Beyond Blue Horizons

An Experiential Learning Manual for B.Sc. (Agri.) Students of KAU, Thrissur

Edited by

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ICAR-Central Marine Fisheries Research Institute

(Department of Agricultural Research and Education, Government of India)

P.B. No. 1603, Ernakulam North P.O., Kochi - 682 018

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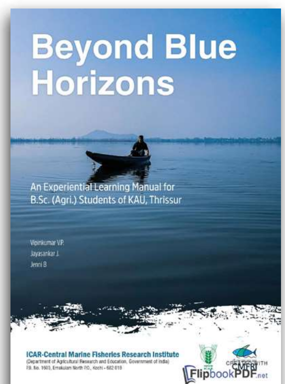

Beyond Blue Horizons
Training Manual for BSc (Agri) students of Kerala Agricultural University

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FOREWORD

It is with great pleasure and deep satisfaction that I present this foreword to the Training Manual of the Science Camp titled "Beyond Blue Horizons: An Experiential Training Manual for B.Sc. Agriculture Students." Conducted from July 14 to 18, 2025, at the STI Hub Digital Training Hall, ATIC, ICAR-CMFRI, Kochi, this programme exemplifies our continued commitment to innovative, experiential, and interdisciplinary learning in agriculture and allied sectors.

Organized by ICAR-Central Marine Fisheries Research Institute through its Agricultural Technology Information Centre (ATIC), the training served as a dynamic platform for B.Sc. Agriculture students from the College of Agriculture, Vellanikkara, Thrissur. The thematic focus on integrating field-based experiences with advanced laboratory analyses reflects a progressive approach to education—one that fosters a seamless continuum between knowledge generation, validation, and application. Such initiatives are vital in equipping students with the skills and perspectives required to address emerging challenges in agriculture and fisheries.

I place on record my sincere appreciation to Dr. Vipinkumar V.P., Principal Scientist and ATIC Manager, ICAR-CMFRI, for his exemplary leadership, meticulous planning, and unwavering dedication in organizing this programme. His efforts, along with those of the entire team, have ensured the successful conduct of this Science Camp, setting a high standard for future capacity-building initiatives.

The programme was thoughtfully designed to bridge the gap between theoretical understanding and practical application. It offered participants a rich blend of innovative lectures on emerging topics, hands-on training sessions, field exposure visits, and institutional interactions. The opportunity to access advanced laboratories, aquarium facilities, and the museum at CMFRI significantly enriched the learning experience. Equally important were the interactive sessions with farmers, which fostered meaningful exchanges between academia and practitioners, grounding scientific knowledge in real-world contexts.

Such experiential learning opportunities are invaluable in enabling students to appreciate the dynamic flow of information from field observations to laboratory insights, ultimately supporting informed decision-making and innovation in production systems. I am confident that the knowledge and exposure gained through this Science Camp will contribute significantly to the academic growth and professional development of the participants.

I extend my warm congratulations to all the students and faculty members who actively engaged in this programme. Your enthusiasm, curiosity, and commitment to learning are truly commendable. May this experience inspire you to strive for excellence and contribute meaningfully to the advancement of agriculture and fisheries.

I am confident that this training manual will serve as a lasting resource, capturing the essence of the programme and reflecting the collective efforts that made this initiative both impactful and memorable.

Dr. Grinson George
Director, ICAR-CMFRI
Kochi

PREFACE

It is with immense pleasure and a deep sense of fulfilment that I present this compendium, "Beyond Blue Horizons: A Training Manual for B.Sc. Agriculture Students of Kerala Agricultural University." This volume encapsulates a unique and inspiring journey of experiential learning, meticulously designed and conducted at the STI Hub Digital Training Hall, ATIC, ICAR-CMFRI, Kochi, from July 14 to 18, 2025.

