

Nanotechnology as a Novel Tool in Fisheries and Aquaculture Development: A Review

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Abstract: Application of nanotechnology has revolutionized many frontier areas; it is paving a way for the researchers for possible application in all sectors. Nanotechnology holds promise for various aspects of fisheries and aquaculture development, like fish health management, fish breeding, aquatic environment management and other areas. Nanotechnological intervention will help to meet the global challenges associated with aquatic organism production, including environmental sustainability, human health, disease control and food security. This aspect of aquaculture and Fisheries is still in infancy and require attention of the scientific fraternity for its widespread use to harness its potential benefit. In the present paper a review on the application of nanotechnology in fisheries and aquaculture is presented.

Key words: Nanotechnology · Environmental sustainability · Fish breeding · Human health · Food security

INTRODUCTION

Nanotechnology has been defined by the U.S. National Nanotechnology Initiative (NNI) as “understanding and control of matter at dimensions of roughly 1 to 100 nm where unique phenomena enable novel applications”. More elaborately it may be defined as “the study, design, creation, synthesis, manipulation and application of functional materials, devices and systems through control of matter at the nanometer scale (1-100 nanometers, one nanometer being equal to 1×10^{-9} of a meter) that is at the atomic and molecular levels and the exploitation of novel phenomena and properties of matter at that scale”. There are several applications of nanotechnology for aquaculture production that are being developed. With a strong history of adopting new technologies, the highly integrated fish farming industry may be among the best to incorporate and commercialise nanotech products.

The Fisheries and aquaculture industry can be revolutionized by using Nanotechnology tools for rapid disease detection, targeted delivery of drugs, DNA vaccines and nutrients. As per National Science Foundation (USA), current predication estimates value global nanotechnology industry at one trillion by 2015.

This could be possible due to vast potential of nanotechnology not only in electronic and materials science but also in human, animals, food and agriculture sectors including aquaculture. The application of nanotechnology in biomedical and biological science for analysis of biomolecules, cancer therapy, development of non-viral vectors for gene therapy, as transport vehicle for DNA, protein and cells, has already received much attention from the scientific fraternities. Although much research and development are needed for potential use of nanotechnology in aquaculture; there are numerous glimpses of the future in application of this technology in fish health management, water treatment in aquaculture, animal breeding and harvest and post-harvest technologies.

Fish/Shellfish Health Management & Nano-Vaccines:

Outbreak of disease is one of the major stumbling blocks in the development and sustainability of aquaculture. Numbers of approaches have been applied in an attempt to solve disease problem in aquaculture and vaccination is one of them. But the use of oil emulsion as adjuvant may cause major drawbacks as some fishes and shellfishes show unacceptable levels of side effect. Thus using nanoparticles carrier like chitosan and poly-lactide-

co-glycolide acid (PLGA) [1] of vaccine antigens together with mild inflammatory inducers, one may achieve high levels of protection to fishes and shellfishes not only against bacterial but also from certain viral diseases with vaccine induced side effect. Further the mass vaccination of fish can be done using nanocapsules which will be resistant to digestion and degradation. These nanocapsules containing short strand DNA are absorbed into the cell of fish, when applied to water. The ultrasound mechanism is used to break the capsules which in turn release the DNA thus eliciting an immune response to fish due to the vaccination. Similarly oral administration of these vaccine and site specific release of the active agent for vaccination will reduce the cost and effort of diseases management, application of drug and vaccine delivery lead to sustainable aquaculture.

Nanoparticles have been used as oral drug carriers for several reasons such as improvement of the bioavailability of drugs with poor absorption characteristics [2], prolongation of the residence time and digestive stabilization of drugs in the intestine [3], high dispersion at the molecular level and consequently efficient absorption [4], delivery of vaccine antigens to gut-associated lymphoid tissue [5] and control of the release of the drugs [6].

Nanoparticles for Enhancement of Fish Growth:

Scientists from the Russian Academy of Sciences have reported that young carp and sturgeon exhibited a faster rate of growth (30% and 24% respectively) when they were fed nanoparticles of iron [7]. Research had demonstrated that different Selenium source (nano-Se and selenomethionine) supplemented in basal diet could improve the final weight, relative gain rate, antioxidant status as glutathione peroxidase (GSH-Px) activities and muscle Selenium concentration of crucian carp (*Carassius auratus gibelio*). Moreover, nano-Se appeared to be more effective than that of organic selenomethionine in increasing muscle selenium content [8].

