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FEED EFFICIENCY VERSUS SURVIVAL RATE: DETERMINANTS OF PRODUCTIVITY IN SANGKURIANG CATFISH (*Clarias gariepinus*) CULTURED UNDER TROPICAL AQUACULTURE SYSTEMS IN LAMPUNG PROVINCE, INDONESIA

Efisiensi Pakan Versus Tingkat Kelangsungan Hidup: Penentu Produktivitas Ikan Lele Sangkuriang (*Clarias gariepinus*) Pada Sistem Budidaya Tropis di Provinsi Lampung, Indonesia

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ABSTRACT

Feed efficiency and survival rate are two key parameters determining the success and productivity of Sangkuriang catfish (*Clarias gariepinus*) aquaculture, particularly under intensive tropical culture systems. This study aimed to quantitatively analyze the relationship between feed efficiency and survival rate in determining the productivity of Sangkuriang catfish cultured in Lampung Province, Indonesia. The study was conducted over one production cycle using a completely randomized design with three different feed treatments (Feed A, B, and C), without specifying commercial brands, and using eight replicates. Observed parameters included feed conversion ratio (FCR), survival rate (SR), and biomass productivity. Data were analyzed using the Kruskal–Wallis test, correlation analysis, and multiple linear regression. The results showed that differences in feed formulation significantly affected feed efficiency, as indicated by variations in FCR. Still, they did not result in significant differences in survival rate or final productivity. Correlation analysis revealed a significant positive relationship between survival rate and productivity, while FCR showed a negative but statistically insignificant relationship with productivity. Regression analysis further confirmed that the survival rate was the dominant predictor of productivity, whereas feed efficiency primarily functioned as a factor optimizing resource utilization. This study concludes that under tropical aquaculture systems with low and stable mortality, productivity is more strongly determined by population stability than by variations in feed efficiency alone. These findings contribute to the understanding of productivity determinants in tropical catfish farming and provide practical insights for feed formulation strategies and aquaculture management aimed at improving efficiency and sustainability.

Keywords: Feed Efficiency, Productivity, Sangkuriang Catfish, Survival Rate, Tropical Aquaculture

ABSTRAK

Efisiensi pakan dan tingkat kelangsungan hidup merupakan dua parameter utama yang menentukan keberhasilan dan produktivitas budidaya ikan lele Sangkuriang (*Clarias gariepinus*), khususnya pada sistem budidaya tropis intensif. Penelitian ini bertujuan untuk menganalisis hubungan kuantitatif antara efisiensi pemanfaatan pakan dan tingkat kelangsungan hidup dalam menentukan produktivitas ikan lele Sangkuriang di Provinsi Lampung, Indonesia. Penelitian dilakukan selama satu siklus pemeliharaan menggunakan rancangan acak lengkap dengan tiga perlakuan pakan berbeda (Pakan A, B, dan C) tanpa mencantumkan merk dagang serta menggunakan 8 ulangan. Parameter yang diamati meliputi *feed conversion ratio* (FCR), *survival rate* (SR), dan produktivitas biomassa. Data dianalisis menggunakan uji Kruskal-Wallis, analisis korelasi, dan regresi linier berganda. Hasil penelitian menunjukkan bahwa perbedaan formulasi pakan berpengaruh signifikan terhadap efisiensi pemanfaatan pakan, namun tidak menimbulkan perbedaan yang nyata terhadap tingkat kelangsungan hidup maupun produktivitas akhir. Analisis korelasi menunjukkan bahwa tingkat kelangsungan hidup memiliki hubungan positif dan signifikan dengan produktivitas, sedangkan FCR menunjukkan hubungan negative namun tidak signifikan. Hasil regresi mengonfirmasi bahwa tingkat kelangsungan hidup merupakan prediktor utamaproduktivitas, sementara efisiensi pakan berperan sebagai faktor optimasi penggunaan sumber daya. Penelitian ini menyimpulkan bahwa pada sistem budidaya tropis dengan mortalitas rendah, produktivitas lebih ditentukan oleh stabilitas populasi ikan dibandingkan oleh variasi efisiensi pakan. Temuan ini memberikan kontribusi penting bagi pengembangan strategi formulasi pakan dan manajemen budidaya yang berorientasi pada keberlanjutan dan efisiensi produksi ikan lele di daerah tropis.

Kata Kunci: Budidaya Tropis, Efisiensi Pakan, Kelangsungan Hidup, Lele Sangkuriang, Produktivitas

INTRODUCTION

Indonesia is one of the countries with a rapidly growing freshwater aquaculture sector, particularly catfish (*Clarias gariepinus*) cultivation, including the superior Sangkuriang catfish variety. According to data from the Ministry of Maritime Affairs and Fisheries (2025), national catfish production continues to increase annually, reaching 1.13 million tons in 2023. This reflects the high domestic market demand for this commodity. Regionally, Lampung Province is one of the centers of freshwater fish production in Indonesia, contributing 34,590 tons of catfish production. The high intensity of catfish cultivation in this region places production system efficiency as a key factor in maintaining the sustainability of the cultivation business. In this context, feed efficiency and survival rate are two core parameters that determine the success of catfish cultivation and productivity, with feed contributing approximately 60-70% of total production costs (Amri & Aisyah, 2025). Therefore, improving feed utilization efficiency is crucial for reducing input costs, increasing aquaculture profits, and supporting the sustainability of aquaculture systems in tropical regions such as Lampung Province.

