NANO-TECHNOLOGICAL INTERVENTIONS FOR THE PREVENTION OF BIOFOULING IN AQUACULTURE CAGES

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Introduction

In an era marked by an ever-expanding global population, the quest for sustainable nutrition sources has intensified, triggering a heightened demand for food production. Amidstthis quest, aquaculture has emerged as a pivotal solution that offers both economic prosperity and enhanced food security. Various techniques for aquaculture such as RAS, bio-floc, and Cage culture, have gained substantial popularity and that driving the industry's growth. However, the persistent challenge of biofouling, particularly in cage aquaculture within marine and inland settings, poses a formidable hurdle to achieving efficient and sustainable production. The enduring development of the aquaculture industry is a key factor in the strategy to guarantee global nutritional safety. Nanotechnological interventions in cage aquaculture refer to the application of nanotechnology to improve various aspects of cage-based aquaculture systems. Nowadays, different types of nanotechnology-based systems have been employed to increase aquaculture production, efficiency and sustainability. In cage aquaculture one of the threats is disease spreading and its management. Nanoparticles can be designed to deliver targeted treatments such as vaccines or antimicrobial agents to combat diseases that affect culturedaquatic species (for example; DNA nano vaccines in nanocapsules). Cage aquaculture is generally practiced in lotic ecosystems so monitoring of environmental parameters is difficult butit is essential for successful farming. Nano sensors can monitor various parameters in real time such as water temperature, pH, and dissolved oxygen and ammonia levels. Nano sensors aid in the prompt detection of any unfavorable conditions. In addition, recent efforts have been made inthe fields of processing and preservation of seafood and water treatment, enhancement of fishand shellfish development by dietary supplementation with nutraceuticals, and Nano sensors to monitor stock. Therefore, nanotechnology has a significant role to play in the improvement ofthe efficiency and the environmental impact of aquaculture. Application of nanotechnology in aquaculture cages and cage nets is considered the effective way to controlling the biofouling in cages and can be efficient and sustainable aquaculture production through cage can ensure.

Cage Aquaculture

Cage aquaculture is considered as a method of rearing or raising fish or any aquatic organisms in an enclosed space or caged enclosure while in captivity that maintains the free flowof water with the surrounding water body. Cage aquaculture is a low-impact farming practice with high profit in terms of harvest and price. Nowadays cage aquaculture is receiving more attention from commercial producers and farmers. Mainly due to the declining wild fish stocks, and increasing demand and high cost for fish. Commercial cage culture has been mainly restricted to the culture of higher-value and compound-feed-fed finfish species and more than 80 species presently cultured in cages.

Prior to starting cage aquaculture, several factors need to be considered such as site selection, cage size, material for cage construction, selection of species for culture, stocking density, feed management, etc.

Site selection: -one of the important factors which determine the success and sustainability ofcage culture. Criteria that must be considered for site selection are depth of water column, water current, pollution-free area, etc. The depth of the water column required for cage culture varies with resources for example reservoir cage culture requires 5m or more whereas 3m for cage culture in wetlands.

Cage size: - The costs per unit volume decrease with increasing cage size. The size of the cage depends on the species and site selected for culture. The ideal size for a grow-out cage is 6m due to its easy maneuvering and reduced labor.

Material for construction: - Earlier locally available materials were used for the construction of cages such as wood and bamboo for the framework, and empty plastic barrels as floats. Strong and advanced materials like polyvinylidene chloride, galvanized iron pipe, high-density polyethylene, and stainless steel, were used for the sustainability of cages. Netting material used for cage construction includes polyethylene and polyamide. The former one was used for the construction of a nursery and grow-out cage culture and the latter one was used for hapa.

Selection of species: -Factors such as fast growth, high feed conversion ratio, availability of seed, and disease resistance are considered for the selection of species

Stocking density: - Depend on species requirement, operational factors, carrying capacity of the cage and the feeding habits of the cultured species.

Cage aquaculture offers the chance to utilize existing water resources even on a small scale. In addition, other advantages of cage culture include the low carbon footprint, Low operational expenses, possibility of high stocking density, no energy requirement for natural water exchange for cage culture in the lotic ecosystem, and Simplified harvesting. Like other aquaculture technologies cage culture is also affronted by some problems such as the chance of occurrence ofpathogens in running water, fast-flowing water may carry the feed that results in loss of feed, more over the biofouling activities over the cage nets and cage frame.

