Nanoparticle as an Immunostimulant in Aquaculture

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ABSTRACT

Nanotechnology, which involves the manipulation of particles at the nanoscale (1 to 100 nanometers), has led to significant advancements in various fields, including nanomedicine. This paper explores the application of engineered nanoparticles, particularly metal nanoparticles, in combating microbial resistance in aquaculture. We focus on silver (Ag-NPs), gold (Au-NPs), zinc oxide (ZnO-NPs), and titanium dioxide (TiO2-NPs) nanoparticles due to their potent antimicrobial properties against bacteria, fungi, and viruses. Silver nanoparticles (Ag-NPs), notable for their wide range of applications due to their antimicrobial, optical, electrical, and magnetic properties, have shown efficacy against pathogens such as Aeromonas species and Vibrio harveyi in aquaculture settings. Studies indicate that Ag-NPs can improve survival rates and physiological health in aquatic animals when used as dietary supplements. Zinc oxide nanoparticles (ZnO-NPs) are critical for providing essential trace minerals that support the growth and metabolism of fish. Adequate zinc levels, derived from dietary sources, are crucial for maintaining biochemical and physiological functions, highlighting the importance of ZnO-NPs in aquaculture nutrition.

INTRODUCTION

Nanotechnology focuses on manipulating and utilizing particles at nanoscale dimensions, typically ranging from 1 to 100 nanometers. Recent advancements have enabled us to comprehend and control matter at this minute scale, unveiling unique properties and innovative applications. There are two broad categories of nanomaterials: naturally occurring ultrafine nano-sized particles and intentionally produced engineered nanoparticles (Sahoo *et al* 2017). The latter are meticulously crafted in controlled settings

Nanomedicine, an extension of nanotechnology, finds applications in both human and veterinary medicine, involving the design and deployment of nanoparticles and nanodevices for biomedical purposes. A notable application is in addressing microbial resistance to antibiotics in aquaculture, where researchers explore the use of nanoparticles as effective antimicrobials. Metal nanoparticles, in particular, exhibit potent antimicrobial properties against bacteria, fungi, and viruses

In the following sections, we will delve into investigations on the application of metal nanoparticles specifically targeted at combating fish pathogens

- ✓ Silver nanoparticles (Ag-NPs)
- ✓ Gold nanoparticles (Au-NPs)
- ✓ Zinc oxide nanoparticles (ZnO-NPs)
- ✓ Titanium dioxide nanoparticles (TiO2-NPs)

SILVER NANOPARTICLES (Ag-NPs)

In the past few years, there has been a significant surge in the production and utilization of silver nanoparticles (Ag-NPs) They constituted more than half of the worldwide nanomaterial products in 2015, and it is anticipated that their prevalence will grow by approximately 13% by the year 2024, according to Inshakova and Inshakov (2017) The surge in the production and application of silver nanoparticles (Ag-NPs) can be attributed primarily to their antimicrobial, optical, electrical, and magnetic properties. These nano-particles find widespread use in various industries, including cosmetics, textiles, toothpaste, shampoo, paint, washing machines, food supplements, water treatment, and more, as highlighted by Inshakova and Inshakov (2017). AgNPs, along with various other nanoparticles, have become a focal point of attention in aquaculture. They are recognized as a targeted solution for managing bacterial, fungal, and viral diseases, particularly in light of the escalating challenge posed by antibiotic-resistant bacteria.

AgNPs have demonstrated bactericidal effectiveness against Aeromonas species, identified as a prevalent pathogenic bacterial strain posing a significant threat to the aquaculture industry (Ghetas *et al* 2022). When Rainbow Trout (*Oncorhynchus mykiss*) challenged with *A salmonicida* were exposed to AgNPs at a rate of 100 µg L-1 h-1 in the short term, no mortality or clinical indications were observed compared to the controls (challenged but not exposed to AgNPs) (Shaalan *et al*, 2018)

Silver nanoparticles (AgNPs) have demonstrated effective antimicrobial properties against *A hydrophila* and *Vibrio harveyi* in diverse aquatic animals, as documented by Acedo-Valdez *et al* (2017) and Antony *et al* (2013). Additionally, research indicates that maintaining suitable dietary levels of AgNPs can positively impact survival rates, zootechnical performance, and physiological well-being in aquatic animals.

ZINC OXIDE NANOPARTICLES (ZnO-NPs)

Inadequacies in essential minerals can lead to biochemical, structural, and functional abnormalities, the severity and nature of which are influenced by various factors, such as the duration and extent of mineral deprivation Zinc (Zn) emerges as a crucial trace mineral indispensable for the growth and metabolism of all vertebrates, including fish. Its significance is underscored by its involvement in over 1000 structural, catalytic, and regulatory proteins that play pivotal roles in the growth, development, and overall physiology of animals (Chen *et al* 2015; Simonis *et al* 2024). Serving as a specific cofactor for numerous enzymes engaged in diverse metabolic pathways and contributing to the conformation of nucleoprotein filaments, zinc occupies a key position in sustaining essential biological processes (Chen *et al* 2015).

Nevertheless, for Atlantic salmon (*Salmo salar*), the prescribed dietary zinc (Zn) levels required to uphold whole-body and serum Zn concentrations within the physiological range were identified to be elevated, falling within the range of 37 to 67 mg Zn kg-1 dry diet (Silva *et al* 2019).

CONCLUSION

The integration of these nanoparticles into aquaculture practices offers a promising solution to the growing challenge of microbial resistance, supporting the sustainable development of the industry. Future research and technological advancements will likely continue to enhance the efficacy and safety of these nanomaterials, further cementing their role in improving aquaculture health management

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