Feed efficiency reflects the ability of fish to convert feed into body biomass (feed conversion ratio and feed efficiency), where a low FCR value can reflect adaptation, health conditions, and the quality of the applied aquaculture management (Abdel-Aziz et al., 2021). In the context of Sangkuriang catfish cultivation, studies have shown significant variation in survival rates and feed utilization efficiency, influenced by feed formulation, feeding methods, and environmental conditions (Nuraisyah & Mukti, 2022).

Although several previous studies have discussed the effect of feed on the growth and

survival of catfish (Kovalenko et al., 2021; Tiamiyu et al., 2021), there is still limited understanding of the quantitative relationship between feed efficiency and survival rates in intensive culture systems in tropical environments. For example, studies on feeding locally sourced feeds show variations in feed efficiency and survival rates but have not explored the causal relationship between these variables in an integrated statistical manner, particularly in the Sangkuriang catfish population in Indonesia. In line with this, Melaku (2024) reported that *C. gariepinus* larvae fed local feeds with different protein levels (40%, 45%, and 50%) showed significant variations in feed conversion ratio (FCR) and survival rate (66.5-81.5%). However, the causal relationship between feed efficiency and survival rates has not been analyzed in depth.

Furthermore, the state of the art in aquaculture feed nutrition emphasizes an integrative approach that focuses not only on increasing growth but also on how efficient feeding strategies can maintain fish health, minimize feed waste and environmental impacts, and maximize fish biomass production and survival rates (Jimoh et al., 2024; Langi et al., 2024). This concept is crucial in addressing the challenges of modern aquaculture amidst global food demand pressures and resource constraints (Ruben et al., 2025). Especially for flagship species like the Sangkuriang catfish, which boasts rapid growth potential and high adaptability, a deeper understanding of the synergy between feed efficiency and survival rates is an urgent research need for optimizing sustainable aquaculture in tropical regions (Buwono et al., 2023).

In this context, this research focuses on a quantitative analysis of the relationship between feed efficiency and survival rate of Sangkuriang catfish (*C. gariepinus*) in a tropical aquaculture system in Lampung Province. This focus is intended to fill the gap in knowledge regarding the contribution of feed nutrient efficiency to catfish survival rate and productivity, and to provide empirical evidence that can serve as a basis for efforts to improve sustainable aquaculture practices. The research questions raised include: (1) To what extent does feed efficiency influence survival rate of Sangkuriang catfish?; (2) What nutritional or feed management parameters most dominantly influence this relationship?; and (3) How can statistical models explain variations in aquaculture productivity based on these two main variables?

Therefore, the primary objective of this study is to assess the strength and character of the quantitative relationship between feed efficiency and survival rate in Sangkuriang catfish under intensive tropical aquaculture conditions, while also testing the hypothesis that higher feed efficiency is positively and significantly correlated with higher survival rate, thus directly influencing overall aquaculture productivity. The research results are expected to provide theoretical and practical contributions to the disciplines of feed nutrition and aquaculture, as well as offer strategic recommendations for farmers and policymakers in improving aquaculture production efficiency.

METHODS

Research Time and Location

This research was conducted in a Sangkuriang catfish (*C. gariepinus*) culture system in Lampung Province, Indonesia, which represents tropical freshwater culture conditions. Culture activities were conducted in intensive culture units with controlled environmental management and common culture practices in the region. Culture activities took place from May 10 to July 25, 2025, encompassing one culture cycle with controlled environmental management until the fish reached harvestable size.

Materials and Equipment

This study used Sangkuriang catfish (*C. gariepinus*) fry of relatively uniform initial size as the test organisms throughout one culture cycle. The feeds used consisted of three types of

feed with different formulations, each coded as Feed A, Feed B, and Feed C, without including trademarks to maintain objectivity and ethical scientific publications. The culture medium used was freshwater, with water quality management tailored to the needs of catfish cultivation in an intensive system.

The equipment used in this study included a rearing container as the experimental unit, an aeration system to maintain dissolved oxygen availability, and a digital scale to measure fish biomass and feed intake. Additionally, water quality measuring instruments were used to monitor environmental parameters during culture, as well as supporting equipment such as nets, buckets, and other sampling equipment. All data recording equipment, both manual and electronic, was used to document fish production performance parameters throughout the study period.

