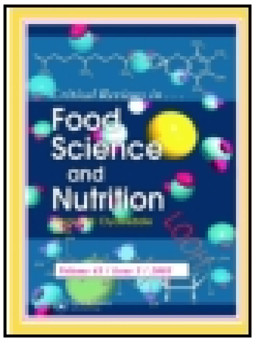

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REVIEW

Nanotechnology interventions in aquaculture and seafood preservation

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ABSTRACT
The inclusion of nanotechnologies in aquaculture and seafood preservation confronts a new edge that deserves attention in the recent trends of global food sector. Nanotechnology, being a novel and innovative approach has paved way to open up new perspective for the analysis of biomolecules, targeted drug delivery, protein or cells, clinical diagnosis, development of non-viral vectors for gene therapy, as transport vehicle for DNA, disease therapeutics etc. The current and potential use of nanotechnology would show the way to progression of smart and high performing fish. The comparative evaluation of extremely sophisticated nanotechnology with conventional process engineering proposes new prospectus in technological developments for superior water and wastewater technology processes. Nanoparticles have comprehensive advantages for management of drugs as liberation of vaccines and therefore hold the assurance for civilized protection of farmed fish against disease-causing pathogens. This review article explores the present concerns of food security, climate change as well as sustainability that are explored by the researchers in the area of nanotechnology, development of marine produce, along with its preservation and aquaculture.

KEYWORDS
Nanotechnology; nanoparticles; seafood; nanoemulsions; fish genetics; nanoice; nanovaccines; preservation; nanochitosan

Introduction

The continual and striking growth in the supply of sea foods for human consumption is reflected by the increase in global fish production with about 171million tons in the year 2016. The production surge worth USD 362 billion, accounting to USD 232 billion from aquaculture production, and out of which about 47 percent of the total represents aquaculture and nearly 53 percent non-food uses (including reduction to fishmeal and fish oil). The increase in production is not considered to be the sole factor for increased consumption of sea foods, but certain factors like decrease in wastage by suitable packaging material are considered worth consideration. Furthermore, the contribution of aquaculture and sea foods towards food safety and security can be a promising pillar with regards to 2030 agenda (FAO 2018). There are many challenges for achieving this sustainability and set aim of the 2030 agenda and one related aspect involves the packaging of sea foods. To face the challenges related to packaging and achieve progress towards sustainability the nanotechnological aspect of packaging has a crucial role to play in order to exploit the full potential of aquaculture and fisheries (Sekhon 2014).

In the fish industry, the quality of fish is becoming of chief apprehension globally due to reasons associated with spoilage (Huss 2007). As a result of globalization of food trade, fish and fish products tend to became more prone to rejection due to their exceptionally perishable nature and poor raw material quality despite the technological advancements in sea food production (FAO et al. 2009).

One of the technological advancements included the packaging of seafood products that remained passive, with the purpose to protect them from microbial spoilage, desiccation and oxygen. In the context of above mentioned packaging functions, tamper evident packaging was used later followed by modified atmosphere packaging (MAP). The regulations regarding use of MAP is strictly governed by the United States due to certain issues of toxin production by *Clostridium botulinum* and temperature abuse. However, the Time-temperature indicators (TTIs) used in MAP are the probable remedy to these problems however their use is limited due to involvement of huge costs. The concept of nanotechnology in food processing and packaging is novel which also eventually requires detailed information about their long-term impact on human wellness. The current inertia of aquaculture and sea food preservation drives them towards the intervention of nanotech-based packaging with well-defined properties and regulations. The retail packaging for case-ready sea foods desire for standard package sizes requiring minimal effort for rapid stock purpose which can be met by nanotechnology based packaging (Lampila and McMillin 2012). The sole reason for the use of matrices including nanomaterials is their enhanced functionalities while converting from micro to nanodimensions

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(O'Callaghan and Kerry 2016). The ultra fine nanodimensional particles in combination with natural polymers have ample applications in packaging (Naito et al. 2008), in the form of nanobio-composite films (Falguera et al. 2011). Further striking features that attribute to versatility of nanoparticles is their improved permeability, increased activity, increased suspension and dissolution stability, enhanced loading availability and capacity (Gokce et al. 2014; Il'ina et al. 2008; Wang et al. 2014). Thus, the formation of bio nanocomposites has proven to be an efficient way of improving the competitiveness of bio based polymers over nonrenewable plastics (Mittal 2011).

