

Novel Feed Ingredients in Aquaculture

Vikash Kushwaha^{1*}, Dinesh Kumar^{1*}, Mitrasen Maurya¹, Suman Dey², Shivm Saroj¹,
Anil Singh¹

¹Department of Aquaculture. ANDUA&T, Kumarganj, Ayodhya, Uttar Pradesh

²Department of Fisheries Extension. ANDUA&T, Kumarganj, Ayodhya, Uttar Pradesh

[DOI:10.5281/ScienceWorld.15523826](https://doi.org/10.5281/ScienceWorld.15523826)

1. Introduction

Aquaculture, which is the fastest growing food production sector globally, is facing increasing pressure to meet the demand for protein of the growing population, as well as solving the challenges of stability. Traditional aquatic agricultural feed depends a lot on fish food and fish oil obtained from wild pelagic fishes, causing excessive fishing, ecosystem effects and resource instability (FAO, 2018). To reduce these issues, the industry is turning to new feed material innovative options that reduce dependence on limited marine resources, increase cyclicity, and maintain nutrition quality for cultivated species. New components include unconventional protein and lipid sources, such as insect food (eg, black military fly larvae), microbial protein for example, single-cell protein from algae or yeast and plant-based concentrations (Henry *et al.*, 2018). These ingredients have been developed through extensive research to ensure that they meet the dietary requirements of aquatic species, support growth performance, and maintain fish health and well-being (Herrero *et al.*, 2021). For example, insect protein provides a permanent solution by converting biological waste into high-quality nutrient, while giving the required omega-3 fatty acids (EPA and DHA) without reducing microalgae marine stocks such as Schizochetrium (EPA and DHA) required.

Adopting new components aligns with circular economy principles' stability and broad goals. Agricultural-food industries (eg, fish clipping, rice husk) or biotechnology using by-products from resources for example fermented algae, can reduce aquatic agricultural waste and reduce their environmental footprints. However, challenges remain, including measuring, cost-effectiveness, regulatory approval, and consumer acceptance (Gosco *et al.*, 2023). Cooperative efforts between researchers, feed manufacturers and policy makers are important to remove these obstacles and ensure the business viability of the next generation aquafeeds (Glencross *et al.*,

2007).

2. Drivers of Innovation in Aquafeeds

The search for novel feed ingredients is driven by several interlinked factors:

1. **Environmental Sustainability:** Overfishing of forage fish for fishmeal production threatens marine biodiversity. Alternatives help reduce pressure on wild fish stocks.
2. **Economic Volatility:** Fishmeal and fish oil are subject to price fluctuations based on supply, leading to unstable production costs.
3. **Food Security:** Novel ingredients can make aquaculture more accessible and affordable, ensuring long-term food security.
4. **Nutritional Advancements:** New ingredients can be tailored to meet species-specific dietary needs more precisely than conventional feeds.

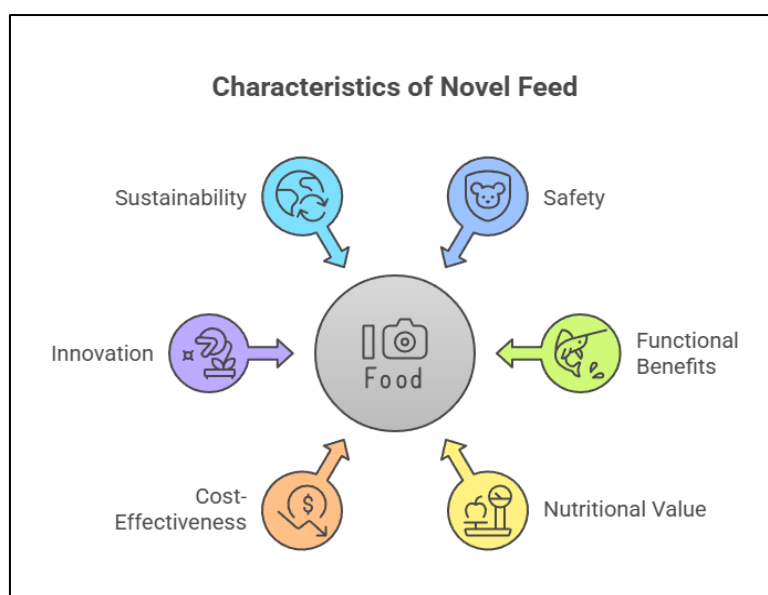
3. Characteristics of Novel Feed

The products may not be dangerous to animals which are feed.

- 1) **Functional benefits:** Some ingredients boost immunity, disease resistance, and growth performance in fish.

- 2) **High nutritional value:** Rich in proteins, lipids, essential amino acids, and omega-3 fatty acids.

- 3) **Cost-effective:** Potential to reduce feed costs compared to fishmeal, depending on availability and production scale.



- 4) **Unconventional and Innovative:** Derived from non-traditional sources like plants, insects, microbes, and agro-industrial by-products.
- 5) **Sustainable and Eco-Friendly:** Reduces reliance on marine resources, lowers environmental impact, and supports circular economy practices.

