Nano-Technology in Aquaculture Feed: A Review

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Abstract—*Aquaculture industry playing a great role in the nutrition security of several countries. There are three pillar on which successful fish culture depend i. e. quality seed, quality feed and quality management. Formulation of aqua feed is the most expensive and difficult task depends on several factor like the age, habitat and physiochemical parameter for the optimal requirement of aquatic organism. Traditional feeds like mixture of brans and cakes in various proportion is an age old practices but in the current scenario where high quality fish/shellfish are cultured under various production system like RAS, Pens, Raceways, Bio-flock etc. various new feed formulation techniques are employed. Generally pellet is chiefly formulated based on the daily nutritional fish requirements for components such as fats, proteins, carbohydrates, minerals and vitamins. One new approach called "Nanotechnology" can be used for revolutionised the feeding practices. The basic concept of this technique is that the fish food nutrients are coated in Nano-particles which increasing the proportion of that pass across the gut tissue and into the fish, rather than passing directly through digestive system unused. Other benefits are Nanoparticles pass into cells more readily than their larger counterparts which not only accelerates assimilation process but also resolve the problem of leaching of nutrition and hence reduce the water pollution. Apart of this nanoparticle offer a scope of efficient drug delivery system through feed for better health management. Additionally, the cautious use of this technology, could reduce the feed cost and offer an eco-friendly crop.*

Keywords: *Aquaculture, Nutrition, Aqua feed, Nanotechnology.*

1. INTRODUCTION

Ever growing population & limited available resources coupled with environmental threats i. e. frequent climate changes would certainly effect food productivity and hence food security. In this context, it is imperative to ensure intensification of production system, coupled with efficient food handling, processing and distribution. Fisheries is playing promising role to the food security of country,India holds second rankglobally in overall fish production and second largest producer of fresh water fish in the world. India is contributing 5. 68% to the global fish production (FAO 2014) and total export of the county during 2013-14 approx. Rs. 30213 crore. Fisheries sector not only contributes significantly to the national economy but providing livelihood to approximately 14. 49 million people in the country (DAHD&F 2012-13). Generally Success of any aquaculture venture mainly depends on "Three Pillars" i. e. quality seed, quality feed and quality management. Nutritionally balanced aqua feed is the most important and crucial input for the successful fish production as it is one of the major limiting factors in the expansion of the total fish production. The cost associated with feeds and feeding typically constitute the largest of operating expenses in the production of fishes. Sub-optimal feeds and inefficient feeding regimes result in direct economic losses through food wastage and sub-optimal growth, deterioration of water quality and increased environmental pressure from excessive waste production. Effective delivery system of feed and medicinein aquaculture is more challenging task to accomplish after effective feed formulation to achieve sustainable fish production which enable optimal use of feed and reducing the economic loss and environment deterioration. The formulation of cost-effective, nutritionally optimaldiets along with efficient delivery system for all the stages of fishes/shellfishes are therefore imperative to maximized profitability and reducing the waste output on marine fish farms. Larval stages of fishes/shell fishes are delicate in nature, optimal nutrition requirement and pelletsize of feed are the main constrain for the growth and development of larval stages. Suitable feed formulation depends upon several factors viz. raw material (quality & quantity) and the technique of feed preparation, leaching of nutrition etc. (leaching of valuable nutrition and the desirable feed size is the main hurdle for aquaculture industry). Therefore there is utmost need to development not only suitable size nutritionally adequate, cost-effective feed formulation but also effective delivery system which not only bind the essential nutrition but reduce the leaching for all the stages of fishes (spawn, fry fingerlings) and shell fishes (PL, juvenile) to meet the demand. Nanotechnology applications in food and agriculture sector encompass development of new functional materials and products as well as methods and instrumentation to ensure food safety and bio-security (Sozer and Kokini, 2009).

