Proximate composition, efficiency, and economic impact on-farm feed in *Pangasianodon hypophthalmus* (Sauvage, 1878) aquaculture in Kampar Regency, Indonesia

[1]Netti Aryani, [2]Hafrijal Syandri, [2]Azrita Azrita, [2]Weni Septiawati

[1] Department Aquaculture, Faculty of Fisheries and Marine, Riau University, Pekanbaru, Riau Province, Indonesia; [2] Department Aquaculture, Faculty of Fisheries and Marine Science-Bung Hatta University, Padang, West Sumatera Province, Indonesia. Corresponding author: H. Syandri, syandri_1960@bunghatta.ac.id

Abstract. This study evaluated the proximate composition, feed efficiency, and economic implications of on-farm feed used in Striped catfish, *Pangasianodon hypophthalmus* (Sauvage, 1878) aquaculture in Kampar Regency, Indonesia. Feed samples were analysed using standard AOAC methods, while feed efficiency was assessed using field-observed feed conversion ratio (FCR). Economic losses were estimated using a scenario-based approach. Results showed that on-farm feed exhibited high variability and did not meet recommended nutritional standards, particularly in crude protein (18.25-19.51%) and crude fibre (10.74-21.11%). FCR values ranged from 1.82 to 1.90, indicating moderate but suboptimal feed efficiency compared to commercial diets. This condition resulted in feed loss of up to 47.37% and economic losses of approximately USD 1,830.84 per 10 tons of feed. Scenario analysis showed that improving FCR ≤ 1.50 could substantially reduce losses. These findings highlight that suboptimal feed efficiency represents both a nutritional and economic constraint, emphasizing the need for improved feed formulation and management to support sustainable aquaculture.

Keywords: economic loss, feed conversion ratio, feed inefficiency, production cost, protein-sparing effect.

Introduction. Global aquaculture production has grown significantly, reaching 130.9 million tons in 2022 with an economic value of approximately USD 312.8 billion, accounting for 59% of total global fisheries production. Inland aquaculture contributes the largest share, underscoring its strategic role in ensuring global food security and supplying animal protein (FAO 2024).

In Indonesia, freshwater aquaculture commodities such as nile tilapia, *Oreochromis niloticus* (Linnaeus, 1758), African catfish, *Clarias gariepinus* (Burchell, 1822), common carp, *Cyprinus carpio* (Linnaeus, 1758), striped catfish, *Pangasianodon hypophthalmus* (Sauvage, 1878), and giant gourami, *Osphronemus goramy* (Lacepède, 1801) contribute substantially to national production. Among these, *P.hypopthalmus* is a key species, with Kampar Regency in Riau Province recognized as a major production centre that significantly contributes to national output (MMAF 2025). This underscores the need to improve production efficiency in the region.

Feed represents the largest production cost component in aquaculture, accounting for more than 60-70% of total costs and strongly influencing farm profitability (Tacon & Metian 2015; Ragasa et al 2022; Hidir et al 2026; Syandri et al 2026). In Kampar Regency, farmers commonly use on-farm (farm-made) feeds formulated from locally available ingredients such as low-value fish, rice bran, and agricultural by-products. However, these feeds are often not formulated according to standardized nutritional requirements, potentially resulting in nutrient imbalances that reduce feed utilization efficiency and increase feed conversion ratio (FCR), theraby affecting economic performance.

Nutritional imbalance can adversely affect growth performance, feed utilization efficiency, and fish health (Muin & Taufek 2024). Poor feed quality may increase FCR, elevate feed losses, and ultimately reduce economic efficiency in aquaculture systems (NRC 2011; White 2013).

Despite its importance, studies linking feed composition, feed utilization efficiency, and economic consequences in small-scale *P. hypophthalmus* farming systems remain limited. This research gap is particularly evident in Kampar Regency, where on-farm feeding practices are widely adopted. Moreover, previous studies rarely quantify the direct economic impacts of nutritional imbalance in on-farm-made feed systems.

Therefore, this study aims to: (1) analyse the proximate composition of feed ingredients and formulated feed; (2) evaluate feed utilization efficiency using FCR and feed conversion efficiency (FCE); and (3) assess the economic implications of feed inefficiency through feed loss estimation. By integrating nutritional, technical, and economic analyses, this study provides a comprehensive understanding of feed performance in small-scale *P. hypophthalmus* aquaculture. This study is also among the first to quantitatively link proximate composition, feed efficiency, and economic loss in small-scale P*. hypophthalmus* aquaculture systems.

