ruckeri* causes enteric redmouth disease in trout, resulting in symptoms such as hemorrhagic septicemia (blood poisoning) and bleeding. *Y. pseudotuberculosis*, though less common, can cause slow-developing infections and intestinal problems in trout (Hickey & Lee, 2018; LaFrentz et al., 2022). These bacteria become more active and spread rapidly under factors such as weakened immune systems, stress, poor water quality, and high-density rearing. Treatment is typically done with antibiotics, but since Yersinia species can develop antibiotics resistance, proper water management, hygiene and stress reduction are vital to preventing diseases (Chettri et al., 2012).

2.1.e *Lactococcus garvieae*

Lactococcus species, especially *Lactococcus garvieae*, are important pathogens in trout and can cause lactococcosis. *L. garvieae* presents with symptoms such as septicemia, inflammation, and skin lesions in trout (Semwal et al., 2023). This bacterium is usually more active in fish with weakened immune system overcrowded conditions or poor water quality. Infected fish may exhibit symptoms such as general weakness, decreased appetite, difficulty breathing, and swelling of the eyes (Abdelsalam et al., 2023. As the disease progresses, bleeding, skin ulcers, and white pus lesions can be observed in infected fish. In addition, since some strains of *L. garvieae* can develop resistance to antibiotics, the treatment process can be challenging. Therefore, the best strategy for preventing the disease is to ensure healthy rearing conditions by regularly monitoring water quality, providing appropriate nutrition, and minimizing stress (Juárez-Cortés et al., 2024).

2.1.f *Flavobacterium psychrophilum*

Fry Mortality Syndrome is a bacterial infection that causes significant economic losses in trout farming. The causative agent of the disease is a gram-negative bacterium called *Flavobacterium psychrophilum*. This bacterium is generally effective in cold waters below 18°C and causes high mortality, especially in young individuals (fry trout). The disease can be seen in acute and chronic forms and usually manifests itself with symptoms such as fin rot, skin lesions, anemia and loss of appetite (Henryon et al., 2005). The disease is transmitted through direct contact, contaminated water or equipment. In addition, vertical transmission, i.e. the transfer of bacteria from infected broodstock to eggs, is also an important means of spread (Bebak et al., 2007). Treatment and control methods include the use of antibiotics, vaccine development studies and biosecurity measures. However, the development of resistance to antibiotics has limited effective treatment methods. Improving environmental conditions, reducing intensive stocking rates and protecting water quality are of critical importance in controlling the disease. Additionally, alternative approaches such as probiotic and herbal supplements that enhance the immune response to the disease are also being investigated. Future genetic resistance development studies hold promise in reducing the effects of cold water disease (Boyacioglu & Akar 2012).

2.2. Treatment of Bacterial Infections

Bacterial infections are diseases that are frequently seen in trout and need to be treated. Bacteria such as *Aeromonas salmonicida* can lead to the death of trout. Antibiotic treatment is widely used for such infections, but excessive use of antibiotics can lead to the development of antibiotic resistance (Radosavljevi et al., 2022; Semwal et al., 2023). Therefore, it is important to use antibiotics in a controlled manner and only when necessary. Antibiotic treatment is a common method to control bacterial diseases. Antibiotics used for diseases such as aeromonosis can stop the spread of infection and help fish recover. However, the use of antibiotics can have harmful effects on the environment and accelerate the development of resistance (Brunt et al., 2007; Duman et al., 2023). Therefore, antibiotics should only be used with the advice of a veterinarian and at the correct dose.

2.3. Viral Diseases

Viral diseases can be extremely devastating for trout and often spread rapidly, leading to major production losses. Since there is currently no medication available to treat viral fish

diseases, preventive measures are of great importance. Viral fish infections usually require quarantine, vaccinations, and early intervention (Mancheva et al., 2021).

2.3.a Infectious Hematopoietic Necrosis (IHN)

Infectious Hematopoietic Necrosis is a fatal viral disease seen in trout, typically causing high mortality rates in young fish. The IHN virus affects the hematopoietic (blood-forming) tissues of fish, leading to bleeding in internal organs, necrosis (tissue death), and weakening of the immune system (Wang et al., 2024). This disease can spread rapidly in trout production facilities causing significant losses. IHN usually manifests through changes in the swimming behavior of fish, making it difficult for them to move. Deterioration of water quality paves the way for the spread of the disease (Dupuy et al., 2019). There is no effective treatment method for IHN, but strategies such as improving water quality, implementing quarantine measures, and isolating infected fish can be applied to control the disease. Vaccination is also used as an effective method for preventing IHN in some countries (Lin et al., 2022).

