Review Article

Dietary Supplementation of Nanomaterials in Aquaculture - A Review

Vijayaram Seerengaraj [1,2*], Yun Zhang Sun[1], Muthuchamy Maruthupandy[3], Suruli Kannan[2], Vasantharaj Seerangaraj[4]

[1]Fisheries College, Jimei University, Xiamen 361021, China.

[2]Dept of Environmental Studies, School of Energy Environment and Natural resources, Madurai Kamaraj University, Madurai 625021, Tamil Nadu, India.

[3]Lab of toxicology, Department of Health Sciences, The Graduate School of Dong-A University, 37, Nakdong-daero, 550 Beon-gil, Saha-gu- Busan - 49315, Republic of Korea.

[4]Department of Biotechnology, Hindusthan College of Arts and Science, Coimbatore 641028, Tamil Nadu, India.

***Corresponding author's E-mail:** vijayarambiotech@gmail.com

Received: 19-07-2021; **Revised:** 24-09-2021; **Accepted:** 03-10-2021; **Published on:** 15-10-2021.

ABSTRACT

Aquaculture is the best growing food production division in the globe. Infection outbreaks are also a most important problem for the aquaculture productions. Different types of technological development are uses to improve healthy aquaculture production and enhance the aquatic environment. Nanotechnology is most significant tool for the development of aquatic productions. These techniques are used to detect the infection at short time, deliver the vaccine, drugs and feed for aquatic animals. This review provides information about dietary feed with supplementation of different nanomaterials such as copper, selenium, magnesium, manganese, iron, zinc, chromium, chitosan is utilized to enhance immune system, digestive function, disease resistance, antioxidant activity, growth performance, survival, regulate the metabolic functions, gut health, bio availability, feed intake, feed conversion of diverse aquatic animals. These nanomaterials are mainly focused to improve the nano-nutrient in the feed supplements in aquaculture and enhance the healthy aquatic production.

Keywords: Feed additives, nanomaterials, immune system, fishes, aquaculture.

QUICK RESPONSE CODE →

DOI: 10.47583/ijpsrr.2021.v70i02.027

DOI link: http://dx.doi.org/10.47583/ijpsrr.2021.v70i02.027

INTRODUCTION

In aquaculture industries, nanotechnology might be utilized as a hopeful tool in fast infection detection and delivery of drugs, vaccines, nutrients and hormones cultivable organisms [1]. The main objective for fish industry is to make bigger cost effective fish feed [2]. Fish meal is the vital nutrients for growth element in fish feed. The suitable fish feed ingredients are helpful to enhance for fish growth, disease resistance, immunity and health promoting factors [3]. Minerals are vital nutrients for normal body process as well as requirement differed from depending on fish farms and connections with other elements. Minerals are required lower amounts compared than other nutrients e.g. protein, carbohydrates and fat [4]. They are active in fish contain iron, calcium, zinc, iodine (from marine fish), phosphorus, selenium, fluorine and these elements are tremendously bio available once simply taken through the body. Vitamin B complex is better source for fish species. At same time, liver oil has a vital quantity of fat-soluble vitamins A, D, E, K and vitamin C [5]. Fish oil is highly rich with polyunsaturated fatty acids particularly omega fatty acids that cannot synthesize by human body [5].

Feed supplementation has been more familiar administration method in fish cultivating technique and many supplements have been shows that a capable to enhance the fish immune system or regulating the harshness of infections[6, 7]. Nanotechnology plays an important role in the future areas of research in animal nutrition [8]. The capability of nanoelements is improve protein stability may effects in number of biological functions such as digestion, metabolism and nutrient uptake [9]. Nowadays nanotechnology received great attention in agriculture and related fields including aquaculture and fisheries. In aquaculture, nanotechnology involves the preparation and utilization of various nanoparticles is very helpful for many ways like, nutrient supplements, therapeutic agents and gene delivery, etc. [10].

