ISSN:0976-0172

Journal of Bioscience And Technology
www.jbstonline.com

Role of Cyanobacteria-Derived Carotenoids in Enhancing Coloration and Health of Ornamental Fish in Aquaculture: A Review

[1]Simon Ranjith A & [2]Poolpandi K

[1]Assistant Professor ,
R.M.P.C.S.I.P.S.K B.Ed College in Sathankulam,
Thothukudi District, Tamil Nadu, Ind

[2]Research Scholar, Department of Zoology, Kamaraj College, Thoothukudi,
(Affiliated to Manonmaniam Sundaranar
University)Tirunelveli-12,
Tamil Nadu, India

Article Info

Received: 23-03-2026 Revised: 02-04-2026 Accepted: 10-04-2026 Published: 20-04-2026

Abstarct

Carotenoids play a critical role in pigmentation, antioxidant defense, and physiological regulation in ornamental fish; however, their inability to synthesize these compounds necessitates dietary supplementation. Cyanobacteria represent a promising and sustainable source of bioactive carotenoids, including β-carotene, zeaxanthin, and echinenone, with significant applications in aquaculture nutrition. This review critically evaluates the efficacy of cyanobacteria-derived carotenoids in enhancing integumentary pigmentation, modulating oxidative stress, and improving immunophysiological responses in ornamental fish species. Experimental evidence demonstrates that carotenoid-enriched cyanobacterial biomass enhances chromatophore-mediated pigment deposition, resulting in increased coloration intensity and improved market value. Furthermore, these compounds exhibit potent free radical scavenging activity, thereby mitigating lipid peroxidation and enhancing innate immune responses. Despite these advantages, challenges such as strain-dependent variability in carotenoid yield, scalability of production, and risks associated with cyanotoxin contamination must be addressed. Future research should focus on optimizing

cultivation systems and bioavailability to maximize their application in sustainable ornamental aquaculture.

Keywords: cyanobacteria, carotenoids, ornamental fish, pigmentation, antioxidant activity, fish health, natural feed additives, immune response, sustainable aquaculture

1. Introduction

The ornamental fish industry represents one of the most dynamic and economically significant sectors within global aquaculture, driven primarily by the aesthetic appeal of brightly colored fish species. Coloration is a critical determinant of market value, consumer preference, and overall quality in ornamental fish. Among the various pigments responsible for coloration, carotenoids play a central role in producing yellow, orange, and red hues in fish integument. In addition to their role in pigmentation, carotenoids are involved in several physiological processes, including antioxidant defense, immune modulation, reproduction, and stress tolerance.

Unlike plants and certain microorganisms, fish lack the metabolic capability to synthesize carotenoids de novo. Consequently, they rely entirely on dietary sources to obtain these essential compounds. Traditionally, synthetic carotenoids have been incorporated into aquafeeds to enhance pigmentation; however, concerns regarding their high cost, environmental impact, and potential health risks have prompted increased interest in natural alternatives. In this context, naturally derived carotenoids from biological sources have gained prominence due to their higher bioavailability and additional functional benefits.

Cyanobacteria, a diverse group of photosynthetic prokaryotes, have emerged as a promising and sustainable source of natural carotenoids. These microorganisms are capable of producing a wide range of bioactive compounds, including β-carotene, zeaxanthin, and echinenone, which are known for their potent antioxidant and immunostimulatory properties. Furthermore, cyanobacteria can be cultivated under controlled conditions with relatively low resource input, making them an environmentally friendly and economically viable option for large-scale production.

Recent studies have demonstrated that the incorporation of cyanobacteria-derived carotenoids into aquaculture diets can significantly enhance pigmentation, improve growth performance, and strengthen immune responses in ornamental fish species. These compounds not only contribute to improved coloration through deposition in chromatophores but also play a protective role against oxidative stress by scavenging reactive oxygen species. As a result, fish exhibit better health, increased resistance to diseases, and higher survival rates.

