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Growth Performance of Nile Tilapia (*Oreochromis niloticus*) Fed Liquid Bioslurry-Supplemented Feed in Floating Net Cages

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ABSTRACT

This study aimed to evaluate the effect of liquid bioslurry supplementation in feed on the growth performance and body composition of Nile tilapia (*Oreochromis niloticus*) cultured in a floating net cage (FNC) system. The experiment was conducted from June to September 2024 in the waters of Makassar, using a Completely Randomized Design (CRD) with four concentrations of liquid bioslurry: A (33.33mL/100g of feed), B (66.66mL/100g), C (100mL/100g), and D (133.33mL/100g), each with three replicates. Observed variables included absolute growth, specific growth rate, survival rate, feed efficiency, feed conversion ratio, and body composition (crude protein, fat, fiber, ash, and nitrogen-free extract). The results showed that the addition of liquid bioslurry had a significant effect on the growth and feed efficiency of Nile tilapia ($P<0.05$). Treatment C (100mL/100g of feed) produced the best results in terms of absolute growth, feed efficiency, and body protein content. Quadratic regression analysis indicated that the optimal dosage of liquid bioslurry ranged between 95–105mL/100g of feed. In addition, water quality remained within acceptable ranges for aquaculture throughout the study period. The use of liquid bioslurry as a feed additive shows potential as an economical, environmentally friendly supplement that supports the principles of the circular economy in aquaculture. These findings highlight the opportunity to utilize livestock waste as a natural probiotic source in Nile tilapia farming.

Keywords: *Oreochromis niloticus*, Liquid bioslurry, Fish feed, Floating net cages, Fish growth.

INTRODUCTION

Aquaculture has rapidly developed as a solution to overfishing issues (Gephart et al. 2021; Nugroho et al. 2020). One of the key commodities is Nile tilapia (*Oreochromis niloticus*), which ranks third globally in aquaculture production due to its fast growth, high environmental tolerance, and stable market demand (FAO 2022).

One commonly used farming technology is the Floating Net Cage (FNC) system, recognized for its efficiency and environmentally friendly characteristics (Aizonou et al. 2021; FAO 2024). Nile tilapia is widely cultured in FNCs, particularly in reservoirs, lakes, and rivers (Nugroho et al. 2020; Wiradana et al. 2022; Junaidi et al. 2022). This system allows for high stocking densities but requires proper feed management to support fish growth and maintain environmental quality (Lamo et al. 2023).

Feed accounts for over 60–70% of total production costs, posing a major challenge for small to medium-scale farmers. Consequently, the development of more affordable and sustainable feeds using locally sourced ingredients has become a key focus (Hansen 2019). A good feed should be easily digestible and rich in nutrients (Zaenab et al. 2025). One innovative approach is the inclusion of bacteria that produce digestive enzymes (protease, amylase, lipase), which help break down complex compounds into simpler, more absorbable forms for the fish.

A promising source of probiotic bacteria is liquid bioslurry, a by-product of biogas fermentation based on livestock manure (Zaenab et al. 2025; Masriah et al. 2025). Bioslurry contains essential nutrients such as nitrogen, phosphorus and potassium (Azile et al. 2022; Kumar et al.

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2023), as well as beneficial microorganisms like *Lactobacillus*, *Bacillus* spp., and *Methanobacillus actinomycetes* (Hidayati et al. 2018; Islam et al. 2019; Lara-Moreno et al. 2022). Identified *Bacillus* species include *B. subtilis*, *B. licheniformis*, *B. idriensis*, *P. cineris*, *P. cookii*, and *B. cereus* (Dubey et al. 2014; Jamaluddin et al. 2025; Zaenab et al. 2025).

These microbes can enhance nutrient availability, degrade crude fiber (Dubey et al. 2014), improve digestibility, and strengthen the immune system of fish (Liaqat et al. 2024). Other studies have shown that bioslurry can also serve as a natural probiotic that improves gut microbiota and nutrient absorption in Nile tilapia (Kusuma and Afrianisa 2021; Mulu et al. 2025). Furthermore, the use of bioslurry supports circular economy principles by reducing livestock waste and recycling it into the aquaculture sector.

However, the use of liquid bioslurry as a feed supplement for Nile tilapia, especially in FNC systems, remains limited. This study aims to evaluate the effect of different concentrations of liquid bioslurry in feed on the growth performance of Nile tilapia cultured in FNCs. The findings are expected to offer an alternative feed solution that is cost-effective, environmentally friendly, and supports sustainable tilapia aquaculture.

