Journal of Aquaculture and Fish Health Vol. 14(1) - February 2025
P-ISSN: 2301-7309 / E-ISSN: 2528-0864
doi : 10.20473/jafh.v14i1.63715

Effectiveness Growth Performance and Feeding Efficiency of Tilapia (*Oreochromis niloticus*) Through Solid Bioslurry Feed in Floating Net Cages

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Received : 2024-09-28
Accepted : 2025-01-25

Keywords :
Bioslurry, Feed Efficiency, Floating Net Cages, Growth, Tilapia

Abstract

The biggest challenge in cultivation activities is the availability of sufficient quantities of feed with optimal nutritional content. Bioslurry is a local material from biogas production waste with good nutritional content. This research aims to determine the amount of solid bioslurry in feed composition that effectively increases fish growth and feed efficiency. This research used a complete design of 4 treatments and 3 replications (12 experimental units). The treatments tested were solid bioslurry as a substitute for corn flour, pollard flour, and fine bran with 0% (control) percentages, 5%, 10%, and 15%. The parameters observed were proximate bioslurry, specific growth rate, survival, feed efficiency, and feed conversion ratio. Data were analyzed using analysis of variance (ANOVA), followed by the W-Tuckey test. The proximate analysis of solid bioslurry shows crude protein was 5.54%, crude fiber 15.36%, BETN 7.19%, ash 34.13%, crude fat 0.53%, and water 37.25%. The best treatment is feed C with 5% bioslurry content produced growth of 31.5 g, the best feed efficiency (116.67%), and an FCR of 0.87%. In this research, information regarding feed formulations containing bioslurry can help make feed on tilapia fish raised in floating net cages for sustainable fisheries.

INTRODUCTION

Tilapia (*Oreochromis niloticus*) is a fishery commodity with excellent development potential. Tilapia cultivation is easy to do with a small risk of death, the ability to adapt to various environmental conditions, high reproductive rates, and resistance to environmental stress and disease. (Ritu *et al.,* 2024). Consumer demand for tilapia continues to show an increase. The primary source of tilapia for human consumption comes from aquaculture. Based on FAO (2022) data, tilapia is the world's third most widely cultivated type of fish, accounting for 9% of world production. By 2030, two-thirds of the world's fish will be supplied by aquaculture activities. (Li and Du, 2022; Zhang *et al.,* 2023a).

Cite this document as Jamaluddin, R., Suardi, A.H.A., Zaenab, S., Masriah, A. and Nurfadilah, 2025. Effectiveness Growth Performance and Feeding Efficiency of Tilapia (*Oreochromis niloticus*) Through Solid Bioslurry Feed in Floating Net Cages. *Journal of Aquaculture and Fish Health*, *14*(1), pp.79-90.

Cultivation technology has been developed in Indonesia. One of them is the floating net cage. Utilizing rivers for fish cultivation is commonplace in Indonesian waters. Cultivation technology in floating net cages is currently widely used by communities on the banks of the Jeneberang River. Floating net cage fish cultivation is an efficient and effective way of cultivating fish by utilizing rivers as a cultivation environment with large fish harvests. Floating net cage uses cheap, easy-to-obtain, durable, and environmentally friendly materials to reduce production costs.

Feed is an essential factor that must be considered when cultivating fish using floating net cage technology (Banerjee and Ray, 2017). Feed plays an important role because the availability of feed will affect the growth and survival of fish (Hao, 2016; Karimah *et al.,* 2018; Zhang *et al.,* 2023b). The most critical factor in raising fish is the availability of sufficient amounts of feed with good nutritional content to produce optimal growth (Syahrizal *et al.,* 2019). The ever-increasing cost of feed production presents quite a big challenge for tilapia farmers.

In general, tilapia farmers rely on artificial feed at very high prices, causing a decrease in the efficiency of the cultivation business (Zaenab and Massiseng, 2021). One way to reduce production costs is to use alternative raw materials with sufficient nutritional content sourced from non-commercial raw materials (Azaza *et al.,* 2020).

