Vidyabharati International Interdisciplinary Research Journal
ISSN 2319-4979

Animal-Derived Protein Ingredients in Aquaculture Feeds: A Review of Their Potential to Reduce Fish-Meal Dependence

Bhagyashri K. Lohakar
PhD Research Scholar,Department of Zoology,Indira Mahavidyalaya, Kalamb, Maharashtra, India

Ved Patki
Assistant Professor,Department of Zoology,Indira Mahavidyalaya,Kalamb,Maharashtra,India
vedpatki@gmail.com

Abstract
Fish meal remains a valued aquafeed ingredient, but its cost and supply challenges have motivated research into alternative protein inputs. This review considers terrestrial rendered materials, insect meals, and residues from seafood processing as ways to replace some fish meal in formulated diets. Reviews and meta-analyses report that these ingredients can support production in some settings, but outcomes are not uniform: ingredient type, processing, inclusion rate, fish species, and life stage shape nutritional performance. Pooled evidence for poultry by-product meal, for example, found no significant overall difference in final weight but a higher feed conversion ratio, while subgroup results varied. Insect-meal evidence is also heterogeneous, with study outcomes depending in part on species and replacement level. Processing residues can be recovered as meals, silages, or hydrolysates, but their composition and quality depend on the source and processing pathway. The evidence therefore supports cautious, partial substitution and complementary formulations rather than a single replacement rate applicable across aquaculture. Feed trials should assess growth, feed utilization, health, ingredient safety, economic feasibility, and environmental impacts together. (Luthada-Raswiswi et al., 2021; Galkanda-Arachchige et al., 2019; Gougbedji et al., 2022; Serra et al., 2024).[1–4]

Keywords: *aquaculture nutrition; fish-meal replacement; animal by-products; poultry by-product meal; insect meal; fisheries by-products; feed formulation*

Introduction

Fish meal is used in many aquafeeds because it provides concentrated protein and a useful nutrient profile. Its price and supply have nevertheless encouraged investigation of alternative feed ingredients (Luthada-Raswiswi et al., 2021; Serra et al., 2024).[1, 4] Potential animal-derived alternatives include rendered terrestrial by-products, insect biomass, and ingredients recovered from seafood processing. Their suitability depends on more than crude protein:

production outcomes can vary with the ingredient, its processing, the cultured species, and the amount included in the diet (Luthada-Raswiswi et al., 2021; Serra et al., 2024).[1, 4]

This review summarizes the strengths and constraints of these ingredient groups, considers how feeding studies evaluate replacement, and identifies practical questions for formulation and future research. It treats environmental and economic benefits as questions to assess—not guaranteed consequences of replacing fish meal.

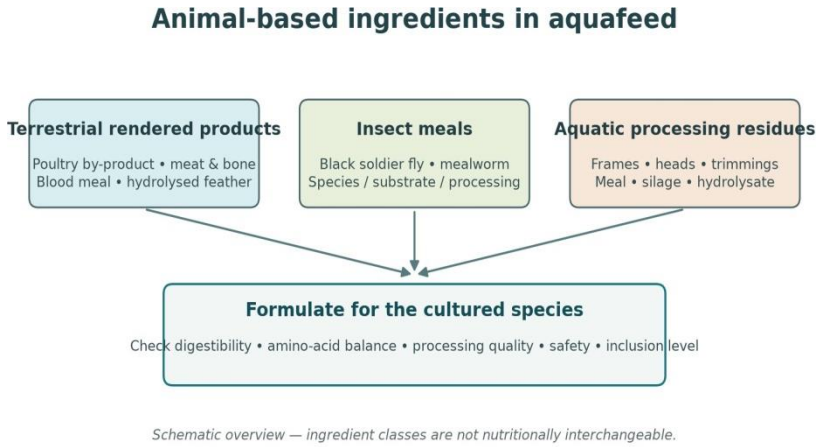


Figure 1. Conceptual schematic prepared for this review. It groups candidate ingredients and highlights formulation checks; it is not a quantitative ranking. (Luthada-Raswiswi et al., 2021; Serra et al., 2024).[1, 4]

Why fish-meal replacement requires formulation, not simple substitution

An alternative ingredient may contribute protein yet differ from fish meal in digestibility, amino-acid balance, minerals, palatability, or processing history. Accordingly, a replacement percentage alone does not fully describe the nutritional equivalence of two diets. Broad reviews report a wide range of inclusion levels across ingredient groups and species, and note that higher inclusion can negatively affect growth or other biological outcomes (Serra et al., 2024).[4]

Ingredient blends may help combine complementary nutritional characteristics, but any proposed blend still needs experimental validation in the intended species and production context. The available review evidence supports considering combined protein sources; it does not establish one optimal recipe for all aquaculture diets (Serra et al., 2024).[4]

