Smart Feed Formulation: Reducing Costs and Increasing Production

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Abstract

Aquaculture is a rapidly growing sector that plays a crucial role in global food security and animal protein production. However, feed accounts for the largest proportion of production costs, making efficient feed management essential for profitability and sustainability. Smart feed formulation involves developing nutritionally balanced and cost-effective diets that meet the specific requirements of cultured species while minimizing waste and environmental impacts. This article highlights the importance of understanding nutrient requirements, selecting appropriate feed ingredients, adopting least-cost formulation techniques, and improving feed conversion efficiency. It also discusses the use of alternative protein sources, feed additives, precision feeding technologies, and on-farm feed production as strategies to reduce feed costs and enhance productivity. Furthermore, emerging innovations such as insect-based proteins, single-cell proteins, and AI-driven feeding systems are explored. Smart feed formulation is fundamental to achieving profitable, sustainable, and environmentally responsible aquaculture production.

Keywords: Aquaculture, Feed Formulation, Feed Conversion Ratio, Precision Feeding, Alternative Feed Ingredients, Sustainability, Fish Nutrition

Introduction

Aquaculture is one of the fastest-growing food production sectors and plays a vital role in global food security by supplying high-quality animal protein. As wild fish catches have stagnated, aquaculture now provides more than half of the aquatic animals consumed worldwide (FAO, 2024). However, feed remains the largest operational expense, accounting for 50–70% of production costs in intensive farming systems. Therefore, efficient nutrition and feed management are essential for improving profitability and fish performance. Fish require balanced diets containing proteins, lipids, carbohydrates, vitamins, and minerals for optimal growth, health, and disease resistance. Traditionally, fish meal and

fish oil have been key feed ingredients, but their rising cost and limited availability have increased the need for alternative feed resources. In response, smart feed formulation has emerged as an important strategy for sustainable aquaculture. It involves designing nutritionally balanced and cost-effective diets using nutrient databases, digestibility information, and least-cost formulation techniques. Smart feed formulation improves feed efficiency, reduces production costs, minimizes nutrient waste, and lowers environmental impacts, thereby supporting profitable and sustainable aquaculture development. Feed Strategies focus on balancing nutritional adequacy, ingredient availability, economic efficiency, and environmental sustainability. By accurately matching dietary nutrient levels to the requirements of cultured species, farmers can improve production performance while reducing feed expenses and nutrient waste (Hasan & New, 2009).

Why Feed Formulation Matters

Feed formulation is a key factor in successful aquaculture because nutrition directly affects fish growth, health, survival, reproduction, and farm profitability. Fish require balanced nutrients to support growth, metabolism, immunity, and normal physiological functions. A well-formulated diet improves feed utilization and production efficiency, while poor nutrition can lead to slow growth, disease susceptibility, and economic losses (NRC, 2011).

A balanced fish feed should provide:

Protein: Essential for growth, tissue repair, and enzyme production; it is usually the most expensive feed component (Hardy & Kaushik, 2022).

Lipids (Fats): Provide energy and essential fatty acids needed for growth and reproduction (NRC, 2011).

Carbohydrates: Serve as an economical energy source and help spare protein for growth (Wilson, 1994).

Vitamins and Minerals: Support metabolism, immunity, skeletal development, and physiological functions (NRC, 2011).

Essential Amino Acids and Fatty Acids: Must be supplied through the diet because fish cannot produce them in sufficient quantities (Hardy & Kaushik, 2022).

Feeds that do not meet nutrient requirements can reduce growth, feed efficiency, health, and survival. Conversely, excessive nutrient inclusion increases feed costs and may contribute to environmental pollution through nutrient waste. Therefore, the main objective of feed formulation is to provide the right nutrients in the correct proportions at the lowest possible cost while maximizing fish performance and sustainability (Cho & Bureau, 2001).

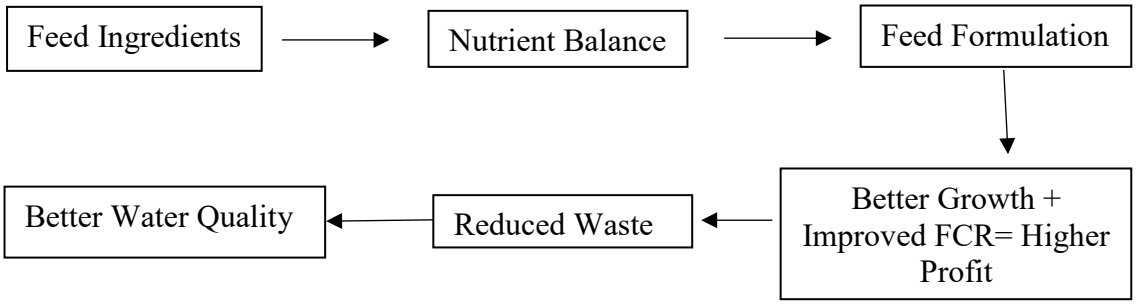

Fig. 1 Importance of feed formulation in aquaculture

Principles of Smart Feed Formulation

Understanding Nutritional Requirements

Different fish species have different nutrient requirements depending on their feeding habits and life stages.