Despite these advantages, several challenges remain in the application of cyanobacteria in aquaculture, including variability in carotenoid content among strains, optimization of cultivation techniques, and the potential risk of cyanotoxin production under certain conditions. Therefore, a comprehensive understanding of their benefits and limitations is essential for their effective utilization.

This review aims to critically evaluate the role of cyanobacteria-derived carotenoids in enhancing coloration and health in ornamental fish, with a focus on their biochemical properties, mechanisms of action, and applications in sustainable aquaculture systems.

2. Review of Literature

2.1 Importance of Carotenoids in Ornamental Fish

Carotenoids are lipid-soluble pigments widely distributed in nature and are primarily responsible for the yellow, orange, and red coloration observed in ornamental fish species. These pigments are deposited in specialized pigment cells known as chromatophores, which contribute to the visual appeal and commercial value of fish. Beyond pigmentation, carotenoids perform several essential biological functions, including antioxidant activity, enhancement of immune response, and regulation of reproductive performance.

Several studies have demonstrated that dietary carotenoid supplementation significantly improves coloration intensity and uniformity in ornamental fish such as goldfish (*Carassius auratus*), guppy (*Poecilia reticulata*), and cichlids. Moreover, carotenoids have been reported to reduce oxidative stress by neutralizing reactive oxygen species (ROS), thereby protecting

cellular components from damage and improving overall fish health.

2.2 Dietary Requirement and Sources of Carotenoids

Fish lack the enzymatic machinery required for the biosynthesis of carotenoids and must therefore obtain them through their diet. Common dietary sources include plants (e.g., carrots, marigold petals), microalgae (e.g., *Spirulina*), crustacean by-products, and microbial sources. Among these, natural sources are increasingly preferred over synthetic carotenoids due to their higher bioavailability, safety, and additional nutritional benefits.

Synthetic carotenoids, such as astaxanthin and canthaxanthin, have traditionally been used in aquaculture feeds; however, their high cost and potential environmental concerns have led to a shift toward natural alternatives. Natural carotenoids not only enhance pigmentation but also provide bioactive compounds that support physiological functions.

2.3 Cyanobacteria as a Source of Carotenoids

Cyanobacteria, also known as blue-green algae, are photosynthetic microorganisms that have gained considerable attention as a sustainable source of carotenoids. They are capable of producing a diverse range of pigments, including β-carotene, zeaxanthin, echinenone, and myxoxanthophyll. In addition to carotenoids, cyanobacteria contain valuable compounds such as phycobiliproteins, vitamins, essential amino acids, and polyunsaturated fatty acids.

The cultivation of cyanobacteria is relatively cost-effective and environmentally sustainable, as they require minimal inputs and can be grown in various conditions, including wastewater systems. This makes them an attractive option for large-scale production of natural pigments for aquaculture applications. Studies have shown that cyanobacterial biomass can be directly incorporated into fish feed, providing both nutritional and functional benefits.

2.4 Role of Cyanobacteria-Derived Carotenoids in Fish Coloration

The enhancement of fish coloration through dietary carotenoids is primarily attributed to their absorption in the intestine, transport via the bloodstream, and subsequent deposition in chromatophores. Cyanobacteria-derived carotenoids have been found to significantly

improve pigmentation intensity and brightness in ornamental fish.

2.5 Effects on Growth Performance and Health

In addition to pigmentation, cyanobacteria-derived carotenoids contribute to improved growth performance and overall health of ornamental fish. These compounds exhibit strong antioxidant properties, which help in reducing oxidative stress and preventing cellular damage. By scavenging free radicals, carotenoids enhance the stability of cellular membranes and improve metabolic efficiency.

Cyanobacteria also provide additional nutrients such as proteins, vitamins, and essential fatty acids, which contribute to better growth rates and feed conversion efficiency. Consequently, fish exhibit improved weight gain, survival, and overall performance.