Envisioned as a transformative academic engagement, this Science Camp brought together bright and inquisitive B.Sc. Agriculture students from Kerala Agricultural University, Thrissur, and guided them through a rich continuum of learning—from field-level realities to the precision of laboratory analytics. At a time when agriculture is rapidly transitioning into a data-driven and innovation-led enterprise, the programme provided a vibrant platform for students to explore the convergence of traditional knowledge systems with modern scientific advancements, with a special emphasis on the fisheries sector.

The training was thoughtfully structured to deliver an immersive and practice-oriented learning experience. Through a dynamic blend of expert lectures, hands-on sessions, field exposure visits, institutional interactions, and meaningful dialogues with farmers, participants were encouraged not only to learn but to question, analyse, and innovate. The focus was on nurturing scientific curiosity, strengthening practical competencies, and inspiring a forward-looking approach to sustainable agriculture and fisheries development.

This manual, comprising ten thoughtfully curated chapters, reflects the thematic depth and diversity of the programme. It covers a wide spectrum of subjects including integrative analytics, digital interventions, field diagnostics, and emerging marine agri-technologies. What makes this volume particularly engaging is its strong practical orientation—each chapter offers insights, methodologies, and experiences that readers can readily connect with and apply. The concluding chapter, featuring the comprehensive report prepared by the students, stands as a testament to their active engagement and the effectiveness of the experiential learning model adopted during the camp.

I place on record my sincere gratitude to Dr. J. Jayasankar, Head of the FRAEE Division, and Dr. B. Jenni, ACTO, ATIC, for their scholarly contributions, editorial excellence, and steadfast support as co-editors of this compendium. Their efforts have been instrumental in shaping this manual into a valuable and enduring academic resource.

As the Course Director and Chief Editor, I consider this compendium not merely as a documentation of an event, but as a celebration of collaborative learning and an invitation to explore the vast and promising interface between agriculture and fisheries sciences. While this endeavour represents only a beginning—a glimpse into a much larger horizon—it is my earnest hope that this volume will inspire readers to delve deeper, think innovatively, and contribute meaningfully to this evolving domain.

I warmly invite students, researchers, academicians, and practitioners to engage with the chapters that follow—rich in practical insights, field-based observations, and scientific perspectives—and to draw inspiration for future learning and innovation.

Dr. Vipinkumar V. P.
Principal Scientist & ATIC Manager
ICAR-CMFRI, Kochi

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Role of Probiotics in Aquaculture Nutrition and Health Management

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Introduction

Aquaculture as one of the fastest-growing food production sectors globally, which is largely driven by increasing protein demands of a growing human population, which is projected to reach 9.7 billion by 2050 (Rahayu Silvana, 2024, Torres-Maravilla E 2024). Intensification of aquaculture practices has brought with it several challenges, including deteriorating water quality, increased susceptibility to infectious diseases cause's disease outbreaks, and the overuse of antibiotics and chemotherapeutics (FAO, 2022). These issues not only result in significant production losses but also pose threats to environmental sustainability and public health due to the emergence of multidrug-resistant pathogens, chemical residues in aquaculture products which is threatening food security. Thus the search for eco-friendly, sustainable, and effective alternatives to conventional disease management strategies has gained momentum. Among these alternatives, probiotics have received considerable attention in recent decades.

Probiotics is defined as "live microorganisms when administered in adequate amounts, confer a health benefit on the host" (Ngasotter 2025). The exploration of probiotics in aquatic environments have opened a new frontier in nutritional and health management. Commonly used probiotics in aquaculture include beneficial bacteria from genera such as *Bacillus, Lactobacillus, Enterococcus, Pediococcus, Saccharomyces* etc. In aquaculture, these microorganisms are delivered through water, feed, or live-feeds to improve host nutrition, enhance immunity, modulate gut microbiota and mitigate disease outbreaks (Ringø et al., 2020). Their impact is in benefiting the host animal, the aquatic environment, and the microbial community within the culture system. The integration of probiotics into aquaculture practices also supports the global drive towards reducing antibiotic dependence, aligning with the principles of sustainable aquaculture and one health. By reducing reliance on antibiotics and chemicals, probiotics not only safeguard aquaculture productivity but also protect consumer health and environmental integrity. With the rise of advanced tools such as next-generation sequencing and metagenomics, new avenues have opened for the identification, characterization and application of effective probiotic strains tailored to specific aquaculture systems.