Table 1 Requirement (%) of Nutrients for better growth (NRC, 2011; Hardy & Kaushik, 2022)

Species	Carp	Tilapia	Catfish	Trout	Shrimp
% of Protein Required	25–35	28–35	28-32	35-50	30-45
% of Lipid Required	5-10	5-10	4-8	15-25	6-10
% of Carbohydrate Required	25-40	25-45	25-40	Less than 20	20-30
% of Vitamin Premix Required	1-2	1-2	1-2	1-2	1-2
% of Mineral Premix Required	1-2	1-2	1-2	1-2	1-2

Juvenile fish generally require higher protein levels than adults because of their rapid growth rates.

Least-Cost Formulation

The objective of modern feed formulation is not to create the cheapest feed but to formulate the least-cost diet that satisfies all nutritional requirements.

This approach uses:

- Nutrient requirement data
- Ingredient composition tables
- Market prices of ingredients

- Linear programming software

The least-cost formulation concept has become a standard tool in commercial feed manufacturing because it minimizes feed costs while maintaining nutritional adequacy.

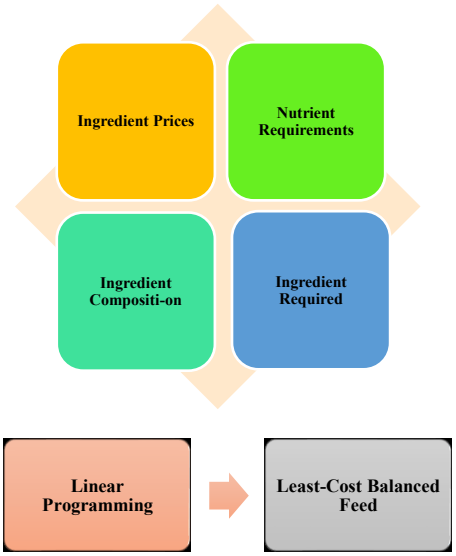

Fig. 2 Least-cost feed formulation approach

Selection of Feed Ingredients

Feed ingredient selection is a critical step in aquaculture feed formulation because it directly influences feed cost, nutrient availability, fish growth, and farm profitability. An ideal ingredient should be nutritious, highly digestible, readily available, cost-effective, and free from contaminants. Since feed represents the largest production expense, careful ingredient selection is essential for developing efficient and economical diets (Hardy & Kaushik, 2022).

Protein Sources

Protein is the most expensive component of aquaculture feeds and is essential for growth, tissue repair, and metabolism. Fish meal has traditionally been the preferred protein source due to its high digestibility and balanced amino acid profile. However, rising costs have increased the use of alternatives such as soybean meal, groundnut cake, mustard oil cake, cottonseed meal, sunflower meal, and insect meal. Soybean meal is widely used because of its high protein content, while black soldier fly larvae meal has emerged as a promising sustainable alternative (Tacon & Metian, 2015; Henry et al., 2015).

Energy Sources

Energy ingredients such as rice bran, wheat bran, maize, broken rice, and cassava meal provide energy for metabolic activities and help spare dietary protein for growth. Maintaining an appropriate energy-to-protein ratio is important for efficient feed utilization and fish performance (NRC, 2011).

Alternative Ingredients for Cost Reduction

To reduce feed costs, aquaculture increasingly utilizes alternative ingredients such as Azolla, duckweed, black soldier fly larvae meal, brewery waste, distillery by-products, and agricultural residues. These materials are often inexpensive, locally available, and can partially replace conventional feed ingredients without compromising fish growth. Their use promotes sustainability, reduces dependence on fish meal, and supports circular economy practices by converting waste products into valuable feed resources (Hasan & New, 2009; Hua, 2021).

Feed Conversion Ratio: The Key to Profitability

Feed Conversion Ratio (FCR) is one of the most important indicators of feed efficiency and farm profitability. It represents the quantity of feed required to produce a unit of fish biomass and is calculated using the following formula:

FCR = Feed Consumed (kg) ÷ Weight Gain (kg)

❖ Relationship Between FCR and Profitability

Lower FCR

↓

Less Feed Required

↓

Reduced Production Cost

↓

Higher Profit Margin

Precision Feeding: Feeding the Right Amount

Effective feeding management is essential for maximizing the benefits of a well-formulated feed. Overfeeding causes feed wastage, poor water quality, and increased disease risks, while underfeeding reduces growth and feed efficiency. Modern aquaculture increasingly uses automatic feeders, sensor-based systems, and AI-assisted technologies to determine optimal feeding rates, reduce waste, and improve feed conversion efficiency, thereby enhancing both profitability and sustainability (Føre et al., 2018).