The use of nanotechnology in recent years for more than 1300 products with an incurred cost of $50 billion reflects its demand (Suppan 2011). There has been an extensive range of applications of engineered nanoparticles including bacteriostatic effect on food contact surfaces and controlled release of microencapsulated antimicrobials in packaging. Nano engineered particles like; silver nanoparticles have been used for extension of shelf life, reduction of pathogens and in conveyer belts in meat processing industries. On the contrary, absorption of silver nanoparticles has been found to hinder the replication of DNA by re-routing within neural networks and resulting in genetic mutations (Suppan 2011). The disposal of silver based nanoparticles also adds to the environmental concerns (Otles and Yalcin 2008). Currently there is no regulatory agency over the usage of nanoengineered particles but Codex declared its inclusion or exclusion in its strategic plan for 2013–2018 (Suppan 2011).

Nanotechnological interventions in food processing

In the beginning of the 21st century, the food industry has already adopted an emerged technique like food nanotechnology. Nanotechnology is the science of manipulation of matter at atomic and molecular scale with at least one characteristic dimension measured in nanometer. It is a general technology, like other technologies including biotechnology and information technology, integrated in a larger technological system. In addition, it has an enormous potential to revolutionize agriculture and other allied areas, including aquaculture and fisheries. It can be applied to develop new and advanced tools and techniques for aquaculture, fish biotechnology, fish reproduction, fish genetics, aquatic health, amongst several others. Their applications in aquaculture and food processing industries are relatively recent. Many food scientists have recognized the tremendous potential of nanotechnology to lead all the food processing industries though the successful interventions of nanotechnology in this field are still limited. For example, the leading brand: Kraft Foods in year 2000 established a Nanotec-K Research Consortium of 15 universities and national research laboratories to conduct research in nanotechnology for potential food applications including nanosensors for improving food security, nanodevices for traceability of food supply chain, and the development of smart delivery. The food producing organizations novel technologies, which are indispensable to remain relevant in the food processing industry in order to produce fresh, suitable, flavored and safe food products. One of the important objectives of food processing is to prolong shelf life of the product and to maintain the freshness as well as the quality of the food. Nanotechnology is one of the key pioneering technologies in the current arena with varied and extensive applications in food processing division. It augments the food nutrition and also enhances packaging and preservation processes. Nanotechnology is swiftly emerging in the modern times and has acquired a great consideration to the prospectus bought out from diminutive packages in the nanoscale. It has a stimulating relevance in food and food related products.

Nanotechnology in seafood preservation

Fish preservation is a very important processing aspect of the fisheries. Typically, the fish farms or other fish capturing sites are located at large distances from retail points and there is high frequency of fish decomposition and the uncertainties of their sale in market. When the fish is harvested in large quantity, greater than the market requirement, their preservation and processing becomes necessity for their future application. Preservation and processing therefore are indispensable components of commercial fisheries. They are performed with the purpose that the fishes remain fresh and safe for a long time, with a minimum loss in essential quality attributes, nutritive value and the digestibility of their flesh. To prevent fish spoilage and lengthen the shelf life of sea foods, many preservation techniques are required. These techniques are designed to inhibit the growth, proliferation of spoilage bacteria and the metabolic changes which result in the loss of fish quality (Ikape 2017).

Moreover, the safety of seafood is under threat because of the increased population of humans. These tribulations divulge necessity to preserve the superiority of seafood. Though the development of microbes in fish are prohibited by traditional techniques of preservation like irradiation, besides relevance of the present conservation methods throughout storage period, patrons in recent times have favored the utilization of different preservation methods of food as these methods would have disagreeable consequences on health of humans (Tassou, Drosinos, and Nychas 1996). The apprehensions have directed researchers to stumble on new substitutes. Consequently, at the present time, an immense attempt is brought forth to develop up fresh antimicrobial agents for the purpose of managing microbial contamination in seafood. In recent times, substitute techniques are anticipated for pulling out stability of food. In this regard, nanotechnology in relation to food immersed concern of processors has proven to be an efficient unconventional methodology to increase the stability of food and hence being functionalized in order to retain the color and also increase the flavor (Rather et al. 2011). As earlier mentioned, seafood yield is extremely delicate, so the purpose of nanotechnology to tackle with the problems in handling associated concerns is of immense significance. On another note, literature reviews regarding the relevance of nanotechnology in correspondence to the preservation of seafood divulge that its purpose is limited to the use of nanoparticles and nanoemulsions. Utilization of the nanofibers serves as a substitute to preserve fish products. Based on the scientific proven fact that nano fibers can as well be utilized for the encapsulation of a several antimicrobial composites for the purpose to avert microbial infectivity as well as disease, the application of nanofibers could be competent to reduce microbial activity. In the reverence, the outward surface layer of fish with electro spun nanofibers possessing antimicrobial properties would be a new approach to thwart the growth of microbes in meat of fish (Perreault et al. 2015).