MATERIALS AND METHODS

Research location and duration

The study was conducted from June to September 2024 at a floating net cage (FNC) system located in Balang Baru Subdistrict, Makassar. Feed preparation was carried out at the Fisheries Laboratory of Cokroaminoto University Makassar, while the liquid bioslurry was collected from Kanaungan Village, Pangkajene and Islands Regency.

Experimental design

This study employed a Completely Randomized Design (CRD) with four levels of liquid bioslurry concentration in the feed: A (33.33mL/100g), B (66.66mL/100g), C (100mL/100g) and D (133.33mL/100g), each with three replicates, resulting in a total of 12 experimental units. All units were randomly assigned to minimize environmental bias in the results.

Bioslurry preparation and feed formulation

The liquid bioslurry was collected from the outlet of a biogas digester using livestock manure as substrate. It was filtered to remove coarse particles and stored in non-metallic containers to avoid heavy metal contamination. The feed formulation consisted of fish meal (30%), tofu residue (25%), solid bioslurry (15%), wheat pollard (8%), cornmeal (7%), fine rice bran (5%), fish oil (5%), and vitamin-mineral premix (5%). After mixing and pelleting, the feed was dried and then coated with liquid bioslurry according to each treatment. The mixture was re-dried and stored in sealed containers.

Experimental fish and maintenance

The test animals used in this study were Nile tilapia (*O. niloticus*) fingerlings with an initial average weight of approximately ±10grams. Before stocking in the FNC system, the fish were acclimated to the farming environment. Each experimental unit contained fifteen fish. Feed was administered at 5% of total biomass per day over a 60-day rearing period. Sampling was conducted every seven days to adjust feeding rates and monitor growth performance.

The primary parameters observed included growth performance indicators: absolute growth, specific growth rate (SGR), survival rate (SR), feed conversion ratio (FCR), and feed efficiency. In addition, proximate analysis of fish body composition was conducted to assess crude protein, crude fat, crude fiber, nitrogen-free extract (NFE), and ash content, following AOAC (2005) methods. Water quality was monitored regularly, including temperature, pH, dissolved oxygen (DO), ammonia, and nitrate levels (Boyd 1998).

Data Analysis

Growth performance and body composition data were analyzed using one-way analysis of variance (ANOVA), followed by Tukey's post-hoc test if significant differences were found ($P<0.05$). A quadratic polynomial regression was used to determine the optimal dosage of liquid bioslurry (Steel and Torrie 1997). All statistical analyses were performed using SPSS, and data visualization was conducted with Orange Data Mining.

RESULTS AND DISCUSSION

The response of Nile tilapia (*O. niloticus*) fed diets containing various concentrations of liquid bioslurry and reared in FNC is presented in Table 1. The evaluation focused on several key variables reflecting the growth performance of the test fish, including absolute growth, specific growth rate (SGR), survival rate, feed conversion ratio (FCR), feed efficiency, and the chemical composition of the fish body.

Table 1: Effect of liquid bioslurry concentration in feed on growth performance and body chemical composition of Nile tilapia (*Oreochromis niloticus*)

Variable	Treatments (mL/100g feed)			
	33.3	66.7	100	133.3
Absolute growth (g)	30.17±6.01[a]	19.67±1.04[b]	20.83±1.52[ab]	23.17±4.48[ab]
Specific growth (%)	20.36±2.95[a]	14.82±0.62[b]	15.49±0.88[ab]	16.75±2.54[ab]
Survival rate (%)	63.33±5.77[a]	86.67±5.77[b]	96.67±5.77[b]	96.67±5.77[b]
FCR	1.030±0.026[a]	1.300±0.176[b]	0.866±0.104[ab]	1.730±0.435[b]
Feed Efficiency (%)	94.443±3.705[ab]	69.743±14.123[a]	116.667±14.695[b]	68.520±19.331[a]
Chemical composition of tilapia ±STD (%)				
Crude protein	84.16±0.155[a]	86.53±0.115[b]	87.20±0.190[c]	83.95±0.040[a]
Crude fat	1.36±0.030[a]	1.02±0.001[b]	1.57±0.010[c]	1.73±0.040[d]
Crude fiber	0.66±0.030[a]	0.69±0.020[a]	0.46±0.030[b]	0.54±0.030[c]
Nitrogen-free extract	7.65 ±0.040[a]	5.62 ±0.010[b]	3.95 ±0.030[c]	6.68 ±0.010[d]
Ash	6.17±0.020[a]	6.14±0.020[a]	6.18±0.020[b]	7.10±0.010[c]

Values (mean+SD) bearing different superscript letters in the same row indicate significant differences among treatments ($P<0.05$).

