JUST AGRICULTURE
multidisciplinary e-Newsletter

Actinobacteria and Their Potential Applications in Aquaculture

Indulata Tekam[1], Pravesh Kumar[2], Roshan Kumar Ram[3] and Samad Sheikh[4]

[1]Ph.D. scholar, Department of Aquaculture, College of Fisheries, RPCAU, Muzaffarpur, Bihar

[2]Assistant Professor, Department of Aquaculture, College of Fisheries, RPCAU, Muzaffarpur, Bihar

[3]Assistant Professor, Department of Fisheries Resource Management, College of Fisheries, RPCAU, Muzaffarpur, Bihar

[4]Ph.D. Scholar, Department of Aquatic Animal Health Management, ICAR-CIFE, Mumbai

ARTICLE ID: 02

Abstract

Aquaculture, a growing sector of animal husbandry, faces challenges such as disease emergence, high stocking densities, waste accumulation, and microbial pathogens. The use of antibiotics and chemotherapeutics has led to increased antibiotic resistance, necessitating alternative strategies like probiotics and bioaugmentors to improve aquatic organisms' health and productivity. Actinobacteria, a diverse group of Gram-positive bacteria have shown potential in aquaculture by improving water quality, stimulating immune responses, and promoting growth. They also contribute to bioremediation by transforming organic waste into less harmful substances, maintaining water quality and supporting sustainable practices. However, the use of Actinobacteria in aquaculture presents challenges such as slow growth rates than other fungi and eubacteria and complex isolation and identification processes. Future research should focus on overcoming these challenges and optimizing the application of Actinobacteria in aquaculture to fully harness their potential for enhancing the health and sustainability of aquatic farming systems.

Keywords: Actinobacteria, Aquaculture, Probiotics, Improve water quality, Immune responses.

Introduction

Aquaculture, an expanding sector of agriculture, is confronted with growing challenges of disease emergence attributed to elevated stocking density, accumulation of waste, and a

JUST AGRICULTURE
multidisciplinary e-Newsletter

range of microbial pathogens. Diverse chemical and biological interventions are implemented to mitigate this pressing issue (Serrano, 2005). Still the regular utilization of antibiotics and chemotherapeutics within aquatic system results in their accumulation, consequently enhancing the development of multiple antibiotic resistance. Hence alternative approaches such as probiotics and host-associated microorganisms have the potential to enhance the well-being of aquatic organisms. Actinobacteria, along with other microorganisms, are employed in aquaculture for diverse purposes, such as improving water quality, stimulating immune response, and fostering growth in different aquatic organisms and culture environments. Actinobacteria are gram positive, spore-forming, aerobic and filamentous type bacteria having higher guanine and cytosine (G + C) composition within their DNA, positioning them as one of the most prominent bacterial phyla. The phylum of Actinobacteria is composed of six main classes: *Actinobacteria*, *Acidimicrobiia*, *Coriobacteria*, *Nitriliruptoria*, *Rubrobacteria*, and *Thermoleophilia*. This phylum includes a total of 15 orders, such as *Actinomycetales, Actinopolysporales, Bifdobacteriales, Catenulisporales, Corynebacteriales, Glycomycetales, Jiangellales, Kineosporales, Micrococcales, Micromonosporales, Propionibacteriales, Pseudonocardiales, Streptomycetales, Streptosporangiales*, and *Frankiales* (Ludwig *et al*., 2012; Law *et al*., 2019; Salam *et al*., 2020)

Actinobacteria exhibit notable ecological importance due to their significant capacity for the synthesis of organic acids, nitrogen fixation, and participation in the breakdown of various organic compounds such as cellulose and chitin. This results in their crucial contribution to the turnover of organic matter and the carbon cycle (Anandan *et al*., 2016). Different groups of Actinobacteria including Bacillus spp, *Lactobacillus* spp, *Bifdobacterium* spp, *Saccharomyces* spp, *Streptococcus* spp, and *Streptomyces* are viable options for utilization as probiotics and bioaugmentors in the field of aquaculture (Hasan and Banerjee 2020; James *et al*., 2021; Mugwanya *et al*., 2022).