2.3.b Viral Hemorrhagic Septicemia (VHS)

Viral Hemorrhagic Septicemia is another viral disease commonly seen in trout. VHS causes bleeding, swelling and necrosis in the organs of fish. This disease can rapidly increase mortality rates in trout and, in some cases the entire fish population (Kasai & Nishikawa, 2018; Baillon et al., 2020). VHS virus poses a significant threat especially to cold-water fish, and becomes more active during periods of increased water temperature. The effect of VHS not only increases fish mortality rates, but also leads to economic losses due to the spread of the disease (Danion et al., 2012; Oslon, 2013). Treatment of Viral Hemorrhagic Septicemia is usually done using antiviral drugs, but treatment methods are limited. Therefore, biosecurity measures and quarantine practices are crucial for preventing the spread of the disease (Mohammadisefat et al., 2023).

2.3.c Infectious Pancreatic Necrosis (IPN)

Infectious Pancreatic Necrosis is a viral infection that predominantly affects juvenile trout. IPN is a disease that affects the pancreas of trout and can be fatal. It is more frequently observed in young fish and in densely populated fish farms. The disease is caused by the IPNV (*Infectious Pancreatic Necrosis Virus*) and the virus spreads through water. In trout, this disease is characterized by necrosis (death) of the pancreatic tissue, which leads to digestive and metabolic disorders in the fish (Pajdak-Czaus et al., 2021; Chandra, 2024).

Symptoms of IPN include weakness, swimming near the surface, abdominal swelling, bloody stools, and death. Once the virus enters the body of trout, it can spread rapidly and mortality can be high, especially in fish with weak immune systems. To prevent the spread of IPN, isolation from infected fish, attention to hygiene conditions and regular monitoring of water quality are required. In addition, there are some vaccines and antiviral treatment methods available to prevent and control the disease (Terech-Majewska, 2016; Chandra, 2024).

2.4. Treatment of Viral Infections

Viral diseases cannot be treated with antibiotics, so the fight against viral diseases is usually limited to preventive measures. There is no effective treatment for diseases such as Infectious Pancreatic Necrosis (IPN), Viral Hemorrhagic Septicemia (VHS) and Infectious Hematopoietic Necrosis (IHN), so prevention of diseases is much more important. However, in some cases, antivirals such as interferon can be used (Wang et al., 2024). Vaccination plays an important role in trout farming in order to prevent viral diseases. For diseases such as Viral Hemorrhagic Septicemia (VHS) and Infectious Hematopoietic Necrosis (IHN), water vaccination methods are widely used (Lin et al., 2022; Mondal & Thomas, 2022). Vaccination helps prevent the spread of diseases by providing immunity to fish. However, vaccination programs may vary depending on the type of disease and regional conditions (Pajdak-Czaus et al., 2021; Mohammadisefat et al., 2023). Vaccines are generally inactive and are applied as immersion during the juvenile period (2-3 g), while when they are 20-30 g, vaccination is done by injection to prevent such diseases. In addition, vaccination strengthens the immune system due to factors such as environmental stress and water quality.

2.5. Parasitic Diseases

Parasitic diseases are infections that affect the health of trout and spread rapidly when environmental conditions are poor. Parasites are usually found on the skin, gills and internal organs of fish. Parasitic diseases cause loss of appetite, slow growth and often even death in trout.

2.5.a Whirling Disease (*Myxobolus cerebralis*)

Myxobolus cerebralis causes a parasitic disease known as "whirling disease" in trout. This disease increases mortality rates, especially in young trout, and causes damage to the skeletal system of fish (Kaeser, 2006; Fetherman et al., 2011). Whirling disease causes trout to swim in circles by constantly turning their heads, which prevents them from performing normal swimming movements. The disease causes serious deformations in organs such as the gills and spine. The disease can spread rapidly in environments with poor water quality and where fish are raised intensively. If left untreated, whirling disease can lead to death (Sarker et al., 2015; Akram et al., 2023). Practices to combat whirling disease include improving water quality, quarantining infected fish and using biological control methods.