2 Benefits of Probiotics in Aquaculture

2.1 Improvement of Growth Performance

Probiotics have gained widespread attention for their ability to enhance growth performance and feed efficiency in a variety of cultured aquatic species. These beneficial microorganisms, when administered through feed or the aquatic environment, contribute to better nutrient absorption, digestive health, and overall physiological function of aquatic animals. When probiotics colonise the gastrointestinal tract of host animals, they helps to maintain a balanced microbiota and reduce gut inflammation. Additionally, it improves the structure of the intestinal lining by increasing villi height and crypt depth which increases the surface area available for nutrient absorption. The improved gut health leads to better energy conversion from feed to body mass, resulting in increased weight gain and growth rate weight gain, feed conversion ratio (FCR) and specific growth rate (SGR).

2.2 Nutrient digestibility

It refers to the ability of the fish to break down and absorb essential macronutrients—proteins, lipids and carbohydrates—as well as micronutrients from their diet. Probiotic bacteria are known to produce extracellular enzymes such as amylases, proteases, and lipases, which complement the digestive enzymes of the host and facilitate more efficient breakdown and absorption of nutrients from feed. Several probiotic strains, particularly *Bacillus, Lactobacillus*, and *Pediococcus*, can secrete enzymes such as amylase, protease, cellulase and lipase, which augment the host's own digestive enzyme activity. This facilitates more efficient breakdown and absorption of nutrients from feed. This enzymatic contribution leads to improved assimilation of proteins, carbohydrates and lipids, thereby supporting faster growth and better feed utilization. Additionally, it plays an increasingly recognized role in the nutritional enhancement of fish by contributing to the synthesis and bioavailability of essential nutrients. These include amino acids, vitamins, fatty acids and minerals, all of which are crucial for optimal growth, immunity and physiological functioning in aquaculture species. It further supports lipid metabolism by improving the digestion and absorption of dietary lipids. Some probiotic strains may assist in the emulsification and breakdown of fats, enhancing the availability of essential fatty acids like EPA and DHA. This is particularly valuable in larval and juvenile stages of fish when the requirement for essential lipids is high. Further it produces short-chain fatty acids (SCFAs) such as acetate, propionate and butyrate during carbohydrate fermentation. These SCFAs serve not only as energy sources for intestinal cells but also enhance the absorption of minerals such as calcium and magnesium, contributing to better nutrient utilization. Organic acids produced during fermentation, such as lactic acid and acetic acid, can lower the pH in the intestinal tract, thereby increasing the solubility and uptake of minerals like calcium, magnesium, phosphorus, and iron. In addition, some strains can chelate minerals or produce siderophores that facilitate iron acquisition, further supporting metabolic activity and hemoglobin synthesis. These findings suggest a direct link between probiotic-mediated nutrient provision and enhanced growth performance.

2.3 Disease Control and Health Management

Probiotics are also known to enhance both innate and adaptive immune responses, leading to improved resistance against bacterial, viral and parasitic infections. Disease outbreaks are a major challenge in aquaculture, often leading to significant economic losses. Probiotics enhance the **innate immune response** by increasing the activity of phagocytic cells, production of lysozyme and expression of immune-related genes. This immune stimulatory effect enables the host to mount a quicker and more efficient defense against invading pathogens. In addition to strengthening the immune system, probiotics enhance **overall disease resistance**. By maintaining a favourable gut microbiome, probiotics prevent colonisation by harmful bacteria such as *Vibrio*, *Aeromonas* and *Pseudomonas*. Probiotics occupy physical niches on the gut epithelium, effectively **blocking pathogens from adhering to the intestinal lining and also** by **competitive exclusion**. This protective effect reduces the likelihood of gastrointestinal infections and systemic diseases. It competitively exclude and antagonize pathogenic bacteria by producing **antimicrobial compounds** such as bacteriocins, lactic acid, and hydrogen peroxide and short-chain fatty acids. These substances inhibit the growth of pathogens by disrupting their cell walls, lowering pH, or interfering with microbial signaling systems. The incorporation of probiotics into aquaculture systems has proven to be an effective strategy for improving both nutritional efficiency and health outcomes. Their immune stimulatory and antimicrobial properties make them essential tools for disease management and environmental adaptation.

