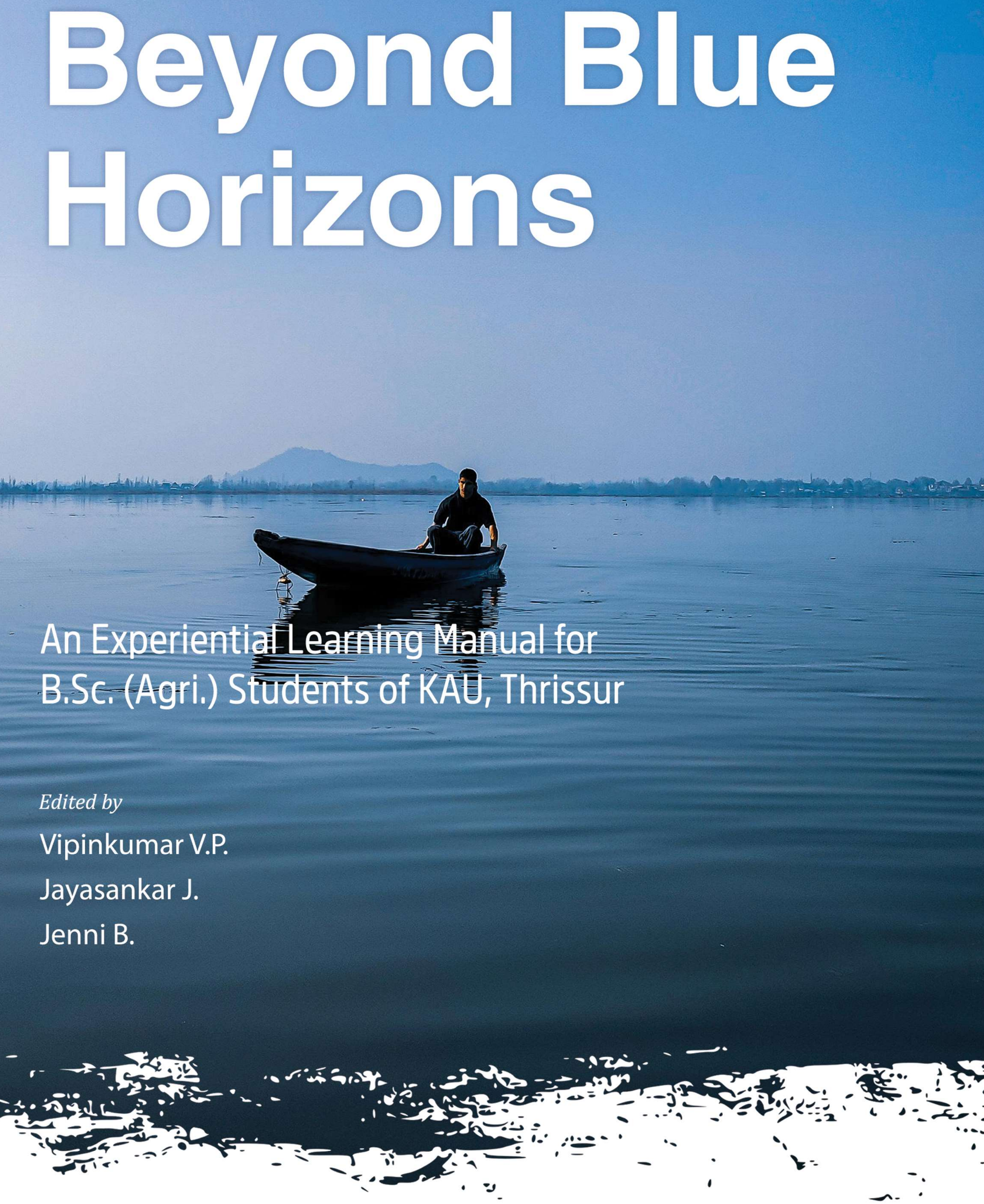

Beyond Blue Horizons

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

Edited by

Vipinkumar V.P.

Jayasankar J.