2. WHY NANOTECHNOLOGY

Nanotechnology is an emerging science which is has a tremendous potential to revolutionize agriculture and allied fields including aquaculture and fisheries. It can provide new tools for aquaculture, fish nutrition, fish biotechnology, fish genetics, fish reproduction and aquatic health etc.

Nanotechnology has a wide usage potential in aquaculture and seafood industries. For instance, production of more effective fish feed for aquaculture species by application of nanotechnology.

3. DEFINITION AND CONCEPT OF NANOTECHNOLOGIES

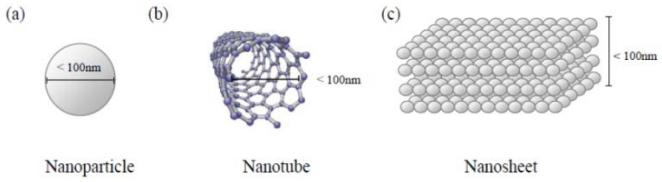
The term "nanomaterial" is based on the prefix "nano," which originates from the Greek word meaning "dwarf. " More precisely, the word nano means 10^{-9} or one billionth of a meter. The word nanomaterial is generally used for materials with a size ranging between 1 and 100 nm (Rai and Ingle 2012). Areas of Nanotechnologies hold great potential for creating new materials with enhanced properties. A number of nanotech based products are finding applications in industries such as medical devices, imaging, sports, biosensing, electronics, drugs, environmental cleanup, cosmetics and sunscreens (NCPI 2011; USEPA 2007), agriculture, textiles, food, etc. Sharon et al. 2010; Sastry et al. 2011).

According to "RAS report No. 41, Nanotechnology and Food Safety, Hong Kong 2010" of nanotechnology derived products can be:

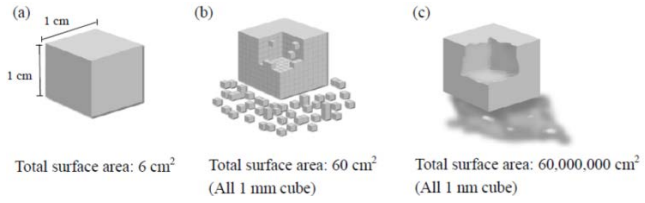
(a) Nanoparticle: A discrete entity that has all three dimensions in the nanoscale.

(b) Nanotube: A discrete hollow fibre entity which has two dimensions in the nanoscale.

(c) Nano sheet: Nano-object with one external dimension in the nanoscale.



To understand the concept of nanoparticle following illustration are given



(a) A solid cube with 1 cm on each side has 6 cm^2 of surface area.

(b) Volume of 1 cm^3 filled with cubes with 1 mm on a side has a total surface area of 60 cm^2.

(c) Volume of 1 cm^3 filled with cubes with 1 nm on a side has a total surface area of 60,000,000 cm^2.

4. SYNTHESIS OF NANOMATERIALS

Nanomaterials can be produced using two building strategies, either a "top-down" or a "bottom-up" approach.

4. 1 Top-down approach

In the top-down approach, nanomaterials are created by breaking up bulk materials using means such as milling to reduce the size of a complex object to the point where this scale reduction begins to alter the very principles it is based upon. However, this method encounters major problem of speed that the slow production rate make it incompatible with the requirement of mass production. (Hsieh & Ofori 2007; Labrune & Palmino 2004)

4. 2 Bottom-up approach

The bottom-up approach is radically different, since it involves the building of nanomaterials from individual atoms or molecules that have the capacity to self-assemble like crystal growth. The resources required for building of nanomaterials with the bottom-up approach are considerably reduced since growth and assembly of nanoparticles can be controlled in a single step, and in a natural and self-regulating manner. However, invention and study on the compatibility of different components are needed before any new nanomaterials are synthesised. (Labrune & Palmino 2004)