Independent feed uses abundant local raw materials and has good nutritional content. Bioslurry is waste from processing cow dung into biogas, which is easy to obtain and affordable. The significant increase in growth in feed with high bioslurry content indicates that bioslurry contains nutrients that can increase growth energy in milkfish (Zaenab *et al.,* 2022). Bioslurry also increases the value of soluble protein and bioslurry concentration in fish feed (Masriah *et al.,* 2024). Using easy and cheap raw materials, such as bioslurry, with sufficient nutritional content, is one strategy for overcoming feed problems in cultivation activities. Previous research shows that the best-quality catfish pellets contain 25% bioslurry composition, which can increase catfish growth (Hariyoko *et al.,* 2018). Making feed using bioslurry is expected to reduce the use of commercial feed to reduce production costs, especially feed costs, and the production of reared fish can increase along with high fish growth. Feed selection and feed management play an essential role in cultivation activities. This research aims to see the effectiveness of providing feed containing solid bioslurry on tilapia fish's growth and feed efficiency in floating net cages.

METHODOLOGY
Ethical Approval

No animals were harmed or treated inappropriately during this study. The test animals were handled properly, taking into account factors such as optimal environmental conditions, good water quality, and the availability of suitable feed.

Place and Time

This research was carried out from May to August 2024 in floating net cages in Balang Baru Village, Tamalate District, Makassar City. Bioslurry proximate measurements were carried out at the Feed Chemistry Laboratory, Faculty of Animal Husbandry, Hasanuddin University, and feed production was carried out at the Fisheries Laboratory, Cokroaminoto Makassar University.

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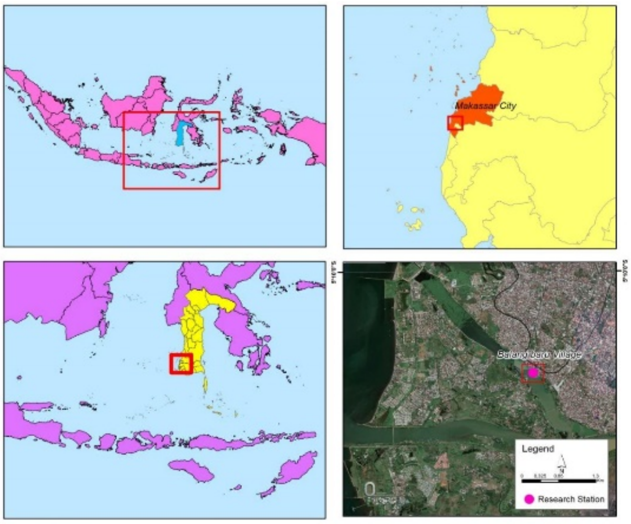

Figure 1. Map of research location.

Research Materials

The materials used are tilapia and artificial feed with bioslurry treatment. Meanwhile, the equipment used is a grinder and feed printer (JCW-10-2, China), blender (BL-102 PL, Indonesia), analytical scales (CH-305, Indonesia), floating net cages, and a ruler.

Research Design

The research design was completely randomized, consisting of 4 treatments and 3 replications (12 experimental), namely feed A (15% bioslurry), feed B (10% bioslurry), feed C (5% bioslurry), and feed D (control without bioslurry).

Work Procedure

Bioslurry preparation

Bioslurry comes from biogas reactor waste. The solid bioslurry taken is then dried in the sun for 2 days. After that, grind it until it becomes flour.

Feeding Experiment

The 120 tilapia (10 fish per treatment x 12 experimental) with an average body weight of ± 30 g were cultured for 40 days. They are fed twice a day, at 08.00 am and 04.00 pm. Sampling is carried out every 10 days. The tilapia used are shown in Figure 2. The floating net cages measuring 70 x 70 x 150 cm were made using green waring sewn in a rectangular shape. The treatment was arranged based on a completely randomized design. They were divided into 12 experimental units shown in Figure 3.