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ICAR-Central Marine Fisheries Research Institute

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

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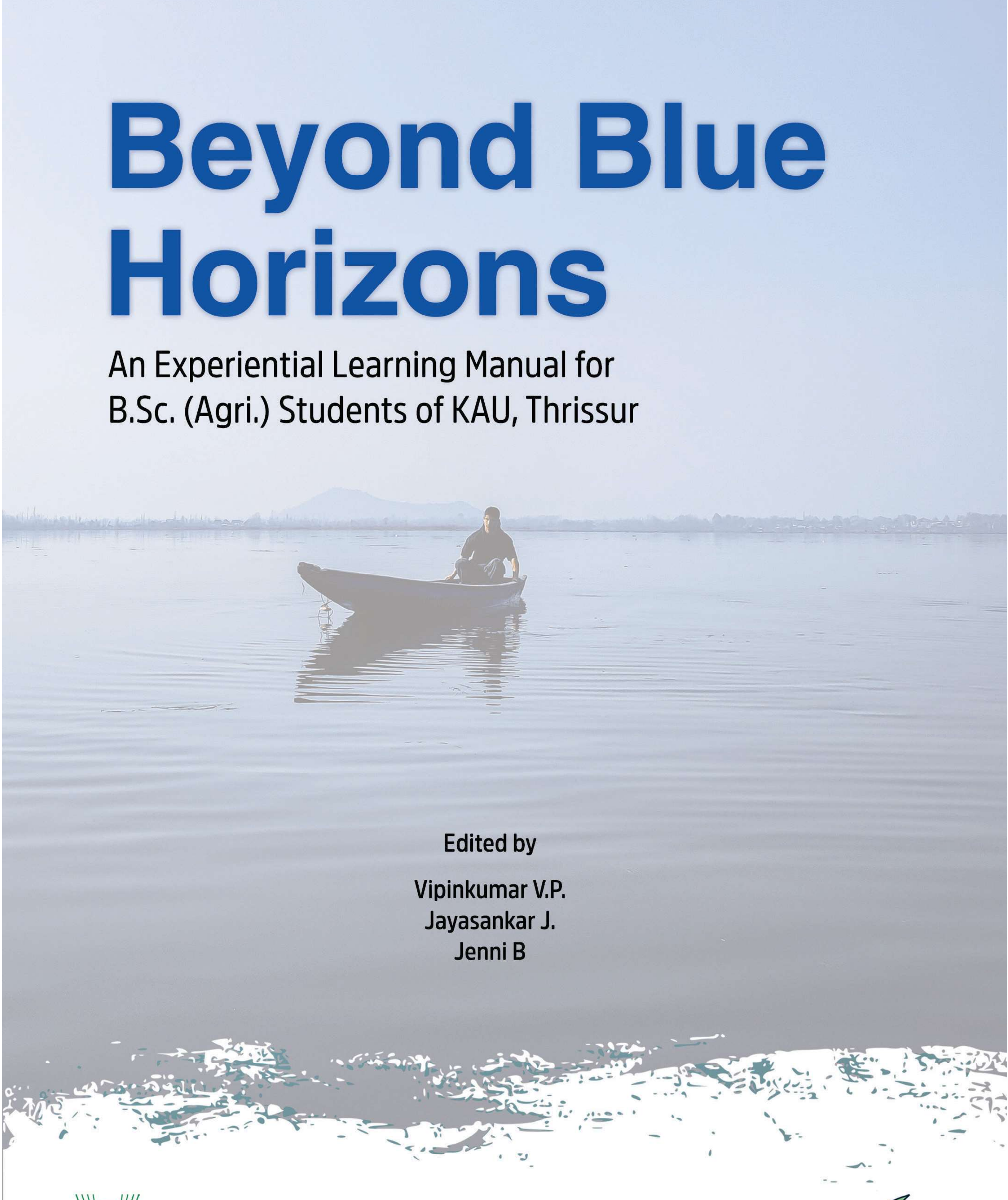

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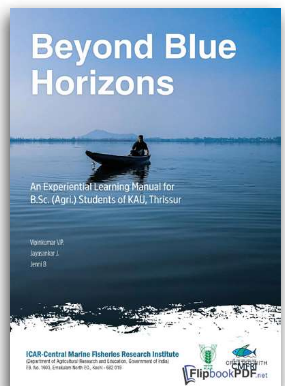