Test Fish and Culture System

The test fish used in this study were Sangkuriang catfish (*C. gariepinus*) fingerlings with relatively uniform initial sizes. Prior to treatment, the fish were acclimatized to the culture environment to minimize initial stress. The fish were reared in an intensive freshwater culture system, where water quality was maintained within the optimal range for catfish culture through water exchange and aeration management. Stocking densities and environmental conditions were kept uniform across all treatments to ensure that observed differences in production performance were primarily due to the feeding treatment and not to variations in other environmental or managerial factors.

Feed Treatments and Experimental Design

This study used three types of feed with different formulations as the main treatments, with eight replications. To maintain research objectivity and comply with scientific publication ethics, which prohibit the use of trademarks, the three feeds are not named by their commercial names but are instead coded as Feed A, Feed B, and Feed C. This designation is intended to avoid interpretation bias and ensure that the evaluation of feed performance is based entirely on the biological responses of the Sangkuriang catfish (*C. gariepinus*), not on the identity of the feed manufacturer. Feed was provided to the Sangkuriang catfish at a dose of 4% of the total fish biomass per day throughout the rearing period. Feeding was carried out three times daily, at 8:00 a.m., 1:00 p.m., and 5:00 p.m., to ensure even feed distribution and increase nutrient utilization efficiency. The total feed given to each treatment was carefully recorded for the purposes of calculating the feed conversion ratio (FCR) and analyzing feed utilization efficiency.

To support the interpretation of the research results, a proximate analysis was conducted on the three types of feed to determine their basic nutritional characteristics, including moisture, ash, crude protein, crude fat, and crude fiber content. This composition information was used as a basis for evaluating the relationship between feed nutritional quality and feed utilization efficiency, survival rate, and productivity of Sangkuriang catfish. The proximate composition of each feed is presented in Table 1.

Table 1. Proximate Composition of Treatment Feeds

Types of Feed	Water Content (%)	Ash Content (%)	Crude Protein (%)	Crude Fat (%)	Crude Fiber (%)
Feed A	12	13	32	5	6
Feed B	12	12	36	6	7
Feed C	12	13	31	5	8

Note: Values are presented as averages. Moisture content is expressed on an as-fed basis, while ash, crude protein, crude fat, and crude fiber are expressed on a dry matter basis.

The three feed types were applied as treatments in a completely randomized design (CRD), with maintenance conditions and environmental management uniform across all experimental units. This approach aims to minimize the influence of non-treatment factors on fish production performance, so that observed differences in response can be more accurately attributed to differences in feed formulation.

Observed Parameters

The observed Sangkuriang catfish production performance parameters include:

1. Survival Rate (SR)
   Calculated as the percentage of fish surviving until the end of the rearing period compared to the number of fish at the beginning of the rearing period.
2. Feed Conversion Ratio (FCR)
   Calculated as the ratio of total feed provided to total fish biomass produced during the rearing period.
3. Productivity
   Expressed as the total biomass of Sangkuriang catfish produced per unit area or volume of the culture container at the end of the rearing cycle.

Data Analysis

Sangkuriang catfish production performance data were statistically analyzed using the nonparametric Kruskal-Wallis test to examine the effect of feed treatments on survival rate (SR), feed conversion ratio (FCR), and productivity. The Kruskal-Wallis test was chosen because the data were not assumed to be normally distributed and had heterogeneity of variance. Differences between treatments were declared significant at the 95% confidence level ($P < 0.05$). If the Kruskal-Wallis test showed a significant difference, the analysis continued with further nonparametric tests to identify differences between treatments. To analyze the relationships between production performance parameters, a correlation analysis was conducted between survival rate (SR), feed conversion ratio (FCR), and productivity. Correlation analysis was used to identify the direction and strength of the relationship between the main variables in the Sangkuriang catfish culture system in Lampung Province.

Next, multiple linear regression analysis was conducted to evaluate the relative contribution of survival rate and feed efficiency to productivity. In this regression model, productivity is used as the dependent variable, while SR and FCR are the independent variables. Regression analysis is used to identify factors that have a dominant influence on productivity when both parameters are analyzed simultaneously. All statistical analyses were performed using appropriate statistical software, and the results are presented as mean values ± standard deviations.

Analytical Framework and Conceptual Approach

The methodological approach in this study was designed to evaluate the productivity of Sangkuriang catfish as a multifactorial parameter influenced by the interaction between survival rate and feed utilization efficiency. The use of the Kruskal-Wallis test combined with correlation and regression analysis aims to provide a more comprehensive understanding of the determinants of productivity in tropical catfish aquaculture systems in Lampung Province.

RESULTS

Sangkuriang Catfish Production Performance under Different Feed Treatments in Lampung Province

The production performance of Sangkuriang catfish (*C. gariepinus*) farmed in a tropical

aquaculture system in Lampung Province with different feed treatments, including survival rate (SR), feed conversion ratio (FCR), and productivity, is presented in Table 2. These parameters are used as the basis for evaluating the effect of feed formulation on efficiency and production performance in intensive catfish aquaculture systems in tropical areas.

