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Theoretical Evaluation of Fish Feed Pellet Formulations Based on Estimated Nutritional Composition and Raw Material Cost Efficiency: A Case Study of the MAPAN Innovation in Kalanganyar Village

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ABSTRACT

Aquaculture communities face challenges associated with high fish feed costs and the underutilization of fishery by-products, particularly shrimp heads. This study aimed to identify the optimal fish feed pellet formulation based on nutritional composition and production cost efficiency using the MAPAN (Fish Feed Machine) innovation developed by the Undergraduate Geophysics Team of Universitas Negeri Surabaya in Kalanganyar Village, Sidoarjo. A quantitative descriptive approach was employed to evaluate four pellet formulations containing different proportions of fish meal and dried shrimp heads, while other ingredients were maintained at constant levels. Nutritional composition was estimated using literature-based nutrient data and weighted-average calculations, while production costs were determined from local market prices of raw materials and compared with commercial fish feed prices. The results showed that increasing fish meal inclusion from 25% to 40% increased protein content from 30.92% to 34.90%, while lipid content remained relatively stable and carbohydrate content decreased. Sample 3 exhibited a theoretically estimated nutritional composition of 33.57% protein, 10.51% lipid, and 33.99% carbohydrate, with an estimated raw-material cost of IDR 8,961.92/kg, approximately 10.4% below the retail price of commercial fish feed. However, this comparison reflects only ingredient costs and excludes processing expenses, including electricity, labor, fermentation, drying, equipment depreciation, and packaging. Therefore, the calculated difference should not be interpreted as an actual reduction in total production costs.

INTRODUCTION

Aquaculture has become one of the fastest-growing food production sectors, playing a vital role in meeting the increasing global demand for animal protein. The Food and Agriculture Organization reported that aquaculture continues to expand as an important contributor to global food security and sustainable aquatic food production (FAO, 2024). However, the sustainability of aquaculture remains constrained by high feed costs, which can account for a substantial proportion of total production expenses, making feed formulation efficiency critical to farmers' profitability. Fish meal remains an important protein source in aquafeed because of its high protein quality, balanced essential amino acid profile, and digestibility, but its limited supply and fluctuating price encourage the development of alternative ingredients (Gao et al., 2024). Recent research has demonstrated that replacing part of the fish meal with alternative protein sources can reduce feed costs, although the nutritional effectiveness and economic benefits depend on the ingredient type and inclusion level (Mugwanya et al., 2023; Akter et al., 2024). Consequently, developing feed formulations based on locally available resources is a promising strategy for balancing nutritional adequacy, production costs, and the sustainability of community-based aquaculture.

One promising resource is shrimp-processing waste, particularly shrimp heads, which may provide protein and valuable minerals for aquafeed formulations. Research

on alternative aquafeed ingredients has highlighted the potential of processing by-products to support resource recovery and reduce dependence on conventional feed ingredients, although their nutritional quality and suitability must be assessed before practical application (Naylor et al., 2021; Animal Production Science, 2023). In addition, fermentation has been investigated as a processing strategy for improving the utilization of alternative feed ingredients. For example, Geonges et al. (2024) examined the use of Lactobacillus sp.-fermented feed in whiteleg shrimp (Penaeus vannamei) culture, demonstrating the relevance of fermented-feed approaches to aquaculture research. Nevertheless, the performance of an ingredient or processing technique cannot be assumed to be identical across aquatic species or formulations. Previous research has examined alternative protein sources in relation to growth, feed utilization, and other biological outcomes (Mugwanya et al., 2023; Akter et al., 2024), while market-oriented assessments have also emphasized the importance of ingredient processing, product characteristics, and economic considerations in evaluating seafood by-products for aquafeed (Animal Production Science, 2023). These findings indicate the need to evaluate nutritional composition and ingredient costs together when selecting a formulation for practical, community-scale production.