2.4. Water Quality Improvement and Environmental Impact

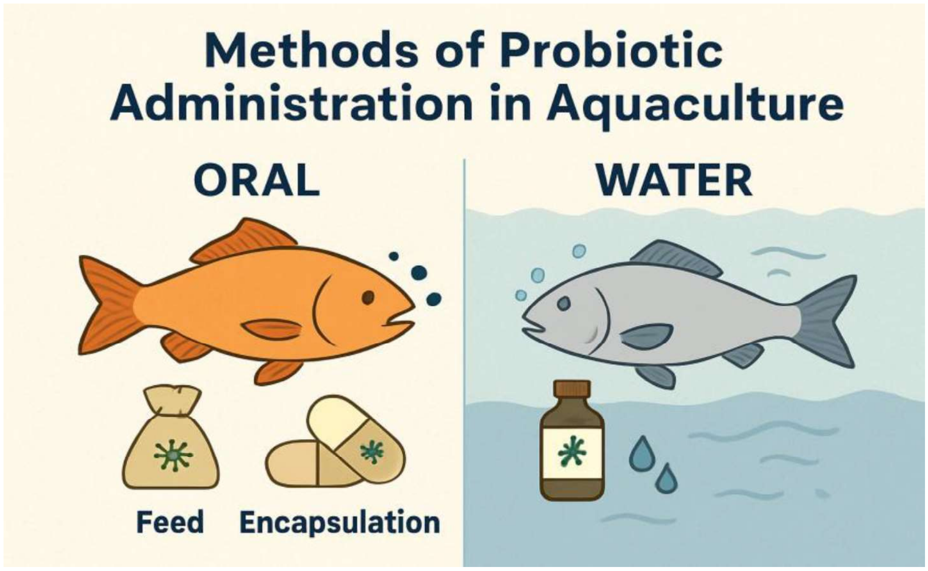
Probiotics not only benefit the host but also plays a vital role in maintaining water by participating in nutrient cycling and decomposition of organic matter in aquaculture systems. It includes nitrifying (*Nitrosomonas sp., Nitrobacter sp.*) and denitrifying bacteria (*Pseudomonas*, *Bacillus*) which converts toxic ammonia to less harmful nitrate and nitrogen gas. Intensive aquaculture practices often lead to the accumulation of organic wastes, including uneaten feed, feces, and excreted metabolites such as ammonia, nitrite, and hydrogen sulfide, which can deteriorate water quality and predispose cultured species to stress and disease outbreaks Probiotics also support nutrient cycling which helps to stabilize the aquatic system. Additionally, some probiotics suppress the growth of harmful waterborne microbes and limit the proliferation of harmful algae. Collectively, these probiotic-mediated improvements in water quality not only enhance growth and survival rates of farmed species but also contribute to environmentally friendly and sustainable aquaculture practices.

3. Administration of probiotics

The efficacy of probiotics in aquaculture largely depends on their mode of delivery, optimal dosage and duration of administration, which together determine colonization success, microbial balance and host benefits. Probiotics are administered in aquaculture through three methods.