Table 2. Average Survival Rate (SR), Feed Conversion Ratio (FCR), and Productivity of Sangkuriang Catfish with Different Feed Treatments

Types of Feed	SR (Mean ± SD)	FCR (Mean ± SD)	Productivity (Mean ± SD)
Feed A	92.55^{a}±4.62	1.06^{c}±0.01	10.61^{a}±1.86
Feed B	90.16^{a}±7.96	0.97^{a}±0.02	10.83^{a}±1.59
Feed C	91.78^{a}±7.47	1.00^{b}±0.02	10.53^{a}±1.20

Note: Different superscripts in the same column indicate significant differences ($P < 0.05$).

The provision of different feed formulations for Sangkuriang catfish cultivation in Lampung Province did not significantly affect survival rates or final productivity. These results indicate that all feed types tested were able to meet the basic nutritional needs of catfish during the rearing period, thus supporting optimal survival and biomass accumulation. Conversely, feed utilization efficiency was significantly influenced by the type of feed provided, as reflected in differences in feed conversion ratio (FCR) values. Feed B demonstrated better feed efficiency than the other treatments, while Feed A produced a relatively higher FCR value. However, these differences in feed efficiency were not accompanied by significant differences in productivity, indicating a compensatory mechanism between feed efficiency and survival rates.

Analysis of the Relationship Between Survival Rate, Feed Efficiency, and Productivity of Sangkuriang Catfish in Lampung Province

The relationship between survival rate (SR), feed conversion ratio (FCR), and productivity in Sangkuriang catfish (*C. gariepinus*) culture in Lampung Province was analyzed to understand the relative contribution of each parameter to production performance in a tropical culture system. Correlation analysis was conducted to identify the direction and strength of the relationship between the main variables in the intensive catfish culture system, the results of which are presented in Table 3.

Table 3. Results of the Analysis of the Relationship between SR, FCR, and Sangkuriang Catfish Productivity

Variable	R	P
SR with FCR	0.222	0.297
SR with Productivity	0.528	0.008
FCR with Productivity	-0.086	0.688

Note: Only the survival rate (SR) showed a statistically significant correlation with productivity ($p < 0.05$).

The correlation analysis showed that the feed conversion ratio (FCR) had no significant relationship with the biomass productivity of Sangkuriang catfish ($p > 0.05$), indicating that variations in feed efficiency do not directly translate into differences in productivity under conditions of high survival rates. The analysis of the relationships between variables showed that the survival rate had a significant positive relationship with productivity, indicating that increasing the number of Sangkuriang catfish surviving to the end of the rearing cycle directly contributed to increased biomass output. Conversely, the feed conversion ratio showed a negative relationship with productivity, confirming that feed utilization efficiency is an

important factor in determining production performance. However, no significant relationship was found between the survival rate and the feed conversion ratio. This indicates that these two parameters operate relatively independently in influencing productivity, so changes in feed efficiency are not always followed by changes in survival rate, and vice versa.

Contribution of Survival Rate and Feed Efficiency to Sangkuriang Catfish Productivity in Lampung Province

A multiple linear regression analysis was conducted to evaluate the relative contribution of survival rate (SR) and feed conversion ratio (FCR) to the productivity of sangkuriang catfish (*C. gariepinus*) farmed in a tropical aquaculture system in Lampung Province. This approach was used to identify variables that have a dominant influence on productivity when both parameters are analyzed simultaneously. The results of the regression analysis are presented in Table 4.

Table 4. Multiple Linear Regression Analysis of the Effect of Survival Rate (SR) and Feed Conversion Ratio (FCR) on Biomass Productivity of Sangkuriang Catfish

Predictor Variables	Unstandardized Coefficients (B)	Standard Error	Standardized Coefficient (β)	t value	p value
(Constant)	6.578	7.662	0.000	0.859	0.400
SR	0.108	0.045	0.472	2.389	0.026
FCR	-5.717	7.310	-0.155	-0.782	0.443

Note: Dependent variable = Productivity. Only survival rate (SR) was statistically significant.

The results of the regression analysis showed that survival rate had a positive and significant contribution to the productivity of Sangkuriang catfish. This indicates that increasing the number of surviving individuals directly increases the total biomass produced during the rearing period. Conversely, the feed conversion ratio showed a negative contribution to productivity, but this effect was not statistically significant when analyzed together with survival rate. This finding indicates that, in the productivity prediction model, survival rate is a stronger predictor than feed efficiency. Thus, productivity variation in catfish farming systems in Lampung Province is explained more by fish population stability than by variations in feed utilization efficiency.

