**DISEASE PREVENTION STRATEGIES IN AQUACULTURE**

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**Introduction**

Aquaculture is the controlled cultivation and farming of the aquatic organisms, including fish, shellfish, and aquatic plants, in various aquatic environments such as ponds, tanks, or enclosures. This practice involves the breeding, rearing, and harvesting of these aquatic species under managed conditions. Aquaculture has expanded beyond traditional fish species to include a broader range of organisms, including shellfish, crustaceans, and even aquatic plants. Aquaculture is a significant contributor to global seafood production, providing essential sources of fish and other aquatic products for human consumption.

 As the world's population continues to grow, there is a rising demand for the seafood. Advances in aquaculture technology, genetics, and management practices have resulted in increased efficiency, higher yields, and improved product quality. Fish are often perceived as a healthy protein source, rich in essential nutrients such as omega-3 fatty acids. Increased awareness of the health benefits associated with seafood consumption has contributed to its growing demand. The intensification of aquaculture, while providing increased fish production, has also been associated with several factors that can contribute to the prevalence of diseases in fish.

The intensification of aquaculture, characterized by high stocking densities and concentrated fish populations, has led to an increased risk of diseases in fishes. The close confinement of fish in such systems creates an environment conducive to the rapid transmission of pathogens, as they can easily spread among densely packed individuals. High stocking densities, often a feature of intensive aquaculture, can induce stress in fish, compromising their immune systems and making them more vulnerable to infections. Limited water exchange in some intensive systems, combined with stressful farming practices, can further contribute to the buildup and persistence of pathogens. Monoculture practices, where a single species dominates, increase the risk of disease outbreaks, as a pathogen affecting one individual can quickly disseminate throughout the population due to genetic similarity. The use of antibiotics, common in intensive aquaculture for disease control, raises concerns about the development of antibiotic-resistant strains of pathogens, posing threats to both fish health and the effectiveness of treatment measures. Efforts to address these challenges require a holistic approach, incorporating stringent biosecurity measures, responsible farming practices, and innovations in disease management to ensure the health and sustainability of aquaculture operations. As the aquaculture industry continues to intensify to meet global demands for seafood, there is a critical need for sustainable and responsible practices that prioritize fish health and welfare. This includes the adoption of advanced technologies for water quality management, the development of disease-resistant strains through genetic improvements, and the implementation of effective biosecurity measures throughout the aquaculture supply chain. Balancing the benefits of increased production with proactive disease prevention and management strategies is essential for the long-term viability of intensive aquaculture systems.

Controlling fish diseases in aquaculture systems involves a multifaceted approach that incorporates various preventive and several scientific management measures. Rigorous biosecurity measures are implemented to restrict access to aquaculture facilities, minimizing the risk of pathogen introduction and transmission. Quarantine protocols for the new fish stock helps to identify and mitigate potential diseases before their integration into the main production system. Regular disease surveillance through health checks and diagnostic testing enables early detection and response. Water quality management ensures optimal conditions, reducing stress and bolstering fish immune responses. Vaccination programs and selective breeding for disease resistance contribute to enhancing the overall health and resilience of fish populations. Prophylactic treatments, such as the use of probiotics and immunostimulants, further support disease prevention. Integrated pest management strategies, including biological controls and habitat management, are employed to minimize disease vectors.

**Immunostimulants:**

Immunostimulants are crucial components in the realm of aquaculture particularly in managing aquatic animal health. by boosting immune system of the animals being treated These products elevate the immune system's activity and responsiveness. Employed to fortify the natural defense mechanisms of organisms, these compounds activate various facets of the immune system, such as phagocytic cells and immune-related proteins. Operating through both natural sources like yeast extracts and synthetic formulations, immunostimulants play a pivotal role in disease prevention and stress management. Whether providing a general boost or exerting specific effects, these substances contribute to the overall health and resilience of aquatic organisms. Ongoing research focuses on refining immunostimulants, tailoring their application to diverse species and aquaculture conditions. By integrating these compounds into aquaculture practices, a proactive stance is made to ensure the well-being and productivity of aquatic populations, reflecting the commitment to sustainable and effective farming methods.

**Mechanism of Immunostimulants:**

The mechanism of immunostimulants in fish involves triggering and enhancing various components of the immune system. When administered, immunostimulants interact with specific cells and molecules, fostering a more robust immune response. The workings of the mechanism are as follows:

**1. Activation of Phagocytic Cells:** Immunostimulants often stimulate phagocytic cells like macrophages. These cells play a crucial role in engulfing and digesting foreign particles, including pathogens.

**2. Release of Cytokines:** Immunostimulants can induce the production and release of cytokines, which are signaling molecules that facilitate communication between immune cells. This orchestration enhances the coordination of the immune response.