Nanodelivery of Nutraceuticals: Use of nutraceuticals for health management, value addition and stress mitigation in fish and shellfish is an emerging area of aquaculture research. In spite of their low requirement, incorporation of nutraceuticals involves higher cost. Thus, it needs to be used in such a way that wastage of feeding is minimized and there is efficient utilization of the nutrients. Development of Nanodelivery system for these kinds of molecules may address the problems of their application

in aquaculture practices at commercial level. There is an immense opportunity to use the nano delivery system of nutraceuticals in fish feed. Moreover, various nanoformulations of feed help to maintain better consistency and taste of feed [9].

Water Treatment: Nano-enabled technologies are available today for the removal of contaminants from water. Nonmaterial in the form of activated materials like carbon or alumina, with additives like zeolite and iron containing compounds can be used in aquaculture application for holding aerobic and anaerobic biofilm for the removal of ammonia, nitrites and nitrate contaminants [10].

Animal Breeding: Management of breeding is an expensive and time consuming problem for culturing animals. One solution that is currently being studied is a nanotube implanted under the skin to provide real time measurement of changes in the level of estradiol in the blood. The nanotubes are used as a means of tracking oestrus in animals [11] because these tubes have the capacity to bind and detect the estradiol antibody at the time of oestrus by near infrared fluorescence. The signal from this sensor will be incorporated as a part of a central monitoring and control system to actuate breeding.

Transgenesis: Microinjection to deliver DNA into mammalian/fish cells is time-consuming and needs to be precise, using micropipets and micromanipulators to dispense very small volumes of material past into the nucleus. Microinjection is the common method for genetic engineering (GE) and the making of GE animal and fish. A novel method of DNA delivery has recently been described by using arrays of vertically aligned carbon nanofibers (VACNFs) [12]. Cells are pressed onto the DNA-coated VACNFs which then penetrate the cells and introduce the DNA. VACNFs could help to overcome the tedious microinjection involved in genetic manipulation and the temporal expression of genes that are not introduced into the inheritable genetic material of embryos but could affect them at crucial times [12]. This temporary expression could ameliorate the concerns that have accompanied GE livestock, including safety of GE animal food and products, cross-contamination of GE livestock with non-GE varieties and long-term effects on animal health and welfare from introduced genes [13].

The use of nanotechnology for DNA delivery could provide benefits to animal health and the safety of animal derived products. However, the safety of the silica

nanoparticles and their effects on early embryo development post treatment warrant some investigation, although they have been shown to have little toxicity [14]. Similar nanodelivery system may be attempted for DNA incorporation in fish and shellfish.

Nanotechnology Devices for Aquatic Environment

Management: Nevada-based Altair Nanotechnologies deliver a water cleaning product for swimming pools and fishponds called 'NanoCheck.' It uses 40 nm particles of a lanthanum-based compound which absorbs phosphates from the water and prevents algae growth. NanoCheck is currently undergoing large-scale testing in swimming pools. It also holds promise for its use in thousands of commercial fish farms worldwide where algae and heavy metal removal and prevention are costly at present.

Nanotechnology Studies in India: Though work on nanotechnology is still in infancy which has been initiated only a few years ago in India, the Central Institute of Fisheries Education in Mumbai is currently working with nanotechnology to encapsulate hormones like LHRHa for breeding of fishes which showed a sustained effect on the physiology of the fish than the commercially available hormonal formulations or other inducing agents (personal communication). Works are going on for development of nano DNA vaccines against certain viral diseases of fish and shellfish. Research is also going on nanodelivery of different types of nanoencapsulated nutraceuticals through feed for enhancement of growth.

