International Research Journal of Multidisciplinary Scope (IRJMS), 2026;7(3):1379-1386

IRJMS

Original Article | ISSN (O): 2582-631X DOI:10.47857/irjms.2026.v07i03.011236

Effects of Locally Formulated and Commercial Diets on the Growth and Economic Performance of Red Tilapia

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Abstract

Aquaculture is a critical applied science for ensuring global food security, yet its sustainability is often challenged by the high cost of feeds, which represent over 50% of production expenses. This study applied principles of sciences and feed technology to formulate cost-effective aquafeeds using locally available resources in the Caraga Region, Philippines. Fish meal (63.4% CP), soybean meal (40% CP), rice bran, malunggay, duckweed, cassava flour and coconut oil were processed into pelleted feeds and tested against standard commercial diets in red saline tilapia (Oreochromis sp.) culture from fry to market size. Growth performance, feed conversion ratio (FCR), survival and economic indicators were assessed over a 150-day culture period. Results showed that commercial feeds yielded significantly higher final weight (305 g vs. 207 g) and weight gain (290 g vs. 192 g), while locally formulated feeds achieved superior feed efficiency (FCR 1.74 vs. 2.0) and equal survival rates (95%). More importantly, the experimental diets reduced feed costs by over 50% (Php 26,217.50 (457 USD) vs. Php 59,498.60 (1,037 USD)), resulting in higher gross profit (Php 30,177.58 (526 USD)) and return on investment (ROI 1.151) compared to commercial feeds (Php 21,561.40 (375 USD); ROI 0.362). These findings demonstrate how locally sourced feed formulations can enhance economic viability, reduce reliance on imported inputs and support environmentally sustainable aquaculture systems. By integrating applied sciences, food technology and resource-efficient practices, this research provides a practical pathway toward resilient smallholder aquaculture and sustainable food production.

Keywords: Commercial Diet, Feed Efficiency, Local Feed Formulation, Sustainability, Tilapia.

Introduction

The Philippines is among the world's fish-producing countries (1, 2). From 2014 to 2018, aquaculture was the largest contributor among the three fisheries production sectors in the country (3, 4). It is the only sector that has shown continuous development compared to municipal and commercial fisheries even in global aspect (5-7). In aquaculture sector, the major contributor accounting to 53% of its total production are seaweeds, milk fish, tilapia and shrimps/prawn. (1, 8, 9). Since tilapia is commonly produced in ponds, cages and pens it ranks as the second most important farmed fish among the major cultured aquaculture species worldwide (10). This is due to its broad adaptability to diverse environmental conditions; it has become one of the most accessible fish for both consumers and producers. Its popularity is largely attributed to its adaptability to rural aquaculture systems in Asia, where tilapia farming provides sustainable source of income for small-scale farmers and supports family- and community-based livelihood (11). The relatively short production cycle, high-capacity production and efficient feed conversion further enhance its suitability for small scale operations making it a family- and community-based livelihood. While this species also provides affordable source of protein, essential amino acids, vitamins and minerals; making it important to human health. As one of the most promising aquaculture fish groups in the world, tilapia has gained significant interest and has been introduced in many parts of the world (10). Their popularity is largely due to their fast growth, resilience and

(Received 17th March 2026; Accepted 15th July 2026; Published 23rd July 2026)

ability to adapt to diverse environmental conditions. Despite its global success and economic importance, the Philippine tilapia industry continues to face challenges in achieving optimal production efficiency. Fish production efficiency among local farmers remains relatively low, even though the local economy highly depends on profits from tilapia aquaculture industry (12). This is because tilapia aquaculture has faced the same systemic pressures and operational constraints common to the country's broader aquaculture sector. These includes high water temperature, lack of government assistance, poor breeding, lack of capital and high-cost production (10). In the Philippines, studies revealed that the most serious problems hindering efficient tilapia production are poor water quality and the high cost of fish feed (12). The first problem has become less critical with the advancement of modern technologies that provide promising tools for aquaculture management, including highly accurate machine learning models for optimizing water quality management in tilapia production systems (13). In contrast, the second challenge—production cost—continues to pose a major constraint, as it is highly dependent on factors such as feed ingredient costs, marketing channel structures and oil price fluctuations (14). As the largest operational expense, feed costs continue to fluctuate and increase due to their heavy reliance on protein-rich ingredients such as fish meal, soybean meal and other imported feed components, which are affected by global market conditions and fuel. Thus, high production costs, particularly feed expenses, remain the most critical challenge in tilapia farming, accounting for more than 50% of total production costs (15, 16). Therefore, improving feed utilization and reducing feeding costs are key strategies for enhancing production efficiency and profitability. Although tilapia is widely recognized as a profitable aquaculture species, its economic success depends on the adoption of efficient production practices and sound cost management to ensure long-term sustainability (17, 18). In response, different approaches have been developed to help address this issue. Among of these strategies is the use of mixed feeding schedules—a practiced in semi-intensive aquaculture and formulate feeds from locally available ingredients to reduce the feed cost (19-21).