Beyond Blue Horizons
Training Manual for BSc (Agri) students of Kerala Agricultural University

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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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Advances In The Use Of Alternative Protein Sources For Fish Feeds

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Introduction

Aquaculture industry has experienced significant growth in recent decades, and has become a major contributor to global fish consumption. According to the Food and Agriculture Organization (FAO 2022), approximately half of the world's fish consumption comes from aquaculture. However, this growth has brought about challenges, particularly in terms of feed production and sustainability. Among the different dietary components, protein is the single most important and expensive nutrient in fish feed, typically accounting for 30–50% of the diet. It plays a vital role not only in supporting growth and tissue development but also in maintaining immune competence, reproduction and overall health. Unlike terrestrial animals, fish have limited capacity to utilize carbohydrates and often depend more heavily on dietary protein for both energy and structural functions, making the choice of `protein source critical for aquaculture productivity and profitability. Conventional aquaculture feeds often contain expensive and potentially unsustainable ingredients such as fishmeal, soya bean meal etc., which are facing increasing demand and limited availability. To address these challenges, researchers have been actively seeking alternative feed ingredients to reduce the production costs and address sustainability concerns while meeting the nutritional requirements of aquatic organisms (Maulu et al., 2022, Xiong et al., 201). This focus on developing sustainable and cost-effective feed alternatives which are crucial for the continued growth and long-term viability of the aquaculture industry.

For decades, **fishmeal has served as the "gold standard"** in aqua feeds due to its high protein content (60–72%), excellent amino acid balance, superior digestibility and high palatability. Its inclusion has been closely linked to optimal growth rates, improved feed efficiency and enhanced disease resistance. Alongside fishmeal, other animal-derived ingredients such as poultry by-product meal, blood meal and fish offal are also used as protein sources. On the plant side, soybean meal, corn gluten meal and cottonseed meal have become the most common alternatives due to their availability and cost-effectiveness. However, these conventional sources have notable limitations. Fishmeal production depends heavily on wild-caught fisheries, raising concerns over sustainability, climate vulnerability and fluctuating prices. Plant proteins, while more accessible, often contain **anti-nutritional factors** (e.g., trypsin inhibitors, lectins, phytic acid) and may lack essential amino acids such as lysine or methionine, potentially affecting nutrient utilization and fish health.

These challenges have driven research toward **innovative protein alternatives** that are nutritionally viable, environmentally sustainable and economically feasible. Novel ingredients such as insect meals, single-cell proteins (SCPs) and algal biomass have attracted significant attention. Insects like the black soldier fly can efficiently convert organic waste into high-quality proteins, while microbial proteins (from yeast, fungi, or bacteria) and algal non-fertile substrates, reducing competition with human food production. Beyond their nutritional value, several of these alternatives also contribute functional benefits, including enhanced gut health, immunity and stress tolerance.

Recent advances in feed formulation have enabled many of these alternative proteins to move from experimental stages to **commercially viable ingredients**. However, barriers such as production costs, variability in nutrient composition and long-term impacts on fish performance still need to be addressed. Nevertheless, the adoption of alternative proteins represents a critical step toward building a sustainable and resilient aquaculture sector.

Major Protein Sources in Aquafeeds

1. Fish Meal

Fish meal has long been regarded as the benchmark protein source in aquaculture diets. It typically contains 60–72% crude protein, with a highly digestible amino acid profile that closely matches the nutritional requirements of most cultured fish species. Its palatability, high digestibility (often exceeding 90%) and balanced content of essential amino acids (EAAs) make it a superior ingredient for promoting growth, feed efficiency and disease resistance. Additionally, fish meal provides essential fatty acids, vitamins and minerals that support overall fish health.

However, reliance on fish meal is increasingly problematic. Production is dependent on wild-caught fisheries, which are vulnerable to overexploitation, climate variability and ecosystem pressures. Rising demand coupled with limited supply has led to significant price volatility, posing economic challenges for feed manufacturers and farmers. Sustainability concerns—both environmental and socio-economic—have therefore driven the search for alternative protein sources that can partially or fully replace fish meal in aquafeeds.