Candidate animal-derived protein sources

Poultry by-product meal

Poultry by-product meal is studied as a fish-meal substitute because it is a protein ingredient that may be broadly available and comparatively inexpensive. Its performance is variable, so a general claim of equivalence would overstate the evidence (Galkanda-Arachchige et al., 2019).[2]

A meta-analysis drawing on 47 articles and 33 species found no significant overall difference in final weight, while pooled feed conversion ratio was significantly higher in groups fed poultry by-product meal. Results for feed conversion differed by organism group, and species and replacement level helped explain variation in responses (Galkanda-Arachchige et al., 2019).[2] These results illustrate why growth and feed efficiency should be examined separately and why performance in one species should not automatically be transferred to another.

Meat and bone meal

Meat and bone meal represents a route for recovering protein and minerals from animal-processing streams. Its nutritional contribution will depend on the material and manufacturing process, so the ingredient should be characterized before a diet is formulated. More broadly, syntheses of animal-derived feed ingredients report variation in their limitations and outcomes across species, sizes, and inclusion rates (Luthada-Raswiswi et al., 2021).[1]

Blood meal

Blood meal can be considered as one component in a mixed protein formulation, but it should not be assumed to provide a complete nutritional replacement on its own. Diet designers need to account for the amino-acid requirements of the cultured species and assess the whole formulation. Meta-analytic and review evidence indicates that animal-protein alternatives have ingredient-specific limitations and that inclusion levels influence outcomes (Luthada-Raswiswi et al., 2021; Serra et al., 2024).[1, 4]

Feather meal

Feather-derived protein requires processing to make it useful as a feed ingredient; therefore, the processing method and resulting digestibility matter. A formulation based only on crude protein may not represent how much of that protein is available to the fish. The broader evidence base similarly emphasizes variation among animal by-products and the need to evaluate nutritional performance in the target species (Luthada-Raswiswi et al., 2021).[1]

Insect meal

Black soldier fly and mealworm are among the insect groups most frequently investigated for aquafeeds. Their nutrient composition and digestibility can change with rearing conditions and processing, and recommended inclusion levels vary according to insect product and aquatic species (Maulu et al., 2022).[5]

A meta-analysis of black soldier fly meal reported substantial heterogeneity across studies;

fish species and the proportion of fish-meal protein replaced were important contributors to that variation. The authors also noted that further economic analysis is needed to judge commercial viability (Gougbedji et al., 2022).[3] Thus, a result obtained with one insect product or fish species cannot by itself define an inclusion target for another.

Fish-processing by-products

Seafood-processing residues can be converted into feed ingredients, including meals, silages, and hydrolysates. Reviews describe processing approaches such as enzymatic hydrolysis and silage as ways to improve properties such as nutritional value, digestibility, or shelf life; they also emphasize tailoring methods to the source material and intended use (Torsabo et al., 2025).[6]

These ingredients can recover nutrients that might otherwise be underused, but their source remains aquatic. Their use can therefore support by-product valorization without necessarily removing dependence on fisheries-derived raw materials. Source quality, processing, storage, and transport are relevant to whether recovery is practical at a particular site (Torsabo et al., 2025).[6]

Comparative formulation overview

Ingredient group	Potential role in a diet	Questions to resolve before use
Poultry by-product meal	Terrestrial rendered protein source	Batch composition, palatability, species response, and effects on feed conversion (Galkanda-Arachchige et al., 2019).[2]
Meat and bone meal	Protein and mineral contribution	Composition, processing consistency, and digestibility for the target species (Luthada-Raswiswi et al., 2021).[1]
Blood meal	Possible complementary protein input	Whole-diet amino-acid balance and inclusion level (Luthada-Raswiswi et al., 2021; Serra et al., 2024).[1, 4]
Feather meal	Recovery of poultry-derived protein	Processing effectiveness and available nutrient value (Luthada-Raswiswi et al., 2021).[1]
Insect meal	Alternative protein biomass	Species, rearing substrate, processing, digestibility, inclusion level, and economic scale-up (Maulu et al., 2022; Gougbedji et al., 2022).[3, 5]
Seafood-processing residues	Recovered aquatic nutrients	Source freshness, processing route, storage, and continued dependence on aquatic raw materials (Torsabo et al., 2025).[6]

The table is a qualitative planning aid, not a ranking of ingredients or a claim that any one source is suitable at a specific inclusion rate. Across alternatives, the published synthesis points to both potential benefits and inclusion-related risks, and suggests that blends may offer nutritional complementarity (Serra et al., 2024).[4]