The research material is feed made with the feed raw material formulation used in this research presented in Table 1.

Figure 2. Tilapia (*Oreochromis niloticus*) used in this study.

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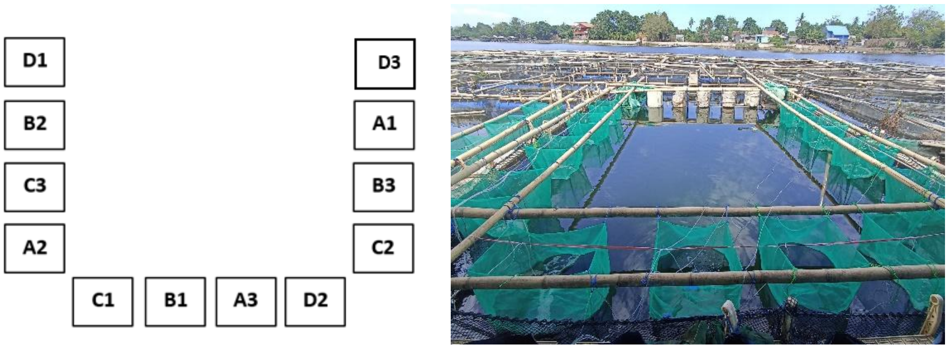

Figure 3. A floating net cage layout was used in this study.

Table 1. Feed formulation.

Raw Material	Percentages of feed (%)			
	A	B	C	D
Fish meal	30	30	30	30
Tofu dregs meal	25	25	25	25
Solid bioslurry	15	10	5	0
Pollard meal	8	10	12	14
Corn starch	7	9	11	13
Fine bran	5	6	7	8
Vitamins and minerals	5	5	5	5
Fish oil	5	5	5	5
Total	100	100	100	100

Table 2. Proximate content of fish feed.

Feed	Proximate (%)				
	Protein	NNFE	Fiber	Carbohydrate	Lipid
A	27.6	24.8	7.0	31.7	16.2
B	27.7	27.3	6.5	33.9	16.3
C	27.9	29.9	6.1	36.0	16.4
D	28.1	32.5	5.6	38.1	16.5

Parameters

The parameters observed were the proximate content of bioslurry, absolute weight growth (Wm), specific growth rate (SGR), survival rate (SR), Feed Conversion Ratio (FCR), and Feed Utilization Efficiency (FUE).

Proximate Analysis

The proximate analysis method of solid bioslurry is water, ash, crude protein, crude fat, crude fiber, and non-nitrogen-free extract (NNFE) by the Association of Official Analytical Chemists (AOAC, 1970).

Absolute Body Weight

Absolute body weight growth is calculated using the Effendie (1997):

$$Wm = Wt - Wo$$

Where:

Wm = absolute body weight (g)
Wt = final weight (g)
Wo = initial weight (g)

Specific Growth Rate (SGR)

The specific growth rate is the percent of the difference between the final and initial weight, divided by the length of maintenance time. According to Zonneveld *et al.* (1991), the formula for calculating specific growth rate is:

$$SGR = \frac{\ln Wt - Wo}{T} x100\%$$

Where:

SGR = specific growth rate (%),
Wo = average initial weight (gram),
Wt = final initial weight (gram),
T = time (days)

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Survival Rate (SR)

Survival rate (SR) is calculated using the formula (Effendie, 1997):

$$SR=\frac{No}{Nt-No} \times 100\%$$

Where:
SR = survival rate (%)
Nt = final number of tilapia
No = initial number of tilapia

Feed utilization efficiency (FUE)

Feed utilization efficiency is calculated using the following formula (Tacon, 1987):

$$FUE=\frac{Wt-Wo}{F} \times 100\%$$

Where:
FUE = feed utilization efficiency (%)
Wo = initial biomass of tilapia (g)
Wt = final biomass of tilapia (g)
F = amount of feed given (g)

Feed Conversion Ratio (FCR)

The feed conversion ratio (FCR) is calculated using the following formula (Effendie, 1997):

$$FCR=\frac{F}{(Wt+D)-Wo}$$

Where:
FCR = feed conversion ratio
F = amount of feed given (g)
Wt = final average weight (g)
D = weight of dead fish (g)
Wo = initial average weight (g)

Data Analysis

The variance values were analyzed using ANOVA with a confidence interval of 95%. Tuckey's test analyzed the difference between each treatment and the response. For proximate of solid bioslurry was analyzed descriptively.