Material and Method

Sampling locations and feed collection. On-farm (farm-made) feed samples were collected from three *P. hypophthalmus* aquaculture centres in Kampar Regency, Riau Province, Indonesia: Sambat Village (Kampar Kiri Hulu District), Sungai Paku Village (Kampar Kiri District), and Koto Mesjid Village (XIII Koto Kampar District).These locations were purposively selected based on their aquaculture intensity and widespread use of farm-made feed. Samples, collected between March and April 2026, represented the typical feed formulations used by farmers in each area. Feed was prepared by mixing ingredients, pelleting, and air-drying under ambient conditions for approximately 24 h, producing a semi-moist product.

Proximate composition analysis*.* The feed samples were analysed for proximate composition, including moisture content, crude protein, crude lipid, crude fibre, ash content, and nitrogen-free extract (NFE) were conducted according to AOAC (2005) procedures. Major ingredients used in feed formulation, including bycatch fish, rice bran, and expired commercial wheat flour, were also analyses to determine their nutritional contributions (Table 1). NFE was calculated by difference:

$$\text{NFE (\%)} = 100 - (\text{moisture} + \text{crude protein} + \text{crude lipid} + \text{ash} + \text{crude fibre})$$

Proximate composition data were analyzed using one-way analysis of variance (ANOVA) to determine significant differences among sampling locations. When significant differences were observed ($p < 0.05$), Tukey’s Honestly Significant Difference (HSD) test was applied for post hoc comparisons. All statistical analyses were performed using SPSS version 18.

Feed conversion ratio (FCR) and feed conversion efficiency (FCE). Feed efficiency analysis was conducted using FCR values obtained from three aquaculture sites through semi-structured interviews with *P. hypophthalmus* farmers. The use of semi-structured interviews enabled in-depth data collection on feeding practices while ensuring consistency across respondents. A total of five fish farmers were selected from each aquaculture site as respondents. The observed FCR values ranged from 1.82 to 1.90, representing actual farming conditions.

For comparative purposes, two additional FCR scenarios were applied. An FCR of 1.5 represents improved feed efficiency achievable through better feed management and the adoption of semi-intensive aquaculture practices. Meanwhile, an FCR of 1.1 was used as an optimal efficiency target aligned with the policy direction of the Ministry of Marine Affairs and Fisheries toward 2029. These scenarios were used to evaluate potential reductions in feed requirements under different levels of production efficiency.

FCR was calculated using the following formula:

$$FCR = \text{Total feed input} / \text{Total fish biomass}$$

Where:
FCR = Feed conversion ratio;
Total feed input = total feed supplied during the culture period;
Total fish biomass = total harvested fish biomass.

FCE was calculated using the following formula:

$$FCE = 1 / FCR$$

Where:
FCE = Feed conversion efficiency;
FCR = Feed conversion ratio.

Production projection and feed requirement estimation. Production projections for 2025-2029 were estimated using a simple linear regression model based on *P. hypophthalmus* production data from 2021-2024 obtained from Kampar Regency statistics. The regression model followed the equation: $Y = a + bX$, where Y represents fish production, X denotes time (year), a is the intercept, and b is the regression coefficient. The fitted model was then used to estimate future production trends. Feed requirements were subsequently calculated under FCR scenarios of 1.9, 1.5, and 1.1 by multiplying projected production values by each FCR coefficient

Estimation of feed loss and economic implications. Feed loss was estimated as the proportion of feed not converted into biomass:

$$\text{Feed loss } (\%) = (1 - FCE) \times 100$$

To evaluate the economic implications of feed inefficiency, a scenario-based analysis was performed using a standardized feed input of 10 tons. Economic losses were estimated by multiplying the quantity of feed lost by the feed price. A feed cost of USD 1,830.84 per 10 tons of feed was assumed. This approach allows for the evaluation of the relationship between feed efficiency (FCR/FCE), feed loss, and associated economic losses under different efficiency scenarios.

Results and Discussion

Proximate composition of on-farm feed ingredients. Table 1 presents the proximate composition of the main ingredients used in on-farm feed formulation in Kampar Regency on % as fed basis. The ingredients showed complementary nutritional characteristics that support balanced feed formulation. Bycatch fish contributed high protein content, whereas expired commercial wheat flour provided a higher digestive processes. Rice bran additionally contributed fibre, which may support contributions that may affect feed nutritional quality.

Additional components, including crude palm oil, mineral premix, and probiotics, were incorporated to improve feed quality and functionality. Crude palm oil served as concentrated energy source, while mineral premix and probiotics were included to support mineral balance and nutrient utilization.