To address this need, an appropriate-technology initiative known as MAPAN (Fish Feed Machine) was implemented in Kalanganyar Village, Sedati District, Sidoarjo Regency, by an interdisciplinary team working with collaborators involved in feed preparation and community-based aquaculture. MAPAN is designed to process locally available ingredients, including fish meal, dried shrimp heads, rice bran, corn, and other formulation components, into fish feed pellets through mixing and pelletizing. By converting locally available materials into feed products, this initiative also seeks to increase the value of fishery by-products and support more resource-efficient production. However, the nutritional and economic performance of the formulations produced using MAPAN has not yet been systematically evaluated within a single assessment framework. In particular, the relative contribution of different ingredient proportions to estimated nutrient composition and raw-material costs requires quantitative comparison before a formulation can be recommended for practical use. This study therefore aims to identify the most suitable fish feed pellet formulation based on literature-derived nutritional composition and market-based raw-material cost calculations. The contribution of this study lies in integrating these two assessment dimensions to identify a nutritionally appropriate and economically feasible formulation for community-scale feed production using MAPAN. The findings are intended to provide an initial evidence base for formulation selection, rather than to claim verified biological performance, because feeding trials and laboratory-based proximate analyses are outside the scope of the present evaluation.

CASE STUDY

Kalanganyar Village, Sedati District, Sidoarjo Regency, East Java, Indonesia, was selected as the study area because of its coastal aquaculture activities, particularly milkfish (*Chanos chanos*) farming. The study focused on the application of MAPAN, a fish feed pellet production technology designed to utilize locally available raw materials, including fish meal, dried shrimp heads, rice bran, and corn. The use of dried shrimp

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heads represents an effort to valorize fishery by-products that may otherwise remain underutilized.

Within this community-based context, the study evaluated several feed pellet formulations prepared using the MAPAN technology. The formulations were compared based on their estimated nutritional composition, calculated from ingredient-specific nutritional data reported in the literature, and their production costs based on ingredient prices. This assessment was intended to identify a formulation that balances nutritional value and cost efficiency for potential application in small-scale milkfish aquaculture.

METHOD

A. Research Design

This study employed a quantitative descriptive approach to evaluate the optimal fish feed pellet formulation produced using the MAPAN in Kalanganyar Village, Sedati District, Sidoarjo Regency. The evaluation focused on two main aspects, namely the nutritional composition and the production cost efficiency of four pellet formulations. The study consisted of formulation preparation, nutritional content estimation, production cost calculation, and comparative analysis to identify the most feasible formulation.

B. Fish Feed Pellet Formulation

Four pellet formulations (Sample 1–Sample 4) were prepared using locally available raw materials consisting of fish meal, dried shrimp heads, rice bran, ground corn, tapioca flour, and Lactobacillus sp. as a fermentation additive. The proportion of fish meal was gradually increased from 25% to 40%, while the proportion of dried shrimp heads was reduced from 25% to 10%. Other ingredients were maintained at constant proportions to evaluate the influence of protein-source composition on nutritional quality and production cost.

Table 1. Composition of Fish Feed Pellet Formulations (in percent)

Ingredients	Sample 1 (%)	Sample 2 (%)	Sample 3 (%)	Sample 4 (%)
Fish meal	25.00	30.00	35.00	40.00
Dried shrimp heads	25.00	20.00	15.00	10.00
Rice bran	24.95	24.95	24.95	24.95
Ground corn	20.00	20.00	20.00	20.00
Lactobacillus sp.	0.05	0.05	0.05	0.05
Tapioca Flour	5.00	5.00	5.00	5.00

C. Nutritional Composition Analysis

The nutritional evaluation was performed using a literature-based proximate calculation method. The protein, lipid, and carbohydrate contents of each raw material were collected from published scientific literature and feed composition databases. The nutritional composition of each formulation was then calculated using the weighted-average equation 1 (NRC, 2011; Glencross *et al*., 2007):

$$N = \sum_{i=1}^{n} \left(\frac{P_i x C_i}{100}\right) \quad \text{(eq. 1)}$$

where
N = nutrient content of pellet (%)
Pi = percentage of ingredient *i* in the formulation (%)
Ci = nutrient content of ingredient *i* (%)

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The estimated nutritional composition of the proposed formulations was compared with published dietary nutrient references specifically addressing milkfish (*Chanos chanos*). Benitez (1989) reviewed nutritional studies on milkfish and reported dietary protein levels of approximately 30–40%, lipid levels around 10%, and carbohydrate levels around 25% for fingerlings. Similarly, the FAO Aquaculture Feed and Fertilizer Resources Information System (AFFRIS) provides a species-specific summary of milkfish nutrient requirements, including a protein reference range of 30–40% for fingerling and juvenile stages, a lipid reference range of 7–10%, and a carbohydrate maximum of approximately 25% on a dry-feed basis.