Presence and Environments

Actinobacteria predominantly inhabit soil, vegetation, or aquatic environments. The density of Actinobacteria populations is primarily determined by the specific habitat and climatic conditions. The most significant habitat for actinobacteria is soil. They are reported to have between 10^6 - 10^9 cells per gram of soil (Goodfellow & Williams, 1983; Balagurunathan *et al*., 2007). Tropical rainforests are rich habitats for endophytic actinomycetes, with plant response being crucial. Research explores the benefits of endophytic communities for plants and rhizospheric bacteria. Plants' endosphere contains diverse microbial endophytes, creating a complex micro-ecosystem (El-Shatoury et al., 2013). Researchers have documented the prevalence of actinobacteria in marine settings and their capacity for synthesizing organic compounds. The field of marine microbiology is advancing in various nations, placing emphasis on the exploration of biologically active substances. Prior to 2003, the majority (67%) of natural compounds derived from marine sources originated from locations such as Australia, the Caribbean, the Indian Ocean, Japan, the Mediterranean, and sites in the Western Pacific Ocean (D.J. Faulkner., 2001).

Application of actinobacteria in aquaculture

Actinobacteria are increasingly acknowledged as efficacious probiotics in aquaculture, providing a sustainable substitute for chemical and antibiotic therapies. Principal strains, such as Streptomyces and Nocardiopsis, have exhibited encouraging outcomes in augmenting growth performance, improving water quality, stimulating gut microbiota, and protecting against pathogens such as Aeromonas, Vibrio spp. Furthermore, Actinomycetes generate potent immunoactive peptides that amplify the immune response in fish and shrimp, presenting feasible choices for oral or injectable administration. Actinobacteria are prolific producers of diverse biologically active enzymes, essential for various biotechnological purposes. These enzymes encompass lipase, phytase, proteases, chitinases, and xylanases, pivotal in food processing, fermentation, animal feed, and biomedical uses. Additionally, Actinomycetes assume a crucial function in bioremediation, aiding in the preservation of water quality through the degradation of organic substances and the conversion of pollutants into less harmful compounds. They also possess the capability to decompose pesticide chemical categories, fostering more sustainable and eco-friendly aquaculture methodologies.

1. Actinomycetes as probiotics

Traditional aquaculture disease management relies on chemical compounds and antibiotics, but due to side effects, drug resistance, and decreased consumer preference, non-antibiotic-based environmentally friendly agents are in high demand. Antibiotics can lead to antibiotic-resistant bacteria, potentially transferring resistance genes to other pathogens. This is particularly concerning for dominant fish pathogens like Vibrio. Alternative strategies like probiotics and immunostimulants are needed to regulate diseases. Probiotics suppress fish pathogens through bacteriocin production, quorum quenching activity, and competitive exclusion. Common aquatic probiotics include *Bacillus*, *Lactobacillus*, *Pseudomonas*, and *Burkholderia* due to their beneficial properties. Literature indicates that probiotics can act as growth promoters, inhibitory compounds, nutrient digestion enhancers, water quality improvement, immune responses, and competition for nutrients in aquaculture. (Defoirdt *et al*., 2007; Cruz *et al*., 2012). According to Das *et al*. (2010) and Tan *et al.* (2016), Actinomycetes are suitable choices for probiotic use in aquaculture.

Table: 1 Water probiotics used in aquaculture systems

Water Probiotics	**Method of administration**	**Culture organisms**	**Outcome**	**References**
Streptomyces coelicofavus, Streptomyces diastaticus, Nocardiopsis alba, Streptomyces parvus and Streptomyces champavatii	Added to rearing water	*Penaeus monodon*	Enhance growth performances and water quality	Babu *et al.* (2018)
EM.1® (lactic acid bacteria, photosynthetic bacteria, yeasts and Actinomycetes)	Added to rearing water	Nile tilapia	Enhance growth performances and water quality	Bahnasawy *et al*. (2019)

Table: 2 Gut probiotics used in aquaculture systems

Gut Probiotics	**Method of administration**	**Culture organisms**	**Outcome**	**References**
Streptomyces	Feed	*Litopenaus vannamei*	Stimulation of gut microbiota and protection against *V. parahaemolyticus*	Mazón-Suástegui *et al*. (2020)
Nocardiopsis alba	Feed	*Penaeus monodon*	improving immunity, growth and protection from vibriosis	Sunish *et al.* (2020)

JUST AGRICULTURE
multidisciplinary e-Newsletter

S.amritsarensis	Feed	Grass carps	Antagonism against fresh water fish pathogens and enhances the growth and disease resistance	Li *et al.* (2020)
Streptomyces antibioticus	Feed	Freshwater catfish	Enhances growth, feed intake, nutrient digestibility, and survivability, while providing protection against fungi like *Aeromonas veronii* and *Stenotrophomonas maltophilia*	Das *et al.* (2021)

