Revolutionizing Larval Nutrition: Biotechnology in aquaculture live feed

Vatsalya Bhatt[1] and A. Arthi[2*]
[1]G. B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand- 263145
[2]TNJFU-Dr. MGR Fisheries College and Research Institute, Nagapattinam-614 712, Tamil Nadu.
[*]Corresponding author email: arthi.alagumalai@gmail.com

ABSTRACT

The increase in demand for seafood and decline in feed resources has shifted the focus of researchers towards integration of potential technologies like biotechnology and nanotechnology in feed production. Larval rearing is one of the crucial phases in the culturing of aquatic animals due to its sole dependency on live feed for nutrition. Live feed has its own limitations such as an imbalanced nutrition profile, scalability, economic feasibility, and inadequate advancement in production technology. Hence, incorporating biotechnological approaches, such as strain improvement, bioencapsulation, gene editing, and metagenomics, will enhance the efficacy of live feed. This article emphasizes on recent breakthrough of biotechnological applications in live feed industry. The responsible and optimal use of this technology will help us to overcome the milestones in live feed production.

Keywords: Live feed, Biotechnology, Nutrition, Larvae, Insect, Supercharged microalgae.

Introduction:

Early life stages of fish and shellfish in aquaculture are especially vulnerable and need food that is high in nutrients and simple to digest in order to survive, grow, and develop normally. The larvae depend upon live feed for its nourishment. It provides essential nutrients such proteins (essential amino acids), lipids (essential fatty acids), vitamins, enzymes such as proteases, lipases and other bioactive substances.

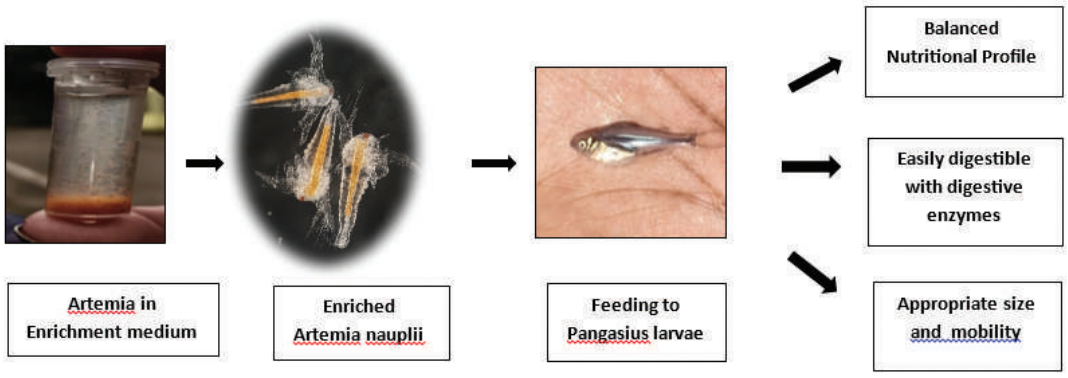
Biotechnology addresses these challenges such as inconsistent nutrition, difficulty in large-scale production, contamination, and environmental concerns. Thus, by increasing their nutritional value, advancing culture techniques, and maintaining biosecurity, it transforms live feed optimisation, enhancing growth potential, disease resistance and increasing survival rates of larvae (Khan & Rahman, 2025).

Importance of Live Feed in Aquaculture:

As the intensification in aquaculture proceeds, it demands the more seed supply from the hatchery. The hatchery depends upon on live feed for its production as it serves as a primary food from the hatched larvae till it able to digest artificial feed.

The early life stages have small mouths, undeveloped digestive systems, lack of digestive enzymes and requires high and balanced nutritional demands. Artificial diets are usually indigestible at this stage and fish larvae cannot survive or grow properly without it. (Faudzi, et al., 2024).

Live feed is critical in aquaculture because :



1. Digestibility and Behavioral Stimulation

• Live deed such as rotifers, artemia, and copepods are small in size , motile, and easy for larvae to ingest, their soft bodies and enzymes help larvae digest nutrients.

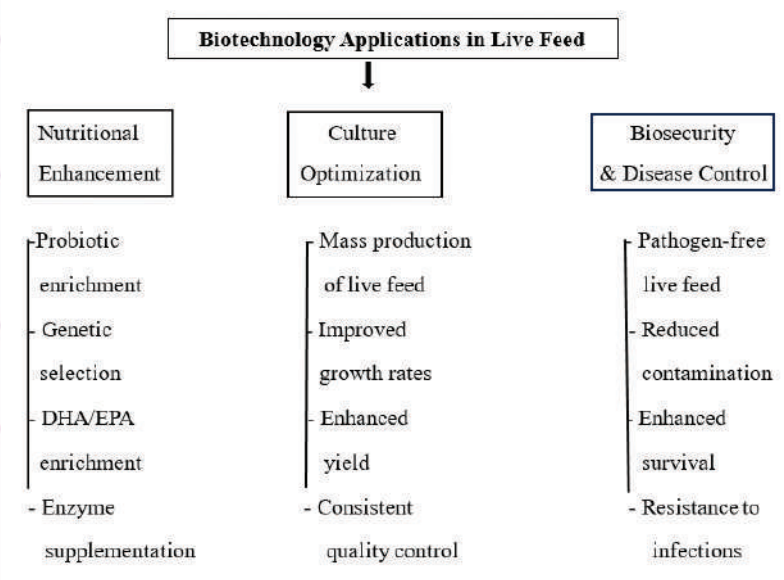
• It triggers feeding reflexes in larvae which inert feeds cannot replicate.