DISCUSSION

Sangkuriang Catfish Production Performance under Different Feed Treatments in Lampung Province

The high and relatively uniform survival rate of Sangkuriang catfish across all treatments indicates that the feed used did not negatively impact the fish's physiological condition. In aquaculture nutrition studies, survival is often used as an early indicator of feed safety and nutritional adequacy, particularly in controlled culture systems (Kutte et al., 2024; Hu et al., 2025). The absence of significant differences between treatments indicates that variations in feed formulation do not affect fish tolerance to environmental conditions in Lampung Province, as long as essential nutritional requirements are met and environmental quality is maintained (Idam & Degais, 2025).

Unlike survival, the feed conversion ratio shows a more sensitive response to differences in feed formulation. The lower FCR performance of feed B indicates higher nutrient utilization efficiency, which is likely related to raw material quality, protein-energy balance, and feed digestibility (Phan et al., 2022; Langi et al., 2024). Feed efficiency is a key parameter in catfish cultivation because it is directly related to production costs and environmental impact (Ojelade

et al., 2025). Feed with a low FCR not only reduces cultivation operational costs but also reduces the accumulation of residual nutrients in the water, thus supporting the sustainability of the culture system (Jimoh et al., 2024).

Despite significant differences in FCR, the final productivity of Sangkuriang catfish did not show significant differences between feed treatments. This suggests that productivity is a multifactorial parameter influenced by the interaction between survival rate, growth rate, and feed utilization efficiency (Diatin et al., 2021). The high survival rate across all treatments is thought to compensate for differences in feed efficiency, resulting in relatively equal productivity (Amri & Aisyah, 2025). This phenomenon is commonly reported in aquaculture nutrition studies, particularly in culture systems with low mortality and good environmental management, such as those used in catfish farming in Lampung Province.

From an application perspective, the results of this study indicate that all tested feed types are suitable for use in the Sangkuriang catfish culture system in Lampung Province because they are able to maintain high survival rates and productivity. However, feeds with better conversion efficiency offer additional economic and environmental benefits. Therefore, future development of Sangkuriang catfish feed should focus on increasing nutrient utilization efficiency through optimized feed formulations, the use of high-quality raw materials, and the application of feed processing technologies that improve nutrient digestibility and retention.

Overall, the results of this study confirm that differences in feed formulation in Sangkuriang catfish culture in tropical culture systems in Lampung Province have a greater impact on feed utilization efficiency than on survival and final productivity, thus making FCR a primary indicator in evaluating aquaculture feed performance under low mortality conditions.

Analysis of the Relationship Between Survival Rate, Feed Efficiency, and Productivity of Sangkuriang Catfish in Lampung Province

The positive relationship between survival rate and productivity confirms that survival rate (SR) is a fundamental component in determining the final yield of Sangkuriang catfish cultivation in Lampung Province. In tropical aquaculture systems, productivity is strongly influenced by the number of individuals surviving to harvest, especially under conditions where growth is relatively uniform (Diatin et al., 2021). This finding aligns with research (Hildebrand et al., 2024), which found that increased survival directly increases total biomass, even without significant changes in feed efficiency or individual growth rate. Therefore, culture management strategies and feed formulations capable of maintaining high survival rates remain a priority in intensive catfish farming systems.

The negative relationship between FCR and productivity indicates that the more efficient feed utilization, the higher the productivity that can be achieved. A low FCR value reflects the ability of Sangkuriang catfish to optimally convert feed into biomass, which is generally related to nutritional balance, raw material digestibility, and energy metabolism efficiency (Buwono et al., 2023). However, this relationship is not always linear in practice, as productivity is also influenced by other factors such as stocking density, environmental quality, and survival (Diatin et al., 2021). Therefore, FCR needs to be evaluated in conjunction with other biological parameters to obtain a more comprehensive picture of production performance.

The absence of a significant relationship between SR and FCR indicates that feed utilization efficiency does not directly affect the survival rate of Sangkuriang catfish within the conditions of this study. This suggests that as long as basic nutritional needs are met and the cultivation environment in Lampung Province is well maintained, catfish can maintain survival despite varying feed efficiency. This reflects a biological compensation mechanism, where final productivity is the result of a complex interaction between SR and FCR (Gagelonia et al., 2024).

Practically, the results of this study confirm that evaluating feed performance in Sangkuriang catfish cultivation in Lampung Province cannot rely on a single parameter. Survival rate plays a significant role in determining productivity, while feed efficiency contributes to optimizing resource use and environmental sustainability. Therefore, future aquaculture feed formulations need to be directed not only at improving feed conversion efficiency but also at maintaining fish physiological stability to maintain high survival rates, thus achieving optimal and sustainable productivity in tropical aquaculture systems.

Contribution of Survival Rate and Feed Efficiency to Sangkuriang Catfish Productivity in Lampung Province

The significant contribution of survival rate to productivity confirms that survival rate (SR) is a key factor in determining the final outcome of Sangkuriang catfish cultivation. In tropical aquaculture systems, productivity is primarily a function of the number of individuals that survive and reach harvestable size, so increased survival directly increases biomass output (Diatin et al., 2021). These results align with research by Wei et al. (2024), which states that production success is determined not only by individual growth efficiency but also by the system's ability to maintain the fish population throughout the rearing cycle.