Despite the number of existing studies investigating the use of alternative feeds using locally available ingredients as a partial or complete substitute for commercial feeds, most studies have primarily focused on evaluating nutritional composition, feed efficiency, growth performance and survival rates. While these parameters are important for evaluating feed quality, they do not reflect the economic viability of adopting alternative feeds under actual farming conditions. Farmers ultimately make management decisions based not only on biological performance but also on production costs, profitability, return on investment and overall financial sustainability. Furthermore, the availability, quality and cost of local feed ingredients differ considerably among geographic regions because they depend on locally accessible agricultural by-products and agro-industrial waste. Moreover, variations in local feed resources, farming practices and market conditions across different regions highlight the need for location-specific evaluations. Therefore, a comprehensive assessment of growth performance together with economic indicators is essential to determine the practical feasibility and profitability of locally formulated feeds for tilapia farming. These limitations highlight the need for location-specific studies that combine biological performance with economic evaluation to determine whether locally formulated feeds can serve as a practical and financially sustainable alternative commercial diets.

In the present study, we evaluate the growth and economic performance of tilapia from fry to grow-out production using locally formulated feeds in comparison with standard commercial feeds. The overarching aim of this research is to develop cost-effective feeds derived from locally available ingredients and to determine their potential to enhance production efficiency, reduce dependence on imported feed inputs and improve the profitability of smallholder aquaculture systems.

Methodology

Study Site

The study was conducted at the Bureau of Fisheries and Aquatic Resources–Region XIII (BFAR-13) Masao Technology Outreach Station (MTOS) in Masao, Butuan City, Philippines (approximate coordinates: 8.9868° N, 125.4982° E). The grow-out phase was implemented at a selected fishpond operator site located in Trento, Agusan del Sur. Both locations are characterized by a tropical climate with average water temperatures ranging between 27–31 °C, suitable for tilapia culture. The experiment was carried out over a period of four months, from fry nursing to marketable size.

Experimental Design

A completely randomized design (CRD) was employed with two dietary treatments: T1 – Standard commercial tilapia feed (control) and T2 – Locally formulated tilapia feed (experimental). Each treatment was replicated in separate earthen ponds with similar surface areas and environmental conditions. Equal numbers of fry were stocked per pond to ensure uniform initial conditions. The experiment aimed to compare growth and economic performance between the two feeding strategies.

Feed Formulation and Preparation

The locally formulated feeds were prepared using regionally available raw materials following standard BFAR protocols. Key ingredients included fish meal from Tamban (Sardinella sp.) with 63.4% crude protein, soybean meal (40% CP), rice bran (11% CP), malunggay meal (25% CP) and duckweed meal (27% CP). Other ingredients such as cassava flour, coconut oil and powdered shells were incorporated as binders and energy sources. The locally formulated feeds were developed based on the nutritional composition of commercially available feeds in the market, using ingredients that are readily available and abundant in the local area to ensure accessibility and practical utilization by local livestock farmers. The feed preparation process involved weighing, grinding, mixing, pelleting and bagging. Dry ingredients were ground to achieve uniform particle size, then mixed thoroughly with liquids to form a homogenous blend. Pelleting was done using a pelletizer at BFAR-Masao and finished feeds were sun-dried to a moisture content of approximately 10–12% to prevent spoilage. Quality control checks were performed at each stage and feed samples were submitted to the Department of Agriculture–Integrated Laboratory Division (DA–ILD) for proximate analysis. Commercial feeds used in the control treatment were standard commercial starter, grower and finisher pellets commonly available in the Philippine market.

