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Short Communication

DNA Vaccines for Viral Diseases in Aquaculture Species

Meera Iyer*

Department of Fish Health, Coral Bay University, Visakhapatnam, India

DESCRIPTION

Viral infections represent one of the most persistent challenges in aquaculture, causing high mortality rates and significant economic losses. Traditional vaccination approaches sometimes fail to provide consistent protection against rapidly evolving viral pathogens. Deoxyribonucleic Acid (DNA) vaccines have emerged as an innovative solution, offering precise targeting of viral genes and stimulating both humoral and cellular immune responses in fish [1]. These vaccines introduce plasmid DNA containing specific viral gene sequences into the fish, allowing host cells to produce viral proteins that activate the immune system without exposing the fish to live pathogens. One advantage of DNA vaccines is their ability to induce long-lasting immunity. The expressed viral proteins serve as antigens that activate T and B lymphocytes, producing a comprehensive immune response. This includes the generation of antibodies against viral surface proteins as well as cytotoxic T cells capable of destroying infected cells [2]. Such responses provide protection against both initial infection and subsequent exposures, making DNA vaccines particularly effective for viral diseases that are difficult to manage using traditional methods.

Common viral pathogens targeted with DNA vaccines include Infectious Pancreatic Necrosis Virus (IPNV), Viral Hemorrhagic Septicemia Virus (VHSV) and Koi Herpesvirus (KHV). Each virus has unique surface antigens that serve as ideal targets for plasmid design. By carefully selecting gene sequences that encode these proteins, researchers can ensure strong and specific immune activation while minimizing unintended reactions [3]. DNA vaccines allow rapid adaptation to new viral strains, offering flexibility in response to emerging threats in aquaculture environments. Delivery methods for DNA vaccines vary depending on species, life stage and production scale. Intramuscular or intraperitoneal injection is commonly used in experimental trials and high-value fish species, ensuring accurate dosing and consistent expression of antigens [4]. Oral and immersion-based methods are under development for large-scale applications, especially for juvenile fish or species cultured in high-density tanks or ponds. Encapsulation and nanoparticle-based formulations improve stability and enhance uptake of DNA in these methods, increasing efficacy in practical aquaculture settings.

Safety is a key consideration in DNA vaccine development [5]. Unlike live attenuated vaccines, DNA vaccines do not carry the risk of causing disease in the host. The plasmid DNA is designed to remain in host cells temporarily, producing viral proteins without integrating into the genome. Extensive studies have shown that DNA vaccines are well-tolerated in a range of finfish and shellfish species, with minimal adverse effects and no significant environmental impact. DNA vaccines also support the control of multiple viral strains through multi-antigen or polyvalent formulations [6]. By including sequences from several viral proteins, these vaccines stimulate immunity against multiple pathogens or variants simultaneously. This approach is especially beneficial in aquaculture systems where co-infections are common, ensuring broader protection and reducing the need for repeated interventions.

Monitoring immune responses following DNA vaccination is critical to ensure efficacy. Measuring antibody titers, cytokine production and gene expression profiles provides insight into the strength and duration of immunity. Challenge trials, where vaccinated fish are exposed to the target pathogen under controlled conditions, confirm protective outcomes [7]. Data from these assessments guide vaccination schedules, dosing strategies and deployment recommendations for commercial aquaculture operations. The environmental benefits of DNA vaccination are also notable. Healthy fish populations reduce the need for chemical treatments and antibiotics, decreasing the risk of environmental contamination and development of antimicrobial resistance [8]. Sustainable vaccination programs contribute to responsible aquaculture practices, enhancing production efficiency and maintaining ecosystem balance in surrounding waters. In addition, DNA vaccines have accelerated

Correspondence to: Meera Iyer, Department of Fish Health, Coral Bay University, Visakhapatnam, India, E-mail: meera.iyer.cbu@edu.in

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research on fish immune systems. Studying immune responses to specific viral genes improves understanding of host-pathogen interactions, aids in identifying biomarkers of resistance and guides the design of future vaccines [9]. Insights gained from DNA vaccine trials inform broader disease management strategies and strengthen the capacity of aquaculture systems to withstand viral threats.

CONCLUSION

In conclusion, DNA vaccines offer a precise, effective and safe method for preventing viral diseases in aquaculture species. Through the introduction of plasmid DNA encoding specific viral proteins, these vaccines induce comprehensive immune responses, provide long-lasting protection and allow rapid adaptation to emerging viral strains. Combined with suitable delivery methods and careful immune monitoring, DNA vaccination supports healthy populations, sustainable aquaculture practices and improved productivity across diverse aquaculture species.

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