- Incorporating with feed
- Adding directly to aquatic system
- Encapsulating with live feeds such as rotifers and artemia

Feed supplementation is the incorporation of probiotics into feed formulations, either during manufacturing or through topical application. It is the most widely used method as it ensures direct delivery to the gastrointestinal tract, where probiotics can exert their beneficial effects on digestion and immune function. However, this approach requires probiotic strains that can survive feed processing conditions (mainly pelleting) and remain stable during storage. Direct water application is another method used for extensive and semi-intensive systems. This approach allows probiotics to act on both the aquatic environment and the host, by improving water quality and potentially benefit the host indirectly by colonising the **external surfaces**. For early larval stages where digestive systems are underdeveloped, water application is often the only feasible method. It can be influenced by environmental variables such as temperature, pH, salinity, and dissolved oxygen, which may affect the survival and activity of the microorganisms. Therefore, careful management and regular dosing are essential to maintain an effective probiotic population in the water. To improve probiotic stability and targeted release in the gastrointestinal tract, **encapsulation techniques** are increasingly employed. Encapsulation involves encasing probiotic cells within protective materials such as alginate, chitosan, lipids, or polymers. This provides a barrier against adverse environmental factors such as stomach acid, bile salts, or high pelleting temperatures. Encapsulation not only improves the shelf-life and survivability of probiotic strains but also enables controlled release, ensuring that a significant number of viable cells reach the intended site of action in the host’s gut. All methods of probiotic administration play essential roles in aquaculture health management.



4. Commercial Formulations

The use of probiotics as an environmentally friendly alternative in aquaculture has grown significantly, supported by both scientific evidence and practical application. The global probiotic market, encompassing ingredients, supplements and functional foods, has expanded rapidly, reflecting increasing demand in aquaculture production systems. Today, a wide range of commercial probiotic preparations containing one or more live microorganisms are available to enhance the health and productivity of aquatic species. These can be applied directly to culture tanks or incorporated into feed, and many now include prebiotics such as mannans, glucans and yucca extract to further stimulate beneficial microbial activity. Commercially available probiotics originate from various microbial sources, including *Bacillus* spp., *Lactobacillus* spp., *Enterococcus* spp., *Clostridium* spp. and beneficial yeasts like *Saccharomyces cerevisiae*. They have been shown to improve survival rates, feed conversion, growth performance, immune response, reproductive efficiency and disease resistance in species such as shrimp, tilapia, catfish, rainbow trout and eels. Interestingly, studies reveal that higher probiotic dosages do not always correlate with better protection, underscoring the importance of optimal dosing strategies. Mixed-culture preparations often deliver superior results, boosting nonspecific immune parameters, lysozyme activity, neutrophil migration and plasma bactericidal capacity. Advances in formulation technology have improved the stability and efficacy of probiotics. They are now produced in liquid and powdered forms, with optimized fermentation processes that ensure high microbial viability and functional activity. Microencapsulation techniques using materials like alginate, chitosan, or pectin now protect probiotics from harsh conditions such as low pH and digestive enzymes, ensuring they reach the intestine alive. Methods like emulsion, extrusion, spray drying and adhesion to starch are widely applied, and encapsulated probiotics have been shown to survive gastrointestinal transit in various fish species. Lyophilized (freeze-dried) products offer advantages for storage and transport, but proper reconstitution considering temperature, hydration and osmolarity is crucial to preserve bacterial viability. Ultimately, effective commercial probiotics in aquaculture must survive both storage and passage through the host's digestive tract, remain metabolically active and deliver measurable health and productivity benefits. According to producers and field experience, modern formulations are safe, reliable and play a vital role in maintaining the health and sustainability of aquatic farming systems.

Conclusion

Probiotics in aquaculture not only contributes to improved growth performance and feed efficiency but also supports sustainable production by reducing the need for antibiotics and enhancing animal welfare. It offers a promising, multifaceted approach to boost health and performance without compromising environmental or food safety. Continued advancements in probiotic formulation, strain selection, and delivery methods will further enhance their efficacy of probiotics in aquaculture not only supports improved growth and feed utilization but also aligns with the goals of sustainable aquaculture. With responsible application and ongoing research, probiotics will remain a cornerstone of sustainable aquaculture health management.

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