RESULTS AND DISCUSSIONS

Proximate of solid bioslurry

Bioslurry results from biogas processing waste consisting of solid and liquid bioslurry. Solid bioslurry has the potential to be a source of nutrients for fish growth. Based on the proximate analysis results, solid bioslurry contains nutrients, as shown in Table 3.

Table 3. Proximate analysis of solid bioslurry.

Sample	Composition (%)					
	Water	Crude protein	Crude fat	Crude fiber	NNFE	Ash
Solid bioslurry	37.25	5.54	0.53	15.36	7.19	34.13

In the aquaculture industry, various research has been carried out to obtain sources of raw materials with cost-effective and balanced nutrition. The feed in the aquaculture industry increases every year, and this can be achieved by utilizing local raw materials that are underutilized but have good nutritional content. These nutrients must be per the needs of the fish and can increase feed efficiency and fish growth (Hidayat *et al.*, 2013). The feed contains balanced nutrition important for the fish's growth, development, and health (Dawood, 2021).

Bioslurry is waste from biogas made from cow dung, which is put into the reactor. Utilizing bioslurry as a raw material for making feed is an effective solution to reduce high production costs in aquaculture activities. Proper handling of bioslurry is essential to encourage sustainable fisheries and overcome environmental pollution. Analysis of the nutritional content of bioslurry provides information regarding the nutritional composition contained in bioslurry, which can be used as a raw material for making fish feed. The nutritional composition of feed includes carbohydrates consisting of crude protein, crude fiber, NNFE, ash, crude fat, and water. Based on the research results, the proximate content of bioslurry shows the amount of crude protein 5.54%, crude fiber 15.36%, NNFE 7.19%, ash 34.13%, crude fat 0.53%, and water 37.25% (Table 3).

The fiber and non-nitrogen extract content in fish feed needs to be considered because it is related to the components of organic matter that can be digested and the energy produced. Based on the analysis results, the crude fiber content was 15.36%, and NNFE was 7.19%. The fiber content in bioslurry comes from cow dung that eats plants such as straw, leaves, or grass. Even though fish do not need large amounts of fiber, the presence of fiber in feed is essential to increase digestive efficiency, prevent health problems, and improve feed and water quality.

The price of protein source raw materials is the most expensive in fish feed formulation. Suppose the feed does not contain enough energy sources from carbohydrates and fat. In that case, the fish will use protein as the primary energy source, reducing its efficiency for muscle growth and other body functions. The presence of 7.19% NNFE in feed can reduce the use of protein as an energy source so that protein can be used for growth and tissue repair. The low protein content of bioslurry, namely 5.54%, is caused by the protein decomposition process in anaerobic fermentation and the loss of nitrogen in gas form.

Ash is an indicator of the mineral content in feed. The results of measuring the ash content in bioslurry showed 34.13%. The minerals contained in ash are essential for various physiological functions of fish and play an important role in the growth and development of bone and tissue structures. For tilapia, minerals such as calcium and phosphorus are necessary to develop bones and tissue and achieve optimal growth. The right ash content in the feed is important to maintain the nutritional balance of fish and prevent mineral deficiencies, which can affect fish health and performance of fish in cultivation.

Fat in fish feed has a vital function as an energy source, energy storage, and provider of essential fatty acids, which support various aspects of fish's growth, reproduction, health, and body function. Fat also helps absorb vitamins and maintains the integrity of cell membranes. The right amount and type of fat is vital to ensure fish can grow optimally and healthily. The results of the bioslurry fat content analysis were 0.53%. The low-fat content in bioslurry results from an efficient anaerobic fermentation process, where fat is broken down and converted into biogas.