Based on the results of the analysis of variance (ANOVA), the addition of liquid bioslurry to the diet of Nile tilapia cultured in FNC had a significant effect ($P<0.05$) on all observed variables, including absolute growth, specific growth rate (SGR), feed conversion ratio (FCR), feed efficiency, and the chemical composition of the fish body. This indicates significant differences among treatments, suggesting that variations in liquid bioslurry dosage in the feed directly affect the growth performance and body composition of Nile tilapia. Specifically, the growth performance of tilapia given various concentrations of liquid bioslurry is shown in Fig. 1, the feed performance in Fig. 2 and the body chemical composition in Fig. 3.

Fig. 1 is a mosaic plot illustrating the relationship between liquid bioslurry dosage in feed (mL bioslurry per 100g feed) and the growth performance of Nile tilapia. The colour visualization in the plot highlights the distribution differences in growth values among fish treated with various bioslurry concentrations, providing insight into how dosage affects growth performance. At lower doses (<49.995mL), the distribution of growth values is relatively widespread, with a significant proportion falling in the higher growth category. Moderate doses (49.995–83.33mL) show a decline in growth proportion, while higher doses exhibit a more varied distribution pattern.

Fig. 2 presents the color and pattern of mosaic plot boxes, illustrating the relationship between liquid bioslurry dosage in feed and the feed response performance of Nile tilapia. Red-colored boxes indicate a positive contribution to the chi-square value, meaning that the observed frequency is higher than statistically expected. In contrast, blue-colored boxes indicate a negative contribution, where the observed frequency is lower than expected. Based on the analysis results, the P value was found to be less than 0.05, indicating that the concentration of liquid bioslurry in the feed significantly affects the feed response performance of Nile tilapia.

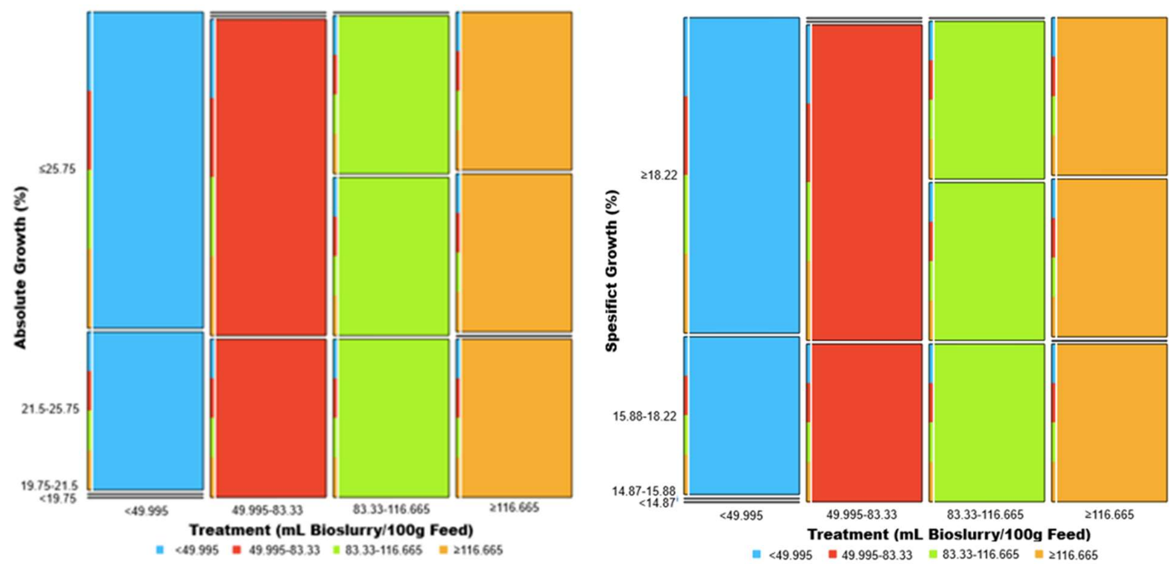

Fig. 1: Growth and performance metrics of tilapia (*O. niloticus*) by bioslurry concentrations.