Many investigators reported that dietary feed additives of nanoelements are consuming numerous beneficial effects in nanomaterials such as iron, zinc, selenium, cobalt, etc as well as these elements fulfil the requirement of fish species[11,10]. Chitosan nanoparticles is useful for multiple purposes like controlled release of drugs and gene delivery [107], also feed supplements for obtaining enhanced growth action and meat quality in several fish species *Oncorhynchus mykiss* [12], *Lates calcarifer* [111], *Oreochromis niloticus* [112] and *Clarias gariepinus* [113]. The competence of

feed supplement within the body depends on their size and chemical structure [114]. Additionally, nanoparticles have involved a lot of notice in the region of aquaculture and nanomedicine due to their elite physical, chemical and biological properties [13]. The small components or trace minerals, such as chromium, cobalt, copper, iodine, iron, manganese, molybdenum, selenium and zinc are necessary in small volumes and contribute in an extensive diversity of biochemical processes [14].

A useful immune system is necessary for the continued existence and activation of shrimp/fish in aquaculture. Every trace mineral factors are contain their exact role in immunity of cultured animals, but the crucial trace metals such as Zn, Mn, Cu and Se that have been linked with an enhancement in immunity or role that maintain immunity. The immune system is uses several methods to detoxify these foreign factors or antigens [15]. The small components have mainly strengthened by the significance of their functions immune protection and antioxidative defence. Feed supplements in nano forms are evaluated to find the different properties between improving growth and immunity through antioxidant consequence to their use in small amount than its bulk counterparts, which increases ration criteria [1, 16].

Different types of metal nanoparticles (NPs) such as Se, Fe, Cu, FeO, and ZnO are utilized in aquaculture responsibility[17, 15]. The metal oxide nanoparticles mainly, trace metal elements are limited with useful immunostimulants in feed additives to fish, it is a novel delivery system for improving the immune capability and infection resistance against to harmful microbes [18]. Dietary additives of chitosan nanoparticles level (1.0 g/kg diet) are utilized to enhance antioxidants and natural immunity response of Nile tilapia [19]. Similarly, Dietary feed with supplementation of copper nanoelements (80mg/kg^{-1}diet) are used to improve the growth, digestive enzyme activities, metabolic enzyme levels, biochemical constituents, antioxidant and non-specific immune response in freshwater prawn (*Macrobrachium rosenbergii*), post larvae [20] and red sea bream (*Pagrus major*) [18].

Dietary feed with supplementation of iron nanoparticles is used to improve growth and better feed efficiency of Nile tilapia (*Oreochromis niloticus*) fish compared to the control group [21]. Similarly, dietary feed with supplementations of selenium NPs (5mg Se/ kg^{-1}) and magnesium NPs (basal diet+500 mg NanoMg/kg diet) are helpful to enhance better growth conditions compared to control group in diverse fish species [22-29]. Dietary additives of various nano elements such as selenium, zinc and manganese are used to enhance stress resistance and bone mineralization of gilthead sea bream (*Sparus aurata*) [30]. This review provides information about different types of nano dietary supplements are used to enhance the healthy aquatic production as well as utilized various process methods like dietary administration, types, doses level in different aquatic animals. Fig. 1 showed that the dietary feed additives of nanomaterials in aquatic animals.