2.5.b White Spot Disease (*Ichthyophthirius multifiliis*)

White spot disease is a common and contagious disease in trout, caused by the parasite *Ichthyophthirius multifiliis*. This parasite settles on the skin, gills and body surface of fish, creating white, cottony lesions (spots) on fish. White spot disease is more prevalent in stressed fish, especially when triggered by factors such as sudden changes in water temperature, poor water quality or overcrowded environments. The parasite can be transmitted from infected fish to healthy fish through direct contact or contaminated water (Lahnsteiner, & Weismann, 2007).

White spot disease can cause significant losses if left untreated. Special drugs and salt water baths can be used among the treatment methods. In addition, it is important to isolate infected fish and control water parameters such as temperature and pH to prevent the disease from spreading. Increasing the water temperature during the treatment can accelerate the cycle of the parasite and make the treatment more effective (Lieke et al., 2020; Abu-Elala et al., 2021; Mondal & Thomas, 2022).

2.5.c *Ichthyobodo necator* (Costia)

Costia (*Ichthyobodo necator*) is a protozoan parasite commonly found in trout and other freshwater fish, causing a disease called costiosis. Costia causes infection by settling on the surface of the skin, especially the gills, of fish. Symptoms of costiosis are respiratory distress, skin irritation, decreased appetite, weight loss and heavy breathing. In more severe cases, opacity, swelling and bleeding in the eyes of infected fish may also occur (Mallik et al., 2015). Costia infections are often triggered by stressful conditions, poor water quality and overcrowding. The infection can spread rapidly, so early diagnosis and treatment are essential. Chemicals such as formalin, potassium permanganate or chloramine T are usually used to treat costiosis, though the treatment process may vary depending on factors such as water temperature and pH levels (Balta et al., 2019).

2.6.Treatment of Parasitic Infections

Parasitic diseases are another important factor that threatens the health of trout. Chemical treatment methods are frequently used in the treatment of Myxobolus cerebralis and other parasitic pathogens (Akram et al., 2023). These treatment methods include chemical substances such as organophosphates, formalin, chloramine T and potassium permanganate.

2.7.Fungal Infections

Fungal infections are common, especially in injured fish. *Saprolegnia* spp. is the most common pathogen causing fungal infections in trout. This fungus forms white, cottony lesions on the body surface of trout and affects the fish's organs, often leading to death (Pavić et al., 2022). Fungal infections are more likely to occur when the fish's immune system is weakened. *Saprolegnia* infections are often associated with poor water quality and stressful conditions (Tedesco et al., 2021).

2.7.a *Saprolegnia poses*

Saprolegnia species are pathogenic fungi that can cause serious infections in trout and other aquatic organisms. *Saprolegnia* poses a significant risk of infection, especially when the fish's immune system is weak, under stressful conditions, in poor water quality, and or due to physical injuries. The most common species is *Saprolegnia parasitica* which can spread rapidly by infecting the skin, gills, and wound areas of the fish (Tedesco et al., 2021). *Saprolegnia* infections typically appear as white or gray cotton-like growths. These lesions develop on the skin or gills and cause tissue damage. In the early stages, infected fish may show symptoms such as decreased appetite, general weakness, difficulty breathing, and swelling. If left untreated, the infection can progress, leading to hemorrhages, skin necrosis (tissue death), and death. In addition, the fungus can settle in the gills, making it difficult for the fish to absorb oxygen, which can be fatal (Pavić et al., 2022).

2.7.b *Achlya flagellata*

Achlya species are pathogenic fungi found in aquatic environments that can cause fungal infections in fish. While similar to *Saprolegnia* species, Achlya infections are less common in fish, but can be more problematic, especially at low temperatures and in environments with poor water quality (Choudhury et al., 2014; Pavić et al., 2022). Achlya infections manifest as white, cottony or gray lesions, typically located on open wounds, non-healing tissues, and damaged skin. These fungi weaken the immune system of the fish, causing inflammation, tissue necrosis and sometimes bleeding in the infected areas. Infected fish may experience symptoms such as decreased appetite, weakness, difficulty breathing, swelling and severe skin damage (Tedesco et al., 2021).