In addition to the ingredients presented in Table 1, crude palm oil, mineral premix, and probiotics were incorporated in the formulation to optimize energy density, ensure mineral balance, and enhance gut health and nutrient utilization efficiency. Crude palm oil is characterized by its very high lipid content (approximately 99%), making it an efficient and concentrated energy source in feed formulation (FAO 2013). Meanwhile, the mineral premix typically contains essential macro- and micro-minerals, such as calcium (Ca), phosphorus (P), magnesium (Mg), iron (Fe), zinc (Zn), manganese (Mn), and copper (Cu), which play critical roles in metabolic processes, skeletal development, and overall physiological functions (NRC 2011).

Table 1

Proximate composition of feed ingredients (% as fed basis) of on-farm feed in Kampar Regency

Feed ingredient	*Moisture (%)*	*Crude protein (%)*	*Crude lipid (%)*	*Crude fiber (%)*	*Ash (%)*	*NFE (%)*
Bycatch fish	54.43±0.90	18.53±0.25	5.11±0.31	0.00±0.00	3.01±0.08	19.12±0.41*
Rice bran	ND	19.24±0.09	4.17±0.14	5.53±0.12	3.36±0.04	67.70±0.21
Expired commercial wheat flour	ND	9.00±0.35	1.84±0.03	0.51±0.03	1.24±0.04	87.43±0.36

Note: Values are expressed as mean ± SD (n = 3). NFE = Nitrogen-Free Extract, calculated by difference; ND = Not detected. *For bycatch fish, NFE was calculated as 100 − (moisture + crude protein + crude lipid + crude fiber + ash).

Proximate composition of on-farm feed in Kampar Regency. The proximate composition of on-farm feed used in the culture of *P. hypophthalmus* in Kampar Regency showed significant differences among locations as well as in comparison with commercial feed ($p < 0.05$). This variation reflects differences in feed formulation, which are strongly influenced by the availability and proportion of locally sourced ingredients (Table 2), resulting in non-uniform nutritional quality across production units.

Visually, differences in the quality of on-farm feed can also be observed from the physical characteristics presented in Figure 1. Variations in colour, texture, and pellet integrity indicate differences in raw material composition and processing methods, which ultimately contribute to differences in nutrient content and potential digestibility. These physical characteristics serve as important preliminary indicators in assessing feed quality, particularly in small-scale production systems that are not yet fully standardized.

Tabel 2

Proximate composition of on-farm feed in Kampar Regency

Proximate composition	*On-farm feed Sambat Village*	*On-farm feed Sungai Paku Village*	*On-farm feed Koto Mesjid Village*	*Commercial feed*
Moisture (% WW)	22.97±0.07^{a}	24.32±0.05^{b}	16.04±0.11^{c}	5.72±0.01^{d}
Crude protein (% DW)	18.65±0.01^{a}	18.25±0.18^{b}	19.51±0.15^{c}	29.16±0.16^{d}
Crude lipid (% DW)	4.79±0.02^{a}	5.52±0.29^{b}	7.55±0.01^{c}	10.69±0.62^{d}
Ash (% DW)	18.97±0.13^{a}	16.37±0.02^{b}	14.33±0.33^{c}	7.22±0.19^{d}
Crude fibre (% DW)	21.11±0.10^{a}	14.77±0.01^{b}	10.74±0.01^{c}	2.06±0.02^{d}
NFE (% DW)	13.49±0.61^{a}	20.77±0.11^{b}	31.80±0.48^{c}	45.15±0.98^{d}
Energy value (MJ kg^{-1} DM)	8.62±0.03^{a}	14.42±0.07^{b}	13.06±0.05^{c}	18.88±0.11^{d}

Note: WW = wet weight; DW = dry weight. Values are presented as the mean ± SD (%), n = 3. Lowercase superscript letters a,b,c and d denote significant variations among feed types ($p < 0.05$).

The moisture content of on-farm feed ranged from 16.04 to 24.32%, with the highest value observed in Sungai Paku and the lowest in Koto Mesjid. These values were considerably higher than those of commercial feed (5.72%), primarily due to the absence of a controlled drying process, as the feed was only air-dried for approximately 24 h prior to use. This indicates that the product is more appropriately classified as semi-moist feed rather than conventional dry pellet feed.

Such practices are commonly found in small-scale aquaculture systems, where feed is produced and used immediately, minimizing the need for long-term storage. Nevertheless, high moisture content may reduce storage stability and increase the risk of microbial growth, thereby accelerating nutrient degradation, as reported by Lovell (1998).