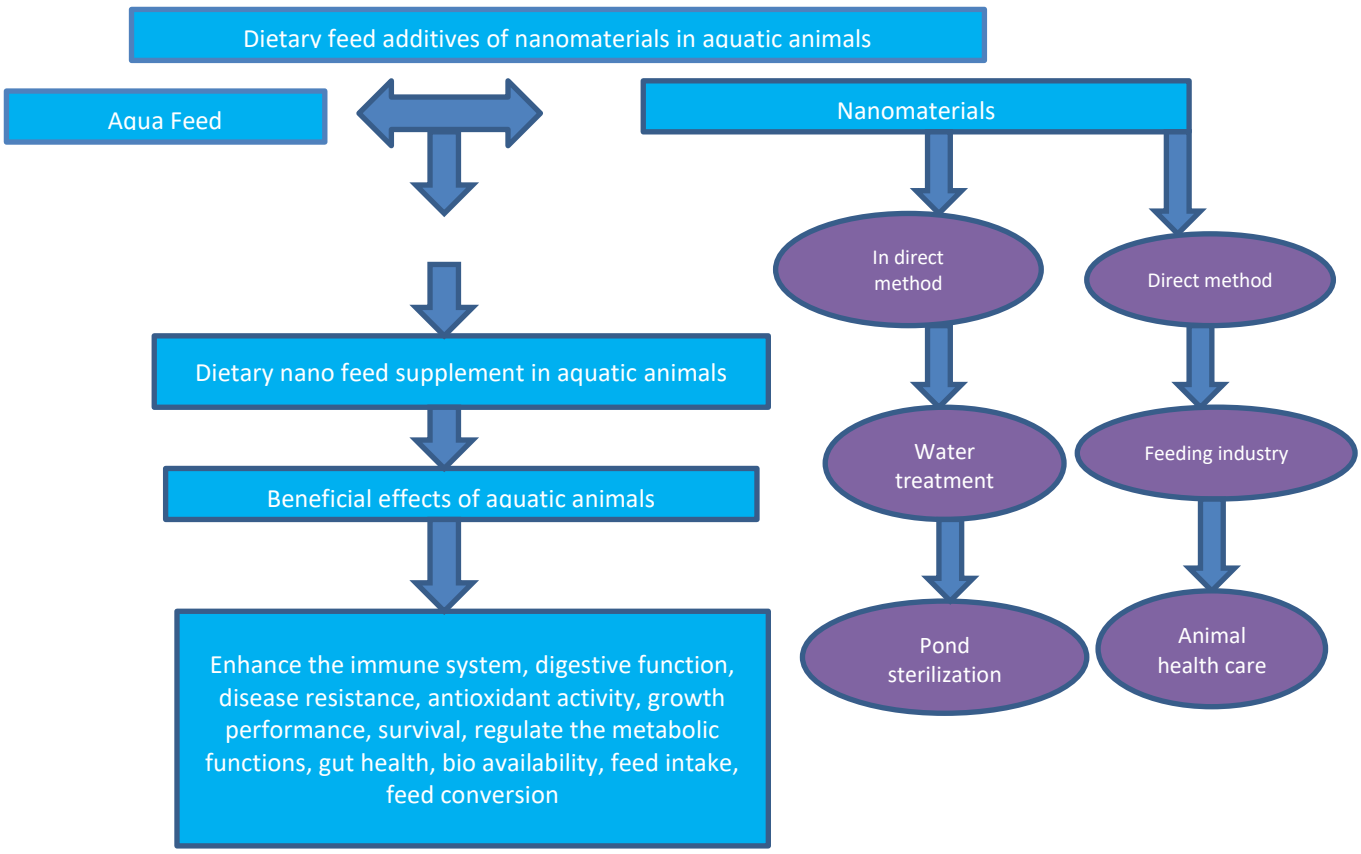

Figure 1: Dietary feed additives of nanomaterials in aquatic animals

Table 1: The function of different nanomaterials feed additives in aquatic animals

Nanomaterials	Aquatic organism	Activity	References
Copper	common carp *M. rosenbergii*	↑Immunity↑ Digestive enzyme action, ↑Survival, ↑Growth and ↑Feed intake	(58) (59) (61)
Selenium	Common carp Catfish Meagre *N. tilapia* European seabass	↑Growth performance ↑Feed efficiency ↑Intestinal morphology ↑Antioxidant capability ↑Immune related gene expression	(26) (62) (63) (64) (65) (74)
Zinc	*M. rosenbergii* Grass carp	↑ Survival, ↑Growth, and ↑Immunity	(80) (84)
Chitosan	Rainbow trout Kelp grouper Gibel carp	↑Immunity, ↑Stress resistance, ↑Growth and ↑Disease resistance	(92) (96) (99) (101)
Magnesium	*M. rosenbergii*	↑ growth, ↑Survival and ↑Digestive enzyme function	(116)
Manganese	*M. rosenbergii* Atlantic salmon *Juvenile tilapia* Channel catfish	↑Growth, ↑ Survival and ↑Protein efficiency	(120) (122) (125) (121)
Iron	Carp *Nile tilapia*	↑ Muscle concentration ↑ Growth, ↑Immune response, ↑Antioxidant activity and ↑Disease resistance	(131) (132)
Chromium	*C. mrigala*	↑ Growth, ↑Nutrient digestibility and ↑Haematological parameter	(141)

