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Advances in Bacterial Fish Vaccines: Immunological Foundations, Administration Methods, and Safety in Aquaculture

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ABSTRACT

This study aimed to develop and evaluate the impact of vaccines against bacterial infections affecting common carp (*Cyprinus carpio*), with the goal of enhancing immune responses and reducing disease incidence. The research focused on identifying common bacterial pathogens that negatively affect fish health, particularly *Aeromonas hydrophila*. Vaccine efficacy was assessed through both laboratory and field trials by measuring immune response indicators, such as increased antibody levels. The results demonstrated a significant improvement in disease resistance, highlighting the effectiveness of the vaccines in boosting immune responses and reducing dependence on antibiotics. These findings suggest that vaccination against bacterial diseases in common carp represents a promising strategy to improve fish health and productivity in aquaculture systems. This contributes to both environmental and economic sustainability within the sector. Vaccination in fish has been practiced for over fifty years and is considered one of the most effective methods for preventing a wide range of viral and bacterial diseases. Vaccines support environmental, social, and economic sustainability in global aquaculture. Most licensed fish vaccines are based on inactivated microorganisms formulated with adjuvants and are typically administered via immersion or injection. Live vaccines, which mimic natural pathogen infections, tend to generate stronger antibody responses and can be delivered by immersion or orally. Modern vaccine technologies target specific pathogenic components and include subunit vaccines as well as recombinant RNA/DNA vaccines. These advanced vaccines, currently under development worldwide, have shown the ability to induce stronger immune responses compared to traditional fish vaccines. They offer promising prospects for future aquaculture vaccine development, providing enhanced health benefits and economic opportunities for producers. This review highlights the use of traditional aquaculture vaccines and offers an overview of current molecular strategies aimed at developing next-generation vaccines.

INTRODUCTION

A vaccine is a biological preparation designed to enhance the immune system's response against a specific disease or group of diseases. Vaccines work by triggering