The crude protein content of on-farm (farm-made) feed ranged from 18.25 to 19.51%. However, these values are considerably lower than those observed in commercial feed (29.16%) and fall below the optimal dietary protein requirement for *P. hypophthalmus* (28-32%). Previous studies have reported that the crude protein content of farm-made feeds for *P. hypophthalmus* typically ranges from approximately 19-25%, depending on ingredient composition and growth stage (Nguyen 2013). Similar findings have also been reported in other regions, such as Bangladesh, where farm-made feeds generally contain around 19-22% crude protein (Ahmed et al 2010), indicating relatively lower protein levels compared to commercial diets.

In accordance with the Indonesian National Standard (SNI 9043-11:2024) for the grow-out culture of *P. hypophthalmus*, the minimum protein requirement for grow-out feed is 25%, indicating that none of the on-farm feeds met this standard. The same standard also specifies a maximum moisture content of 12%, a minimum lipid content of 5%, a maximum crude fibre content of 8%, and a maximum ash content of 13%, suggesting that most on-farm feeds did not comply with the recommended quality criteria.

Protein deficiency can directly affect fish growth performance and feed utilization efficiency, as reported by the National Research Council (2011). Furthermore, poor feed quality combined with inappropriate feeding strategies can significantly influence the environmental impact of aquaculture systems (White 2013).

Crude lipid levels ranged from 4.79 to 7.55%, with most feeds meeting the minimum SNI requirement (≥ 5%), except for Sambat. Lipids play a key role as an energy source and contribute to the protein-sparing effect. Variations in lipid content are likely due to differences in raw materials, including plant oils or animal by-products such as mesenteric fat from *P. hypophthalmus* processing waste (Aryani et al 2023). Adequate lipid balance is essential for efficient energy utilization and growth performance (Halver & Hardy 2002; Susanto et al 2024).

Ash content in on-farm feed (14.33-18.97%) exceeded both commercial feed (7.22%) and the SNI limit (≤ 13%) in several cases, particularly in Sambat and Koto Mesjid. Elevated ash levels may indicate excessive mineral content or contamination, potentially reducing nutrient digestibility and feed efficiency (NRC 2011).

The crude fibre content of the feed exhibited substantial variation, with Sambat feed reaching as high as 21.11%. These values greatly exceed the maximum limit established by SNI (8%), indicating a strong reliance on plant-based ingredients, particularly agricultural by-products, in feed formulation. However, *P. hypophthalmus* species have a limited capacity to digest dietary fibre; therefore, excessive crude fibre levels may reduce nutrient digestibility, impair feed utilization, and ultimately decrease FCR (De Silva & Anderson 1995).

Moreover, high crude fibre content has been linked to inferior binder performance, which in turn compromises both the physical integrity and nutritional quality of the feed (Syandri et al 2025a). Therefore, the incorporation of gelatin derived from *Osphronemus goramy* fish scales represents a promising alternative binder, as it may enhance pellet stability while simultaneously contributing to the nutritional value of the feed (Syandri et al 2025b; Azrita et al 2025).

NFE in the farm-formulated feeds ranged from 13.49 to 31.80%, which is lower than the values reported for *P. hypophthalmus* feed by Prakash et al (2025) (46.89-50.81%). As NFE represents the digestible carbohydrate fraction, lower levels indicate limited availability of non-protein energy sources. Consequently, protein is more likely to be utilized as an energy source rather than for growth, resulting in inefficient protein utilization.

The low energy content (8.62-14.42 MJ kg^{-1} DM) compared to commercial feed (18.88 MJ kg^{-1} DM) indicates insufficient non-protein energy supply, which may force fish to utilize protein as an energy source.

Overall, on-farm feed in Kampar Regency shows considerable variability and generally does not meet recommended nutritional standards for *P. hypophthalmus*, particularly in moisture, protein, fibre, and energy balance. Therefore, improving feed formulation through better raw material standardization, increased protein content, reduced fibre levels, and optimized energy sources is essential to enhance feed efficiency and growth performance.

This finding suggests that feed inefficiency in small-scale systems is not solely a nutritional issue but also a structural limitation linked to ingredient selection and processing constraints.