These values were adopted as preliminary nutritional reference criteria rather than definitive requirements applicable to all milkfish life stages and farming conditions. Comparisons were considered conditional on the consistency of the nutrient definitions and reporting bases. Since the present study relied on theoretical ingredient composition estimates and did not evaluate nutrient digestibility, amino acid availability, or feeding performance, compliance with these reference values was not interpreted as experimental confirmation of nutritional adequacy.

D. Production Cost Analysis

The economic evaluation was conducted by calculating the production cost of each pellet formulation based on the market prices of individual raw materials collected from local suppliers in Sidoarjo Regency during the study period. The production cost per kilogram of pellets was determined using the weighted-cost equation:

$$C = \sum_{i=1}^{n} \left(\frac{P_i x H_i}{100}\right) \quad \text{(eq. 2)}$$

where :
C = production cost (Rp/kg)
Pi = percentage of ingredient *i*
Hi = market price of ingredient *i* (Rp/kg)

The calculated production costs for each formulation were subsequently compared with the average market price of commercial fish feed (Rp/kg) to determine their economic feasibility.

E. Comparative Analysis

The final evaluation was performed using a comparative descriptive analysis between all pellet formulations based on:

1. Protein content
2. Lipid content
3. Carbohydrate content
4. Production cost per kilogram
5. Difference between production cost and commercial fish feed price

The optimal formulation was determined by considering two evaluation criteria simultaneously:

1. nutritional composition approaching the dietary requirements of milkfish, and
2. the lowest production cost while maintaining adequate nutritional quality.

This approach enabled the identification of the most appropriate pellet formulation for community-scale implementation through the MAPAN innovation in Kalanganyar Village.

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RESULT AND DISCUSSION

The theoretical evaluation of fish feed formulations was conducted to examine the relationship between ingredient proportions, estimated nutritional composition, and raw-material costs. Four proposed formulations were compared by systematically varying the proportions of fish meal and dried shrimp heads, while maintaining constant proportions of rice bran, ground corn, tapioca flour, and the nominal Lactobacillus sp. additive. This formulation design was established within the present study to evaluate the compositional and economic implications of substituting shrimp-head-derived ingredients with fish meal. Nutritional composition was estimated using secondary ingredient composition data, whereas raw-material costs were calculated from local ingredient prices. Since no experimental pellet production, fermentation, laboratory proximate analysis, or feeding trials were conducted, the results represent preliminary theoretical estimates rather than experimentally validated feed performance.

Table 2. Estimated Crude Protein Contribution of Feed Ingredients

Ingredients	Protein Contains (%)	Nutrient content of ingredient (%)			
		1	2	3	4
Fish meal	66.0	16.500	19.800	23.100	26.400
Dried shrimp heads	39.5	9.875	7.900	5.925	3.950
Rice bran	10.0	2.500	2.500	2.500	2.500
Ground corn	10.0	2.000	2.000	2.000	2.000
Lactobacillus sp.	43.0	0.022	0.022	0.022	0.022
Tapioca Flour	0.5	0.025	0.025	0.025	0.025

Table 3. Estimated Crude Lipid Contribution of Feed Ingredients

Ingredients	Fat Contains (%)	Nutrient content of ingredient (%)			
		1	2	3	4
Fish meal	8.0	2.000	2.400	2.800	3.200
Dried shrimp heads	6.8	1.700	1.360	1.020	0.680
Rice bran	23.5	5.875	5.875	5.875	5.875
Ground corn	4.0	0.800	0.800	0.800	0.800
Lactobacillus sp.	3.0	0.002	0.002	0.002	0.002
Tapioca Flour	0.2	0.010	0.010	0.010	0.010

Table 4. Estimated Carbohydrate Contribution of Feed Ingredients

Ingredients	Carbohydrate Contains (%)	Nutrient content of ingredient (%)			
		1	2	3	4
Fish meal	1.0	0.250	0.300	0.350	0.400
Dried shrimp heads	18.2	4.550	3.640	2.730	1.820
Rice bran	42.2	10.550	10.550	10.550	10.550
Ground corn	80.0	16.000	16.000	16.000	16.000

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Lactobacillus sp.	28.0	0.014	0.014	0.014	0.014
Tapioca Flour	86.9	4.345	4.345	4.345	4.345