Fry and Fingerling Production

Tilapia fry was sourced from Bureau of Fisheries and Aquatic Resources–Region XIII (BFAR-13) hatchery and reared in nursery ponds at Masao Technology Outreach Station (MTOS). Prior to stocking, nursery ponds were completely drained, sun-dried for 1–2 weeks and limed to stabilize soil pH. Organic fertilizer (vermicast) was applied to promote the growth of natural food and water levels were gradually increased to 75–100 cm.

Fry were acclimated to pond conditions and stocked at a density of 25 fry m^{-2}. They were reared for 60–75 days until reaching fingerling size (1–1.5 inches), with a survival rate target of 85%. Natural food was provided initially, followed by fry booster, fry mash and starter crumble feeds, administered 3–4 times daily by broadcasting.

Grow-out culture Management

Fingerlings were transferred to grow-out ponds at a stocking density of 2 fish m^{-2}. This is to maximize the production output while maintaining the optimal growth performance and feed utilization of red tilapia. This stocking density is a critical management factor because it directly influences competitions for feed and space, stress levels and water quality. Culture duration lasted in 150 days. Both treatments were maintained under identical pond management protocols, including regular monitoring of water quality parameters and pond maintenance.

Feeding Regime

Starter pellets were fed for the first 30 days at 20% of estimated biomass, administered 3 times daily (08:00, 11:00, 16:00). Grower pellets were provided from day 31 to day 90 at 50% of total feed allocation. Finisher pellets were used from day 91 until harvest at 30% of feed allocation. The rations were adjusted biweekly based on Average Body Weight (ABW) determined through sampling. Feeding rates followed BFAR-recommended schedules for intensive pond culture.

Water Quality Management

Water depth was maintained at 0.8–1.0 m. Parameters including temperature, dissolved oxygen (DO), pH and transparency were monitored weekly using standard instruments (DO meter, pH meter, refractometer, Secchi disk). Pond water was partially replaced (30–60%) during low dissolved oxygen events or after heavy rainfall. Water quality is monitored to avoid deterioration that could increase high mortality rate (22-25).

Harvesting

After four months, fish were harvested by draining the ponds and using fine-mesh nets to minimize stress and physical damage. Harvested fish were immediately placed on ice at a 2:1 ice-to-fish ratio to maintain freshness before weighing and economic analysis.

Data Collection

Growth and production parameters were recorded throughout the culture period. Biweekly sampling of 30 fish per pond was performed to measure Average Body Weight (ABW) using Equation [1] and to monitor growth trends. This was done to determine the most important indicators of tilapia growth performance. Daily Feeding Rate (DFR) was measured using Equation [2], which provides an important information about feed intake and management and can directly influence tilapia growth and production efficiency. Feed utilization and growth efficiency were also calculated using the Feed Conversion Ratio (FCR) in Equation [3]; a lower value of indicates greater efficiency in both growth and feed utilization. Feed consumption and mortalities were also recorded daily. To address the economic performance and profitability for each feeding diets, the Return of Investment (ROI) were measured using Equation [4]. This indicator is included because it reveals whether an investment produces adequate financial returns, while growth indicators like ABW and FCR only show the biological performance of each diet.

Average Body Weight (ABW):

$$\text{ABW} = \frac{\text{Total Weight of Fish Randomly Sampled}}{\text{No.of Fish Sampled}} \qquad [1]$$

Daily Feeding Rate (DFR):

$$\text{DFR} = \frac{\text{SD x SR x ABW x FR}}{\text{1000grams}} \qquad [2]$$

Feed Conversion Ratio (FCR):

$$\text{FCR} = \frac{\text{Total Amount of Feeds Consumed}}{\text{Total Net Weight}} \qquad [3]$$

Where, SD – Stocking Density, SR – Survival Rate, ABW – Average Body Weight, FR – Feeding Rate.

Return on Investment (ROI):

$$\text{ROI} = \frac{\text{Net Income x 100\%}}{\text{Production Cost+Depreciation Cost}} \qquad [4]$$

Data Analysis

To assess whether the means for the local and commercial diets differed significantly, the data were subjected to independent-samples t-tests. Statistical significance was judged at $\alpha = 0.05$; results with $p < 0.05$ were considered statistically significant. Assumptions of normality and homogeneity of variances were examined.

Results and Discussion

Growth Performance

The growth performance of red saline tilapia fed with locally formulated feed and standard commercial feed is summarized in Table 1. Fish fed the commercial feed exhibited significantly higher ($p < 0.05$) average final weight (305 g) and weight gain (290 g) compared to those fed the locally formulated feed (207 g final weight; 192 g weight gain). Average final length and length increment did not differ significantly between treatments, although slightly higher values were observed in the commercial feed group (17.08 cm and 9.28 cm, respectively) compared to the locally formulated feed group (16.9 cm and 9.1 cm, respectively).