Traditionally developed fish and other sea food products have been proven to generate high impending risk for health of humans for histamine, halophytic pathogenic bacteria and parasites. Nano scale food additives maybe utilized to manipulate product textural properties, shelf stability and nutritional profile, or even distinguish food pathogens and present functions as food quality indicators. Nanotechnologies related to food packaging are principally measured to augment product shelf life, specify spoilt components, or usually amplify product eminence by preventing gas flow across packaging of the product (Nickols-Richardson and Piehowski 2008).

Nanomaterials produced biosynthetically have gained significant attention in present epoch in a variety of fields of natural science because of their distinguishing assets, environment compatible nature and chemical individuality. Despite the fact that nanotechnology, being considered as an advanced science, the chronological proceedings go rare to about 4500–5000 years to when restricted strengthening of a ceramic matrix with innate asbestos nanofibers were utilized. The craftsmen of Mesopotamia used silver and gold nanoparticles for beautification of their utensils (Srikar et al. 2016; Heiligtag and Niederberger 2013). The functions of nanotechnology has revolutionized various boundary areas and thus creating the route to diverge into feasible uses in diverse segments. Amid various different fields, aquaculture and fisheries are those industrial sectors where nanotechnology is utilized competently as a source for quick disease recognition and target liberation of specific DNA vaccines, drugs, as well as certain nutrients (Ashraf et al. 2011). Nanotechnology, in addition is acting a crucial part in seafood industries, for example in manufacture of extra efficient feed for the consumption of species of fish. Literature recommends the fundamentals like selenium when given as a substitute can perk up development of fish (Pacitti et al. 2015). In addition from bacteria, fungi, and plants, the mangrove bionetwork is house to a huge amount of microorganisms, like yeasts, actinomycetes, algae, etc. Few animals and various supplementary species have also been utilized for synthesis of nanoparticles like prawns, fish, and oysters. Such organisms serve as complimentary and plentiful resources of bioactive compounds, like carotinoids, terpenoids, few polysaccharides (alginate, fucoidan and laminaran), fibers, polyphenols, vitamins, flavonoids, fats, proteins, oils, and minerals with numerous ethnobotanica probable functions (Kushnerova et al. 2010).

A number of researchers have recently been spending a great attempt to increase shelf life of fish by trying new methods. In this regard, nanotechnological applications have been attracting consideration by scientists. Nanostructures such as nanoparticle, nanoemulsion, and nanofibers could be utilized to uphold the color and flavor of fish and also limit the quick deterioration of sensory quality (Chellaram et al. 2014; Ozogul et al. 2017). Rather et al. (2011) opined that nanotechnology treatments in the fish processing could be utilized for providing stronger sensory characters such as color and aroma.

Nano ice in seafood preservation

Since the time immemorial, the function of ice has been extremely vital in food preservation and also its freshness. Devoid of any aging or decay, ice can conserve organic materials for example ice aged mammoth potted in glacier (Willerslev, Hansen, and Poinar 2004). Ice has been used widely from prehistoric times to preserve delicate foods particularly fish and fish based harvests from food-borne pathogens. Due to advancement in technology, new methods and treatments have been opted for better and long lasting preservation of sea foods. One of such is the use of tetracycline based antibiotic-ice that has been used for fish preservation. Due to the antimicrobial power of ozone, ozonated ice has also been used for food preservation especially for the control of surface food borne pathogens on fish skin (Shin, Chang, and Kang 2004).

The only compound used in the formation of antimicrobials and approved by USFDA is Per Acetic Acid (PAA) that could be used for fish preservation (Buschmann and Del Negro 2009). Similarly Wild Thyme hydrosol (*Thymus serpyllum*) has been utilized for the production of antimicrobial ice (Oral et al. 2008). Silver nanoparticles biosynthesized by using *Musa paradisiacal* (Banana) midrib extract present in the Nano ice has proven to be able to decrease the microbial load on the *Mugilcephalus* (Mullet fish) fish surface and also inhibit the growth of *Acinetobacter* to a greater extent due its antimicrobial activity (Daniel, Sureshkumar, and Sivakumar 2016). Biosynthesized silver nanoparticles are gaining more relevance than chemically-synthesized silver nanoparticles in seafood preservation. Nano particle impregnated ice can be further utilized for many other food packaging applications. The antimicrobial ice has been found to inhibit the growth of *Acinetobacter* to a greater extent due to the antimicrobial activity of silver nanoparticles in *Mugil cephalus* (Huang et al. 2018).