Table 5. Total Nutritional Content of Each Sample per Kg

Sample	Total Nutritional Content (%)		
	Protein	**Fat**	**Carbohydrate**
1	30.922	10.387	35.709
2	32.247	10.447	34.849
3	33.572	10.507	33.989
4	34.897	10.567	33.129

The calculated contribution of protein from each ingredient demonstrates that fish meal was the dominant contributor to the overall protein content of the pellet formulations. As presented in Table 2, increasing the proportion of fish meal from 25% in Sample 1 to 40% in Sample 4 increased its protein contribution from 16.50% to 26.40%, whereas the protein contribution of dried shrimp heads gradually decreased from 9.88% to 3.95% due to the reduction in their inclusion level. These findings indicate that fish meal remained the primary protein source because of its substantially higher crude protein content (66%) compared with dried shrimp heads (39.5%), rice bran (10%), and ground corn (10%). Similar observations have been reported by Glencross *et al*. (2007), who emphasized that fish meal continues to be one of the highest-quality protein ingredients in aquaculture feeds owing to its balanced essential amino acid profile, superior digestibility, and excellent palatability (Abdel-Latif *et al*., 2020).

Although the contribution of dried shrimp heads decreased progressively with increasing fish meal inclusion, this ingredient still played an important role as an alternative protein source while providing additional minerals, chitin, and bioactive compounds. According to Eggink *et al*. (2024), shrimp processing by-products possess considerable nutritional value because they contain digestible protein, calcium, phosphorus, and chitin, all of which may improve feed quality when incorporated at appropriate levels. Therefore, the reduction in dried shrimp head inclusion in Samples 3 and 4 should not be interpreted as eliminating its nutritional function, but rather as an optimization strategy to achieve a better balance between nutritional quality and production cost (Belton *et al*., 2020).

A different pattern was observed in the lipid composition of the formulated pellets. The data presented in Table 3 indicate that increasing the proportion of fish meal resulted in only a slight increase in total lipid content, from 10.39% in Sample 1 to 10.57% in Sample 4. This relatively small variation occurred because rice bran, which contains approximately 23.5% crude lipid, was maintained at a constant proportion of 25% in all formulations, making it the largest contributor to total lipid content. Rice bran consistently contributed approximately 5.88% lipid to every formulation, exceeding the

contribution from either fish meal or dried shrimp heads. Consequently, lipid concentration was influenced more strongly by the fixed inclusion of rice bran than by variations in the protein sources. Hua *et al*. (2019) explained that dietary lipids serve as an essential energy source in aquaculture feeds, allowing protein to be utilized more efficiently for tissue growth through the *protein-sparing effect*. Nevertheless, excessive lipid levels may negatively affect pellet quality and increase fat deposition in fish tissues, thereby reducing feed efficiency (Naylor *et al*., 2021).

A gradual decline in carbohydrate content accompanied the increase in fish meal inclusion, as illustrated in Table 4. Total carbohydrate decreased from 35.71% in Sample 1 to 33.13% in Sample 4, primarily because dried shrimp heads, which contain higher carbohydrate levels than fish meal, were progressively reduced in the formulations. Furthermore, ground corn and tapioca flour remained constant at 20% and 5%, respectively, making them the principal carbohydrate contributors throughout the study. Ground corn consistently supplied approximately 16% carbohydrate, whereas tapioca flour contributed about 4.35% in every formulation. Consequently, the observed reduction in carbohydrate content was primarily associated with the substitution of dried shrimp heads by fish meal. According to the National Research Council (2011), dietary carbohydrates function mainly as an energy source in fish feeds, thereby reducing the utilization of protein for energy metabolism. Maintaining an appropriate balance among protein, lipid, and carbohydrate is therefore essential to achieve optimal feed utilization and sustainable fish growth.

