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A Mini-Review of the Application of Nanotechnology in Fishery for the Detection and Control of Diseases: An Emerging Tool

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Abstract

The application of nanotechnology has emerged as an extensive approach in the research field of medicine. Thus, the use of nanoparticles as a diagnostic method is now developing. Nanoparticles are considered a sensitive tool and have a vast range of applications in different areas like vaccination, drug delivery, medicines, and disease diagnosis. In this regard, this review focused on the various areas of nanoparticle applications in fisheries.

Keywords: *Nanoparticles, Nanotechnology, Fisheries, Vaccines, Drug*

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Introduction

Nanotechnology is a science that is applied in the production and utilization of nanometer-sized particles (known as nanoparticles). Nanotechnology is a highly promising and rapidly progressing science that is applied in different fields such as biotechnology, chemistry, engineering, and physics. Nanomaterials are present in various structural dimensions like clusters, crystalline, and molecules, and these particles work within the range of 1–100 nm (Chandra, 2016). Nanoparticles are used in different shapes such as dendrimers, nanocapsules, nanospheres, and nanotubes (Wu *et al.*, 2015).

In medicine, nanotechnology can be applied in both human and veterinary medicines in what is known as nanomedicine. In the domain of nanomedicine, the main focus is to design and utilize nanoparticles and nanodevices for biomedical applications (Cavalieri *et al.*, 2014). Moreover, these particles are known to provide several advantages including drug efficacy, enhanced bioavailability, dose reduction, decreased toxicity, tissue-specific targeting, and reducing secondary adverse effects (Shah and Mraz, 2020). Due to their physicochemical characteristics, these particles have a wide range of applications in the healthcare system, food preservation, and water treatment (Ogunkalu, 2019).

Additionally, the use of nanoparticles in the seafood industry is now attracting attention. The seafood industry is growing very fast and producing above 50% of the food. Worldwide, in 2018, fish production reached about 180 million tons while its consumption grew to 20.5 kg per capita (FAO, 2020). Therefore, regarding Sustainable Development Goals for 2030, the seafood industry can contribute efficiently making a prominent effect on global food security (FAO, 2018). But various factors negatively affect this food sector such as chemical contamination, environmental degradation, disease prevalence, and improper nutrition (Shah and Mraz, 2020). In the seafood industry, nanotechnology can bring significant changes due to its several applications like pathogens detection, disease control, ponds sterilization, water treatment, nutrients distribution, and drug delivery system (Luis *et al.*, 2019). Nanoparticles provide great stability against environmental degradations due to their high absorption, enhanced bioavailability rate, improved solubility, dispersion, and stability (Pathakoti *et al.*, 2017).

Thus nanomaterials can be used in delivery systems to improve nutritional profiles (Bhattacharyya *et al.*, 2015). The huge potential of nanotechnology has been seen to improve fish health and immune system with an increase in its reproduction and production rate along with its enhanced nutritional value through the use of nanoparticle-based drug and gene delivery systems (Muruganandam *et al.*, 2019). Given this perspective, the main goal of this short review is to focus on different applications of nanotechnology in fisheries to control their health issues.

Disease control of fisheries

Health management of fisheries is an emerging challenge because changing climate and environmental pollution are increasing the issues of diseases and pathogens in fisheries (Zhang *et al.*, 2016). It is essential to reduce the burden of diseases and to prevent the infestation of pathogens in fisheries which are the major threat to the health management system in fisheries. In this regard, nanotechnology can play a significant role and perform better as compared to conventional techniques (Kaul *et al.*, 2018). In disease control of fisheries, the approach of nanotechnology is discussed in three spheres including diagnosis of fish diseases, nanotechnology-based fish medicine, and nanoparticles for drug delivery.

Diagnosis of fish diseases

In this modern age, scientists are trying to develop and use methods which can help in the rapid diagnosis and detection of disease in fisheries. Nowadays, typical diagnostic techniques are replaced by novel and rapid diagnostic methods such as nanoparticle-based diagnostic approaches which are named nanodiagnostics (Jain, 2003). Gold nanoparticles (AuNPs) are one of the most suitable nanoparticles for the diagnosis of different diseases (Saleh *et al.*, 2015) that occurs in fish and shrimp, details are provided in Table 1. Numerous nanoparticles due to their exclusives properties are excellent carriers for the distribution and supply of vaccines, drugs, and genes. For these kinds of applications, Poly D, L-lactide-co-glycolic acid (PLGA), and polymeric chitosan nanoparticles are widely studied in fish medicines (Cavalieri *et al.*, 2014; Wang *et al.*, 2011; Costa *et al.*, 2015; Makadia and Siegel, 2011; Myhr and Myskja, 2011). Tables 2 & 3 shows the function & types of nanoparticles.

Table 1: Application of gold nanoparticles for the diagnosis of different diseases in fisheries.

Category	Virus/ Bacteria	Assay/ Biosensor	Reference
Shrimp	Yellow Head Virus	The colorimetric assay comprises gold nanoparticles with loop-mediated isothermal amplification (LAMP)	(Jaroenram *et al.*, 2012)
	White Spot Syndrome Virus	DNA-functionalized AuNPs with LAMP	(Seetang-Nun *et al.*, 2013)
Fish	Aphanomyces Invadans	Electrochemical DNA biosensor	(Kuan *et al.*, 2013)
	Nervous Necrosis Virus	Au-NPs based biosensor	(Toubanaki *et al.*, 2015)
		Immunomagnetic reduction assay	(Yang *et al.*, 2012)
	Spring Viremia of Carp Virus	Colorimetric assay	(Saleh *et al.*, 2012)

Table 2: Different functions of nanoparticles in fisheries.