**3. Increased Production of Immune Proteins:** Certain immunostimulants prompt the fish's immune system to produce more immune proteins, including antimicrobial peptides and complement proteins. These proteins contribute to the defense against pathogens.

**4. Enhanced Activity of Natural Killer Cells:** Immunostimulants may boost the activity of natural killer cells, which are immune cells that target and destroy infected or abnormal cells.

**5. Improvement of Antigen-Presenting Cells:** Some immunostimulants improve the function of antigen-presenting cells, facilitating a more efficient recognition of pathogens by the immune system.

**6. Adaptive Immune System Modulation:** Immunostimulants can influence the adaptive immune system by promoting the production of antibodies and modulating the activity of T cells. This aspect contributes to a more specific and targeted immune response.

**Types of Immunostimulants:**

There are various types of immunostimulants used in fish, each exerting its effects through different mechanisms. Here are some common types along with examples:

1. Beta-Glucans:

Example: Beta-glucans derived from yeast cell walls.

1. Probiotics:

 Example: Beneficial bacteria like Lactobacillus and Bacillus species used as probiotics in fish feed.

1. Vitamins and Minerals:

Example: Vitamin C, known for its role in immune function, and minerals like zinc.

1. Nucleotides:

Example: Nucleotide supplements derived from yeast or fish.

1. Mannan Oligosaccharides (MOS):

Example: MOS derived from yeast cell walls.

1. Thymic Peptides:

Example: Thymosin, a peptide that can stimulate immune responses.

1. Microbial Extracts:

Example: Extracts from various microorganisms, such as those derived from bacteria or microalgae.

1. Synthetic Immunostimulants:

Example: Poly I:C, a synthetic double-stranded RNA mimicking viral infection.

1. Antioxidants:

Example: Astaxanthin, a carotenoid with antioxidant properties.

1. Essential Fatty Acids:

Example: Omega-3 fatty acids, which play a role in immune function.

These immunostimulants may be incorporated into fish diets or administered through other methods to enhance the immune response in fish. The choice of immunostimulants depends on factors such as the target pathogen, fish species, the specific goals of disease prevention and the kind of management practices adopted in aquaculture systems.

**Vaccine:**

Vaccinology is a multidisciplinary field at the forefront of preventive medicine, focusing on the development, production, and application of vaccines. It encompasses a wide range of scientific disciplines, including immunology, microbiology, molecular biology, and epidemiology. The goal of vaccinology is to create effective and safe vaccines to prevent infectious diseases by stimulating the immune system to recognize and defend against specific pathogens. Through continuous research and technological advancements, vaccinologists strive to address emerging infectious threats, improve existing vaccines, and expand immunization coverage globally. This field plays a crucial role in public health, contributing to the control and eradication of infectious diseases, ultimately saving lives and promoting well-being on a global scale.

Vaccinology in fisheries involves the application of vaccine technology to enhance the health and disease resistance of aquatic organisms, particularly fish. As in terrestrial animals, fish are susceptible to various infectious diseases that can impact aquaculture productivity. Vaccination in fisheries aims to mitigate the spread of these diseases and improve the overall well-being of fish populations. The development of fish vaccines involves identifying specific pathogens, understanding the immune responses of fish, and creating vaccines that stimulate effective immune reactions. Vaccines for fish are administered through various methods, including immersion, injection, or incorporation into feed. Implementing vaccination strategies in aquaculture helps reduce the reliance on antibiotics and other disease management methods, contributing to sustainable and environmentally friendly practices. By bolstering the immune defenses of fish, vaccinology plays a pivotal role in ensuring the health and productivity of aquaculture systems, ultimately supporting the global demand for fish products and safeguarding the economic viability of the fisheries industry.

**Types of vaccines:**

In fisheries, several types of vaccines are used to protect aquatic organisms, primarily fish, from infectious diseases. These vaccines are designed to stimulate the immune system of the fish, providing a defense mechanism against specific pathogens. Common types of vaccines used in fisheries include:

**1. Inactivated Vaccines:** These vaccines consist of killed or inactivated forms of the target pathogens. While the pathogens are no longer capable of causing disease, they retain their ability to trigger an immune response in the fish.

**2. Live Attenuated Vaccines:** Live attenuated vaccines contain weakened forms of the target pathogens. Although they are live, they are modified to be less virulent, reducing the risk of causing disease in the fish while still eliciting a robust immune response.

**3. Subunit Vaccines:** Subunit vaccines use specific components of the pathogens, such as proteins or peptides, to stimulate an immune response. By focusing on key antigens, subunit vaccines can be designed to be highly specific and safe.

**4. DNA Vaccines:** DNA vaccines involve introducing genetic material from the pathogen into the fish. This genetic material encodes antigens, prompting the fish to produce them and triggering an immune response.