2.6 Comparative Advantages over Synthetic Pigments

Cyanobacteria-derived carotenoids offer several advantages over synthetic pigments. They are natural, biodegradable, and environmentally friendly, making them suitable for sustainable aquaculture practices. Additionally, they provide multiple health benefits beyond pigmentation, including antioxidant and immunomodulatory effects.

3. Results and Discussion

3.1 Effect of Cyanobacteria-Derived Carotenoids on Fish Coloration

The primary outcome observed across multiple studies is the significant enhancement of pigmentation in ornamental fish fed with cyanobacteria-enriched diets. Carotenoids such as β-carotene and zeaxanthin are efficiently absorbed in the intestinal tract and transported via the bloodstream to the skin, where they are deposited in chromatophores. This process results in intensified coloration, particularly in red, orange, and yellow hues.

Experimental findings indicate that fish species such as goldfish and guppies exhibit increased color brightness and uniformity when fed diets supplemented with cyanobacterial biomass. The degree of pigmentation improvement is influenced by factors such as carotenoid concentration, duration of feeding, and species-specific absorption efficiency. Compared to control groups, treated fish consistently demonstrate higher carotenoid accumulation in skin

tissues, leading to enhanced aesthetic appeal and market value.

3.2 Impact on Growth Performance

In addition to improving coloration, cyanobacteria-derived carotenoids positively influence growth performance in ornamental fish. This is attributed to the presence of additional nutrients in cyanobacterial biomass, including proteins, vitamins, and essential fatty acids. These nutrients enhance feed utilization efficiency and metabolic activity, resulting in improved weight gain and growth rates.

Studies have reported that fish fed with cyanobacteria-supplemented diets exhibit better feed conversion ratios (FCR) compared to those receiving conventional diets. The synergistic effect of carotenoids and other bioactive compounds contributes to improved physiological performance, making cyanobacteria a valuable functional feed additive in aquaculture.

3.3 Antioxidant Activity and Stress Reduction

Carotenoids derived from cyanobacteria exhibit strong antioxidant properties, which play a crucial role in reducing oxidative stress in fish. Oxidative stress, caused by the accumulation of reactive oxygen species (ROS), can damage cellular components such as lipids, proteins, and DNA.

Dietary supplementation with carotenoid-rich cyanobacteria enhances the activity of antioxidant enzymes such as superoxide dismutase (SOD) and catalase. This leads to improved cellular protection and reduced lipid peroxidation. As a result, fish are better equipped to withstand environmental stressors such as temperature fluctuations, poor water quality, and handling stress.

3.4 Immunological Benefits

Another significant outcome of cyanobacteria-derived carotenoid supplementation is the enhancement of the immune system in ornamental fish. Carotenoids act as immunostimulants by improving both innate and adaptive immune responses.

Research findings show increased levels of immune parameters, including lysozyme activity, phagocytic activity, and antibody production in fish fed with cyanobacteria-based diets. These improvements contribute to enhanced disease resistance and reduced mortality rates. Consequently, the use of cyanobacteria not only improves fish

appearance but also promotes overall health and survival.

3.5 Comparative Effectiveness with Synthetic Carotenoids

When compared to synthetic carotenoids, cyanobacteria-derived pigments demonstrate comparable or superior performance in terms of pigmentation and health benefits. While synthetic carotenoids primarily serve as coloring agents, natural carotenoids from cyanobacteria provide additional functional benefits such as antioxidant protection and immune enhancement.

However, synthetic carotenoids may offer more consistent pigmentation results due to standardized composition. In contrast, natural sources may exhibit variability depending on cultivation conditions and strain differences. Despite this limitation, the growing demand for eco-friendly and safe aquaculture practices favors the use of natural carotenoids.

3.7 Future Perspectives

Future research should focus on improving the efficiency of carotenoid production through genetic and biotechnological approaches. Optimization of feed formulations to enhance carotenoid bioavailability and stability is also essential. Furthermore, the development of cost-effective cultivation systems will facilitate large-scale adoption of cyanobacteria in aquaculture.