Nano chitosan in sea food preservation

The battered and breaded product fish fingers are produced from minced fish flesh. It is commonly stored in the frozen state. However, frozen storage does not completely inhibit the microbial and chemical reactions which may lead to quality deterioration of fish (VidyaSagar and Srikar 1996).

Moreover, fish and its products can undergo undesirable changes during frozen storage that will lead to quality deterioration which may limit their storage time. These undesirable changes are as a result of protein denaturation (Benjakul et al. 2005), and lipid oxidation (Sarma, Reddy, and Srikar 2000). Edible coatings of polysaccharides, proteins, and lipid can extend the shelf life of foods by functioning as solute, gas, and vapor barriers. Generally, meat and other foods are covered with dry particles (breaded) or dipped in liquid solutions of these particles called battering (Ojagh et al. 2010). These include its antimicrobial activity and ability to form protective films (Jeon, Kamil, and Shahidi 2002). Many researchers have studied chitosan as an edible coating material for fishery products to enhance their microbiological quality and extend the shelf life (Mohan et al. 2012). The nanotech approach of different conservation and packaging techniques provides seafood safety by prolonging mildew and microbial spoilage (Can et al. 2011).

The deacetylated product of chitin having molecular weight of about 800 kDa is known as chitosan. It is a known to be a cationic polymer with recyclable and nontoxic nature (Kerry 2012). Chitosan is considered to be a good antimicrobial agent due to the presence of positively charged poly cation (Suptijah, Gushagia, and Sukarsa 2008). CSNPs (Chitosan nanoparticles) possess extraordinary bioactivity and physiochemical properties (Yang et al. 2010). Numerous studies reported the incorporation of nanoparticles in bionanocomposite films. The nanocomposite film made from varying concentrations of CSNPs and gelatin possessed improved mechanical and barrier properties Hosseini et al. (2015). The amalgamation of starch composites with CSNPs has been found to enhance the thermal stability, glass transition temperature, storage modulus, tensile strength, and water vapor barrier properties. The improvement in functionalities by dispersing CSNPs at lower concentrations is ascribed to the filler/matrix interactions Chang et al. (2010).

Nanochitosan was verified to be extra dense and more effective antibacterial agent when compared to the efficacy of chitosan and its coating on silver carp fillets (*Hypophthalmicthys molitrix*) in refrigeration at 4 °C. In Indonesia, the use of chitosan as a preservative agent for freshly harvested fish has been studied intensively but the endeavor was further determined on pond raised groups including Catfish (*Pangasius hypopthalmus*) (Suptijah, Gushagia, and Sukarsa 2008) and Nile Tilapia (*Oreochromis* sp.) (Tapilatu et al. 2016). Though earlier research studies on chitosan applications in tropical marine fishes were rare and frequently functional on pretreated products, like salted Indian Scads (*Decapterus* sp.) (Swastawati, Wijayanti, and Susanto 2008).

Nano composites as antimicrobials

Many types of CSNPs possessing antimicrobial activity has been developed by O'Callaghan and Kerry (2016) and one type includes the nanocomposite films developed from gelatin and CSNPs, with the incorporation of origanum EO. The fabricated films are found to present remarkable antimicrobial activity for list: *monocytogenes*, *E. coli*, *Staphylococcus aureus*, and *Salmonella enteritidis*, which are the four common test food pathogens Hosseini et al. (2016). The nanocomposites were proven to possess effective antimicrobial activity as a result of the high surface-to-volume ratio. Furthermore, their increased surface activity is due to their nanosize dimensions that enable them to act as effective antimicrobials in comparison to their larger dimension counterparts (Rhim, Wang, and Hong 2013). The different nanocomposites used as antimicrobials are mentioned in Table 1.