2. Role of nanotechnology in aquaculture

Nanoparticles synthesized are different kinds of methods such as physical, chemical and biological methods. The significant role of nanoparticle is used for drug delivery and other additives are biological substances across the cell membrane in the biological process. Green synthesis nanoparticles are great attention of other chemical synthesized materials and their combination with the various parts of cell [31]. Traditional methods are not suitable for the synthesis of nanomaterials and these methods are utilizing lot of reagent and chemical for the biggest productions of nano elements both industrial and commercial level [31-33]. Nanoparticles are demonstrated that various responses by cell decrease the mortality rate of fish species. Different kinds of nanomaterials are able to enter antigen-presenting cells by different pathways and stimulate immune responses to the antigen. Role of nanoparticles is designed to perform the specific cell and different kinds of nanomaterials are used in fish vaccine delivery, biodegradable polymers, nano liposomes, carbon nanotubes, calcium phosphate, and immunostimulating complexes [34].

The nanomaterials are desired in relation to fishes and other organisms via various routes with less negative impacts [34-37]. Nanotechnology is plays a significant function in fish nutrition, drugs and vaccines in efficient manner. Nanotechnology possesses a great attention of novel nanoparticles with cost effective production. Nanoparticles relate field is more niches for researchers and fast growing impacts are providing novel nano-labelled products with unique role [38-40]. Nanoparticles are mainly linked to target with specific antigen of the pathogen and suppress their replication at the cellular level. Fish food is playing a significant role in nutrition, food security and livelihoods [41].

Fish has provided the high quality of proteins and other nutrients particularly, amino acids, fatty acids, vitamins and other vital elements [41]. Nanotechnological application process are the most important role in aquaculture feed production and the nanoparticles contains to successful prove the micronutrient delivery, quantity produced feed and growth promotion [42]. In addition, chitosin nanoparticles are more encapsulators that are efficient and carriers utilized for oral delivery of vaccines and bioactive substances due to their high resistant to intestinal degradation. These components are more helpful to protect the encapsulated ingredients, increase their shelf life and improve intestinal absorption without cytotoxicity [43, 44]. Gastrointestinal microbial diversity in fishes that are strongly involved to control the intestinal immune system depending on the relation between the composition of beneficial and pathogenic microorganisms of the aqua feed nutrients [45]. In addition, beneficial microbes are secreting their digestive enzymes to digest the nutrients via intestines of fish and beneficial microbes are enhancing the feed efficiency and growth rate [46].

Dietary additives of chitosan nanoparticle are continuously prepared to utilize for fish feed and this nano feed contain the positive impact on anti oxidant activity when orally

treated for fishes [47]. Dawood et al. (2020) reported that dietary additives chitosan nano elements are utilized to improve the growth performance of feed utilization and intestinal histo morphometric features in *L. ramada*. In addition, numerous study reports are suggested that role of nanotechnology in effective delivery of dietary feed additives and nutraceuticals in fisheries. These techniques are helpful to improve bioavailability, bio accessibility and the effectiveness of dietary nutrients are enhancing their solubility and defence from unfavourable environment of the gut. Dietary additive of selenium (1 mg/kg) is used to enhance growth and anti oxidant activity of common carp; these results are confirmed to compare with control groups [48]. Nanotechnology is considered solution to prevent and monitor diseases and pathogens and numerous positive effects in aquaculture [49].