Although feed efficiency is conceptually closely related to productivity, the effect of FCR in this regression model did not show statistical significance. This indicates that when survival rates are high and relatively stable, variations in feed efficiency have little contribution to productivity variation. This phenomenon indicates that the role of FCR in determining productivity is contextual and highly dependent on other biological and managerial conditions. Several previous studies have reported that feed efficiency is influenced by nutrient formulation and culture conditions. Under environmental stress, high-quality feed with an optimal energy-to-protein ratio is crucial for maintaining productivity and reducing mortality (Langi et al., 2024).

These regression results confirm that Sangkuriang catfish productivity is a multifactorial parameter that cannot be adequately explained by a single indicator. Survival rate acts as the primary structural factor determining production capacity, while feed efficiency plays a role in optimizing resource use within the constraints of the existing fish population (Basharat et al., 2024). Thus, increasing feed efficiency without stable survival does not always result in significant productivity increases. The interaction between these two parameters reflects a biological compensation mechanism commonly found in aquaculture systems with good environmental management and low mortality, such as catfish farming in Lampung Province.

From an applied perspective, the results of this study indicate that the development of aquaculture feed for Sangkuriang catfish needs to focus not only on increasing feed conversion efficiency, but also on the nutritional and functional aspects of the feed that support the fish's health, physiological resilience, and survival. Feed that can maintain physiological stability and reduce mortality will have a more significant impact on long-term productivity. Therefore, future feed formulation strategies should integrate functional nutrition approaches, raw material quality, and feed processing technology to support high survival and efficient nutrient utilization in tropical catfish aquaculture systems.

The Dominant Role of Survival Rate as a Determinant of Productivity in Tropical Aquaculture Systems

This study provides evidence that in intensive tropical aquaculture systems with high and relatively stable survival rates, productivity is determined more by fish population stability than by feed efficiency alone. Although the feed conversion ratio (FCR) showed significant differences between treatments, these variations were not accompanied by differences in final productivity. This indicates that high survival rates compensate for differences in feed

utilization efficiency, resulting in relatively uniform total biomass production. This finding confirms research (Hardiana, 2024) that in tropical aquaculture systems with low mortality, survival rates play a key structural role in determining production output.

Global Contextualization: Tropical Aquaculture Systems in Southeast Asia

Similar patterns have been reported in various tropical freshwater fish aquaculture systems in Southeast Asia, where the implementation of good water quality management and the use of feed with adequate basic nutrients enable the achievement of high survival rates. In this context, increased feed efficiency does not always translate directly to increased biomass productivity, especially when individual growth is relatively uniform and environmental stress is manageable (Sulis et al., 2025). Therefore, the sensitivity of productivity to changes in FCR is lower than the effect of fish population stability throughout the rearing cycle.

Comparison with Study on Clarias and Freshwater Omnivorous Fish

The results of this study align with the findings of Young et al. (2023), who found that other freshwater omnivorous fish cultured in tropical environments demonstrated that the role of feed efficiency on productivity is contextual and highly dependent on mortality rates and the intensity of the culture system. In culture conditions with high survival rates, the influence of FCR on productivity variation tends to decrease, while survival rates become more dominant. Conversely, in systems with high mortality or significant environmental stress, feed efficiency has been reported to have a stronger influence on production output.

Scientific Implications and Direction for Aquaculture Development

Overall, this study broadens our understanding of specific productivity factors in tropical fish aquaculture systems by confirming that survival rate is a key determinant of productivity under low-mortality conditions. Feed efficiency remains crucial for optimizing resource use and environmental sustainability, but increasing feed efficiency without stabilizing survival does not always result in significant productivity gains (Zahra et al., 2025). Therefore, future feed development and aquaculture management strategies should not only focus on reducing FCR, but also on improving the nutritional quality and functional aspects of feed to support fish health and maintain high survival in tropical aquaculture systems.

CONCLUSION

This study confirms that in the intensive tropical culture system of Sangkuriang catfish (*C. gariepinus*) in Lampung Province, variations in feed formulation significantly affected feed utilization efficiency, but did not cause significant differences in survival rates or final productivity. All tested feeds were able to meet the fish's basic nutritional needs, thus supporting high and relatively uniform survival rates. This finding suggests a biological compensation mechanism, where variations in feed efficiency do not directly translate into differences in productivity when survival rates are at optimal levels.

Correlation and regression analyses indicate that survival rates have a positive relationship and a significant contribution to productivity, while feed efficiency exhibits a negative but statistically insignificant relationship when analyzed in conjunction with survival rates. Thus, the hypothesis that higher feed efficiency directly correlates positively with increased survival and productivity is only partially confirmed. This places survival rates as the primary predictor of productivity in tropical catfish culture systems with low mortality, while feed efficiency plays a role in optimizing resource use.