2. Soybean Meal (Plant-Based Protein)

Soybean meal is the most widely used plant-derived protein in aquaculture feeds. It contains around 44–48% crude protein, with a relatively balanced amino acid profile, although it is often deficient in methionine, an essential amino acid required for optimal fish growth. Soy protein concentrate, a more refined form, offers higher protein levels (65–70%) and reduced levels of anti-nutritional factors, improving digestibility.

Soybean meal is valued for its abundant availability, cost-effectiveness and adaptability in fish diets, making it a practical alternative to fish meal in many formulations. However, its inclusion is limited by the presence of anti-nutritional factors such as trypsin inhibitors, lectins, saponins and phytic acid, which can impair digestion, nutrient absorption and gut health if not properly processed (e.g., heat treatment). Moreover, over-reliance on soy cultivation raises concerns related to land use, deforestation and competition with human food supply.

Limitations of Major Protein Sources

While fish meal remains the gold standard in aquafeeds due to its superior digestibility and balanced amino acid profile, its use is constrained by several limitations, including high cost, price volatility and heavy dependence on wild-caught fisheries, which raises sustainability concerns related to overfishing, climate change and ecological imbalance. In addition, competition with livestock and pet food industries further intensifies pressure on its limited supply. On the other hand, soybean meal, the most common plant-based alternative, though more accessible and cost-effective, is restricted by the presence of anti-nutritional factors such as trypsin inhibitors, lectins, saponins and phytic acid that reduce digestibility and can impair gut health. It also suffers from amino acid imbalances, particularly deficiencies in methionine and lysine, reduced palatability at higher inclusion levels and variable digestibility depending on processing. Moreover, large-scale soybean cultivation carries environmental drawbacks, including deforestation, high land use and competition with human food resources, making its sustainability questionable when used excessively in aquafeeds.

Major Alternative protein sources

- Insect Based Protein,
- Plant based Protein,
- Fish Meal Alternative,
- Single-cell proteins,
- Others (Seaweed & Algae, Algal Oil)

➢ Insect-Based Protein Meals

Black Soldier Fly (BSF, *Hermetia illucens***)**

The black soldier fly (BSF) larval meal has rapidly emerged as one of the most promising and commercially viable alternatives to fish meal in aquaculture feeds. BSF larvae are highly efficient bioconverters, capable of transforming low-value organic by-products, agricultural residues and food waste into high-quality protein, thereby contributing to waste reduction and circular bio economy principles. The crude protein content of BSF meal generally ranges between **40–55%,** depending on processing and fat removal and it contains a favourable essential amino acid (EAA) profile that closely matches the requirements of many fish species. In addition, BSF meal provides bioactive compounds such as antimicrobial peptides, medium-chain fatty acids (notably lauric acid) and minerals like calcium, which may improve fish immunity, gut health and disease resistance.

Several studies have shown that **partial replacement of fish meal with BSF meal (10–50%)** supports comparable growth performance, feed conversion efficiency and survival rates across a variety of cultured species, including tilapia, salmonids and catfish. The optimal inclusion level, however, is species- and life-stage dependent. High dietary inclusion can be limited by the presence of **chitin**, a structural polysaccharide in the insect exoskeleton, which may reduce protein digestibility and nutrient availability. Processing strategies such as defatting, chitinase enzyme supplementation, or microbial fermentation have been explored to improve digestibility and nutrient utilization.

Despite its promise, BSF meal still faces challenges. Nutrient composition can vary considerably depending on the **rearing substrate** used, which affects protein, fat and mineral levels. Large-scale production also requires consistent rearing conditions, processing technologies and regulatory approval to ensure safety and quality standards. Additionally, the current cost of production is higher than conventional plant proteins, though advances in mass rearing, automation and waste valorization are expected to reduce costs in the near future.

Overall, BSF larval meal is not only a sustainable and environmentally friendly protein source but also a functional feed ingredient with potential health-promoting properties. With ongoing technological improvements and supportive regulatory frameworks, insect-based proteins such as BSF meal are likely to play a significant role in reducing reliance on fish meal and enhancing the sustainability of global aquaculture.

- **Plant Proteins**

Plant-based protein sources are widely used in aquaculture feed due to their availability, cost-effectiveness and relatively high protein content. Common plant protein sources include corn gluten meal, cottonseed meal and soy protein concentrate, with protein levels ranging from 15% to 50% depending on the type and processing method.