3. Different kinds of nanoparticles application in aquaculture

3.1 Copper nanoparticles (Cu NPs)

Dietary inorganic copper such as copper oxide, copper chloride and organic chelated copper or nano form of copper is new method of copper dietary feed additives. Recently, many researchers recommended that bioavailability of organic chelated copper is elevated than copper inorganic salts in chick, pig, lamp [50, 52,53] and fishes [54- 56]. These results indicated that Cu NPs level (2.59 mg/kg) has been improved the immunity in common carp [57]. Although, the system of action of Cu NPs on humoral immunity is unidentified, it has been expressed that Cu NPs might not directly control humoral immunity by cellular immune responses [58, 59]. The connection between the immunity and against dietary feed with supplementation of Cu NPs is known by a polynomial model focused on lysozyme action (R^2 = 0.7528; P = 0.001). Lysozyme and phagocytic action are focused on the Cu NPs needed for common carp (*Cyprinus carpio*) (2.59 to 2.68 mg/kg) (59). IgM is also improved by Cu NPs in parallel with *Russian sturgeon* [59]. The system behind the role of Cu iron enhancing the immunity of fish is not clear right now, but Cu iron deficiency is responsible for the immunosuppression, decrease of T cell proliferations and cytokine production [60]. Muralisankar et al. (2016) concluded that the Cu NPs inclusion of dietary feed supplements are used to increasing the digestive enzymes activity, feed intake, better survival, growth with elevated the biochemical constituents and whole body mineral contents in *M. rosenbergii* feed with (20mg/kg^{-1}) Cu NPs supplemented diet (Muralisankar et al*.,* 2016). These dietary feed with supplementation level is sustainable culture of freshwater prawn *M. rosenbergii* [61]. The functions of different nanomaterials feed additives in aquatic animals have been summarised in Table 1.

3.2 Selenium nanoparticles (Se NPs)

Dietary feed with additives of Se NPs are utilized to enhance growth performance, feed efficiency of several aquatic species such as common carp of *Cyprinus carpio*[26,62], catfish of *Clarias gariepinus* [63], and meager of *Argyrosomus regius* [64]. Single or combined dietary feed with supplementation of Se NPs and/or Vitamin C is used to enhance intestinal morphology, antioxidant capability, and immune related gene expression in Nile tilapia (*Oreochromis niloticus*) [65]. Se-chitosan is regulates the immune system response by increasing their innate immunity and regulating pathogen-induced inflammation through Toll-like receptor-regulated signalling pathways[66,67].[68] Hoffmann, (2007) and [64] Mansour et al. (2017) have recommended that Se pretentious immune function by modifiable thyroid hormone metabolism. Moreover, nutritional Se NPs and/or Vitamin C extensively improved superoxide dismutase, glutathione peroxidase, catalase, nitro-blue tetrazolium (NBT) level, the phagocytic index, lysozyme and phagocytic activities ($P < 0.05$). However, particularly decreased levels of malonaldehyde are evaluated in fish feed Se NPs and/or VC ($P < 0.05$) [64].

TNF-α and IL-1β showed gene expressions in the liver and spleen of the fishes are extensively upregulated by Se NPs and/or VC ($P < 0.05$). The results exposed that the possible function of Se NPs and/or VC in improving growth, intestinal morphometry, immune and antioxidative functions in Nile tilapia (*Oreochromis niloticus*) [68, 64]. Dietary feed with supplementation of Se NPs is used to improved physiological parameters, immune response and antioxidant activity in the fish fed diet supplemented with (1 mg/kg) of Se NPs [69]. These dietary feed supplements are used to enhance disease resistance; muscle proximate composition and economic efficiency improved with (1 mg/kg) of Se NPs incorporated diet. In addition, the Se necessary by monosex Nile tilapia (*Oreochromis niloticus*) that results are in best growth performance, feed utilization (1.23 and 1.26 mg Se/kg) and diet respectively [69]. Dietary feed with supplementation of Se NPs are showed that increased the fish body weight, , significant growth ratio, lowest feed conversion ratio compared to Se. The basal diets and also good bio available sources for tilapias growth [70] as well as dietary feed with nano selenium additive are positive impact on several fish species [26, 62, 71-73]. Dietary feed with additives Se NPs range between 0.5 and 1 mg/kg is most favourable for growth performance, hemato-biochemical indices, antioxidative status, and immune-related genes in European sea bass (*Dicentrarchus labrax*) [74].