4. Categories of Novel feed ingredients

4.1 Insect based meals

Insects are gaining popularity due to their high protein content and efficient bioconversion

of organic waste. Common species used include black soldier fly larvae (*H. illucens*), mealworms, and crickets. Insects provide essential amino acids and are naturally part of the diet of many fish species.

- ❖ **Black Soldier Fly Larvae (*H. illucens*)**- Rich in protein (40-65%) and lipids (30%), making it an excellent alternative to fishmeal (Henry *et al.*, 2015).
- ❖ **Mealworms (*Tenebrio molitor*)**- Contain around 50% protein and are highly digestible for fish (Van Huis, 2013).
 1. Lesser mealworm (*Alphitobious diaperinus*)
 2. House cricket (*Acheta domesticus*)
 3. Field cricket (*Gryllus assimilis*)
 4. Banded cricket (*Gryllodes sigillatus*)



Fig.1 BSF Larvae



Fig.2 Mealworms



Fig.3 Field

Cricket

Fig Source: https://www.feedipedia.org/node/16388?utm_source=https://www.shutterstock.com/search/meal-worm-farming

Advantages:

- Sustainable and low environmental footprint
- Can be reared on organic waste streams
- High digestibility and palatability

Challenges:

- Regulatory barriers in some regions
- Limited scalability and high production costs

4.2 Single-Cell Proteins (SCPs)

SCPs include bacteria, yeast, and microalgae cultivated using fermentation. They are rich in protein and can be produced on non-arable land using industrial byproducts.

Examples:Fig.4 *Saccharomyces cerevisiae*Fig.5 *K. marxianus*

Fig source: <https://www.sciencedirect.com/topics/agricultural-and-biological-sciences>

Advantages:

- High protein and lipid content
- Stable production independent of climate
- Can be engineered to enhance specific nutrients (e.g., omega-3 fatty acids)

Challenges:

- High production and purification costs
- Limited availability at commercial scale

4.3 Plant based proteins

While not entirely novel, plant derived proteins such as soybean meal, pea protein, and rapeseed meal are increasingly refined to reduce anti-nutritional factors. Advancements include genetically modified (GM) crops designed for aquafeeds and fermentation-enhanced plant proteins.

**Advantages:**

- Readily available and well-established supply chains
- Cost-effective

Challenges:

- May lack essential amino acids
- Digestibility and anti-nutritional factors need to be addressed
- Competition with human food and livestock sectors

4.4 Macroalgae (Seaweed)

Seaweeds like kelp and red algae can supplement fish diets by providing vitamins, minerals, and bioactive compounds. Brown, red, and green seaweeds like *Ulva lactuca* and *Gracilaria edulis* are rich in bioactive compounds, essential fatty acids, and minerals beneficial for fish growth (Hemaiswarya *et al.*, 2011). **Examples:** *Ulva Lactuca*, *Gracilaria edulis*



Fig. 6 *Ulva Lactuca*



Fig.7 *Gracilaria edulis*

(Fig source: Sudhakar and Narayana, 2025)

4.5 Microalgae

Known for their high protein (50-70%) and omega-3 content, these serve as sustainable lipid and protein sources in aquafeeds (Beal *et al.*, 2018).

- Spirulina (*Arthrospira platensis*)
- Chlorella (*Chlorella vulgaris*)



Fig. 8 *Arthrospira platensis*



Fig 9 *Chlorella vulgaris*

Advantages:

- No need for freshwater or arable land
- Carbon sequestration and ecosystem benefits
- Functional properties (e.g., immune boosting)

Challenges:

- Low protein content compared to other sources
- Variable nutritional composition

4.5 Terrestrial Animal By-products

Rendered products such as poultry meal, feather meal, and blood meal are being re-evaluated as sustainable feed options. These are typically by-products from the meat industry and offer high protein concentrations.

- ❖ **Poultry By-Product Meal-** Derived from rendered poultry waste, it contains 55-65% protein and is a cost-effective alternative to fishmeal (El-Haroun *et al.*, 2009).
- ❖ **Blood Meal-** High in protein but require processing to improve digestibility and reduce anti-nutritional factors.

Advantages:

- Cost-effective
- High nutrient density
- Supports circular economy

Challenges:

- Consumer perception and regulatory limitations
- Potential biosecurity concerns

5. Nutritional considerations and Feed formulation

The shift to novel ingredients requires reformulating feeds to ensure they meet the specific nutritional needs of different aquaculture species. Key considerations in this process include digestibility, palatability, amino acid profile, and the presence of anti-nutritional factors. To address these challenges, modern feed formulation is increasingly relying on precision nutrition techniques. These include enzyme supplementation to enhance nutrient absorption, nutrigenomics to better understand gene diet interactions, and precision fermentation to tailor nutrient profiles according to the specific requirements of target species.

6. Economic and Market Considerations

Although many novel ingredients offer long-term sustainability, their commercial adoption is constrained by several challenges. These include high initial investment and production costs, lack of economies of scale, limited supply chains and market infrastructure, and consumer perception, especially concerning genetically modified or unconventional ingredients. Despite these hurdles, collaborations between startups, feed companies, and academic institutions are accelerating progress in the field. Moreover, both public and private investment play a crucial role in scaling up production and reducing costs, thereby enhancing the feasibility of these sustainable alternatives.