On-farm feed in Sambat Village, Kampar Kiri Hulu Subdistrict, Kampar Regency

On-farm feed in Sungai Paku Village, Kampar Kiri Subdistrict, Kampar Regency

On-farm feed in Koto Mesjid Village, XIII Koto Kampar Subdistrict, Kampar Regency

Figure 1. On-farm feed production in different locations of Kampar Regency, Riau Province, Indonesia. Observed differences in colour, texture, and pellet integrity suggest variations in pellet durability and water stability, which may influence feed intake and nutrient leaching.

This study has several limitations that should be considered when interpreting the results. The on-farm feeds evaluated were produced using small-scale, non-standardized methods, particularly in terms of drying processes and formulation consistency, which may lead to variability in nutrient composition and limit direct comparability with commercial feeds. In addition, the analysis was restricted to proximate composition without evaluating digestibility, amino acid profiles, or growth performance parameters, which are essential for a more comprehensive assessment of feed quality. Future studies should include controlled feeding trials to validate the effects of feed composition on growth performance and nutrient utilization.

Despite these limitations, the findings provide important practical implications for small-scale aquaculture practices. The results highlight existing nutritional gaps, particularly in protein content, fibre levels, and moisture control, which can be addressed through simple improvements such as better ingredient selection, improved drying techniques, and formulation standardization. Furthermore, the use of alternative lipid sources, such as oil derived from mesenteric fat of *P. hypophthalmus* processing waste, offers a promising strategy to enhance dietary energy and support the protein-sparing effect (Mock et al 2018; Aryani et al 2025). This approach not only improves nutritional efficiency but also reinforces the principles of circular economy and waste utilization by converting low-value aquaculture by-products into value-added feed ingredients (Thirukumaran et al 2022).

Therefore, the implementation of these improvements has the potential to enhance feed efficiency, reduce production costs, and strengthen the sustainability of *P. hypophthalmus* aquaculture at the local level. Notably, this study highlights a novel approach by integrating the evaluation of locally formulated on-farm feed with the utilization of mesenteric fat-derived oil as an alternative lipid source, thereby linking nutritional optimization with circular economy and aquaculture waste valorization.

Feed requirement estimation. The relatively high FCR observed in this study directly influences the projected feed demand in *P. hypophthalmus* aquaculture systems. Based on production data from 2021 to 2024, *P. hypophthalmus* output shows a consistent increasing trend following a decline likely associated with the COVID-19 pandemic, indicating a recovery phase in the aquaculture sector (Table 3).

Trend analysis using a simple linear regression approach indicates that *P. hypophthalmus* production has increased at an average rate of approximately 741.49 tonnes per year. Assuming that aquaculture conditions, market demand, and other supporting factors remain stable, production is projected to continue increasing in the coming years.

The estimation results suggest that *P. hypophthalmus* production in 2025 is projected to reach approximately 24,875.69 tonnes and is expected to rise further to around 27,841.65 tonnes by 2029. This increase reflects a positive and sustained growth trend in the *P. hypophthalmus* aquaculture sector, driven by rising market demand and advancements in aquaculture technology.

One of the main challenges identified in this study is the relatively high FCR, ranging from 1.84 to 1.9 across the three aquaculture sites. This value represents the ratio between total feed input and fish biomass production. Similar findings were reported by Ahmed et al (2010) in Bangladesh, who observed that FCR values in *P. hypophthalmus* culture generally range from 1.61 to 1.70. This indicates that feed is the dominant cost component in aquaculture systems (FAO 2020)

The higher FCR observed in this study indicates suboptimal feed utilization efficiency. This suggests that a greater amount of feed is required to produce a unit of fish biomass compared to previously reported benchmarks. Such inefficiency contributes to increased production costs and may ultimately reduce the overall profitability of aquaculture operations.

Therefore, innovation and strategic approaches are required in the utilization of alternative feed ingredients based on locally available resources that are economically viable, sustainably available, and capable of meeting the nutritional requirements of fish. Such efforts are expected to improve feed efficiency, reduce FCR values, and support the overall sustainability of *P. hypophthalmus* aquaculture systems.

Nevertheless, it is important to note that this estimation is based on a simple trend model that does not account for external factors such as climate change, feed availability, government policies, or market dynamics. Therefore, these projections should be considered as preliminary insights to support planning and decision-making processes. This projected increase in feed demand may exacerbate resource pressure and feed cost volatility if efficiency improvements are not achieved.