Nanotitanium oxide has a sturdy anti-bacterial effects and can destroy pathogens of fish *in vitro* (Cheng et al. 2009). As a result, accumulation of nanotitanium oxide to the reservoir of fish farms is suggested for the prevention of disease caused by bacteria (Cheng et al. 2008). On the other hand, techniques which are used effectively for destruction of bacteria *in vitro* are usually not competent when applicable to *in vivo* bacterial killings. This may be because of the dissimilarities in the intracellular conditions and the precise antibacterial role of phagocytic cells (Segal 2005). Recently it was confirmed that nanotitanium oxide acts as a potent immune modulator of fish neutrophil function (Jovanović et al. 2011). Another novel usage of nanotitanium oxide is to attain desirable sterilization efficacy on pathogenic microbes like *E. coli*, *Aeromonas hydrophilia*, and *vibrio anguillarumat* a definite concentration and reaction time, without which the sterilization cannot be successful (Huang et al. 2015). Titanium oxide is able to produce extremely active superoxide (–O), hydroxyl (–OH), peroxyl radical (–OOH) and further highly oxidative free radicals under ultra violet light which can interact with biomacromolocules like proteins, enzymes, nucleic acid molecules and lipids in viruses, bacteria and other microbes. These through a sequence of chain reactions destroy their cellular structure, in order to achieve sterilization results and water disinfection (Jimmy et al. 2002). Besides nanocomposite barrier products, active packaging materials with antimicrobial properties are currently available. These materials are believed to preserve the food products by halting the growth of microorganisms. The antimicrobial behavior of silver has been well established and the extremely small size of silver nanoparticles can even increase their antimicrobial effectiveness. Packaging material incorporating Ag (silver) nanoparticles are reported to be commercially available (Vasile 2018).

Nanoemulsions

Nanoemulsions, due to the droplet size of less than 100 nm offer outstanding stability and physicochemical properties (McClements 2011; Solans et al. 2005, Otoni et al. 2016). The smaller size enables higher surface area per unit of mass and thus imparts enhanced biological activity of lipophilic compounds (McClements and Rao 2011). Nanoemulsions provide newer frontiers for the fabrication of new generation edible films. The alginate films with EO-loaded nanoemulsions have been developed to prevent degradation of EOs and increase water dispersion (Acevedo-Fani et al. 2015). The potential of nanoemulsion preparation by EO encapsulation and thus the antimicrobial activity of prepared films integrated with thyme EO have been found to inhibit *Escherichia coli*. In another study nanoemulsified cinnamaldehyde, fabricated edible composite film was reported to possess antimicrobial activity. The effective

Table 1. Outline of different nanocomposites as antimicrobials.

Nanomaterial	Polymer	Functions
Zinc oxide	Bovine skin gelatin	Used for Shrimp packaging
Silver nanofiller	Cellulose	Antimicrobial property
Nanosilver	Agar	Antimicrobial property
Carbon nanotube	Polyamide	Reduces Microbial load, protein toxics and food spoilage
Silver based zeolite	Polypropylene, ABS	Antimicrobial, Removing pathogenic organisms

antimicrobial capacity was ascribed to the increased release of active compounds as a result of higher surface area and decrease in droplet diameter (Otoni et al. 2014).

Nanoliposomes

Current studies have established superior EOs with enhanced antimicrobial abilities upon encapsulation in surfactant nanometric micelles. Within the nucleus of nanoliposomes, EO is able to be relieved gradually, thus enhancing the antimicrobial activity of the film. Wu et al. (2015) devised cinnamon EO nanoliposomes, which were integrated into films of gelatin. The films caused a reduction in the discharge rate, apart from upgradation of the antimicrobial constancy. An increased antimicrobial activity resulted from the encapsulation of eugenol and carvacrol into nanometric surfactant micelles (Gaysinsky et al. 2005). Orange EO were encapsulated with the help of soy lecithin as well as rapeseed which resulted in exceptionally steady nanoliposomes, which further were integrated into sodium-starch caseinate films (Jiménez et al. 2014). In the following study, no appropriate antilisterial commotion was established, excluding soy lecithin nanoliposomes subsequent to a week of storage. The outcome is thus connected to the actuality that a competent encapsulation leads complicacy in the release of antimicrobial agent. Furthermore, Imran et al. (2012) noted the maximum antilisterial activity matches up with the films holding mutually encapsulated and free antimicrobial compounds. The competence of lecithin nanoliposomes for encapsulating EOs has also been established by Valencia-Sullca et al. (2016).The epitomization of eugenol or CLEO in nanoliposomes of lecithin permitted the films to preserve almost 40–50% of the integrated eugenol, while simply 1–2% only when the same constituent was integrated directly through emulsification.

