Chapter 5
Future Prospects of Nanotechnology in Aquaculture

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5.1 Introduction

5.1.1 Intervention of Nanotechnology and Aquaculture

Nanotechnology focuses on the ability to manipulate matter at the molecular and atomic levels, and as a result, it has enormous potential for developing new materials with improved qualities (Sarkar et al. 2015). Nanoparticles (NPs) play an important role in nanotechnology; new NPs have stimulated the growth of nanoscale materials and the rapid expansion of their applications in numerous fields. Because of their small size and high surface-to-volume ratio, NPs are important advertisements in a few initiatives and the development of research areas (Shah and Mraz 2020). Aquaculture is the world's fastest-growing food-producing sector, and it essentially contributes to the world's fish stockpile for human consumption (Diallo 2011). To ensure a sustainable development that meets global needs, the aquaculture movement must overcome a number of negative aspects arising from its own practices, such as the high concentration of natural combinations in untreated wastewater, the extensive use of anti-toxins, and the proliferation of disease vectors.

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Nanotechnology could provide a variety of solutions to such problems, ensuring a manageable increase in the aquaculture movement.

5.2 Future Prospects of Nanotechnology in Aquaculture

Intervention of nanotechnology and aquaculture has come a long way since its beginning. Numerous concepts of nanotechnology have proven effective in increasing the efficiency of aquaculture. A few of the many are as follows:

- Nanoparticles in water purification to reduce toxicity.
- Nanosensors in fish pond cleaning to reduce the probability of contamination in the pond, which may lead to eutrophication.
- Nanoparticles in nutrient distribution.
- Nanotechnology-based vaccines which play a vital role in aquaculture as a defense mechanism against viruses and protecting the host organisms.
- While the growing of aquatic animals and plants may seem to be a relatively new trend, aquaculture actually tackles a nearly 4000-year-old activity. An Egyptian burial site from before 2000 BC is engraved with *Tilapia nilotica* lake culture. Furthermore, carp farming may have provided a source of new fish for the Chinese monarch circa 1000 BC. This erroneous perception may be due to the fact that aquaculture production, as well as its use in human consumption, has increased dramatically in the last three decades.
- Various advantages in receipt of the aquaculture movement.
- Creation of great food, increment of family food supply, and improvement of sustenance.
- Fortified minimal economies by the increment in business and decrease of food prices.
- Improvement of water assets and supplement the executives at family or then again local area levels.
- Conservation of amphibian biodiversity through re-loading and recuperating of ensured species.
- Whenever done reasonably, the board and protection of wild stock pushed by business and sports fisheries.
- Excitement of exploration and innovation improvement.
- Expanded schooling and natural mindfulness.

With a global population of about 7 billion people, the demand for ocean food is only going to grow, necessitating additional expansion and expansion of aquaculture production. To achieve sustainable growth that satisfies global needs, the aquaculture movement must overcome a few unfavorable viewpoints arising from its own training, which could have bad effects on the initial creation and have severe environmental implications (Fig. 5.1).

Nanotechnology is a developing innovation with high potential for application in the aquaculture business. Nanoengineered minerals (<100 nm) are widely perceived

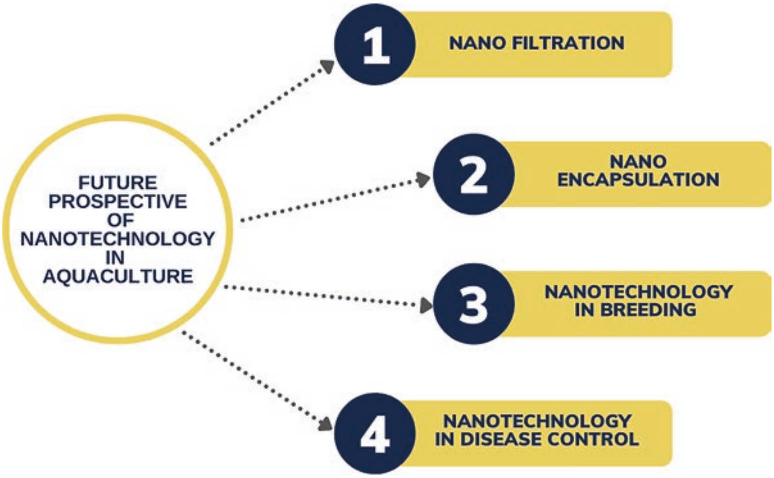

Fig. 5.1 Schematic representation of various future prospects of nanotechnology in aquaculture

in aqua feed due to various factors such as their high dissolvability and dynamic surfaces.

Nanominerals are described by the following factors:

- Higher surface region partiality
- Higher solvency
- Warm opposition
- Low harmfulness
- Slow discharge rate
- Supported delivery

The selection of nanomaterial is based on natural capacity, physiological condition and its metabolic properties.