Interestingly, the FCR was significantly lower ($p < 0.05$) for the locally formulated feed [1.74] compared to the commercial feed [2.0], indicating better feed utilization efficiency in the locally fed group. Survival rates were similarly high and not significantly different between the two groups, both recording 95% survival throughout the 150-day culture period.

Economic Performance

The economic analysis revealed substantial differences between the two feeding regimes. Total feed consumption was considerably higher in the commercial feed group (1,158 kg) than in the locally formulated feed group (700 kg). Consequently, the total feed cost for the commercial feed group (Php 59,498.60 or 1,037.10

USD) was more than double that of the locally formulated feed group (Php 26,217.50 or 456.98 USD). While the commercial feed group achieved a higher total gross sales value (Php 81,060.00 or 1,412.93 USD) due to greater biomass production, the locally formulated feed group yielded a significantly higher gross profit (Php 30,177.58 or 526.01 USD) compared to the commercial feed group (Php 21,561.40 or 375.83 USD). The return on investment (ROI) was also markedly higher for the locally formulated feed, with an ROI of 115.1%, compared with 36.2% for the commercial feed, indicating superior economic efficiency of the local feed strategy, as shown in Table 1.

Table 1: Growth Performance, Survival Rate and ROI of Growing Tilapia Fingerlings in 150 Days

Parameters	T1- Control (Commercial Feeds)	T2- Experimental Feed (Locally Formulated Feeds)
Growth Performance		
Average final weight (g)	305.00^{a}	207.00^{b}
Average final length (cm)	17.08^{a}	16.90^{a}
Average weight gain (g)	290.00^{a}	192.00^{b}
Average length increment (cm)	9.28^{a}	9.10^{a}
Feed Conversion Ratio (FCR)	2.00^{b}	1.74^{a}
Survival rate (%)	95.00^{a}	95.00^{a}
Economic Indicators		
Total Feed Consumed (kg)	1158.00^{a}	700.00^{b}
Total Feed Cost (Php)	$59{,}498.60^{a}$	$26{,}217.50^{b}$
Total Gross Sales (Php)	$81{,}060.00^{a}$	$56{,}395.08^{b}$
Gross Profit (PhP)	$21{,}561.40^{b}$	$30{,}177.58^{a}$
ROI (%)	36.2^{b}	115.1^{a}

Note: Means within the same row followed by different superscript letters (a, b) are significantly different at $p < 0.05$, while means with the same superscript letter are not significantly different at $p < 0.05$.

The results reveal a clear trade-off between biological growth performance and economic efficiency. Fish fed commercial feed displayed superior growth metrics, which aligns with the well-documented effectiveness of commercial aquafeeds that are formulated to meet species-specific nutritional requirements and processed to maximize digestibility and nutrient availability (25). Extrusion technology and the use of high-quality protein sources in commercial diets typically lead to enhanced growth rates and larger final weights.

However, despite the slower growth of fish fed locally formulated feed, the significantly lower FCR indicates more efficient feed utilization. This suggests that the local feed provided nutrients in a form or combination that allowed for better conversion of feed into biomass. The use of locally sourced soybean meal ("bahug manchuria"), known for its high crude protein content (~45%) and favorable amino acid profile, likely improved digestibility and nutrient retention. Similar findings have been reported in studies demonstrating that high-quality soybean meal can successfully replace a significant portion of fish meal without compromising growth or FCR, provided amino acid supplementation is adequate (26-29). Feed physical characteristics may have also influenced FCR outcomes. Locally processed feeds, often produced in mash or crumble forms, can reduce feed wastage, leading to more complete consumption aside from it reduced feeding time (30-32). Additionally, feed stability plays a critical role in nutrient retention and efficiency (33, 34) found that stable pellets with low nutrient leaching contribute to improved FCR. If the local feed had better water stability or less fragmentation, this could explain the lower total feed consumption despite achieving comparable biomass.

From an economic standpoint, the study highlights the cost advantage of locally formulated feeds. While commercial feeds produced larger fish and higher gross sales, the higher feed cost and lower FCR ultimately led to a reduced ROI. In contrast, the locally formulated feed, being significantly cheaper and more efficiently utilized, resulted in higher profitability and ROI despite lower gross sales. This pattern is common in small-scale aquaculture systems where locally available ingredients can lower production costs without negatively affecting fish health or survival (35).