Nanotechnology in aquaculture

The sustainable growth of nanotechnology necessitates a meticulous consideration for shelf-life and life cycle of blended nanomaterials, together with potential health risks, environmental release, exposure, and deposition. ENMs (Engineered nanomaterials) are distinguished to be resources which attain the dimensions varying from 1 to 100 nm in at least one dimension. Owed to their exclusive physicochemical properties, ENMs have been progressively more manufactured and extensively used in various fields, like food processing and packaging, health products, and biomedicine (Yin et al. 2017).

Aquaculture, being the fastest growing food sector could be very useful in maintaining the socio economic status of people. It can significantly contribute to food and nutrition in society by providing highly beneficial aquatic proteins and fats (FAO 2018).

Aquaculture is considered among the largest budding food processing sectors because of escalating requirement for seafood and fish globally, because ongoing development of aquaculture is observed as an important strategy to guarantee universal food and nutritional safety (Souza et al. 2017).

Various food products are extremely perishable because of their composite nature and active ecosystem, where every constituent is varying hastily and determinedly. The biological and chemical contagion of food transpired through diverse routes, such as, unsanitary agricultural or processing conditions leads to microbial growth, unsuitable storage conditions and transportation of food. Supplementary conditions includes deployment of pesticides and fertilizers in agro food products; faulty food packaging or consumers' food handling fault; subsidiary use of additives at unsafe levels in processed foods, or intentional food adulteration via insecure ingredients by profit-leaning producers (Biswas and Maurye 2017)

Nano-biosensors

In the present epoch, nanosensors are utilized for stock scrutiny and fishpond cleaning with nanotechnological equipments. DNA nanovaccines in forms of nanocapsules that contain short strands of DNA are supplemented to fish ponds where they are captivated into the cells of the fishes. The captivated capsules are then ruptured by the use of ultrasounds, which help in releasing the DNA and educing an immune response from the fish. Utilization of iron nanoparticles to pace up the development of fish, and programed drug liberation system are very swift becoming authenticity by this pioneering technology.

In addition, nanotechnological biosensors can be used for microbial control in the aquaculture industry. Researchers at the National Aeronautics and Space Administration have developed a sensitized biosensor based on carbon nanotubes that is capable of detecting minute amount of microbes including bacteria, viruses and parasites and also heavy metals from water and foods. Nano colloidal sliver is one of the most important products of nanotechnology that acts as a catalyst working on a wide spectrum of bacteria, fungi, parasites and viruses by rendering an enzyme that is used for their metabolism. Unlike antibiotic-resistant strains of bacteria, no such strains are known to develop by using colloidal sliver. Sliver nanoparticles are capable to kill methicilin-resistant *Staphylococcus aureus* (Jeong, Hwang, and Yi 2005). Tracking nanosensors such as "smart fish" are being developed to be fitted with sensors and locators that relay data about fish health and geographical location to a central computer. Such technology could be used to control cognitive cage systems or individual fish (Sekhon 2014).

Nanotechnology in water treatment

In recent times, submarine vehicles have turned out to be low cost, consistent and in expensive sources for performing a variety of marine tasks. Despite the fact numerous aquaculture systems are bunged with no detrimental output, land-based fish farms and open net cage fish farms can release noteworthy amounts of wastewater including chemicals, pharmaceuticals and nutrients that brunt on the adjacent environment. Though aquaculture growth has often occurred exterior to a regulatory scaffold, government supervision is progressively more wide spread at both the seafood excellence and quality control level, and at baseline initiatives concentrated on the fundamental problem of contamination produced by culture operations, e.g. the European aquatic and nautical directions. This requires usual, sustainable and cost-effective supervision of the water quality. Such monitoring needs instruments to detect the water quality in large sea region at diverse depths in real time (Karimanzira et al. 2014).