3.3 Zinc oxide nanoparticles (ZnO NPs)

The additional strengthening of ZnO NPs are enhances growth, feed intake, immune reaction, anti-oxidative status, thermal tolerance, reproductive function of animals and response as an antimicrobial factor [75-79]. The ZnO NPs (60 mg/ kg^{-1}) are enhanced the survival, growth and immunity of *Macrobrachium rosenbergii* [80]. The growth of haematological criterion of grass carp and *Ctenopharyngodon idella* are enhanced with dietary feed with supplementation of ZnO NPs (30 mg/kg^{-1}). In addition, the dietary feed additives with ZnO NPs have better thermal resistance of *Pangasius hypophthalmus* kept under lead

contamination and defence this fish against oxidative, cellular metabolic stress [77]. Luo et al. (2015) reported that, ZnO NPs might activate non-specific and specific immune reaction depending on their physicochemical functions. Furthermore, it is well recognized that Zn irons insufficiency reduces immune reaction and infection resistance in human and animals [81].

In the recent research reported that dietary feed with additives of ZnO NPs is used to upregulated the IL-1β and IL-8 expression profile extensively in (ZnO 60mg/kg and ZnO 30mg/kg) supplemented group [82]. Tawfik et al. (2017) reported that the IL1-β gene expression in *O. niloticus* subsequent nZnO and ZnO as a feed supplement. Our conclusion exposed that, antiprotease occurring in serum is higher than the control group, particularly more action is establish in *Pp*β-GBP-ZnO NPs than *Pp*β-GBP and chem-ZnO NPs supplemented diet fed fish [82]. Antiprotease level in serum of *Paralichthys olivaceus* enhanced to notably when fed with propolis added diet [83]. Faiz et al. (2015) stated that dietary feed with supplementation of ZnO NPs is utilized to enhance growth and immune status in grass carp (*Ctenopharyngodon idella*) [80]. Similarly, dietary feed with supplementation of ZnO NPs is used to improve weight, total protein content, digestive enzyme, and antioxidant activity in freshwater prawn of *Macrobrachium rosenbergii* [84, 85].

Dietary feed with supplementation of ZnO NPs is utilized in low (30 mg/kg diet) and high (60 mg/kg) concentration that, high concentration diet can possibly improve immune status and antioxidant status of fish species. On the other side disrupts immune responses and antioxidant status, besides mediating oxidative and inflammatory injuries as well as low concentration diet of ZnO NPs could improve the economics of farming and improve the fish production [86]. Dietary feed with supplementation of ZnO NPs is used in short duration studies (≤45 days) for fish species. These dietary feed of nano supplements are used to enhance the growth, feeding efficiency, metabolic enzymes, serum profile and non-specific immune functions in rohu, *L. rohita* fingerlings and also ZnO NPs supplement is used to increase absorption and bioavailability in the gastrointestinal tract of fish [87]. Dietary feed with supplementation of organic and inorganic ZnO NPs are utilized to enhance growth performance, immunity via modulation of cytokine genes expression, and higher antioxidant activity either in serum or antioxidant gene transcription in *O. niloticus* fish [51]

3.4 Chitosan nanoparticles (Cs NPs)

Many researchers suggested that chitosan nanoparticles (CS NPs) are more capable in reducing the growth of *Staphylococcus aureus*, *Candida albicans*, *Saccharomyces cerevisiae, Escherichia coli*, and *Fusarium culmorum* than ordinary chitosan elements [88, 89]. The antibacterial activity of Cs NPs might be documented to its polycationic nature due to the turnout of main amine groups in their frequent units. These amine groups are connect to the negatively charged bacterial cell wall, changing the membrane permeability, troublesome the cell and consequently connecting to the DNA most important to the inhibition of DNA replication and cell death [90,91]. The use of nano-sized materials with stronger immune stimulatory characteristics would be a unique technique in aquaculture industry for getting better fish growth, health, and immunity by changing the existing usual products. Hence, it is speculated that the use of CS NPs may get better feeds characteristics and in turn, may get better fish performance, health and immunity. Immunostimulants be able to be defined as natural or synthetic molecules capable of stimulating non-specific and/or specific immune responses [92]. The addition of immunostimulants in aquaculture practices is future now.