5. NANO TECHNOLOGY IN AQUA FEED

Nanotechnology has a wide usage potential in aquaculture and seafood industries. Especially to overcome feeding strategies problems of culture organism, Nano technologies offer a promising results, because of it nano size particle and efficient blending property which makes the feed delivery system more efficient and successful. According to the some studies, nanoparticles of elements like selenium, iron, etc. sources supplemented in diet could improve the growth of fish reduce the cost of water treatment. There are numerous potential applications of NMs in aqua feeds (Table. 1). Nanotechnology holds promise for medication and nutrition because materials at the nanometre dimension exhibit novel properties different from those of both isolated atom and bulk material (Albrecht *et al.*, 2006; Wang *et al*., 2007).

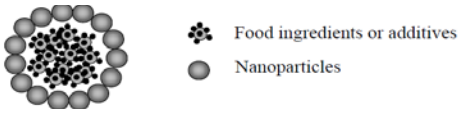


Fig. 1: Nano encapsulation of feed

For instances Iron (Fe) is an indispensable element for the functioning of organs and tissues of higher animals, including fish, because of its vital role in physiological processes such as oxygen transport, cellular respiration and lipid oxidation reactions (Lee et al. 1981; Andersen et al. 1997). 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.

Research had demonstrated that different Selenium sources (nano-Se and selenomethionine) supplemented in basal diet could improve the final weight, relative gain rate, antioxidant status as well as Glutathione Peroxidase(GSH-Px) activities and muscle Se concentration of crucian carp (*Carassiusauratusgibelio*).

Table 1: Potential use of Nano technology in aqua feed.

Sr. No	Function	Justification
1	Antimicrobial or Antifungal agents	Preserving sacks or during storage of fish food
2	Delivery of micronutrients or other less stable ingredients	To enclose or coat (Nanoencapsulation technology) nutrients that would normally degrade, such as fatty acids, or have limited assimilation efficiency. eg. free fatty acid
3	Increasing bioavailability	Carotenoids, Trace minerals, Vitamins and Fatty acids ((Acosta, 2009;see Bouwmeester *et al*., 2009)
4	Nanoscale mineral supplements (trace metals) e. g. Nano forms of sodium selenite	Improve absorption in ruminants e. g. selenium (Romero-Perez *et al*., 2010)., Iron salts (Carriquiriborde *et al*., 2004)) etc.
5	Alternative to organic forms of food supplements	To reduce the antinutritional factors (if present in raw ingredients)
6	Stability of the food ingredients	Alter the physical properties reduce food wastage and pollution improve texture, buoyancy (Handy &Poxton, 1993). Encapsulation and controlled release of food
7	Change the physical properties of food pellets	Single-walled carbon nanotubes (SWCNTs) to trout. hard pellet that does not fragment easily in water (Handy, unpubl. obs.). Ramsden *et al*. ,2009 observed Rainbow trout readily eat food containing NMs (up to 100 mg kg−1 TiO2 NPs)
8	Carrier vehicles of essential nutrients	Nutraceuticals, enzymes, food additives and food antimicrobials

Lipid is an important component having many dietary benefits, but easily oxidised leads to rancidity which impart off flavour to the feed hence rejection of feed by organisms. To overcome this problem β-cyclodextrin a water soluble polymer and polycaprolactone a water-insoluble polymer were used to encapsulatefish oil and the stabilities of freeze-dried fish oil in encapsulated complexes were investigated to determine fish oil release rates at different relative humidity and storage temperatures.