How to evaluate replacement diets

A feeding trial should evaluate more than body weight. Commonly reported outcomes include weight gain, specific growth rate, feed conversion ratio, survival, body composition, and selected health measures. Feed conversion ratio (FCR) expresses feed input relative to weight gain; a lower FCR generally reflects more efficient feed use. Meta-analysis indicates that different outcomes need not move in the same direction: the poultry by-product synthesis, for example, reported a non-significant pooled difference in final weight but a significantly higher pooled FCR (Galkanda-Arachchige et al., 2019).[2]

A useful comparison should also document the ingredient's composition and processing, the

fish species and life stage, diet inclusion and replacement basis, trial duration, and the control diet. These details help readers judge whether results can be applied to a different feed or farming system. The evidence base is heterogeneous across species and inclusion levels, which limits the value of a single average as a universal formulation rule (Luthada-Raswiswi et al., 2021; Gougbedji et al., 2022).[1, 3]

Environmental and economic considerations

By-product recovery and insect production may contribute to circular use of resources, but nutritional performance alone does not establish environmental or commercial superiority. Insect-meal economic feasibility remains an area for evaluation, while seafood by-product processing depends on the source, processing method, preservation, and supply chain (Gougbedji et al., 2022; Torsabo et al., 2025).[3, 6]

Comparative assessments should consider the origin of the feedstock, energy and water used in processing, transport, scale, food-safety requirements, and the fate of residual material. These are assessment criteria for future comparisons; the sources summarized here do not establish that every alternative has a lower environmental footprint or lower delivered cost than fish meal.

Research priorities

Further research should improve ingredient characterization and connect composition to digestibility and feeding outcomes. Trials should be designed around defined fish species and life stages, with sufficiently detailed reporting of ingredient processing and inclusion level. Reviews identify variation among species and products and continuing gaps in determining suitable inclusion levels under different production conditions (Luthada-Raswiswi et al., 2021; Maulu et al., 2022; Serra et al., 2024).[1, 4, 5]

Longer-term studies should consider health, flesh quality, and reproductive outcomes alongside growth and feed utilization. Commercial assessments should evaluate consistent supply, processing costs, safety, and environmental burdens rather than treating ingredient price alone as a measure of economic advantage. The available syntheses support further testing, but do not provide a single cross-species formula or universal optimum replacement rate (Gougbedji et al., 2022; Serra et al., 2024).[3, 4]

Conclusion

Animal-derived ingredients can contribute to reducing the amount of fish meal in aquafeeds, but their performance depends on product characteristics, diet formulation, species, and inclusion level. Pooled findings for poultry by-product meal and insect meal show meaningful between-study variation, so results should be interpreted in the context of the trial population and the outcome measured (Galkanda-Arachchige et al., 2019; Gougbedji et al., 2022).[2, 3]

The evidence best supports carefully formulated, validated partial substitution—not a blanket claim that one animal-derived ingredient can replace fish meal completely in every aquaculture diet. Candidate diets should be evaluated for growth, feed efficiency, health, safety, cost, and environmental performance in the species and production system where they will be used (Luthada-Raswiswi et al., 2021; Serra et al., 2024).[1, 4]

References

1. Luthada-Raswiswi R, Mukaratirwa S, O'Brien G (2021) Animal Protein Sources as a Substitute for Fishmeal in Aquaculture Diets: A Systematic Review and Meta-Analysis. Applied Sciences. https://doi.org/10.3390/app11093854
2. Galkanda-Arachchige HSC, Wilson AE, Davis D (2019) Success of fishmeal replacement through poultry by-product meal in aquaculture feed formulations: a meta-analysis. Reviews in Aquaculture. https://doi.org/10.1111/raq.12401
3. Gougbedji A, Detilleux J, Lalèyè P, et al (2022) Can Insect Meal Replace Fishmeal? A Meta-Analysis of the Effects of Black Soldier Fly on Fish Growth Performances and Nutritional Values. Animals. https://doi.org/10.3390/ani12131700

4. Serra V, Pastorelli G, Tedesco D, et al (2024) Alternative protein sources in aquafeed: Current scenario and future perspectives. Veterinary and Animal Science. https://doi.org/10.1016/j.vas.2024.100381
5. Maulu S, Langi S, Hasimuna OJ, et al (2022) Recent advances in the utilization of insects as an ingredient in aquafeeds: A review. Animal Nutrition. https://doi.org/10.1016/j.aninu.2022.07.013
6. Torsabo D, Danba EP, Akange ET, et al (2025) Recent Advancements in the Fisheries By-Products Processing Technologies as Sustainable Feedstuff for Aquaculture: Current Knowledge and Future Perspectives. Journal of Aquatic Food Product Technology. https://doi.org/10.1080/10498850.2025.2592663