Theoretically, this study reinforces the concept that aquaculture productivity is multifactorial and contextual, with fish population stability playing a dominant role under well-managed culture conditions. Practically and policy-wise, the results emphasize that strategies

to increase Sangkuriang catfish cultivation productivity should integrate efforts to improve feed efficiency with nutritional and environmental management that support fish health and survival. Further research is recommended to examine the dynamics of this relationship under more stressful culture conditions and to explore the role of functional nutrition in enhancing fish physiological resilience and the sustainability of the culture system.

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REFERENCES

Abdel-Aziz, M. F. A., Hassan, H. U., Yones, A. M., Abdel-Tawwab, Y. A., & Metwalli, A. A. A. T. (2021). Assessing the effect of different feeding frequencies combined with stocking density, initial weight, and dietary protein ratio on the growth performance of tilapia, catfish and carp. In *Scientific African*, *12*(2021). 1-15. https://doi.org/10.1016/j.sciaf.2021.e00806

Amri, M., & Aisyah, S. (2025). The effect of feeding frequency on the economic efficiency of catfish (*Clarias gariepinus*) cultivation: a linear regression approach. *Bioflux*, *18*(6). 2591–2603. http://www.bioflux.com.ro/aacl

Basharat, H., Ali, M. R., Ahmed, A., Anjum, M. Z., & Akhter, S. (2024). Growth and production characters of African catfish (*Clarias gariepinus*) stocked at different stocking densities in Earthen ponds under local climatic conditions of Pakistan. *Sarhad Journal of Agriculture*, *40*(2). 637–645. https://doi.org/10.17582/JOURNAL.SJA/2024/40.2.637.645

Buwono, I. D., A. H. S., A., Iskandar, & I., A. (2023). Growth performance in Sangkuriang catfish (*Clarias gariepinus* Var. Sangkuriang) and transgenic Mutiara catfish (*Clarias gariepinus*) using low protein feed. *Asian Journal of Biotechnology and Bioresource Technology*, *9*(3). 10–19. https://doi.org/10.9734/ajb2t/2023/v9i3184

Diatin, I., Shafruddin, D., Hude, N., Sholihah, M., & Mutsmir, I. (2021). Production performance and financial feasibility analysis of farming catfish (*Clarias gariepinus*) utilizing water exchange system, aquaponic, and biofloc technology. *Journal of the Saudi Society of Agricultural Sciences*, *20*(5). 344–351. https://doi.org/10.1016/j.jssas.2021.04.001

Gagelonia, J. D., Leslie, M., Marfil, M., Velasco, R. R., & Suyom, C. P. (2024). Feed maximization of combined culture of Nile tilapia *Oreochromis niloticus* and African catfish *Clarias gariepinus*. *Bioflux*, *17*(1). 352-359. http://www.bioflux.com.ro/aacl

Hardiana, F. (2024). Optimizing feed and water management in Super-intensive *Clarias gariepinus* grow-out: a case study from P2MKP raja lele. *Aquatic Life Sciences*, *1*(2). 53–57. https://doi.org/10.58920/aqlis0102330

Hildebrand, M. C., Hentrich, N., & Palm, H. W. (2024). The role of light in the rearing of *Clarias gariepinus* larvae: Effects on behaviour, growth and survival. *Aquaculture Reports*, *39*(2024). 1-9. https://doi.org/10.1016/j.aqrep.2024.102420

Hu, X., Dong, B., Chen, Z., Liu, H., Zhang, Z., Jin, J., Yang, Y., Han, D., Zhu, X., & Xie, S. (2025). Effects of dietary carbohydrate and protein levels on the growth performance, nutrient metabolism and flesh quality of channel catfish (*Ictarulus punctatus*). *Aquaculture Reports*, *41*(2025). 1-15. https://doi.org/10.1016/j.aqrep.2025.102712

Idam, O. A., & Degais, A. I. (2025). Effect of water quality parameters on Nutritive value of catfish, Khartoum state, Sudan. *International Journal of Multidisciplinary Research and Growth Evaluation*, *6*(2), 666–672. https://doi.org/10.54660/.ijmrge.2025.6.2.666-672

Jimoh, J. O., Rahmah, S., Omitoyin, B. O., Ajani, E. K., Jalilah, M., Okomoda, V. T., Torsabo, D., Fabusoro, A. A., Chang, Y. M., Chen, Y. M., & Liew, H. J. (2024). Growth performances of *Clarias gariepinus* juveniles fed with *Jatropha curcas* seed meal. *Aquaculture Reports*, *39*(2024). 1-13. https://doi.org/10.1016/j.aqrep.2024.102433

Kementerian Kelautan dan Perikanan Republik Indonesia. (2025). KKP Optimalkan serapan catfish dengan pertemukan asosiasi hulu-hilir. Diakses pada 29 Desember 2025. https://www.kkp.go.id/artikel/47014-kkp-optimalkan-serapan-cat-fish