In recent years, chitosan has been exhibited as a successful immunostimulant in diverse fish species [93]. The role of achievement of immunostimulation result of chitosan within fish body is not fully understood yet. Furthermore, the immunostimulation result of chitosan may through improving the action of inflammatory cells namely polymorphonuclear leucocytes, cytokine, and macrophages[94, 95]. The helpful application of chitosan on fish is showed in numerous studies in which Cs NPs are administered via diet. Dietary feed additive with chitosan for *Oncorhynchus mykiss* [96], *Paralichthys olivaceus* [97], *Cyprinus rubrofuscus* [98], *Epinephelus bruneus* [99], *Scophthalmus maximus* [100], *Carassius gibelio* [101], *Cirrhinus cirrhosus* [102], and *Lates calcarifer* [103] are showed that the chitosan might improve the growth, natural immunity, infection, stress resistance, haematological parameters and water quality. From fish immunological view point, Cs NPs are utilized for the delivery of vitamin C [106], RNA (107), or DNA [108,109, 113- 115] owing to their positive charge and solubility in aqueous solution. In addition, chitosan is enhances the encapsulated properties of active molecules from the harsh conditions in the gastrointestinal tract and increases their absorption [114]. The efficiency of recombinant DNA-Cs NPs is examined that defence against *white spot syndrome virus* (WSSV) in shrimps. It is establish that when administered orally, the vaccine improved shrimp immunity, given that a defensive reaction against WSSV [115].

3.5 Magnesium nanoparticles (Mg NPs)

Dietary feed additives of MgO NPs (100–500 mg/kg^{-1}) are used to increase growth, better survival, function of different enzymes like amylase, protease and lipase; and concentration of biochemical components (amino acids, total protein, lipid and carbohydrate) in *M. rosenbergii* PL over the control. This research mentioned that dietary feed additives of MgO NPs (100–500 mg/ kg^{-1}) are utilized to increase general health and non-specific immunity of the test prawns and also these additives level suitable and safe concentration as far as *M. rosenbergii* PL is concerned [116]. Dietary feed additives with Mg NPs are used to reduce the negative impact of magnesium and also smaller particles can easily absorb from intestinal wall of aquatic animals [117]. Single or combined dietary feed with supplementation of nano elements Se NPs and Mg NPs are used to enhanced humoral immunity and improved antioxidant capacity in

Asian sea bass (*Lates calcarifer*) [29] and also Mg NPs having antibacterial and antioxidative effects [118, 119]. Srinivasan et al. (2017) reported that dietary feed with supplementation of Mg NPs (100–500 mg/kg) is used to improve growth performance, non-specific immunity and general health of prawn. However, no information is available about synergistic effect of Se and Mg in fish [116].

3.6 Manganese nanoparticles (Mn NPs)

Dietary feed with supplementation of Mn NPs (18mg/kg) is used to enhance survival, growth, protein efficiency and feed intake of *M. rosenbergii.* Similar studies are reported that dietary feed with supplementation of Mn NPs used to enhance growth performance of diverse fish species such as *Cyprinus carpio* [120], *Ictalurus punctatus* [121], *Salmo salar* [122], *Horabagrus brachysoma* [123], *Scophthalmus maximus* [124]. *Oreochromis niloticus* [125], *Carassius gibelio* [126], *Epinephelus lanceolatus* [127], *Oncorhynchus mykiss* and *Ctenopharyngodon idella* [128] and *Rachycentron canadum*[129]. Muralisankar *et al*. (2015) reported that dietary feed additives with MnO NPs are used to improve digestive enzymes secretion (protease, amylase and lipase) in *M. rosenbergii* [85].