The nutritional evaluation showed that crude protein content increased progressively from 30.92% in Sample 1 to 34.90% in Sample 4, whereas lipid content remained relatively stable, ranging from 10.39% to 10.57%, and carbohydrate content decreased from 35.71% to 33.13% (Table 5). Based on the protein requirement range cited in the original manuscript (30–40%), all four formulations fell within the recommended range for milkfish culture (FAO, 2024). However, this comparison considers protein content only and does not establish the overall nutritional adequacy of the formulations, which also depends on lipid and carbohydrate requirements, ingredient digestibility, amino acid balance, and the nutritional needs of milkfish at different growth stages. Furthermore, the increase in crude protein from Sample 3 (33.57%) to Sample 4 (34.90%) was 1.33 percentage points, accompanied by an increase in estimated production cost. This relationship reflects the linear weighted-average calculation used in this study: increasing the proportion of fish meal while reducing dried shrimp heads by the same amount produces a consistent change in estimated protein content and ingredient cost. Therefore, Sample 4 had the highest estimated protein content, while the selection of an optimal formulation should consider the balance between nutritional composition and production cost rather than protein content alone.

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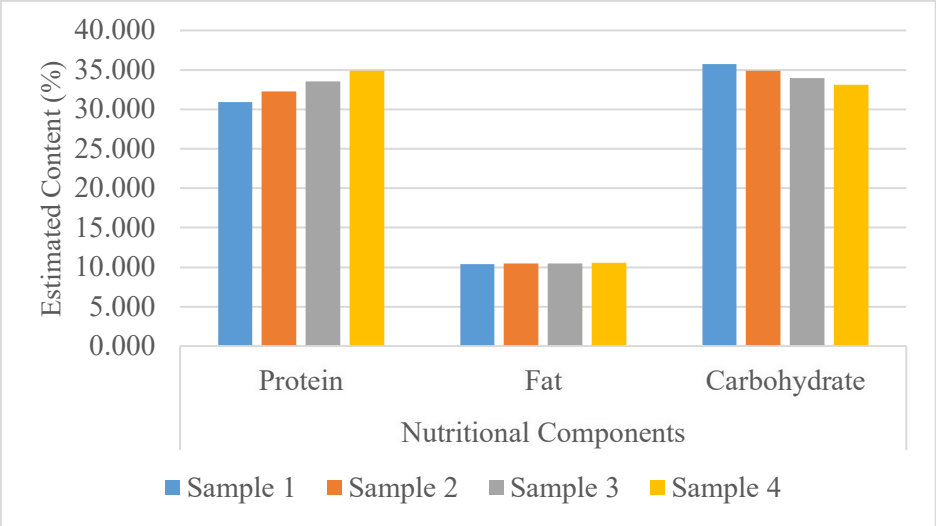


Figure 1. Comparison of Nutritional Composition Among the Four Feed Pellet Formulations.

A comparison among the four formulations is presented in Figure 1. The estimated protein content increased progressively across the formulations, while carbohydrate content decreased and lipid content remained relatively stable. This pattern is consistent with the changes in ingredient proportions, in which increasing the proportion of fish meal while reducing other ingredients altered the estimated contributions of protein and carbohydrates. Aquafeed formulation, however, should consider the overall nutrient composition and the nutritional requirements of the cultured species rather than maximizing protein content alone (Glencross et al., 2007; das Neves et al., 2021).

Among the four formulations, Sample 3 was selected as the preferred option based on the combined consideration of estimated nutritional composition and production cost, rather than on a claim of complete nutritional balance. Its estimated protein content was 33.57%, while lipid and carbohydrate contents were 10.51% and 33.99%, respectively. Although its protein content falls within the 30–40% range cited in the manuscript, the lipid and carbohydrate values must be interpreted against the relevant nutritional reference ranges, and the protein comparison alone does not establish overall nutritional adequacy. Sample 4 had the highest estimated protein content at 34.90%, compared with 33.57% in Sample 3. However, this increase of 1.33 percentage points was accompanied by a higher estimated production cost. Considering the objective of identifying a formulation that combines an appropriate estimated protein level with lower production costs, Sample 3 represents a practical candidate for further evaluation using the MAPAN technology. Nevertheless, its effects on milkfish growth, feed conversion, and overall nutritional performance require validation through feeding trials before its suitability for practical aquaculture can be confirmed.