Nano-enabled techniques are applied to water for removing contaminants or organic pollutants. Nanomaterials of carbon or alumina along with zeolite and iron-containing compounds can be used in aquaculture for holding aerobic and anaerobic biofilm for removal of ammonia nitrites and nitrate contaminants (Gillman 2006). Removal of organic pollutants or contaminants is of major concern from industrial point of view. It possesses the main threat to make water polluted. Contaminated water from industries contain large amount of hydrocarbons which result in bacterial growth, bio-fouling and odor generation that can change the water quality. Water purification is a diverse concept and involves the removal of toxic ions, organic impurities, microbes and their by-products. Removal of organic contaminants, oil spills and other toxic chemicals require specific materials with high absorption capacity, longer retention behavior, and wide range of catalytic activity, recoverability and reusability. These toxic substances are present in small quantities and need to be detected at very low concentrations. Recently, Gold-PDMS foams have been reported for water purification. It has an ability to remove organic hydrocarbons like tolune, thiophenol and thioanisole. Wen et al. (2003) revealed that the applications of nanodevices like nanonets are capable of improving quality attributes of water by increasing the pH of water. It is also believed that nanotechnologies can play a pivotal role in reducing the water exchange rate and had proven to increase the shrimp yield. Another important application of nanotechnology is the effect of nano-863 treated water on shrimp fish breeding which concluded that the nano-863 improved the water quality by changing the water pH which is more suitable to fish growth nano-863 can promote the activity and promotes the growth and development. It also possesses the prolific antibacterial and disease protection efficacy. Nano dispersants are of industrial importance in removing the oil spills. These nanochemicals have surface active agents that migrate to oil/water interface breaks down the oil droplets from oil slick by reducing the surface tension between oil and water. These droplets get dispersed in water and forms suspension. It becomes a good source of food for the naturally occurring bacteria. These nanodispersants catalyze the bio degradation process, thus leads to the removal of oil spills. Modified hydrophobic organic clays containing quaternary amines are efficient absorbers of organic contaminants and are useful in removing oil spills and aids in water purification. Nano materials have shown great potential in a wide range of the pond-ecosystem environmental. Nano scale iron–manganese binary oxide was an effective sorbent for removal of arsenic from field groundwater of fish culture. Furthermore, carbon nanotubes are increasingly used in a wider range in fish culture. Carbon nanotube with certain oils can be introduced on fishes to control the different surface diseases. Nano technological biosensors had got potential applications to control microbial spoilage in the aquaculture industry. A nanotechnological biosensor has been developed by NASA researchers that are capable of detecting minute amounts of microbes, including bacteria, viruses and parasites.

Nanomaterials have distinctive size-dependent characteristics associated to their high meticulous surface area (high reactivity, fast dissolution, strong sorption) and irregular characteristics (such as localized surface plasmon resonance, super para-magnetism, and quantum confinement consequence). These explicit nanobased uniqueness allow the advancement of new high-tech resources for more proficient water and wastewater management processes, namely nanocatalysts, adsorption materials, functionalized surfaces, membranes, reagents and coatings (Gehrke, Geiser, and Somborn-Schulz 2015). The most capable materials and purposes are tinted in Table 2.

Nano vaccines

One of the more vital aspects of aquaculture is the incidence of diseases that take place every so often. New-fangled diseases may source major fatalities for any aquaculture competence. Nanoparticles have comprehensive recompense in drug management as vaccine deliverance and therefore embrace guarantee for civilizing fortification of farm fish against diseases which are sourced by pathogens. On the other hand, there are apprehensions that the reimbursements connected with allocation of nanoparticles may in addition be convoyed with threats to environment and well-being. The intricacy of social and natural system implicated that the information obtained in enumerating risk

Table 2. Outline of categories of nanomaterials used for water and wastewater technologies (Gehrke, Geiser, and Somborn-Schulz 2015).

Nanomaterials	Properties	Applications
Membranes and membrane processes	(+) steadfast, fundamentally mechanized process (−) comparative high energy requirement.	Entire fields of water and wastewater treatment processes
Nanometals and nanometal oxides	(+) diminutiveintraparticledispersal distance compressible, antiabrasant (+) photocatalytic (WO_3, TiO_2) (−) less reusable	Elimination of heavy metals (arsenic) and radionuclide's, media filters, powders, slurry reactors, pellets
Nanoadsorbents	(+) high unambiguous surface, advanced adsorption rates, small footprint (−) high production costs	Point of use, heavy metals, removal of organics, bacteria

estimations may be insufficient for verification based assessments. One controversial strategy for handling this kind of ambiguity is the preventive principle. Few years ago, UNESCO specialist group recommended a novel move towards the accomplishment of the principle. Here we evaluate the UNESCO principle with previous descriptions and discover the advantages and shortcomings by employing the UNESCO report to the exercise of PLGA nanoparticles for release of vaccines in aquaculture. Lastly, it was discussed whether a mutual scientific and ethical investigation that involves the idea of dependability will facilitate approaches that can endow with an enhancement to the preventive principle as foundation for decision-making in parts of scientific ambiguity, like the function of nanoparticles in the vaccination of farmed fish (Myhr and myskja 2011).