Absolute Growth and Specific Growth Rate

The results showed that solid bioslurry had a significant effect on absolute growth and specific growth rate (SGR) and no significant impact on survival rate (Table 4). The results show feed C has the best growth, with a bioslurry content of 5%. The results of analysis of variance (ANOVA) can be seen in Tables 5, 6, and 7.

Table 4. Effect of solid bioslurry concentration in fish feed on absolute growth, specific growth rate, and survival rate of tilapia (*Oreochromis niloticus*).

Treatments	Parameter ± std		
	Absolute growth (g)	Specific growth rate (g)	Survival rate (%)
A (15% bioslurry)	25,50±1.00^{ab}	18.08±0.53^{ab}	100.00±0.00^{a}
B (10% bioslurry)	18.83±3.82^{a}	14.27±2.27^{a}	96.67±5.77^{a}
C (5% bioslurry)	31.50±3.97^{b}	21.07±1.87^{b}	96.67±5.77^{a}
D (control without bioslurry)	18.50±5.22^{a}	14.00±3.27^{a}	83.33±15.27^{a}

Note: Superscript letters in the same table indicate significant differences between treatments (sig.<0.05) at the 95% confidence level.

Table 5. Results of analysis of variance (ANOVA) concentration of solid bioslurry fish feed on absolute growth of tilapia (*Oreochromis niloticus*).

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	344.250	3	114.750	7.835	0.009^{s}
Within Groups	117.167	8	14.646		
Total	461.417	11			

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S: Significant

Table 6. Results of analysis of variance (ANOVA) concentration of solid bioslurry fish feed on the daily growth rate of tilapia (*Oreochromis niloticus*).

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	102.235	3	34.078	6.941	0.013[s]
Within Groups	39.276	8	4.909		
Total	141.511	11			

S: Significant

Feed is an important factor for fish growth. Artificial feed is fed with a particular composition consideration that can satisfy the nutritional needs of fish. The components in the feed determine whether the feed given to the fish is good. Based on the results of ANOVA. It shows that the best absolute growth and specific growth rate is feed C with a bioslurry content of 5%, namely 31.5 g (Table 4). Bioslurry with 5% of the total feed can provide a good growth effect for tilapia.

Furthermore, test results showed that feed C significantly differed in absolute growth (Table 5) and specific growth rate (Table 6). Feed A, with a bioslurry content of 15%, also showed a high growth rate and was not significantly different from feed C. Balanced nutritional content in the feed, especially protein, carbohydrates, and fat, is essential for the growth of tilapia (Konnert *et al.,* 2022). The feed formulation in the treatment contained 5% and 15% bioslurry suitable for tilapia growth to obtain optimal growth results. The NNFE content in bioslurry can be used directly by tilapia for its growth process. Feed B, containing 10% bioslurry, showed a low growth rate, and feed D, without bioslurry or control, showed the lowest growth compared to the other treatments. The nutrients in the control feed are insufficient to provide optimal growth.

Daily Growth Rate

The tilapia's daily growth rate is maintained for 40 days, and weight measurements are carried out every 10 days. The results obtained are presented in Figure 4.

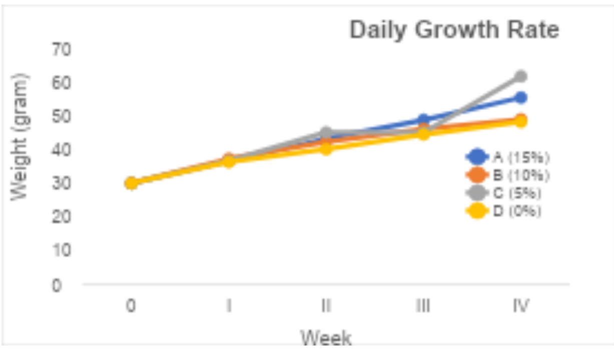

Figure 4. Daily growth rate chart.