Table 6. Market Prices of Feed Ingredients

Contains	Price (Rp)
Fish meal	10,900.00
Dried shrimp heads	4,000.00
Rice bran	6,500.00
Ground corn	12,500.00

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Lactobacillus sp.	43,833.00
Tapioca Flour	8,000.00

Table 7. Estimated Production Cost of Each Feed Pellet Formulation

Formulation	Estimated production cost (IDR/kg)	Commercial feed price (IDR/kg)
Sample 1	8,271.92	10,000.00
Sample 2	8,616.92	10,000.00
Sample 3	8,961.92	10,000.00
Sample 4	9,306.92	10,000.00

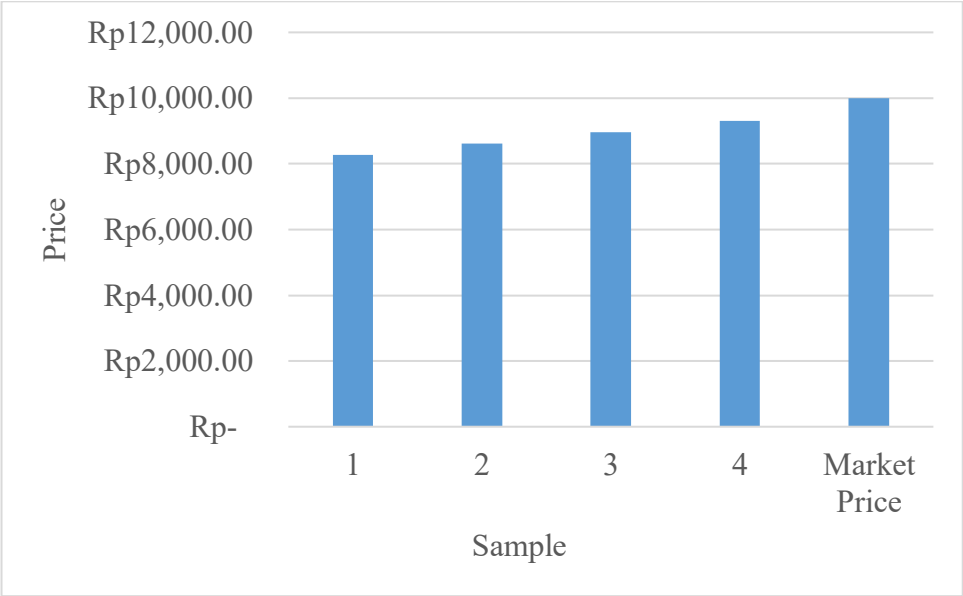


Figure 2. Comparison of Pellet Prices for Each Sample with Market Prices per Kg (Kg^{-1})

Besides nutritional composition, production cost is an important consideration in evaluating alternative aquafeed formulations, particularly for small-scale aquaculture and community-based feed production. Feed costs can represent a substantial proportion of aquaculture operating expenses, making the use of locally available ingredients and the evaluation of production costs relevant to the economic feasibility of alternative feeds (Nunes et al., 2022).

The estimated production costs of the four formulations are presented in Table 7. Costs ranged from IDR 8,271.92/kg for Sample 1 to IDR 9,306.92/kg for Sample 4. This increase was associated with the progressive replacement of dried shrimp heads with fish meal, which had a higher unit price in the ingredient-price dataset used for this study. Across successive formulations, the estimated production cost increased by IDR 345/kg, while crude protein increased by approximately 1.325 percentage points. These consistent increments reflect the linear weighted-average calculation applied to the ingredient proportions and their respective prices and nutritional values. The results therefore demonstrate the direct relationship between formulation composition, estimated protein content, and ingredient cost under the assumptions used in this analysis. However, the cost differences should be interpreted in relation to the actual

ingredient prices and should not be generalized beyond the market conditions represented by the dataset.

Compared with the assumed commercial feed price of IDR 10,000/kg, all four formulations had lower estimated production costs. Sample 1 had the lowest cost at IDR 8,271.92/kg, approximately 17.28% below the commercial benchmark, whereas Sample 3 cost IDR 8,961.92/kg, approximately 10.38% below the benchmark. Sample 4 had the highest estimated protein content (34.90%) and cost IDR 9,306.92/kg, remaining approximately 6.93% below the commercial benchmark. These findings do not establish Sample 3 as the most cost-efficient formulation under every possible criterion. Rather, Sample 3 may be considered a practical candidate if the selection objective is to obtain an estimated protein content of 33.57% while maintaining a production cost below the assumed commercial-feed price. Sample 4 provides a higher estimated protein concentration at a higher cost, whereas Sample 1 minimizes production cost among the tested formulations. Therefore, the preferred formulation depends on the relative priority assigned to protein content and production cost. Further evaluation using verified local ingredient prices and feeding trials would be needed to establish the most suitable formulation for practical milkfish farming.