2.8.Treatment of Fungal Infections

Fungal infections such as *Saprolegnia spp*. usually occur as a result of poor water quality and injuries. Methods used for fungal treatment include antifungal drugs and iodine solutions. If left untreated, fungal infections can cause serious health problems in fish (Lindholm-Lehto & Pylkkö, 2024). Fungicides such as potassium permanganate are added to the water to prevent the spread of infections.

3.INNOVATIVE TREATMENT METHODS AND FUTURE DİRECTIONS IN TROUT FARMING

Disease management and treatment methods in trout farming should be continuously monitored, and new methods should be developed. Recent scientific and technological advancements have made it possible to manage trout diseases more efficiently and in a more environmentally friendly manner (Shah et al., 2014).

In trout farming, the development of disease-resistant fish species stands out as a promising approach that could revolutionize disease management in the future. Genetic modifications can reduce the risk of diseases being transmitted to trout or strengthen their immune systems. This can be particularly effective in preventing the spread of viral diseases (Sarmasik et al., 2002; Ødegård et al., 2011).

In recent years, studies on more advanced vaccination techniques such as DNA vaccines and peptide vaccines have gained momentum in trout. These vaccines provide more effective protection by specifically targeting the immune system of fish. In addition, the fact that these vaccines can be applied without harming the environment is a significant advantage in trout farming. Future research will focus on developing multiple vaccine combinations and genetically engineered vaccines to prevent a broader spectrum of diseases. Moreover, combined vaccination strategies may be developed to target both bacterial and viral diseases (Imtiaz et al., 2024). In addition to synthetic and chemical treatments, probiotics and prebiotics represent important biotechnological applications that support the immune system of fish. By improving the natural bacterial flora, probiotics can prevent the proliferation of pathogens and increase the resistance of fish to diseases. Probiotic bacteria, especially *Lactobacillus* spp. and *Bacillus* spp., colonize the intestinal system of trout and strengthen immune responses (Mugwanya et al., 2021). Probiotic applications also help reduce antibiotic usage and minimize environmental impacts. In addition, fermentation techniques supported by prebiotics improve feed conversion rates in trout, helping to produce healthier and more resilient fish. These biotechnological approaches enable trout producers to make disease management more sustainable (Rohani et al., 2022). Biotechnology and nanotechnology offer revolutionary innovations in the treatment of trout diseases. Nanotechnological treatment methods provide more efficient and targeted application of antibiotics and antifungal drugs to fish. Nanoparticles accelerate the treatment process by delivering drugs directly to infected areas, increasing the effectiveness of therapeutic compounds (Seethalakshmi et al., 2021).

Excessive use of chemical and synthetic drugs commonly used in the treatment of fish diseases can negatively affect fish health. Therefore, in recent years, treatment methods with medicinal aromatic plants have attracted attention and are being researched as natural and environmentally friendly alternatives (Ghiasi et al., 2022). Medicinal aromatic plants contain oils known for their antiviral, antimicrobial and antifungal properties. Plants such as thyme, garlic extract, tea tree, mint and lavender contain substances such as carvacrol, thymol and eugenol, which are particularly effective plants against pathogens. These components have a broad spectrum even at low temperatures and have been reported to be effective against pathogens that negatively affect fish health (Reda et al., 2024).

4.CONCLUSION AND RECOMMENDATIONS

Diseases encountered in trout farming can lead to serious economic losses for both producers and the industry. However, effective disease management is achievable through appropriate environmental management, treatment methods and technological advancements. Measures such as improving water quality, limiting antibiotic use and implementing biotechnological solutions are fundamental strategies to control the spread of diseases and protect the health of trout.

In the future, the use of genetic engineering, vaccination strategies and smart technologies will provide more effective results in disease management. In addition, the adoption of biotechnological applications and sustainable production methods will be critical for both protecting the environment and minimizing economic losses.

The management of trout diseases is an evolving field that requires continuous research and development. Future studies will focus on new treatment methods, the development of disease-resistant fish species and sustainable farming techniques, enabling trout production to become more efficient and environmentally friendly.

Preventing and treating diseases in trout farming is essential for maintaining healthy production. Early detection of diseases, selecting the correct treatment methods and preventing the spread of infections can reduce mortality rates and prevent economic losses.

In conclusion, an integrated approach is required for effective management of diseases in trout farming. Key factors for sustainable production include improving water quality, reducing stress, early diagnosis of infections, and using appropriate doses of drugs and chemicals.

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