Corn Gluten Meal

This by-product of corn processing contains 60–70% protein, making it a concentrated source. However, it is low in lysine, an essential amino acid, limiting its use as a sole protein source. Corn gluten meal is highly digestible and can promote growth when properly balanced with other protein sources.

Cottonseed Meal

Containing around 40–45% protein, cottonseed meal is relatively cheap, but its use is limited due to the presence of gossypol, a naturally occurring toxic compound. Proper detoxification or limiting its proportion in feed is essential to prevent negative effects on fish health. Cottonseed meal is generally low in lysine and sometimes methionine, requiring supplementation for optimal growth.

Soy Protein Concentrate

Soy protein concentrate (SPC) is defined as a commercial vegetable protein product derived from soybeans that contains a mixture of soy proteins, including α-, β-, and γ-conglycinins and glycinin, and has applications in food due to its foaming, gelation, and binding properties. However, SPC is not highly water soluble and is limited in use for certain aqueous food systems. This is a more refined form of soybean protein with protein levels of 65–70%, produced by removing most of the soluble carbohydrates. It has higher digestibility and lower levels of anti-nutritional factors compared to soybean meal. While it is rich in most amino acids, supplementation of methionine is often necessary for species with higher methionine requirements.

- **Animal by-products and shellfish wastes**

They are valuable components in aquaculture feed due to their high protein content, excellent digestibility and rich amino acid profiles, often closely approaching that of traditional fish meal. Common sources include poultry by-product meal, fish offal, blood meal and shellfish waste.

Poultry by-product meal (PBM)

It is produced from rendered parts of poultry such as heads, feet, viscera and undeclared meat fractions. It contains 55–65% crude protein and a well-balanced amino acid profile, particularly rich in lysine and methionine, making it a good alternative to fish meal. Digestibility is generally high, but the quality depends heavily on raw material composition and processing conditions—overheating during rendering can reduce protein availability and damage certain amino acids.

Fish offal

Such as heads, viscera and trimmings from fish processing, can be rendered into fish protein meals. These sources have high protein content (60–70%) and retain essential amino acids, including arginine and lysine, which are critical for carnivorous fish. When properly processed through controlled cooking and drying, fish offal-based meals maintain high digestibility and palatability.

Blood meal

Usually obtained from poultry or cattle, is an extremely rich protein source containing 80–90% crude protein. It is particularly high in lysine but deficient in some sulfur-containing amino acids such as methionine and cysteine. Blood meal is highly digestible if processed carefully to avoid excessive heat, which can cause protein denaturation.

Shellfish waste

From the time of processing, including shells, heads and exoskeletons, is rich in protein (45–60%) and minerals such as calcium and chitin, which may improve fish growth and enhance immunity. However, high chitin content may reduce digestibility in some species, so partial de-chitinization or moderate inclusion is recommended.

- **Algae and single-cell proteins**

Emerging as promising alternative protein sources in aquaculture due to their high protein content and presence of bioactive compounds that can enhance fish health. Microalgae, such as Chlorella, Spirulina and Nannochloropsis, typically contain 40–70% protein and are rich in essential amino acids, vitamins, minerals and polyunsaturated fatty acids, particularly omega-3 fatty acids, which are important for growth and immune function in fish. Macroalgae, or seaweeds, contain lower protein levels (10–30%) but provide other bioactive compounds, such as polysaccharides and antioxidants, which may improve gut health and disease resistance.

Single-cell proteins derived from yeast, bacteria, or filamentous fungi are produced through fermentation of various substrates, including agricultural residues or industrial by-products. These microbial proteins can provide 50–80% protein with a well-balanced amino acid profile, making them a good alternative to conventional protein sources. In addition to nutritional benefits, they may contain immune stimulatory components such as β-glucans and nucleotides that support fish immunity and stress resistance.

Conclusion

Due to the high cost and fluctuations in the availability of fish meal, different alternative sources of protein have been constituted as the most viable option for replacement in aquaculture feed. In conclusion, it can be stated that depending on the species, food habits and cultivation conditions, alternative protein possesses adequate nutritional characteristics to be included in fish cultivation.

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