2. Nutrition and Survival

• It supply essential fatty acids (DHA, EPA), proteins, vitamins, and minerals. Proper nutrition ensures faster growth and successful transition to formulated feed.

• Larvae transition from endogenous to exogenous nutrition, requiring nutrient-rich live foods to support growth and development.

Biotechnology Applications in Live Feed



Role of Biotechnology in Live Feed

Various biotechnological tools are used to enhance the nutritional quality of live feed in several innovative ways:

1. Supercharged Microalgae

• These are nutritionally enhanced microalgae for creating a superior live feed for aquaculture in order to improve the growth, survival and overall health of the fish and shellfish larvae.

• They are specially cultured microalgae through optimization of culture media coupled with various biomolecule enrichment technique which results in efficient nutrient transfer.

• These supercharged microalgae serves as a more balanced and potent food source than a standard microalgae cultures.

Common super charged microalgae are:

• Chlorella vulgaris – high protein content and efficient assimilation of ammonia from water

• Nannochloropsis sp – rich in lipids, particularly poly unsaturated fatty acids

• Dunaliella sp – rich in carbohydrate and other bioactive compounds such as carotenoids.

Microalgae are the base of the aquatic food chain and are consumed by live feed organisms like rotifers and copepods. Genetically modified microalgae can be produced to:

• Boost Omega-3 Fatty Acids – Essential for fish growth and brain development.

• Enhance Vitamin Content – Microalgae rich in vitamins improve survival rates of fish larvae.

• Speed Up Growth – Faster-growing microalgae ensure a steady supply of nutritious feed.

2. The Rise of Probiotics

• The nutritional quality and disease resistance of the live feed can be enhanced with the help of probiotics by integrating beneficial microorganisms, such as bacteria and yeast into copepod, rotifer and artemia, which in turn promotes the health and growth of fish and shrimp larvae.

• This "probiotic enrichment" of live feeds also improves the environmental quality of the culture system by competing with harmful bacteria and assimilating nutrients.

• Probiotics can be added directly to the live feed culture tanks to enrich it before being fed to the target aquatic species.

Fish can benefit from probiotic-enriched feed through special bacterial strains that:

• Improve digestion in fish larvae.

• Strengthen immunity, reducing the need for antibiotics.

• Enhance nutrient absorption, leading to faster growth and better survival rates.

3. Insect Power: The Future of Live Feed

• Efficient conversion of waste into valuable products can be achieved by integration of insects into food and feeding systems.

• Insects are a rich source of high-value protein, vitamins, minerals, and essential fatty acids like omega-3 and omega-6.

• They often exhibit high protein and amino acid digestibility, which is comparable or even superior to some conventional animal proteins.

• Challenges remain in achieving price competitiveness, chitin digestibility and consistent quality due to varying processing methods and nutritional profiles.

Using biotechnology, scientists can modify insect feed to create larvae with:

• Higher protein content (better growth for fish).

• Balanced amino acids for improved digestion.

• Optimized production methods for cheaper and eco-friendly farming.

This approach reduces the industry's reliance on wild-caught feed sources and provides a sustainable alternative.

4. Genetically Enhanced Artemia & Rotifers

Artemia (brine shrimp) and rotifers are staple live feeds, but they often lack essential nutrients. They can be genetically modified to:

• Increase DHA and EPA levels (crucial for fish development).

• Improve resistance to disease, making them easier to farm.

• Enhance survival rates, reducing waste in aquaculture systems.

• Enhancement of traits like stress tolerance, nutritional quality, or the production of specific proteins can be done by genetic modification.

• These modifications, which involve integrating foreign genes, create "transgenic Artemia" that can improve sustainable aquaculture practices, serve as bioreactor materials, and contribute to bioengineering and environmental monitoring.

Genetic enhancement can be achieved through:

Genetic Engineering: Foreign genes are integrated into the organism's genome to produce desired traits.

Gene Expression: The genetically modified organisms can then express these foreign genes, for example, to produce specific proteins like growth hormone (ypGH)

5. Artificial Plankton & Lab-Grown Feed

• Artificial Planktons are composed of a variety of inert microparticles that simulate the nutritional and physical features of live zooplankton for early larvae, even though in some cases, live prey may still offer a superior level of nutrition for some species.

• The purpose of these artificial diets is to help reduce costs and labor of producing live feeds, however, they still need to be carefully formulated to account for the nutritional requirements, particle size and digestive capabilities of the larvae cultured.

Scientists are already working on:

• Encapsulation technology – Tiny nutrient-packed capsules that slowly release essential compounds.

• Bioengineered yeast & bacteria – Lab-grown microorganisms designed to provide custom nutrition for fish larvae.