7. Case Studies and Commercial Applications

Many leading commercial undertakings have demonstrated the practical viability of new feed components in aquatic agriculture, which outlines their ability to increase stability and reduce dependence on traditional resources. Protics, headquartered in the Netherlands, specializes in the production of Black Soldier Fly larvae (*H. Illusance*), which offers a high protein for traditional fish food, and environmentally durable options. In the United States, Calista has developed a microbial protein feedcind® derived from methane fermentation, providing land-independence and resource-skilled protein sources suitable for various aquatic agricultural species. Corbion, which is also located in the US, produces algae-based omega-3 oils that serve as a direct replacement for fish oil in salmon feeds, helping to preserve the marine ecosystem by maintaining the required fatty acid profile. Meanwhile, Unibio, a Danish biotechnology firm, employs methane using bacteria to produce a single-cell protein (SCP), providing a scalable and ecological alternative protein input for aquatic feed. Collectively, these case study examples of successful integration of new biotechnology in professional aquatic agriculture, and highlights the transformative ability of new diet components in increasing the stability and flexibility of global aquatic dietary systems.

8. Future outlook

The future of aquaculture feed lies in diversification, innovation, and sustainability. Novel ingredients are no longer fringe concepts but are entering the mainstream through technological advances and policy support. Key trends expected to shape the future include:

- ❖ Integration of circular economy principles
- ❖ Use of AI and big data in feed optimization
- ❖ Consumer-driven demand for sustainable seafood
- ❖ Advances in synthetic biology and fermentation technologies

9. Conclusion

Novel feed materials are very promising to convert aquatic agriculture into a more durable, flexible and efficient industry. While challenges remain in terms of cost, regulation and consumer acceptance, both environmental and economic benefits make them an important component of future feed strategies. Through continuous research, innovation and investment, these options can reduce industry dependence on limited marine resources and support the global demand for responsible seafood production.

References

Beal, C.M., Gerber, L.N., Thongrod, S., Phromkunthong, W., Kiron, V., Granados, J., Archibald, I., Greene, C.H. and Huntley, M.E., 2018. Marine microalgae commercial production improves sustainability of global fisheries and aquaculture. *Scientific Reports*, 8(1),

p.15064.

- El-Haroun, E.R., Azevedo, P.A. and Bureau, D.P., 2009. High dietary incorporation levels of rendered animal protein ingredients on performance of rainbow trout *Oncorhynchus mykiss* (Walbaum, 1972). *Aquaculture*, 290(3-4), pp.269-274.
- FAO, 2018. The State of World Fisheries and Aquaculture 2018. Meeting the Sustainable Development Goals.
- Gasco, L., Renna, M., Bellezza Oddo, S., Rezaei Far, A., Naser El Deen, S., & Veldkamp, T. (2023). Insect meals in a circular economy and applications in monogastric diets. *Animal Frontiers*, 13(4), 81-90.
- Glencross, B. D., Booth, M., & Allan, G. L. (2007). A feed is only as good as its ingredients—a review of ingredient evaluation strategies for aquaculture feeds. *Aquaculture nutrition*, 13(1), 17-34.
- Hemaiswarya, S., Raja, R., Ravi Kumar, R., Ganesan, V. and Anbazhagan, C., 2011. Microalgae: a sustainable feed source for aquaculture. *World Journal of Microbiology and Biotechnology*, 27, pp.1737-1746.
- Henry, M. A., Gai, F., Enes, P., Pérez-Jiménez, A., & Gasco, L. (2018). Effect of partial dietary replacement of fishmeal by yellow mealworm (*Tenebrio molitor*) larvae meal on the innate immune response and intestinal antioxidant enzymes of rainbow trout (*Oncorhynchus mykiss*). *Fish & shellfish immunology*, 83, 308-313.
- Henry, M., Gasco, L., Piccolo, G. and Fountoulaki, E., 2015. Review on the use of insects in the diet of farmed fish: past and future. *Animal Feed Science and Technology*, 203, pp.1-22.
- Herrero, M., Thornton, P. K., Mason-D'Croz, D., Palmer, J., Bodirsky, B. L., Pradhan, P., ... & Rockström, J. (2021). Articulating the effect of food systems innovation on the Sustainable Development Goals. *The Lancet Planetary Health*, 5(1), e50-e62.
- Sudhakar, D. R. (2025). Sustainable cultivation of *Gracilaria edulis* in poultry manure-derived media: Evaluating growth, biochemical properties, and agar quality. *Food and Bioproducts Processing*, 150, 78-88.
- Turchini, G. M., Trushenski, J. T. & Glencross, B. D. Thoughts for the future of aquaculture nutrition: realigning perspectives to reflect contemporary issues related to judicious use of marine resources in aquafeeds. *N. Am. J. Aquac.* 81, 13-39 (2019).
- Van Huis, A., 2013. Potential of insects as food and feed in assuring food security. *Annual review of entomology*, 58(1), pp.563-583.