Role of Feed Additives

Feed additives are widely used to improve growth, feed utilization, and fish health. Probiotics and prebiotics support gut health, enzymes enhance nutrient digestibility, immunostimulants strengthen disease resistance, and organic acids improve nutrient absorption. Although additives may slightly increase feed costs, they often provide greater economic returns through improved growth, survival, and feed efficiency (Dawood et al., 2018).

On-Farm Feed Production

On-farm feed production offers a cost-effective option for small-scale farmers by utilizing locally available ingredients and agricultural by-products. It can reduce feed and transportation costs while increasing resource utilization. However, proper formulation, ingredient quality, mixing, and storage are essential to ensure nutritional adequacy and maintain fish performance (Hasan & New, 2009).

Environmental Benefits of Smart Feed Formulation

Smart feed formulation promotes environmental sustainability by improving nutrient utilization and reducing nitrogen and phosphorus waste released into aquatic ecosystems. The use of alternative protein sources such as plant, microbial, and insect proteins also reduces dependence on fish meal from wild fisheries, supporting sustainable aquaculture development (Cho & Bureau, 2001; Tacon & Metian, 2015).

Future Trends in Feed Formulation

Future advances in aquaculture nutrition focus on improving efficiency, reducing costs, and enhancing sustainability. Promising innovations include insect-based proteins, single-cell proteins from microorganisms, precision nutrition, AI-driven feeding systems, and functional feeds containing probiotics, prebiotics, and other bioactive compounds. These technologies are expected to improve feed efficiency, fish health, and environmental performance while supporting the growing demand for aquatic foods (Henry et al., 2015; Nasseri et al., 2011; Dawood et al., 2018).

Conclusion

Smart feed formulation represents one of the most effective strategies for increasing profitability in aquaculture. By understanding nutritional requirements, selecting cost-effective ingredients, adopting least-cost formulation techniques, improving feed conversion efficiency, and implementing precision feeding practices, fish farmers can significantly reduce production costs and enhance output. As feed continues to account for the largest share of production expenses, the future success of aquaculture will depend on innovative and sustainable feeding strategies. Smart feed formulation not only supports higher production and profitability but also contributes to environmental sustainability and long-term food security.

References

Agbayani, R.F. (2002). Economics of Feeding. In *Nutrition in Tropical Aquaculture: Essentials of Fish Nutrition, Feeds and Feeding of Tropical Aquatic Species*. SEAFDEC Aquaculture Department.

Aquaculture Feeds. *ScienceDirect Topics*. Elsevier.

Bureau, D.P., & Hua, K. (2010). Towards effective nutritional management of waste outputs in aquaculture. Aquaculture Research, 41(5), 777–792.

Cho, C.Y., & Bureau, D.P. (2001). A review of diet formulation strategies and feeding systems to reduce excretory and feed wastes in aquaculture. Aquaculture Research, 32(S1), 349–360.

Dawood, M.A.O., Koshio, S., & Esteban, M.Á. (2018). Beneficial roles of feed additives as immunostimulants in aquaculture. Reviews in Aquaculture, 10(4), 950–974.

FAO. (2024). *The State of World Fisheries and Aquaculture 2024 (SOFIA)*. Food and Agriculture Organization of the United Nations, Rome.

Føre, M., Frank, K., Norton, T., et al. (2018). Precision fish farming: A new framework to improve production in aquaculture. Biosystems Engineering, 173, 176–193.

Hardy, R.W., & Kaushik, S.J. (2022). Diet Formulation and Manufacture. In *Fish Nutrition* (4th Edition). Academic Press.

Hasan, M.R., & New, M.B. (2009). *On-Farm Feeding and Feed Management in Aquaculture*. FAO Fisheries and Aquaculture Technical Paper No. 583.

Henry, M., Gasco, L., Piccolo, G., & Fountoulaki, E. (2015). Review on the use of insects in the diet of farmed fish. Animal Feed Science and Technology, 203, 1–22.

Hua, K. (2021). A meta-analysis of the effects of replacing fish meals with insect meals on growth performance of fish. Aquaculture, 530, 735732.

Nasseri, A.T., Rasoul-Amini, S., Morowvat, M.H., & Ghasemi, Y. (2011). Single cell protein: Production and process. American Journal of Food Technology, 6(2), 103–116.

NRC (National Research Council). (2011). Nutrient Requirements of Fish and Shrimp. National Academies Press.

Rana, K.J., Siriwardena, S., & Hasan, M.R. (2009). *Impact of Rising Feed Ingredient Prices on Aquafeeds and Aquaculture Production*. FAO Fisheries and Aquaculture Technical Paper No. 541.

SEAFDEC/AQD. (2026). Development of Cost-Efficient Feeds. Southeast Asian Fisheries Development Center.

Tacon, A.G.J. (1993). Feed Formulation and On-Farm Feed Management. In *Farm-Made Aquafeeds*. FAO Regional Expert Consultation Proceedings.

Wilson, R.P. (1994). Utilization of dietary carbohydrate by fish. Aquaculture, 124(1–4), 67–80.