Fishes will eat food containing NMs and nanotechnology could be used to improve the delivery of micronutrients or unstable ingredients in aqua feeds. For example, the use of Nano-encapsulation technology for fat-soluble vitamins, minerals and fatty acids may be advantageous. Some NMs can change the physical properties (*e. g.* buoyancy, hardness) of the feed. Nanotechnologies can be used for water disinfection in fishpond which not only increased water quality but improved in yields and survivals of fish and prawn (Table. 2)

Table 2: Applications of nanotechnology in Aquaculture and Seafood Industries

Sr. No	Function	Justification
1	Water filtration and purification	remove pathogens directly or to enhance photo degradation of Pathogens with ultraviolet (UV) treatment (Li *et al*., 2008).
2	Diagnostics: antimicrobial properties of NMs such as Nano titania and Nano silver (Muhling *et al*., 2009)	Can be exploited to reduce the build-up of bacteria in the aquaculture system.
3	Reducing Bio-fouling	Antibacterial coatings on the sides of fish tanks and pipe
4	Remove low concentrations of halogenated compounds like pesticides and heavy metals eg. Gold and silver NPs	(Pradeep & Anshup, 2009)
5	Photocatalytic degradation of organic chemicalssuch as trichlorophenol	To improve water quality.

6. OTHER IMPORTANT USE OF NANO TECHNOLOGY IN AQUACULTURE ARE AS FOLLOWED

1. **Fish Growth Promoter**:The selenium (Se), iron (Fe) containing nanoparticles are also assumed to promoter of high final body weight gain and improve the antioxidant property.
2. **Nano fertilizer**:emerging technology substituting Nano fertilizers for traditional methods of fertilizer application is a way to release nutrients into the soil gradually and in a controlled way, thus preventing eutrophication and pollution of water resources.
3. **Nanotechnology in hydroponics**:A nanophosphor-based electroluminescence lighting device has the potential to reduce energy costs significantly. Such nanotechnology-based light could reduce energy costs and encourage photosynthesis in indoor, hydroponic agriculture.
4. **Nanotechnology in animal production/reproduction and animal nano-feed applications**: Surface-functionalized nanomaterials and nano-sized additives can

bind and remove toxins or pathogens. Nano-feed (a food supplement for animals) encourages the activation of the animal's own self-healing forces, equal to improved resistance against diseases. Nano-feed also acts as an antioxidant to maintain healthy cell activity and overall animal health. Benefits can be seen in the reduction of antibiotics needed, improved bone growth, improved phosphate utilization, and reduction in mortality rates.

5. **Nanomaterials forenvironmental issues**: Due to the extremely small particle size, large surface area, and high reactivity. Nano-scale iron–manganese binary oxide was an effective sorbent for removal of arsenic (III) and arsenic (V) from both synthetic and actual field groundwater. Calcium–alginate polymer is an excellent choice as an entrapment medium as it is nontoxic and has little solubility in water. The use of nanoscale zero-valent iron (diameter 10–90 nm with an average value of 35 nm) entrapped in calcium–alginate beads showed great promise for aqueous arsenic treatment. A water-cleaning product for swimming pools and fishponds called "Nano Check" (Altair Nanotechnologies, Reno, NV, USA) uses 40 nm particles of a lanthanum-based compound which absorbs phosphates from the water and prevents algae growth.
6. **Health managements**:Nanoparticles have promise for improving protection of farmed fish against diseases caused by pathogens. Chitosan nanoparticles are promising carriers for an oral plasmid DNA vaccine. For example, oral administration with chitosan/pDNA induced an antibody immune response in fish against *Vibrio parahaemolyticus*.

7. CONCLUSION

The potential of nanotechnology to revolutionize the health care, textile, materials, information and communication technology and energy sectors has been well publicized. As in other sectors, the advent of nanotechnology promises to revolutionize the development of products and applications in agriculture and fisheries industries. The long-term impact of these predicted concentrations on fishes is currently unclear, and chronic effects on the environment cannot be excluded. There are chances that Nanoparticles as indirect sources of food contaminants Alter the absorption profile and metabolism in the body. Unknown toxicity of nanoparticles Potential to cause impairment of DNA replication and transcription. Although nanotechnology enhances quality and availability of products, some materials emerging from nanotechnology may pose a risk to aquatic environment. Future studies should be focused on preventing or minimizing the adverse effects of these materials

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