The daily growth rate aims to measure the fish's growth every day. Commercial tilapia cultivation requires optimal feed formulation and increases the daily growth rate (Stauffer *et al.*, 2022). The nutritional needs of tilapia correlate with the age and size of the fish (Montoya-Camacho *et al.*, 2019); therefore, the daily growth rate is measured to determine the amount of feed given each day. Based on the research results, feed with 5% bioslurry (feed C) showed the best daily growth rate (Figure 4). Followed by treatment with 15% bioslurry content (feed A). The control treatment (feed D) showed the lowest daily growth rate.

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The control feed showed the lowest growth because the nutritional composition of the feed was only sufficient for activities, resulting in low energy used for growth. The nutrients contained in the feed will be converted into energy for activities, and the excess will be used for growth (Gamboa-Delgado, 2022). Sustainable tilapia culture requires high-quality and balanced feed, which includes not only basic nutritional needs such as protein, lipids, carbohydrates, vitamins, and minerals but also functional additives (Gule and Geremew, 2022). In this study, bioslurry with optimum content (5%) was able to provide an effect that could increase daily growth in fish farming.

Survival Rate

Table 7. Results of analysis of variance (ANOVA) concentration of solid bioslurry fish feed on the survival of tilapia (*Oreochromis niloticus*).

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	491.667	3	163.889	2.185	0.168 [ns]
Within Groups	600.000	8	75.000		
Total	1091.667	11			

ns: nonsignificant.

This study's Measurement of survival rates showed no significant differences between treatments (Table 7). However, based on the research results, feed D without bioslurry (control) showed the treatment with the highest fish mortality rate compared to other treatments containing bioslurry. This indicates that the bioslurry content in feed can improve fish's health and survival rate. The balance of nutritional content in feed containing bioslurry can play a positive role in supporting healthy fish growth and increasing yields in cultivation. So far, antibiotics have been added to tilapia feed to prevent disease, increase growth rate, and improve animal survival (Vijayaram *et al*., 2024). However, the inappropriate use of antibiotics in tilapia cultivation has increased the emergence of side effects in the aquaculture process (Bortolotte *et al*., 2021). Therefore, in recent years, a search has been carried out for additional feed raw materials derived from nature without the side effects of antibiotics (Vijayaram *et al*., 2024). In this study, bioslurry also contains good microbes that can produce enzymes that play a role in fish digestion (Zhao *et al.,* 2013) and can improve fish survival.

Feed Utilization Efficiency (FUE) and Feed Conversion Ratio (FCR)

Research shows that feeding feed containing bioslurry has a significant effect on feed utilization efficiency and feed conversion ratio (Table 8). The variance analysis (ANOVA) results for FUE and FCR are presented in Tables 9 and 10.

Table 8. Effect of solid bioslurry concentration in fish feed on feed utilization efficiency and food conversion rate of tilapia (*Oreochromis niloticus*).

Treatment	Parameter±std	
	FUE (%)	FCR
A (15% bioslurry)	94.44±3.71[ab]	1.03±0.26[a]
B (10% bioslurry)	69.74±14.12[b]	1.03±0.18[ab]
C (5% bioslurry)	116.67±14.69[a]	0.87±0.10[a]
D (control without bioslurry)	68.52±19.33[b]	1.73±0.43[b]

Note: Superscript letters in the same table indicate significant differences between treatments (sig.<0.05) at the 95% confidence level.

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Table 9. Results of analysis of variance (ANOVA) of solid bioslurry concentration in fish feed on the efficiency of using tilapia feed (*Oreochromis niloticus*).

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	4723.037	3	1574.346	7.844	0.009
Within Groups	1605.715	8	200.714		
Total	6328.752	11			

S: Significant

Table 10. Results of analysis of variance (ANOVA) of solid bioslurry concentration in fish feed on the food conversion ratio of tilapia (*Oreochromis niloticus*).