Table 3

Production of *Pangasianodon hypophthalmus* from 2021 to 2024 and projected production and feed requirements for 2025-2029 in Kampar Regency

Year	*Fish production (tonnes)*	*Feed requirement at FCR 1.9 (tonnes)*	*Feed requirement at FCR 1.5 (tonnes)*	*Feed requirement at FCR 1.1 (tonnes)*
2021	21,909.73	41,628.49	32,864.60	24,100.70
2022	23,029.15	43,755.39	34,543.73	25,332.07
2023	23,616.05	44,870.50	35,424.08	25,977.66
2024	24,134.20	45,855.00	36,201.30	26,547.62
2025	24,875.69	47,263.81	37,313.54	27,363.26
2026	25,617.18	48,672.64	38,425.77	28,178.90
2027	26,358.67	50,081.47	39,538.01	28,994.54
2028	27,100.16	51,490.30	40,650.24	29,810.18
2029	27,841.65	52,899.14	41,762.48	30,625.82

Note: FCR = feed conversion ratio.

Feed efficiency and economic losses. Table 4 presents a simulation of on-farm feed utilization efficiency in *P. hypophthalmus* culture across different FCR values. The results highlight the impact of FCE on feed loss and associated economic losses, demonstrating the economic implications of feed efficiency in on-farm feeding systems.

At an FCR of 1.90, the estimated economic loss reached USD 3,863.53 per 10 tonnes of feed, corresponding to a feed loss of 47.37%. Similarly, at FCR values of 1.84 and 1.82, economic losses remained high at USD 1,763.67 and USD 1,740.49, respectively. These findings indicate that nearly half of the feed input is not effectively converted into biomass under poor feed efficiency conditions. This aligns with the principle that FCR is inversely related to feed efficiency, where higher FCR reflects inefficient feed utilization and increased waste.

Table 4

Simulated on-farm feed utilization efficiency based on feed conversion ratio and feed conversion efficiency in *Pangasianodon hypophthalmus* culture in Kampar Regency

Feed input (tonnes)	*FCR*	*FCE (%)*	*Feed utilized (%)*	*Feed loss (%)*	*Feed cost (USD per 10 tonnes)*	*Estimated economic loss (USD)*
10.0	1.90	52.63	52.63	47.37	3,863.53	1,830.14
10.0	1.84	54.35	54.35	45.65	3,863.53	1,763.67
10.0	1.82	54.94	54.94	45.05	3,863.53	1,740.49
10.0	1.50	66.67	66.67	33.33	3,863.53	1,287.78
10.0	1.10	90.9	90.9	9.09	3,863.53	351.20

Note: FCR = feed conversion ratio; FCE = feed conversion efficiency.

In contrast, improvements in FCR significantly reduced economic losses. At an FCR of 1.50, economic loss declined to USD 1,287.78, with feed utilization increasing to 66.67%. Meanwhile, the lowest loss (USD 351.20) was observed at an FCR of 1.10, where feed loss decreased to only 9.09%. These results highlight that even moderate improvements in FCE can lead to substantial economic benefits.

This pattern is consistent with previous studies in aquaculture, which report that feed can account for approximately 75-90% of total production costs, largely due to the high prices of key ingredients such as fish meal and fish oil. Consequently, feed efficiency is a critical determinant of farm profitability (Ahmad et al 2024; Prakash et al 2025). Inefficient feed utilization not only increases operational costs but also leads to nutrient wastage and greater environmental pressure, particularly in intensive aquaculture systems.

The relatively high FCR values observed in this study are likely associated with the use of on-farm feeds, which often vary in nutritional quality, digestibility, and formulation consistency compared to commercial feeds. According to White (2013), suboptimal feed formulation and poor feeding management practices can significantly reduce nutrient utilization efficiency, thereby resulting in higher FCR values.

Therefore, improving the quality of on-farm feed, through better formulation, ingredient selection, and feeding management, can play a crucial role in reducing FCR and minimizing economic losses. Additionally, optimizing feeding strategies, such as feeding frequency and ration size, has been shown to enhance feed efficiency and growth performance in *P. hypophthalmus* culture.

Conclusion. On-farm feed used in *P. hypophthalmus* aquaculture in Kampar Regency showed high variability in nutritional composition and generally did not meet optimal dietary requirements, particularly regarding protein and fibre content. Feed efficiency was also suboptimal, which may contribute to substantial feed losses and economic inefficiencies. Therefore, optimization of feed formulation, nutrient balance, and processing practices in necessary to improve feed quality, enhance production performance, and support sustainable aquaculture development.

Acknowledgement. The authors express their sincere appreciation to the students, *P. hypophthalmus* farmers, and on-farm feed small-scale industry practitioners in Kampar Regency who actively participated in and contributed to this research.