5.2.1 Nanofiltration

For improved liberation of new components from lake water, nanofiltration technologies are suggested over, for the most part, micron-size filtering. Nanocomposite layers containing nanosilver and polyamide (PA) have been shown to have antimicrobial and biofouling sway on *Pseudomonas* sp. in the presence of water alteration and salt excusal sway (Zodrow et al. 2009). As a result, nanosilver composite can be used to create multifunctional films that act as filtration systems for separating dirty water. Using dendritic polymers, a monodispersive and considerably spread nanosize material, achievements in macromolecular science open up new avenues for designing essential ultrafiltration technologies for water purification. Dendrite polymers can be used to purify lake water because of their carefully designed and planned structure (Zahid et al. 2018; Joseph et al. 2019).

5.2.2 Nanoencapsulation

Nanoencapsulation protects food's delicate and vital bioactive components against a variety of harsh environmental conditions (Fathi et al. 2012). They were involved in the eradication of contradictions and the concealment of objectionable odors and tastes through solubilization, as well as assisting in the revealing of taste. The addition of single-walled carbon nanotubes (SWCNTs) to trout feed, which occurs during the manufacture of hard feed pellets, is an example of nanoencapsulation innovation (Meliana et al. 2017; Aklakur et al. 2016).

5.2.2.1 Selenium Nanoparticles

The role of nanotechnology in aquaculture could be explained using the example of selenium particles. Selenium (Se) particles are among the microelements involved in a variety of activities in a wide range of aquatic animals. The primary function of selenium is to protect cells from oxidation by developing anti-oxidative defenses. Se also functions as a cofactor in the assembly of selenoproteins involved in the catalysis of hydrogen peroxide (Karamzadeh et al. 2021). Se also aids in the digestion of the thyroid organ, as well as the multiplication and improvement of body tissues. Se possesses natural and nonnatural structures that have low bioavailability, dissolvability, and adhesion qualities at first. Accordingly, presenting Se nanoparticles in the aqua feed business is enthusiastically prescribed to augment sea-going creatures' well-being status and usefulness. Se nanoparticles are extensively researched due to their high potential as a development promoter, an antioxidant, and an immunostimulant specialist in aquaculture. Different examinations revealed the need to include Se nanoparticles for upgrading the development execution, physiological, and well-being status in oceanic creatures (Deilamy Pour et al. 2021). Because of the low edge between the advantages and the poisonousness, Se nanoparticles must be remembered for aqua feed in light of a portion explicit way. Unnecessary degrees of dietary Se are unsafe for most creatures, including domesticated animals and fish (Nuttall 2006). The clever Se nanoparticles are characterized by their minimal toxicity and tremendous use. The use of Se nanoparticles, in particular, improved the development, implementation, and efficiency of sea animals. The different roles of Se nanoparticles are presented and explored in this research, with a focus on development progress and feed use impacts, metabolic guideline roles, anti-oxidative and physiological views, and the role of Se nanoparticles as an antistress specialist (Mahdave Jehanabad et al. 2019; Kumar and Singh 2019).

5.2.3 Fish Breeding

Aquaculture research includes a lot of work on fish reproduction and rearing. The most significant advancement is the multiphase transit of compounds by infusions or supplements for the purpose of sustaining a brood stock, which is done to build gonadal tissue. In this manner, animating substances such as human chorionic gonadotropin (HCG) and others are delivered from the prespawning stage, and fish are confronted with pressure, word-related anguish, and other issues. Regular intake of maturational substances such as progesterone or testosterone adds to the problem because they drain into the surrounding water during transportation (Kailasam et al. 2006; Kumari et al. 2013). To dispose of these issues, the implantation of hormonal pellets under the skin was endeavored. Nano-epitomized hormonal conveyance was found to be a more viable option in contrast to this methodology. Chemically stacked nanocarriers can be embedded at the pre-generating stage under the fish skin to trigger development because of their slow delivery and also high maintenance time (Toranzo et al. 2005; Verma et al. 2018).

5.2.4 Fish Disease Control

Infection is one of the most serious threats to the concentrated aquaculture system, and the board of health is critical for preventing pathogenic invasion and recovering fish species. Nanotechnology, like regular innovation, can make a significant contribution in these areas by employing novel tactics (Fig. 5.2).