These developments could redefine aquaculture by providing a stable, predictable, and eco-friendly alternative to traditional live feed.

Challenges and Strategic Analysis of Biotechnology-Based Live Feed

1. Regulatory Issues:

• Biotechnological approaches includes genetic engineered live food organism (GMOs) which face strict regulations in many countries like USA due to environmental concerns and genetic pollution.

2. High Costs and Economic Viability:

• A substantial research and development requires huge investment for the development and application of biotechnological solutions, ranging from probiotic enrichment to genetic selection.

• Also, scaling up to meet commercial aquaculture demands adds financial strain and may hinder acceptance in hatcheries and industries, even though lab-scale production may be possible.

3. Technical Challenges in Scaling Up:

• During mass manufacturing, processes that have been optimised in controlled laboratory settings can run into problems.

• It is difficult to maintain consistent quality, nutritional profiles, and biosecurity standards on a wide scale (Sandeep et al., 2025; Marleen & Annelies, 2024).

Emerging biotechnological approach in Aquaculture

• CRISPR Gene Editing : A powerful tool to modify live feed organisms with pinpoint accuracy.

• AI & Big Data : Artificial intelligence can analyze nutrient compositions to optimize feed formulations.

• Metagenomics : Studying fish microbiomes to create personalized probiotic solutions.

SWOT analysis:

Strengths	Weakness
Enrichment of live feed	High R&D and production costs
Improved disease resistance in larvae through probiotic and microbial enrichment.	Regulatory hurdles and approvals
Sustainable, controlled production.	Technical challenges in scaling up.
Opportunities	**Threats**
Growing global demand for aquaculture products	Consumer skepticism to GMOs and biotech feeds
Integration with precision aquaculture and monitoring	Competition from conventional feed alternatives
Development of functional feeds with added health benefits such as phtyobiotics, immunostim.	Risk of unintended environmental impact from biotech organisms.

Future prospects

The exploration and development of different live feed cultures (including novel micro-sized copepod and rotifer species) is energizing research ranges, to industrial applications. The design, development and production of dormant live feed (e.g., copepod resting eggs) has been included in new research programs, and is likely to be a future development for the marine larviculture industry.

Future programs should explore both indoor and outdoor aquaculture systems integrating appropriate RAS technologies with artificial intelligence (AI) technology to optimize performance of both prey and larval culture in complex aquaculture systems. Developing technologies and management for virus free live feed and bacterial free live feed use in larviculture.

Scientists and farmers can work closely together to make sure pilot studies are up scaled and to have the feedback cycle needed to maintain required interaction between industry needs - science research challenges. As biotech innovations continue to evolve and improve, the aquaculture industry will become more sustainable, efficient, and resilient.

References :

1. Ahmed, I., et al., 2022. Recent trends in live feeds for marine larviculture: A mini review. Frontiers in Marine Science.

2. Anikuttan, K.K. (2024). Marine Microalgae: An Inevitable Live Feed in Fish Hatcheries. In Algal Biotechnology. Taylor & Francis..

3. Faudzi, N. M., Shapawi, R., & Fui, C. F. (2024). The Importance of Rotifer as Live Feed. In Essentials of Aquaculture Practices. CRC Press.

4. Hernández-Vidal, U. (2024). An overview of feeding strategies and challenges in tropical aquaculture. Universidad Juárez Autónoma de Tabasco.

5. Kagali, R.N., 2022. Culturing live foods for fish larviculture using non-conventional methods. Aquaculture and Fisheries, 7(4), pp.231–239. [

6. Khan, N. S., & Rahman, M. S. (2025). Zooplankton in Aquaculture: A Perspective on Nutrition and Cost-Effectiveness. Aquaculture Research, Wiley. DOI:10.1155/are/5347147

7. Lewis, L.A., et al., 2022. Culturing live foods for fish larviculture using non-conventional methods. Aquaculture and Fisheries. [online] Available at:

8. Loboiko, Y.V., Senechyn, V.V., & Shtynda, L.Y. (2024). Efficiency of using experimental feeds with different levels of nutritional value in carp feeding.

9. Marleen, D. S. D. T., & Annelies, D. (2024). Advancing aquaculture sustainability through copepod-based live feed systems. VLIZ.

10. Molinari, G.S., 2023. A novel approach in the development of larval fish diets. Scientific Reports, 13(1), Article 9913688.

11. Sandeep, K. P., Sivaramakrishnan, T., & colleagues. (2025). Live Feeds in Shrimp Aquaculture: An Overview. In Aquatic Animal Health Management. Springer.

12. Singh, B. (2024). Probiotics as Live Biotherapeutics for Veterinary and Human Health, Volume 1. Google Books.

13. Singh, S.K., Deepti, M., Meinam, M., Devi, N.C., & Devi, W.M. (2024). Aquamimicry (Copefloc technology): An innovative approach for sustainable organic farming with special reference to shrimp aquaculture. Blue Biotechnology, Springer.

14. Sorgeloos, P., et al., 2021. Improvement of nutritional quality of live feed for aquaculture. Aquaculture Research.

15. Wang, L., et al., 2022. Microalgae biotechnology for simultaneous wastewater treatment and live feed production.