Kovalenko, B., Kovalenko, V., Sharylo, D., Polishchuk, N., Korzh, O., & Kirakosian, A. (2021). Growth and survival of *Clarias* catfish (*Clarias gariepnus* B., 1822) at different stages of cultivation with the addition to the fodder of "Chiktonik." *Animal Science and Food Technology*, *12*(4). 26–37. https://doi.org/10.31548/animal2021.04.003

Kutte, M., Sogbesan, O., & Sambo, M. (2024). Growth performance and nutrient utilization of *Clarias gariepinus* fed processed rice chaff substituted diet. *International Journal of Fisheries and Aquatic Studies*, *12*(4). 147–151. https://doi.org/10.22271/fish.2024.v12.i4b.2956

Langi, S., Maulu, S., Hasimuna, O. J., Kaleinasho Kapula, V., & Tjipute, M. (2024). Nutritional requirements and effect of culture conditions on the performance of the African catfish (*Clarias gariepinus*): a review. In *Cogent Food and Agriculture*, *10*(1). 1-15. https://doi.org/10.1080/23311932.2024.2302642

Melaku, A. Y. (2024). Growth performance and survival of African catfish (*Clarias gariepinus*) larvae fed on locally formulated feeds. *EIAR-National Fisheries and Aquatic Life Research Center, Sebeta-Ethiopia*, *1*(2024). 1-10. https://doi.org/10.20944/preprints202407.1102.v1

Nuraisyah, A., & Mukti, R. C. (2022). Growth and survival of catfish (*Clarias gariepinus*) with addition of papain enzymes in feed at Karang Dapo village, Pagaralam, South Sumatera. *Acta Aquatica: Aquatic Sciences Journal*, *9*(1). 42–45. https://doi.org/10.29103/aa.v9i1.6067

Ojelade, O. C., Abdulraheem, I., Akinde, A. O., Bashiru, I. O., Iberia, D. K., Badmus, M. O., Abeng, M., & Achor, A. I. (2025). Unpredictable feeding patterns modulate the growth rate, haematological and behavioural responses of *Clarias gariepinus*. *Scientific African*, *28*(2025). 1-12. https://doi.org/10.1016/j.sciaf.2025.e02766

Phan, L. T. T., Kals, J., Masagounder, K., Mas-Muñoz, J., & Schrama, J. W. (2022). Energy utilisation efficiencies of digestible protein, fat and carbohydrates for African catfish (*Clarias gariepinus*). *Aquaculture Reports*, *23*(2022). 1-9. https://doi.org/10.1016/j.aqrep.2022.101051

Ruben, M. O., Akinsanola, A. B., Okon, M. E., Shitu, T., & Jagunna, I. I. (2025). Emerging challenges in aquaculture: Current perspectives and human health implications. In *Veterinary World*, *18*(1). 15–28. https://doi.org/10.14202/vetworld.2025.15-28

Sulis, D. B., Lavoine, N., Sederoff, H., Jiang, X., Marques, B. M., Lan, K., Cofre-Vega, C., Barrangou, R., & Wang, J. P. (2025). Advances in lignocellulosic feedstocks for bioenergy and bioproducts. In *Nature Communications*, *16*(1). 1-13. https://doi.org/10.1038/s41467-025-56472-y

Tiamiyu, A. M., Olatoye, I. O., Olayemi, O. A., Ekundayo, T. C., Adedeji, O. B., & Okocha, R. C. (2021). Medicinal plant feed additives enhanced survivability and growth performance of *Clarias gariepinus* (African catfish) against bacterial infection. *Microbiology Research*, *12*(4). 744–752. https://doi.org/10.3390/MICROBIOLRES12040054

Wei, L. S., Kari, Z. A., Kabir, M. A., Khoo, M. I., Azra, M. N., & Wee, W. (2024). Promoting growth and health of African catfish, *Clarias gariepinus*, through dietary novel supplement, ginger, zingiber officinale rosc, leaf powder. *Aquaculture Studies*, *24*(4). 1-10. https://doi.org/10.4194/AQUAST1719

Young, T., Laroche, O., Walker, S. P., Miller, M. R., Casanovas, P., Steiner, K., Esmaeili, N., Zhao, R., Bowman, J. P., Wilson, R., Bridle, A., Carter, C. G., Nowak, B. F., Alfaro, A. C., & Symonds, J. E. (2023). Prediction of feed efficiency and performance-based traits in fish via integration of multiple omics and clinical covariates. *Biology*, *12*(8). 1-22. https://doi.org/10.3390/biology12081135

Zahra, K., Mateen, A., Sehar, A., Sajid, A., Shahzadi, A., Babar, K., Aslam, N., Ali, N., Rimsha, & Asif, Z. (2025). Sustainable solutions: Integrating fish health and resource efficiency in aquaculture. In Gut Microbiota and Holistic Health: The Role of Prebiotics and Probiotics. *Unique Scientific Publishers*. *25*(1). 1-8. https://doi.org/10.47278/book.hh/2025.429