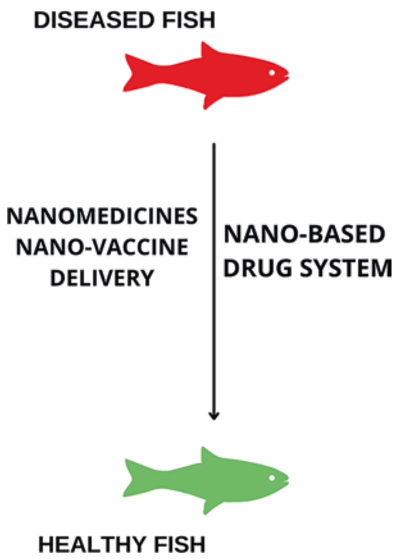

Fig. 5.2 Schematic representation of using nanotechnology-based drugs in aquaculture

Nanomedicine is a fast-emerging field of nanotechnology that offers a wealth of opportunities to improve fish health by utilizing the intrinsic properties of many types of nanoparticles. Nanomaterials with antimicrobial and preventive capabilities, such as nanosilver and zinc oxide nanoparticles, are already being used to lower pathogenic loads in aquaculture systems.

This one-of-a-kind nanomedicine phenomenon is ubiquitous, nonspecific, and extensively applicable. Nanoparticles such as titanium dioxide and copper oxide have antibacterial properties and could be useful nanomedicines for fish.

5.2.5 Nanosensors

Another nanotechnology-mediated method that is used to enhance aquaculture is by using "nanosensors." Nanosensors to screen the stock, cleaning fish lakes with nanotechnology gadgets, and DNA nanovaccines in nanocases containing short strands of DNA are added to a fish lake, where they are consumed by the cells of the fish. Ultrasound is then used to burst the cases, delivering the DNA and getting a safe reaction from the fish. Utilizing iron nanoparticles to accelerate the development of fish and a robotized drug conveyance framework is extremely quick to become reality with this imaginative innovation (Sethi and Panigrahi 2011).

5.2.6 Nanoparticles in Effluent Treatment

Nanoparticles are acquiring ubiquity for their applications in the evacuation of microorganisms, organics, inorganic synthetics, halogenated intensifiers like pesticides, and weighty metals from and anticipation of biofouling in water bodies, outstandingly in inland aquaculture (Iwuozor et al. 2021). The basic attributes of nanostructures that work with this utilization are their sizes, similarly high steadiness, and processing ability. Zinc oxide NPs, iron oxide NPs, tin oxide NPs, silver NPs, and carbon nanotubes (CNTs) are probably the most read-up gatherings of nanomaterials for use in aquaculture water quality administration (Ighalo et al. 2021). Additionally, their presentation has been accounted for to significantly improve in occurrences where they are utilized synergistically with biopolymers, for example, green growth, by taking advantage of their inborn surface hydrology and photosynthetic capacity (Hesni et al. 2021).

5.2.7 Nanomaterials in Reducing Heavy Metals

Iron oxide NPs are extremely appealing due to their small size, high surface-to-area proportion, surface modifiability, outstanding attractive characteristics, and biocompatibility, as demonstrated by Hesni's experiments with the nanoparticle and *Chlorella vulgaris* (Ighalo et al. 2021; Xu et al. 2012). Because of these qualities, iron oxide particles have proven to be quite effective in removing heavy metals from amphibian wastewater. For example, the most severe retention limit for Pb particles by Fe3O4 NPs in a concentrate was 360 mg/g (Nassar 2010), which is higher than recently disclosed characteristics for less expensive adsorbents. To attain the highest limit, a few factors in the batch adsorption cycle were adjusted, including pH, temperature, the grouping of initial Pb particles, and coincident particles. The iron NPs' small size was an important factor in the growth of metal particles from their placement onto metal sites on the adsorbents. Fe_3O_4 NPs were found to be extremely feasible and economical for disposing of and recovering metals in inland amphibian effluents in this way. In a similar vein, a few functionalized materials, such as chelating ligands, have been used to improve the surface modification of nanomaterials to improve their capability for heavy metal evacuation using carbon-encapsulated attractive nanoparticles (CEM NPs), which achieved 95 percent take-up for both ions. The adsorption isotherms for the metals produced adsorption limits, a significant property that determines how much an adsorbent is required for the removal of a specific measure of toxin, that is somewhere between 1.23 and 3.21 mg/g for the two metals, which is significantly higher for initiated carbon. Essentially, NH_2-adjusted Fe_3O_4 NPs were developed for the ejection of Cu^{2+} particles that occurred between the nanoparticles and the amine lot on the altered nanomaterial's outer layer (Bystrzejewski et al. 2009).

This confirms the possibility that modified NPs may perform better in water quality management applications than unmodified NPs. Heavy metals in amphibian biota can also be removed using natural-source NPs, which have the advantage of being more effective due to their biodegradability. After estimating using a Nuclear Assimilation Spectrophotometer, the performance of Vetiveriazizanioides nanoadsorbents in reducing the heavy metal substance revealed that the reduction of the metals is in the range of decreases like Hg > As > Disc > Pb (Kumar et al. 2021).

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