Conceptualization. NA, HS; Methodology: NA, AA, WS; Formal analysis: NA, WS; Investigation: AA, WS; Data curation: AA, WS; Writing - original draft: NA; Writing - review & editing: HS, AA; Supervision: HS.

Conflict of Interest. The authors declare that there is no conflict of interest.

Data Availability. The data supporting the findings of this study are available from the corresponding author upon reasonable request.

Funding. This research was funded by the National Research and Innovation Agency (BRIN) and the Indonesian Endowment Fund for Education (LPDP), Republic of Indonesia, under Grant No. 64/IV/KS/07/2024 dated July 8, 2024. The funding supported the implementation of this two-year research project.

References

Ahmad N., Hussain S. M., Azam S. M., Shahzad M. M., Noureen A., Yaqoob R., Lateef M., Yawar A., Riaz D., Usman A., Faizan M., Hassan S., Ishtiaq A., Riaz P., Ali A., Amini F., Imran M., Kausar R., Ahmed M., Bashir W., Adnan M., Siddique A., Farooq M., Ahmad S., 2024 Effects of Se nanoparticles supplementation on growth performance, hematological parameters and nutrient digestibility of *Labeo rohita* fingerling fed sunflower meal-based diet. Brazilian Journal of Biology 84:e253555.

Ahmed N., Alam M. F., Hasan M. R., 2010 The economics of sutchi catfish (*Pangasianodon hypophthalmus*) aquaculture under different farming systems in rural Bangladesh. Aquaculture Research 41(11):1668-1682.

Aryani N., Heltonika B., Suharman I., 2025 Impact of freshwater fish oil-fortified feed on nutrition and growth of Hemibagrus nemurus larvae. AACL Bioflux 18(3):1079-1091.

Aryani N., Suharman I., Heltonika B., Edison E., Diharmi A., 2023 Changes in fatty acid profile of fish oil derived from *Pangasianodon hypophthalmus* processing waste. F1000Research 12:1255.

Azrita A., Syandri H., Sari R. T., Kusuma H., 2025 Reproductive performance of *Tor tambroides* fed diets with different fish oil sources. AACL Bioflux 18(5):2088-2099.

De Silva S. S., Anderson T. A., 1995 Fish nutrition in aquaculture. Chapman & Hall, London, United Kingdom, 319 p.

Halver J. E., Hardy R. W., 2002 Fish nutrition. Academic Press, San Diego, CA, USA, 824 p.

Hidir A., Aaqillah-Amr M. A., Abdul Rahim K. A., Azra M. N., Ma H., Shapawi R., Noordin N. M., Ikhwanuddin M., 2026 Sustainable feed processing methods to enhance growth and digestibility in freshwater aquaculture: a review. Animal Nutrition 25:228-245.

Lovell R. T., 1998 Nutrition and feeding of fish. 2nd ed. Kluwer Academic Publishers, Boston, MA, USA, 267 p.

Mock T. S., Francis D. S., Jago M. K., Glencross B. D., Smullen R. P., Keast R. S. J., Turchini G. M., 2019 The impact of dietary protein: lipid ratio on growth performance, fatty acid metabolism, product quality and waste output in Atlantic salmon (*Salmo salar*). Aquaculture 501:191-201.

Muin H., Mohd Taufek N., 2024 Evaluation of growth performance, feed efficiency and nutrient digestibility of red hybrid tilapia fed dietary inclusion of black soldier fly larvae (*Hermetia illucens*). Aquaculture and Fisheries 9(1):46-51.

Nguyen T. P., 2013 On-farm feed management practices for striped catfish (*Pangasianodon hypophthalmus*) in Mekong River Delta. In M.R. Hasan and M.B. New, eds. On-farm feeding and feed management in aquaculture. FAO Fisheries and Aquaculture Technical Paper No. 583. Rome, FAO. pp. 241-267.

Prakash P., Mohanta K. N., Sahu N. P., Renuka V., Varghese T., Nayak S. K., Baraiya R., Khalasi Y., 2025 Optimizing dietary protein and lipid levels for better growth performance, nutrient retention and flesh quality of grow-out striped catfish (*Pangasianodon hypophthalmus*). Scientific Reports 15:33874.

Ragasa C., Osei-Mensah Y. O., Amewu S., 2022 Impact of fish feed formulation training on feed use and farmers' income: evidence from Ghana. Aquaculture 558:738378.

Susanto A., Sukarti K., Nikhlani A., Kusdianto H., Almadi I. F., Sidik A. S., 2024 The effects of dietary lipid level on the growth performance, body composition and feed utilization of juvenile kelabau (*Osteochilus melanopleura*). AACL Bioflux 17(4):1551-1559..