Proposed function	Nanoparticle	Nature	Experimental model	Result	Reference
Slow and sustainable drug release	Chitosan nanoparticles	Biocompatible, non-toxic and eco-friendly polymer	In Rainbow trout's scientific name (*Oncorhynchus mykiss*), for which vitamin C was scattered with chitosan Nps	Activate the defensive structure. It was observed that the vitamin was discharged up to 48 hours after being taken orally through the mouth.	(Alishahi *et al.*, 2011; Costa *et al.*, 2015)
Hormones transport system			In *Cyprinus carpio* one set was made of that hormone which was responsible for releasing luteinizing hormone and then tied up with chitosan Nps to match to luteinizing the hormone that is connected with chitosan- Au-NPs	One injection comprised of hormone-chitosan NPs conjugate and hormone-chitosan-gold NPs injected separately for evaluation of egg fertilization rate and found 87% and 83% respectively.	(Rather *et al.*, 2013)
Drug carrier vehicle	PLGA	A co-polymer comprising polylactic and polyglycolic acid. Biocompatible, eco-friendly, and non-toxic	The injection was made for zebrafish embryos survival that was made up of PLGA nanoparticles and on these NPs anti-mycobacterial agent rifampicin is applied for better results	Greater embryo survival was observed along with better therapeutic effect against *M. marinum* when matched with rifampicin only	(Fenaroli *et al.*, 2014; Lü *et al.*, 2009; Makadia and Siegel 2011)

Table 3: Different types of nanoparticles used in the nanovaccines.

Nanoparticles used with culture material	Type of vaccine	Type of organism	Result	Reference
Chitosan	Inactivated virus vaccine	Used against salmon anemia virus	Against ISAV the vaccine showed safety rates that extend up to 77%	(Rivas-Aravena *et al.*, 2015)
Chitosan and chitosan/tripoly phosphate nanoparticles	Oral DNA vaccine	Used against the pathogen *Vibrio anguillarum* that targets the Asian sea bass	Adequate safety against the pathogen	(Kumar *et al.*, 2008; Vimal *et al.*, 2012)
Protein K gene of *Vibrio parahemolyticus* on to chitosan	Oral DNA vaccine	Used against pathogen *Vibrio parahemolyticus* that target the black seabream	Defensive immune reaction	(Li *et al.*, 2013)
Recombinant DNA-chitosan nanoparticles	Administered orally	Used to protect shrimps from the white spot syndrome virus	Improved the shrimp's immunity against the virus	(Rajeshkumar *et al.*, 2009; Vimal *et al.*, 2013)

Nanoparticles based vehicles for drug distribution

Nanoparticle-based delivery is a novel approach in the drug distribution system, as this approach has several advantages such as a specification of location, regulated release, control of shape and size, proper dispersion, and multi-route delivery processes (Patra *et al.*, 2018). The best scientific systems always possess some ideal features which distinguish them from other systems which is applicable in the case of drug delivery systems (Table 2) because of minimum side effects, the safety of a drug, way of transferring drug, stability of the delivery system along with its closeness to nature, are key factors that are counted for the success of the specific delivery system (De Jong and Borm, 2008). Moreso, nanoparticles used in drug delivery systems are popular because they have less volume and a high surface area ratio which permits them to pass from different biological barriers of the body like the blood-brain barrier to improve their reactivity with different compounds as well as conjugates of the body (Wang *et al.,* 2011).

Nanovaccines

For the prevention of pathogenic infestation and resultant diseases in fisheries, vaccination is considered as well recognized as cost-effective method. In this domain, nanovaccine is a new approach (Assefa and Abunna, 2018). Nanovaccines used for controlling fish disease create own identity because they possess key features because they can deliver the antigen slowly or fastly through the delivery system and are also helpful when used as primary immunostimulants (Zhao *et al.,* 2014). For vaccine delivery, different nanoparticles are used according to the situation like metal nanoparticles, liposomes, polymeric nanoparticles, virus-like nanoparticles, and immunostimulant complex (Table 3) (Gregory *et al.*, 2013; Zhao *et al.*, 2014).

Conclusion

Food insecurity is a global challenge. The fishery industry is a fast-growing sector that fulfils the increasing demands for seafood. However, increased disease susceptibility and pathogenic infestation appear to affect the sustainability of the fisheries industry. In the field of fisheries, nanotechnology has emerged as an effective and innovative technique. To strengthen the fisheries nanotechnology can play a significant role in the sustainability of this system. In this regard different nanotechnological applications have been incorporated into the health management system including disease diagnosis, nanovaccination, drug and gene delivery system, and drug distribution.

Declarations

Competing interests

The authors report no conflicts of interest.

Authors' contributions

Abdul Wahab conceptualized the idea. Nazir Ahmed and Syed Saad Mazhar provided technical assistance and guided in the data collection. Sadia Hassan helped with drafting the manuscript.

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