The integration of cyanobacteria into sustainable aquaculture practices has the potential to reduce reliance on synthetic additives while improving fish health and product quality. Continued research and technological advancements will play a key role in overcoming existing limitations and maximizing the benefits of cyanobacteria-derived carotenoids.

4. Conclusion

Cyanobacteria-derived carotenoids have emerged as a highly effective and sustainable alternative to synthetic pigments in ornamental aquaculture. These naturally occurring compounds play a crucial role in enhancing pigmentation by promoting carotenoid deposition in chromatophores, thereby improving the aesthetic quality and market value of ornamental fish. In addition to their role in coloration, carotenoids exhibit significant biological functions, including antioxidant activity, immune enhancement, and stress mitigation.

The incorporation of cyanobacterial biomass into aquafeeds has been shown to improve growth performance, feed utilization efficiency, and survival rates in various ornamental fish species. Unlike synthetic carotenoids, natural pigments derived from cyanobacteria offer additional health benefits, making them more desirable from both a nutritional and environmental perspective. Furthermore, their eco-friendly nature aligns with the growing demand for sustainable aquaculture practices.

However, challenges such as variability in carotenoid content, high production costs, and the potential risk of cyanotoxin contamination must be addressed to ensure their safe and effective use. Standardization of cultivation methods and quality control measures is essential for consistent results.

Overall, cyanobacteria-derived carotenoids represent a promising functional feed additive that can enhance both the visual appeal and physiological health of ornamental fish, contributing to the advancement of sustainable aquaculture systems.

5. Future Scope

- Development of **cost-effective large-scale cultivation techniques** for cyanobacteria
- Genetic and metabolic engineering to **enhance carotenoid yield**
- Improvement of **carotenoid bioavailability and stability** in fish feed
- Exploration of **new cyanobacterial strains** with higher pigment content
- Investigation of **long-term safety and toxicity (cyanotoxins)**
- Integration of cyanobacteria in **circular and sustainable aquaculture systems**
- Use of advanced technologies (e.g., nanotechnology) for **efficient pigment delivery**

6. References (APA 7th Edition Style)

- Carvalho, C. C. C. R., & Caramujo, M. J. (2017). Carotenoids in aquatic ecosystems and aquaculture: A colorful business with implications for human health. *Frontiers in Marine Science, 4*, 93. https://doi.org/10.3389/fmars.2017.00093

ISSN:0976-0172

Journal of Bioscience And Technology
www.jbstonline.com

- Das, A. P., & Biswas, S. P. (2016). Carotenoids and pigmentation in ornamental fish. *Journal of Aquaculture & Marine Biology, 4*(4), 00093.
- Gupta, S., & Jha, A. K. (2017). Use of natural carotenoids for pigmentation in fishes. *Natural Product Research, 31*(7), 793–798.
- Pagels, F., Guedes, A. C., Amaro, H. M., Kijjoa, A., & Vasconcelos, V. (2021). Cyanobacteria as a valuable source of carotenoids: A review. *Biomolecules, 11*(5), 735. https://doi.org/10.3390/biom11050735
- Sathyaruban, S., et al. (2021). Potential natural carotenoid sources for the colouration of ornamental fish: A review. *Aquaculture Research*.
- Shah, M. M. R., Liang, Y., Cheng, J. J., & Daroch, M. (2016). Astaxanthin-producing green microalgae: From single cell to high value commercial products. *Frontiers in Plant Science, 7*, 531.
- Singh, S., Kate, B. N., & Banerjee, U. C. (2005). Bioactive compounds from cyanobacteria and microalgae: An overview. *Critical Reviews in Biotechnology, 25*(3), 73–95.
- Takaichi, S. (2011). Carotenoids in algae: Distributions, biosyntheses, and functions. *Marine Drugs, 9*(6), 1101–1118