Survival rates remained equally high across treatments, indicating that both diets provided sufficient essential nutrients for maintenance and health. This suggests that the differences in performance were primarily due to nutrient formulation and feed processing quality rather than basic nutritional adequacy.

Conclusion

This study demonstrates that while commercial feeds produce superior growth performance, locally formulated feeds provide significantly better economic returns for red saline tilapia grow-out production. Fish fed commercial feed attained higher final weights and weight gains, reflecting the precise formulation and processing advantages of commercial diets. However, the locally formulated feed achieved a lower FCR, reduced feed cost and significantly higher ROI, making it a more economically viable option for small- and medium-scale tilapia producers. For farmers aiming to maximize production volume, commercial feeds remain the optimal choice. Conversely, for those prioritizing profitability and cost-efficiency, well-formulated local feeds represent a sustainable and profitable alternative. These findings support the promotion of local feed formulation strategies using high-quality local ingredients such as soybean meal, as a means to enhance the profitability and resilience of tilapia aquaculture systems in resource-limited settings.

This study does not include other important aquaculture nutrition indices such as Specific Growth Rate (SGR), Protein Efficiency Ratio (PER) and Condition Factor (K). Future studies should incorporate these parameters to provide a more comprehensive assessment of feed performance. Additionally, the possible seasonal variation in the nutrient composition of duckweed, rice bran and malunggay leaves was not examined and may influence feed consistency and effectiveness. Future research should investigate these variations and their effects on fish growth.

Abbreviation

ABW: Average Body Weight, DFR: Daily Feeding Rate, FCR: Feed Conversion Ration, FR: Feeding Rate, ROI: Return on Investment, SD: Stocking Density, SR: Survival Rate.

Acknowledgement

The authors thank the Philippine Rural Development Project (PRDP), BFAR–Caraga and Team Bahug (DA–Caraga) for conducting the experiment and supporting research activities. Special thanks to current RED Engr. Ricardo Oñate Jr. and former RED Engr. Arlan M. Mangelen for their guidance and to Mr. Ian D. Batitang (OIC, MTOS) and Ms. Omnia B. Olama (Regional Director, BFAR–Caraga) for administrative and technical support. The authors also acknowledge the Research, Development, Innovation and Extension Office of Caraga State University for funding the article processing charges.

Author Contributions

Grethyl C Jamero: Conceptualization, Data Analysis, Interpretation, Writing- Original Draft, Gemma A Asufre: Conceptualization, Data Analysis, Interpretation, Writing- Original Draft, Neciforo Jr. B Vallicer: Sampling, Laboratory Analysis, Manuscript Editing, Novelito A Digal: Sampling, Laboratory Analysis, Manuscript Editing, Dominador G Maputol: Sampling, Laboratory Analysis, Manuscript Editing, Johnny Magdura: Sampling, Laboratory Analysis, Manuscript Editing, Frederick U Omay: Sampling, Laboratory Analysis, Manuscript Editing, Karen Kate A Remorosa: Sampling, Laboratory Analysis, Manuscript Editing. All authors have given approval to the final version of the manuscript.

Conflict of Interest

The authors declare no conflict of interests.

Data Availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Declaration of Artificial Intelligence (AI) Assistance

This work was supported by the use of artificial intelligence (AI) to refine grammar and improve the manuscript's coherence and structure. Although AI tools were employed for linguistic editing, the authors maintain full responsibility for all interpretations, conclusions and the original conceptual content of the study.

Ethics Approval

This study did not involve human participants, animals, or sensitive data. Therefore, ethical approval and informed consent were not required.

Funding

The experimental component of this study was funded by the Philippine Rural Development

Project (PRDP), BFAR–Caraga, through the efforts of Team Bahug of the Department of Agriculture–Caraga. Publication funding was provided by Caraga State University.

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How to Cite: Jamero GC, Asufre GA, Vallicer NJB, Digal NA, Maputol DG, Magdura J, Omay FU, Remorosa KKA. Effects of Locally Formulated and Commercial Diets on the Growth and Economic Performance of Red Tilapia. Int Res J Multidiscip Scope. 2026;7(3):1379-1386. DOI: 10.47857/irjms.2026.v07i03.011236