Syandri H., Aryani N., Azrita A., 2025a Biometric indicators, gelatin yield, and functional properties of fish scale waste from three species with different trophic levels. International Journal of Food Science 2025(1):6628788.

Syandri H., Aryani N., Azrita A., Asmaida., 2026 An innovative approach to cost structure adjustment and feasibility analysis of pangasius aquaculture in XIII Koto Kampar,

Kampar Regency, Indonesia. International Journal of Fisheries and Aquatic Studies 14(5):151-157.

Syandri H., Azrita A., Elfrida E., Aryani N., 2025b Functional characterization of gelatin from freshwater fish scales using *Averrhoa bilimbi* acid pretreatment. AACL Bioflux 18(2):822-835.

Tacon A. G. J., Metian M., 2015 Feed matters: satisfying the feed demand of aquaculture. Reviews in Fisheries Science and Aquaculture 23(1):1-10.

Thirukumaran R., Anu Priya V. K., Krishnamoorthy S., Ramakrishnan P., Moses J. A., Anandharamakrishnan C., 2022 Resource recovery from fish waste: Prospects and the usage of intensified extraction technologies. Chemosphere 299:134361.

White P. G., 2013 Environmental consequences of poor feed quality and feed management. In: Hasan M.R. & New M.B. (eds.), On-farm feeding and feed management in aquaculture. FAO Fisheries and Aquaculture Technical Paper No. 583. Rome, FAO. pp. 553-564.

*** AOAC (Association of Official Analytical Chemists), 2005 Official methods of analysis of AOAC International, 18th ed. AOAC International. Available at: https://www.aoac.org/official-methods-of-analysis/?utm_source=chatgpt.com. Accessed at: May 2026.

*** FAO (Food and Agriculture Organization of the United Nations), 2020 The state of world fisheries and aquaculture 2020. Rome, Italy, 224 p. Available at: https://doi.org/10.4060/ca9229en. Accessed at: May 2026

*** FAO (Food and Agriculture Organization of the United Nations), 2013 Dietary protein quality evaluation in human nutrition. FAO Food and Nutrition Paper No. 92. Rome, Italy. Available at: https://openknowledge.fao.org/handle/20.500.14283/i3124e. Accessed at: May 2026.

*** FAO (Food and Agriculture Organization of the United Nations), 2024 The state of world fisheries and aquaculture 2024. Rome, Italy. Available at: https://doi.org/10.4060/cc9999en. Accessed at: May 2026.

*** MMAF (Ministry of Marine Affairs and Fisheries), 2025 Annual report on fisheries production in Indonesia. Jakarta, Indonesia. Available at: https://portaldata.kkp.go.id/portals/data-statistik/layer1. Accessed at: May 2026

*** NRC (National Research Council), 2011 Nutrient requirements of fish and shrimp. National Academies Press. Washington, DC, USA. Available at: https://doi.org/10.17226/13039. Accessed at: May 2026.

Received: 23 April 2026. Accepted: 29 May 2026. Published online: 30 June 2026.

Authors:
Netti Aryani (NA), Department of Aquaculture, Faculty of Fisheries and Marine, Riau University, HR. Soebrantas Street Km. 12.5, Simpang Baru, 28293 Pekanbaru, Indonesia, e-mail: netti.aryani@lecturer.unri.ac.id
Hafrijal Syandri (HS), Department of Aquaculture, Faculty of Fisheries and Marine Science, Bung Hatta University, Sumatera Street, Ulak Karang, 25131 Padang , Indonesia, e-mail: syandri_1960@bunghatta.ac.id
Azrita Azrita (AA), Departement of Aquaculture, Faculty of Fisheries and Marine Science, Bung Hatta University, Sumatera Street, Ulak Karang, 25131, Padang Indonesia, e-mail: azrita31@bunghatta.ac.id
Weni Septiawati (WS), Department of Aquaculture, Faculty of Fisheries and Marine Science, Bung Hatta University, Sumatera Street, Ulak Karang, 25131 Padang, Indonesia, e-mail: weniseptiawati453@gmail.com

How to cite this article:
Aryani N., Syandri H., Azrita A., Septiawati W., 2026 Proximate composition, efficiency, and economic impact on-farm feed in *Pangasianodon hypophthalmus* (Sauvage, 1878) aquaculture in Kampar Regency, Indonesia. AACL Bioflux 19(3):1547-1556.