3.7 Iron nanoparticles

Iron oxide is great potential elements for humans and animals; dietary feed with nano element additive is utilized for aquatic animals and fortified cereals, drinks for human consumption [130]. Dietary feed with additives of metallic nano iron element is consuming positive impact of aquaculture development and also iron nano element used to improve muscle concentration and enhance the growth performance of *Cyprinidae* [131]. El-Shenawy et al. (2019) reported that dietary feed with supplementation of iron sources like iron oxide or iron NPs (63.75 mg/kg) are having numerous beneficial effect such as enhanced growth, immune response, phagocytosis activity, reduced mortality rate, protein and lipid content, muscle concentration, RBC,WBC, antioxidant activity, disease resistance in *Oreochromis niloticus* [132]. Huber (2005) reported that dietary feed with additives of iron oxide nano elements is used to enhance bioavailability of fish species compared to then other form of iron components as well as iron oxide element is highly bio availability (96 % similar with $FeSO_4$) in rats without tissue accumulation [133,134] .

Dietary feed with supplementation of iron nano elements (30-50 mg/ kg^{-1}) is used enhance digestive enzyme function, food intake, better survival and growth of *M. rosenbergii* [135]. Behera (2014) recommended that nano iron element could have a special metabolism pathway and deposition mechanism in fishes. A reduction of macromolecule to nanoscale has been changed their properties and develops their applications [136]. Metallic iron NPs are unique physico chemical properties and great attention for fish growth and fish feed additives [131]. Dietary feed with supplementation of iron nanomaterial range is suitable (40 mg/kg) to improve fish growth, feed utilization of *C.batrachus* [137]. Srinivasan et al. (2016) reported that dietary feed with supplementation of iron nano element range (20 mg/kg^{-1}) is suitable for safe concentration for *M. rosenbergii.* This nano element range contains numerous beneficial effects like enhanced growth, survival, and digestive enzyme action, concentrations of total protein, amino acid, carbohydrate and non-specific immunity [135].

3.8 Chromium nanoparticles (Cr NPs)

Dietary feed with additives of chromium nano element is significantly improving insulin like growth factor, immunoglobulin contents in plasma as well decreases level of serum insulin and cortisol [138]. In addition, dietary feed with supplementation of chromium nano element is significantly increases the concentration of chromium in liver, kidney and heart as well as this additive has beneficial impact in carcass characteristics [139]. Dietary feed with additives of Cr NPs (1.5-2 mg/ Kg^{-1}) with sunflower based meal are used to enhance growth performance in *C. mrigala* fingerlings [140]. Wang et al. (2007) reported that dietary feed with additives of Cr NPs is significantly improving immunoglobulin in blood plasma [138]. Dietary feed with supplementation of chromium nano element to rate (2 mg/ Kg^{-1}) and sunflower based meal diet is helpful to enhance growth, nutrients digestibility and improvement of haematological parameters of *C. catla* fingerlings [141].

4. CONCLUDING REMARKS

In aquaculture industry, NPs are used to develop the different kinds of applications. NPs are utilized in two dissimilar methods such as direct and indirect methods. Indirect method is used to treat waste water, fish pond sterilization and harvested fish packaging for commercialization such as bar coding and tagging and direct method is used to feeding industry and animal health care. Nanotechnology is the modern tool for the development of aquaculture and seafood industries as well as without difficulty to identify different types of bacterial and viral diseases in aquatic animals. In this review concluded that dietary feed with supplementation of different kinds of nano elements are used to enhance immune system, disease resistance, anti oxidant activity, digestive enzyme activity, growth performance and general health development of aquatic animals and also increase the healthy aquatic production. A comprehensive study is needed to helpful for the development of nano dietary feed supplements using in aquaculture applications. This review report helpful for the enhancements of dietary nano feed supplements and develop the modern aquaculture industry as well as this technique is the alternative way to enhance healthy aquatic production. In future studies should be determined on preventing or reducing the unfavourable effects of these materials.

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Source of Support: The author(s) received no financial support for the research, authorship, and/or publication of this article.

Conflict of Interest: The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.