2. Actinomycetes as Immunostimulants

Actinomycetes have the capacity to generate highly potent immune-active peptides aimed at enhancing the immune response in fish and shrimps, thereby serving as viable options for oral or injectable administration as immunostimulants to elevate the immunity of fish. Most of the bioactive compounds derived from Actinobacteria have the potential to be delivered via oral or injectable routes to fish as immunostimulants, with the aim of boosting both their immune response and growth capabilities (Namitha *et al.*, 2021).

Table: 3 Immunostimulants in aquaculture systems

Name of species	Property	Outcome
Actinomycete Nocardiopsis alba	Immune modulatory activity	Enhances immunity against vibriosis in P. monodon
Streptomyces olivaceogriseus	Lactoyltetrapeptide	Enhanced immunity against *Aeromonas salmonicida* and *Yersinia ruckeri* in rainbow
Streptomyces panacagri	Antagonistic activity	Against *Vibrio harveyi*
Streptomyces focculus	Antagonistic activity	Against *Vibrio parahaemolyticus* and *Vibrio vulnificus*

3. Actinomycetes as source of digestive enzymes

JUST AGRICULTURE
multidisciplinary e-Newsletter

Actinobacteria produce various biologically active enzymes, including amylases for extracellular digestion, which are crucial in biotechnological applications like food, and fermentation. They also produce cellulases, hydrolytic enzymes that hydrolyze cellulose and related cello-digosaccharide derivatives. Lipase, produced from Actinobacteria, bacteria, and fungi, is used in detergent, foodstuff, oleochemistry, diagnostics and pharmaceutical industries.

Table: 4 Actinomycetes as source of digestive enzymes

Enzyme	**Producing strain**	**Use and industry**
Lipase	*Streptomyces griseus*	Cheese flavouring, Dairy
Phytase	*Streptomyces luteogriseus* R10	Phytate digestibility, Animal feed
Protease	• *Thermoactinomyces spp.* • *Nocardiopsis spp.* • *Streptomyces spp*	Cheese making, Food industry
Chitinase	• *Streptomyces thermoviolaceus* • *Microbispora spp.* • *Nocardiopsis prasina*	Food additive, biomedical applications, Animal feed
Xylanase	• *Actinomadura spp.* • *Streptomyces spp*	Digestibility, Animal feed

4. Actinomycetes in Bioremediation

Waste water deposition in aquaculture presents a notable risk to the survival of aquatic organisms such as fish and crustaceans. This is due to the degradation of water quality caused by the presence of organic substances like feed and fecal matter, which subsequently impacts the development of cultivated fish. Bioremediation in aquaculture is a practice that upholds water quality through the utilization of biostimulants and bioaugmentors. It has been observed that Gram-positive bacteria exhibit higher bioremediation potential, effectively transforming organic substances into CO_2. This process aids in regulating the accumulation of excessive carbon in culture systems when contrasted with the performance of Gram-negative bacteria (Verschuere *et al*. 2000).

Table: 5 Actinomycetes strains for heavy metals removal

Heavy metals	Strain of Actinobacteria

Copper (Cu)	*Streptomyces, Amycolatopsis, Kineococcus radiotolerans*
Mercury	Actinomycete strains, CHR3 and CHR28, Streptomyces VITSVK9
Lead	Streptomyces VITSVK9,
Zinc	Three strains of Streptomyces NGP (JX843532), *Streptomyces albogriseolus* (JX843531) and *Streptomyces variabilis* (JX43530)
Chromium	*Streptomyces griseus*

Pesticide chemical families, including carbamate (CB), organophosphorus (OP), organochlorine (OC), ureas, pyrethroids, and chloroacetanilide, among others. The most common pesticide-degrading Actinobacteria are Arthrobacter, Streptomyces, Janibacter, Kokuria, Rhodococcus, Mycobacterium, Nocardia, Frankia, Pseudonocardia and Mycobacterium. (Alvarez *et al*., 2017).