Fortunately for some species used in aquaculture, vaccination can provide protection against viral agents present in the water. Disease outbreak is one of the biggest tentative blocks in aquaculture sustainability and growth. Numerous approaches have been applied to resolve disease problem in aquaculture. Vaccination is one among the techniques that will combat with these diseases. Nano particle carriers like Chitosan and polylactidecoglycotidic acid (PLGA) of vaccines along with mild inflammatory inducers may provide higher levels of protection to fishes and shellfishes against bacteria and viruses (Rajeshkumar et al. 2009). Also mass vaccination of fishes using nanocapsules resistant to digestion and degradation can be done. These capsules containing short DNA strands that are absorbed in the cells of fishes in water. Using ultrasound mechanism the DNA strands are released eliciting the immune response of fishes due to vaccination. In fish farming nanovaccination has an important role to play and is never being used in the context of fish vaccine. Therefore, in the recent decade the use of nanoparticles had become crucial for fish vaccination. These particles have multiple advantages in drug administration as they are used in vaccine delivery and hence provide protection of farmed fishes against pathogenic diseases. This can be achieved by nanochitosan as it has ability to wrap around the vaccine. The use of nanoparticles in the vaccination of farmed fish is considered a unique processing technique. Nanoparticles have multifaceted advantages and therefore embrace assurance for civilizing safety of farmed fish besides diseases originated by pathogens. The vaccine can deliver through Chitosan nano that is able to wrap itself around vaccines and act as a carrier used in nanoencapsulation for treatment delivery in the fish physiology. Nano encapsulated vaccines have been used in Asian Carp against the bacterium *Listonella anguillarum* (Bhattacharyya et al. 2015).

Nano feed in fish growth

Traditionally, fish feeding has relied on providing fishes food in the form of a food pellets. This pellet is chiefly formulated based on the daily nutritional requirements of fish. One of the current approach of nanotechnology is that nanoparticles will boost aqua feeds by increasing the proportion of nutrients required by fishes that pass across the gut tissue and into the fish, rather than passing directly through the fish digestive system unused (Handy 2012). Dietary minerals of nanosize may pass into cells more readily than their larger counterpart which accelerates their assimilation into the fish. Additionally, if this technology could be used properly it may reduce the environmental impact of the fish feeding process. Increasing the amount of fish food used by the fishes would decrease the amount of unused food discharged from aquaculture into the environment. Nano particles of selenium, iron were supplemented in fish feed to improve the fish growth. Researchers found that young carp and sturgeon have shown a faster rate of growth i.e. 30% and 24% respectively, when fed on iron nanoparticles (Rather et al. 2011). These nanoparticles boosted the health of fishes making them more productive. Introduction of nanotechnology integrated multi trophic aquaculture approaches, techniques are on rise which promotes economic and environmental sustainability (Wolbring Gregor 2006). This novel technique can be applied to aquariums and other commercial fish ponds to reduce the expenditure on water treatment. Nanotechnological approach may prove beneficial to safe guard the fish ponds from diseases and organic pollution.

Conclusion

Nanotechnology is expected to offer technological interventions in production, processing, storage, transportation, traceability, safety and security of aquaculture and sea foods. However, nanotechnology-derived products need to prove their economic viability prior to commercialization. Up to now, information concerning the economical competitiveness of nanotechnology-derived products is almost lacking. Nanotechnology has an enormous potential to play a key role in food processing as well as preservation. With effective introduction of nanotechnological tools like nanocomposites, nanobiosensors, nanoclays and nanovaccines disease outbreak could be controlled with ease in seafood's.

Glossary

Antibiotics	Chemical substance used to cure bacterial infections.
Aquaculture	Rearing aquatic animals or cultivating aquatic plants for food.
Biosensor	Analytical device used for detection of analyte.
Chitisan	Deacetylated product of Chitin.
Contaminant	Substance that can contaminate.
Encapsulation	Process of enclosing in a capsule.
FAO	United Nations agency concerned with the international organization of food and agriculture.
Innovative	Advanced.
Nanotechnology	Science dealing with things smaller than 100 nanometers.
Omega-3-fatty acid	poly unsaturated fatty acid.
Pathogenic	Able to cause disease.
Perishable	Liable to perish; subject to destruction.
Seafood	edible fish broadly including fresh water fish or shellfish.

Shelf life	Length of time at which food will last without deterioration.
Traceability	Ability to verify the history, location or application of an item by means of a document record.
Vaccination	Precaution against contracting a disease.

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