**5. Recombinant Vaccines:** Recombinant vaccines are created by inserting genetic material from the pathogen into a different, harmless organism. This organism then produces the antigens, serving as the basis for the vaccine.

**6. Vector Vaccines:** Vector vaccines use a harmless virus or bacterium to deliver antigens from the target pathogen into the fish. This approach aims to enhance the immune response by utilizing the natural infection processes of the chosen vector.

The selection of a specific vaccine type depends on factors such as the target pathogen, the species of fish, and the practical considerations of vaccine administration in aquaculture settings. Each type of vaccine has its advantages and limitations, and ongoing research in vaccinology continues to explore new and improved approaches for protecting fish health in aquaculture. While specific vaccines used in fisheries can vary based on the region, target species, and prevalent diseases, here are some examples of important vaccines commonly employed in aquaculture:

1. AquaVac® Relera (AquaBounty Technologies): Used for salmon, this vaccine employs a recombinant approach to protect against specific salmon pathogens.

2. AquaVac® IPN (Pharmaq): Targets Infectious Pancreatic Necrosis (IPN) in salmonids, a disease caused by a virus.

3. AquaVac® POM-V (Pharmaq): Designed to protect against Pancreas Disease (PD) in salmon, another significant viral infection.

4. AquaVac® VHS (Pharmaq): Targets Viral Hemorrhagic Septicemia (VHS), a viral disease affecting various fish species.

5. Alpha Ject® micro (Merck Animal Health): Utilized for the vaccination of salmonids against Infectious Hematopoietic Necrosis (IHN).

6. Novovac® ILA (Zoetis): A vaccine for Atlantic salmon, providing protection against Infectious Salmon Anemia (ISA).

7. Vibrio Vaccine (Various Manufacturers): Vaccines against Vibrio bacteria, which can cause vibriosis in fish, are essential in shrimp aquaculture.

8. Enteric Redmouth (ERM) Vaccines (Various Manufacturers): ERM is a bacterial disease affecting salmonids, and vaccines are employed to combat its spread.

It's important to know that the aquaculture industry continually evolves, and new vaccines may emerge while existing ones undergo improvements. Additionally, the availability of specific vaccines can vary by region and local disease prevalence. Fisheries management authorities and aquaculturists often work closely with veterinary experts to choose the most effective vaccines tailored to their specific needs and challenges.

**Mechanism of vaccines:**

The antigenic components within fish vaccines are carefully selected to represent key elements of pathogens commonly found in aquaculture settings. These components might include proteins, polysaccharides, or other molecules specific to the targeted pathogens. The choice of antigens aims to elicit a robust and specific immune response without causing disease. Upon vaccination, antigen-presenting cells, such as macrophages and dendritic cells play a crucial role. These cells capture and process the introduced antigens, presenting them to other immune cells. This presentation activates B cells, leading to the production of antibodies tailored to recognize and neutralize the specific pathogens. Simultaneously, T cells are activated, contributing to a more comprehensive immune defense, including the identification and elimination of infected cells. The establishment of immunological memory is a pivotal outcome of vaccination. Memory B cells "remember" the encountered antigens, ensuring a faster and more potent immune response upon subsequent exposure to the actual pathogen. This memory-driven response is pivotal in preventing disease outbreaks in aquaculture, where rapid and targeted reactions are crucial for minimizing economic losses and maintaining the health of fish populations.

The use of vaccines and immunostimulants in fish farming presents distinct advantages and challenges. Vaccines offer targeted protection against specific pathogens, contributing to long-lasting immunity and reducing the need for antibiotics. However, their development can be complex, and costs associated with production and administration may pose obstacles. Immunostimulants, on the other hand, provide a broad-spectrum boost to the fish's immune system and aid in stress management, complementing vaccines effectively. Yet, their efficacy can be variable, and improper use may lead to overstimulation. Balancing the advantages of targeted protection with vaccines and the broader immune enhancement provided by immunostimulants is key to a comprehensive approach in aquaculture, striving for optimal health and disease prevention in fish populations.

In conclusion, the utilization of vaccines and immunostimulants in fish farming represents a multifaceted strategy for disease prevention and management. Vaccines offer specific protection, contributing to sustained immunity and decreased reliance on antibiotics, although challenges in development and administration persist. Immunostimulants provide a broad-spectrum immune boost and assist in stress management, serving as valuable complements to vaccines. While both approaches have their merits and limitations, an integrated strategy combining targeted protection with immune enhancement appears to be a promising avenue for ensuring the health and resilience of fish populations in aquaculture. Continued research and advancements in vaccine technology, immunostimulant formulations, and their judicious application are essential for optimizing disease control measures and promoting sustainable practices in the ever-evolving field of aquaculture.

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