Conclusion

Actinomycetes, which belong to the phylum Actinobacteria present a promising alternative to conventional chemical and antibiotic therapies within the realm of aquaculture. They possess the potential to serve as probiotics and bioaugmentors, addressing concerns such as the emergence of diseases, antibiotic resistance, and environmental deterioration. Demonstrating efficacy in enhancing growth performance, ameliorating water quality, and stimulating gut probiotic, strains of Streptomyces and Nocardiopsis have garnered attention. Actinomycetes exhibit the capacity to yield immunoactive peptides that bolster the immune responses of fish and shrimp, thus proving valuable in immunostimulant applications. Their proficiency in enzyme production - encompassing lipases, phytases, proteases, chitinases, and xylanases - renders them indispensable in various sectors, including food processing, fermentation, animal feed, and biomedical domains. Furthermore, they play a pivotal role in bioremediation by decomposing organic substances and transforming pollutants into less hazardous forms, thereby fostering sustainable practices in aquaculture. Continued exploration and advancement are poised to unveil further innovative uses, solidifying actinomycetes as crucial allies in the pursuit of sustainable aquaculture.

References:

Anandan, R., Dharumadurai, D., & Manogaran, G. P. (2016). An introduction to actinobacteria. In *Actinobacteria-basics and biotechnological applications*. IntechOpen.

Balagurunathan, R., & Radhakrishnan, M. (2007). Actinomycetes: diversity and their importance. *Microbiology-applications and current trends. Jaipur: Pointer publishers*, 297-329.

Das, S., Ward, L. R., & Burke, C. (2010). Screening of marine Streptomyces spp. for potential use as probiotics in aquaculture. *Aquaculture*, *305*(1-4), 32-41.

Dhanasekaran, D., & Jiang, Y. (Eds.). (2016). *Actinobacteria: basics and biotechnological applications*. BoD–Books on Demand.

El-Shatoury, S. A., El-Kraly, O. A., Trujillo, M. E., El-Kazzaz, W. M., El-Din, E. S. G., & Dewedar, A. (2013). Generic and functional diversity in endophytic actinomycetes from wild Compositae plant species at South Sinai–Egypt. *Research in Microbiology*, *164*(7), 761-769.

Faulkner, D. J. (2001). Marine natural products. *Natural product reports*, *18*(1), 1R-49R.

Goodfellow, M., & Williams, S. T. (1983). Ecology of actinomycetes. *Annual review of microbiology*, *37*(1), 189-216.

Hasan, K. N., & Banerjee, G. (2020). Recent studies on probiotics as beneficial mediator in aquaculture: a review. *The Journal of Basic and Applied Zoology*, *81*, 1-16.

James, G., Das, B. C., Jose, S., & VJ, R. K. (2021). Bacillus as an aquaculture friendly microbe. *Aquaculture International*, *29*, 323-353.

Law, J. W. F., Pusparajah, P., Ab Mutalib, N. S., Wong, S. H., Goh, B. H., & Lee, L. H. (2019). A review on mangrove actinobacterial diversity: the roles of Streptomyces and novel species discovery. *Progress In Microbes & Molecular Biology*.

Ludwig, W., Euzéby, J., Schumann, P., Busse, H. J., Trujillo, M. E., Kämpfer, P., & Whitman, W. B. (2012). Road map of the phylum Actinobacteria. In *Bergey's manual® of systematic bacteriology* (pp. 1-28). Springer, New York, NY.

Mugwanya, M., Dawood, M. A., Kimera, F., & Sewilam, H. (2021). Updating the role of probiotics, prebiotics, and synbiotics for tilapia aquaculture as leading candidates for food sustainability: a review. *Probiotics and antimicrobial proteins*, 1-28.

Namitha, R., Vasantharaja, R., Radhakrishnan, M., & Govindaraju, K. (2021). Actinobacteria and their bioactive molecules for anti-WSSV activity: A mini review. *Aquaculture Research*, *52*(3), 883-889.

JUST AGRICULTURE
multidisciplinary e-Newsletter

Salam, N., Jiao, J. Y., Zhang, X. T., & Li, W. J. (2020). Update on the classification of higher ranks in the phylum Actinobacteria. *International journal of systematic and evolutionary microbiology*, *70*(2), 1331-1355.

Serrano, P. H. (2005). *Responsible use of antibiotics in aquaculture* (Vol. 469). Food & Agriculture Org.

Tan, L. T. H., Chan, K. G., Lee, L. H., & Goh, B. H. (2016). Streptomyces bacteria as potential probiotics in aquaculture. *Frontiers in microbiology*, *7*, 178998.