Biofouling In Cage Culture and Its Impacts

Submerged aquaculture cage nets are highly susceptible to biofouling especially during summer months due to favorable and nutrient-rich aquatic environments around the cages which attract micro and macro foulers, and also attract invasive species like *Mytella strata*. Biofouling in aquaculture cages develops either through a succession model or a probabilistic model.Biofouling in aquaculture cage nets causes several problems such as occlusion of mesh openings,thereby increasing weight and drag, deformation of cages due to the ensuing stress, reduction of volume, thereby decreased stocking density per area, anoxic condition due to disruption of dissolved oxygen flow, blocking of food waste diffusion, restriction of water exchange, increased hydrodynamic force, all of which makes an unfavorable environment for fish and which adversely impacted fish health. In addition, cnidarians' biofouling can be harmful to the fish; biofouling can facilitate and amplify the presence of pathogens by harboring viral, bacterial,and parasitic organisms that cause various diseases.

Mitigation Methods for Controlling Biofouling in Cages

Frequent visual inspections of cage nets can catch early signs of biofouling. Gently scrubbing or brushing the net surface can remove accumulated organisms before they become a problem. In situ, net cleaning is one of the most common methods employed by farmers. This proactive approach prevents excessive buildup and maintains optimal water flow. Introducing natural predators like certain fish species and invertebrates into the cage ecosystem can help control biofouling organisms. These natural grazers feed on unwanted growth, reducing the need for manual cleaning. This method encourages a balanced ecosystem within the cage. Periodicallymoving aquaculture cages to new locations can disrupt the settlement of biofouling organisms. This method prevents attachment and growth on cage surfaces, reducing the overall impact of biofouling. Applying non-toxic anti-fouling coatings to cage nets can deter the attachment of biofouling organisms. These coatings create a slippery surface or release compounds that discourage settlement, making it easier to clean the cages when necessary. Using UV light systems can inhibit the growth of biofouling organisms on cage surfaces. UV treatment disrupts their reproductive cycles and prevents excessive accumulation. This method is environmentally friendly and helps maintain clean cages. Simple mechanical devices, such as rotating brushes or water jets, can be installed on cages to continuously clean the net surfaces. These devices help prevent biofouling buildup and ensure consistent water flow.

Nano Technological Interventions in Cage Aquaculture

The existing In-situ cleaning, rotational movement, and biological control methods have not successfully tackled biofouling problems effectively and sustainably. Therefore, new surface technologies in combination with current methods like the use of nano-engineered particles should be developed by considering ecological effects. Nanotechnology has enormous potential to provide innovative improvements to aquaculture systems to reduce costs, increase efficiency and reduce our impact on the environment. The non-polar nature of polyethylene aquaculture cage net causes difficulties in antifouling strategies over. For minimizing this problem in antifouling coating CIFT introduced copper oxide (CuO) nanoparticles coating over the modified surface of polyethylene by using polyaniline. The small size and high surface activity of nanoparticles rendered them a potential material that can use in cage nets. Nano copper oxide hasthe efficiency to avoid incrustation of microorganisms and hence prevent biofilm formation. The nano CuO-treated cage net exhibited excellent biofouling resistance in the marine environment and the percentage of occlusion of the mesh by foulers was 56.77% more efficient than the untreated cage net.

Nanomaterials improve the durability and strength of cage materials by improving the adhesiveness and rheological parameters such as viscosity, elasticity, mechanical strength and plasticity that increases the resistance to corrosion and wear and tear in harshaquatic environment. In addition, Nanomaterial coating reduces the maneuverability and cost of cleaning cage frames and cage nets. The continuously flowing water may carry the leached nanoparticles so the probability of accumulation of nanoparticles (CuO) on cultured species inthe cage is very less. While, nano metal oxide–polymer composites as it exhibits hydrophilicity, large surface area, and high toxicity towards microorganisms all these properties make it an suitable option for managing biofouling in cages.

Conclusion

Cage aquaculture holds promise for meeting the rising demand for affordable nutrition. Biofouling remains a challenge, impacting production and fish health. Novel nanotechnology interventions offer potential solutions, enhancing cage materials, resisting biofouling, enabling disease management, and real-time monitoring. Integrating nanotechnology can foster efficient and sustainable aquaculture, ensuring global food security.

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