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1.281	3	0.427	7.369	0.011
Within Groups	0.463	8	0.058		
Total	1.744	11			

S: Significant

Biological mechanisms can influence feed efficiency, including growth, nutrient utilization, and feed intake (Esmaeili *et al.,* 2022). Nutritional requirements, especially macronutrients such as protein, lipids, and carbohydrates, must be balanced with the energy level of the feed because nutritional imbalances can affect fish metabolism (Alam *et al.,* 2020). The FUE in this study shows that feed C with 5% bioslurry obtained the most significant value, 116.67%, followed by treatment A at 94.44%. Furthermore, treatment B was 69.74%, and the smallest FUE value was found in feed D (without bioslurry), namely 68.52% (Table 8). The difference in FUE values between treatments is because the nutritional and energy content influences the use of tilapia feed in the feed. Based on further test results (Table 9), it shows that the treatment with the best FUE is feed C and is not significantly different from feed A but is substantially different from feed B and D. The nutritional composition of feed C and A is by the needs of tilapia fish and can be utilized effectively, suitable for meeting energy and growth needs thereby increasing the FUE value. Based on data from Biogas Technology Training Materials (2010), the nutritional content in bioslurry is amino acids, fatty acids, organic acids, humic acids, vitamin B-12, the hormone auxin, cytokinins, antibiotics, and micronutrients. Feeding without bioslurry shows an imbalance in nutritional content and also causes inhibition of the performance of enzyme activity responsible for digestion in fish. Because the performance of enzymes is specific (Zaenab *et al*., 2020), the fish's ability to digest and absorb nutrients effectively is reduced.

The feed conversion ratio is the ratio between the feed consumed and the increase in fish weight. The feed conversion ratio depends on the feed's species, cultivation conditions, and nutritional composition. Based on the research, the best FCR value of 0.87 was shown in feed C with a bioslurry content of 5% (Table 8). The lower the FCR value, the b, the better the feed conversion ratio. The highest FCR value, 1.73, was shown in feed D, treated without biolsurry (control). Feed without adding bioslurry can increase the feed conversion value, which means fish need more feed to increase body weight gain. The FCR value for treatment C feed is below 1 because the fish in floating net cages contain a lot of natural feed. This makes the feed conversion ratio value low, which means that natural feed is directly related to increasing fish production and the cultivation environment (Pěnka *et al*., 2023). The results of further testing (Table 10) show that the FCR values between treatments are significantly different. The right feed formulation strategy, feeding amount, and frequency can prevent stunted

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growth due to insufficient feeding or excessive feeding (Huang *et al.,* 2024).

CONCLUSION

Based on the results of the proximate analysis of solid bioslurry, the amount of crude protein was 5.54%, crude fiber 15.36%, NNFE 7.19%, ash 34.13%, crude fat 0.53%, and water 37.25%. From the research results, it can be concluded that feeding with 5% bioslurry content (feed C) can provide the best growth rate and feed efficiency for tilapia kept in floating net cages. Absolute weight gain was 31.5 g, daily growth rate 21.07 g, survival 96.67%, FUE 116.67% and FCR 0.87. The nutritional balance contained in the feed formulation with 5% bioslurry nutritional content can show optimal results.

CONFLICT OF INTEREST

The authors declare no conflicts of interest upon writing and publishing this manuscript. All authors have approved the manuscript for publication and are not being submitted to any other journal.

AUTHOR CONTRIBUTION

RJ formulated the research idea, and AH, SZ, and NN developed and designed the experiments. SZ makes feed, and RJ, AH, and NN carry out fish maintenance from stocking to harvest. AM processes research data. All authors contributed significantly to this publication from the beginning to the end of the research.

ACKNOWLEDGMENT

The author thanks the Ministry of Education, Culture, Research and Technology of the Republic of Indonesia for providing funding through the 2024 Peneliti Dosen Pemula (PDP) program.

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