CONCLUSION

Nanotechnology undoubtedly presents a major opportunity for the economy and sustainable development of aquatic resources in many countries although the applications of nanotechnology for animal production are very diverse. But there is growing concern for possible toxicity of nano particles in biological system. Owing to its small size it penetrates through the cell membrane and enters to the body system which sometime cause genotoxicity to the individual. However risks, benefits and societal issues depend on the specific area of application, composition of the nanomaterials, methods of deployment and the ultimate goals. However, such concerns should not prevent us from trying to think upstream about nanotechnology and aquaculture as a field of development. Careful monitoring and controlled use can help us to maximize benefits and minimize risks. It is necessary to develop sound oversight systems,

address socioeconomic impacts and engage the public not only for democratic and ethical reasons, but also to ensure confidence in nanotechnology and animal production.

REFERENCES

1. Rajeshkumar, S., C. Venkatesan, M. Sarathi, V. Sarathbabu, J. Thomas, K. Anver Basha and A.S. Sahul Hameed, 2009. Oral delivery of DNA construct using chitosan nanoparticles to protect the shrimp from white spot syndrome virus (WSSV). *Fish and Shellfish Immunol.*, 26(3): 429-437.
2. Florence, A.T., A.M. Hillery, N. Hussain and P.U. Jani, 1995. Nanoparticles as carriers for oral peptide absorption: studies on particle uptake and fate. *J. Controlled Release*, 36: 39-44.
3. Peters, S.E. and C.H. Brain, 2009. Benefits of a Soy Lecithin Based Nanotechnology for the Animal and Human Food Industry. Chapter, 12: 183-197. Publication Date (Print): March 03.
4. Mohanraj, V.J. and y. Chen, 2006. Nanoparticles- A Review. *Journal Pharmacy Res.*, 5(1): 561-573.
5. Jani, P., G.W. Halbert, J. Langridge and A.T. Florence, 1990. Nanoparticles uptake by rat gastrointestinal mucosa: quantitation and particles size dependency. *J. Pharmacy and Pharmacol.*, 42: 821-826.
6. Eldridge, J.H., C.J. Hammond, J.A. Meulbroek, J.K. Staas, R.M. Gilley and T.R. Tice, 1990. Controlled vaccine release in gut-associated lymphoid tissues. I. Orally administered biodegradable microspheres target the Peyer's patches. *J. Controlled Release*, 11: 205-214.
7. ETC, Down on the Farm, 2003. The Impact of Nanoscale Technologies on Food and Agriculture (2003) Available [http:// www.etcgroup.org/ en/materials/publications.html](http://www.etcgroup.org/en/materials/publications.html), Last Accessed February 15, 2003.
8. Zhou, X., Y. Wang, Q. Gu and W. Li, 2009. Effects of different dietary selenium sources (selenium nanoparticles and selenomethionine) on growth performance, muscle composition and glutathione peroxidase enzyme activity of crucian carp (*Carassius auratus gibelio*). *Aquac.*, 291(1-2): 78-81.
9. Food and Agriculture Organization of the United Nations (FAO) and World Health Organization (WHO). Report of Joint FAO/WHO Expert Meeting on the Application of Nanotechnologies in the Food and Agriculture Sectors: Potential Food Safety Implications. [cited 18 December 2009].

10. Gillman, G.P., 2006. A simple technology for arsenic removal from drinking water using hydrotalcite. *Science Total Environmental*, pp: 336.
11. O'Connell, M.J., S.M. Bachilo, C.B. Huffaman, V.C. Moore, M.S. Strano, E.H. Haroz, K.L. Rialon, P.J. Boul, W.H. Noon, C. Kittrell, J. Ma, R.H. Hauge, R.B. Weisman and R.E. Smalley, 2002. Band gap fluorescence from individual singlewalled carbon nanotubes. *Sci.*, 297(5581): 593-596.
12. McKnight, T.E., A.V. Melechko, G.D. Griffin and M.A. Guillorn, 2003. Intracellular integration of synthetic nanostructures with viable cells for controlled biochemical manipulation. *Nanotechnol.*, 14: 551-556.
13. Thomas, C.E., A. Ehrhardt and M.A. Kay, 2003. Progress and problems with the use of viral vectors for gene therapy. *Nature Reviews Genetics*, 4: 346-351.
14. Luo, D., E. Han, N. Belcheva and W.M. Saltzman, 2004. A self-assembled, modular DNA delivery system mediated by silica nanoparticles. *J. Controlled Release*, 95: 333-341.