A broader comparison between the formulated pellets and commercially available fish feed is presented in Figure 2. All four formulations exhibited lower production costs than commercial pellets, which were priced at approximately IDR 10,000 kg^{-1} during the study period. Sample 1 showed the lowest production cost, representing a reduction of approximately 17.97% compared with commercial feed. However, this formulation also contained the lowest protein concentration among all samples, indicating that minimizing production cost alone may compromise feed quality (Fajardo *et al*., 2022). Conversely, Sample 4 achieved the highest nutritional value but provided the smallest economic advantage because its production cost approached that of commercial pellets. Therefore, neither the lowest-cost formulation nor the highest-protein formulation necessarily represents the most appropriate option for practical aquaculture applications.

The relationship between nutritional quality and production cost clearly demonstrates the importance of balancing technical performance with economic feasibility. Sample 3 achieved a production cost of approximately IDR 8,962 kg^{-1}, which remained about 10.4% lower than the average market price of commercial fish feed while simultaneously providing 33.57% crude protein, a value that falls within the recommended dietary protein requirement for milkfish established by FAO (2024). This balance suggests that Sample 3 can satisfy the nutritional demands of cultured fish without imposing excessive production costs on farmers. Similar conclusions were reported by Nunes *et al*. (2022), who emphasized that economically sustainable aquafeed formulations should maximize nutrient utilization while minimizing dependence on costly ingredients such as fish meal.

From the perspective of community empowerment, the economic performance of Sample 3 also supports the implementation of the MAPAN (Fish Feed Machine) innovation in Kalanganyar Village. The use of locally available raw materials, including dried shrimp heads, rice bran, and ground corn, enables farmers to reduce dependence on commercially manufactured feeds while maintaining adequate nutritional quality. Furthermore, the incorporation of fishery processing by-products contributes to the circular economy by converting waste materials into value-added aquaculture products,

thereby improving both environmental sustainability and resource efficiency (Naylor *et al*., 2021). Eggink *et al*. (2024) highlighted that shrimp processing waste has considerable potential as a sustainable feed ingredient because it simultaneously reduces disposal problems and decreases the overall cost of aquafeed production.

Overall, integrating nutritional evaluation with economic analysis demonstrates that Sample 3 represents the optimal fish feed pellet formulation developed through the MAPAN innovation. Although Sample 4 produced the highest protein concentration, the additional nutritional benefit was not proportional to the increase in production cost. In contrast, Sample 3 achieved an optimal compromise between nutritional adequacy and economic efficiency, making it the most feasible formulation for community-scale milkfish farming in Kalanganyar Village.

CONCLUSION

This study evaluated four fish feed pellet formulations developed using the MAPAN (*Mesin Pakan Ikan*/Fish Feed Machine) innovation by comparing their literature-based estimated nutritional composition and ingredient-based production costs. The results showed that increasing the proportion of fish meal increased estimated crude protein content from 30.92% in Sample 1 to 34.90% in Sample 4, while carbohydrate content decreased and lipid content remained relatively stable. Among the formulations, Sample 3 contained an estimated 33.57% crude protein, 10.51% lipid, and 33.99% carbohydrate, with an estimated production cost of IDR 8,961.92/kg, approximately 10.38% below the assumed commercial feed price of IDR 10,000/kg. Sample 3 may therefore be considered a practical candidate when the selection objective is to obtain an estimated protein content of 33.57% while maintaining production costs below the commercial-feed benchmark. However, its lipid and carbohydrate contents exceeded the reference ranges specified in this study, and the nutritional adequacy of the formulation cannot be established from estimated composition alone. The findings demonstrate the potential of using locally available ingredients, including dried shrimp heads, in community-based feed production, but they do not yet establish the biological effectiveness or overall suitability of the formulation for milkfish (*Chanos chanos*) culture. Further laboratory characterization and feeding trials are required before practical recommendations can be made for implementation through the MAPAN technology in Kalanganyar Village.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest regarding the publication of this article.

ORIGINALITY STATEMENT

The authors confirm that this manuscript presents original work and that all data, analyses, and interpretations are reported honestly and accurately. All sources used in the preparation of this manuscript have been appropriately acknowledged and cited.

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