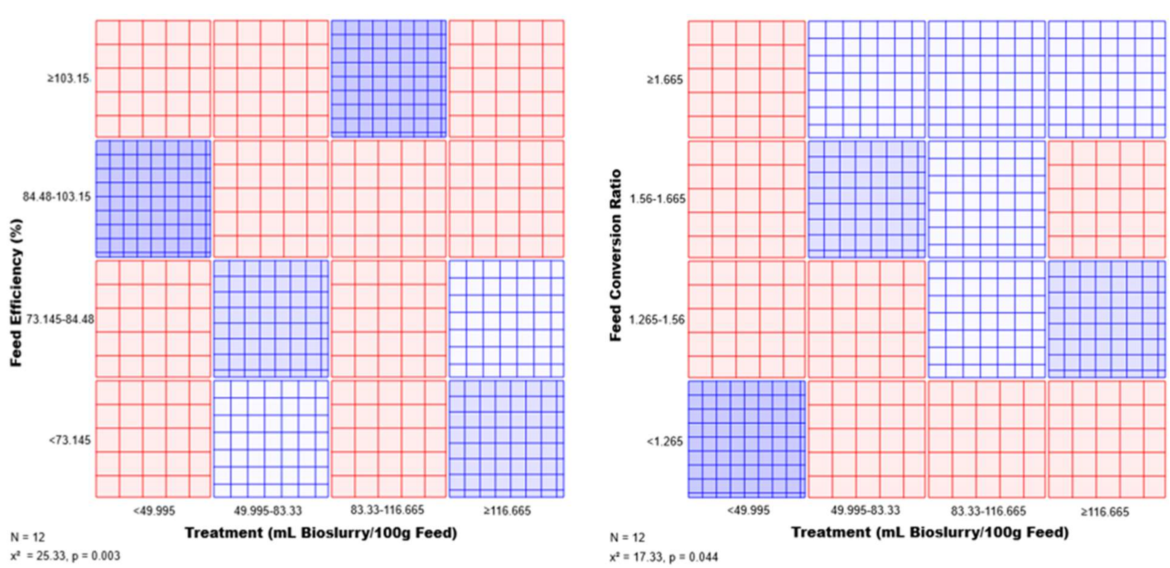

Fig. 2: Mosaic diagram feed performance of tilapia (*O. niloticus*) by bioslurry concentrations.

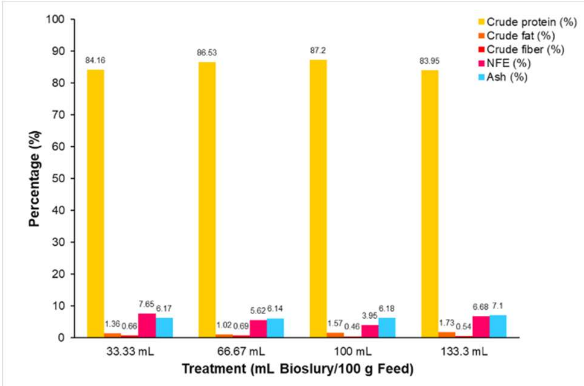

Fig. 3: Chemical composition of Nile tilapia (*O. niloticus*) body by bioslurry concentrations.

The effect of various concentrations of liquid bioslurry in feed can be attributed to the nutritional content of the bioslurry, including nitrogen, phosphorus, amino acids, and probiotic microorganisms (Dubey et al. 2014), which enhance feed digestibility and support the metabolic processes of Nile tilapia (*O. niloticus*), thereby improving feed utilization efficiency and tissue growth. The microorganisms present in the bioslurry can also increase digestive enzyme activity (Liaqat et al. 2024), which accelerates nutrient absorption. Furthermore, bioactive compounds derived from the fermentation of livestock manure in bioslurry may act as natural growth stimulants. These results are consistent with previous studies showing that fermented feeds or those supplemented with microorganisms (e.g., probiotics) significantly improve feed efficiency, body protein levels, and feed conversion ratio (FCR) in Nile tilapia (Mulu et al. 2025). Therefore, the significant differences among treatments are due to the active role of bioslurry in enhancing feed quality and metabolic effectiveness in Nile tilapia.

The results of the polynomial regression analysis illustrating the quadratic relationship between liquid bioslurry concentration in feed and both absolute and specific growth of Nile tilapia (*O. niloticus*) are presented in Fig. 4 and 5.

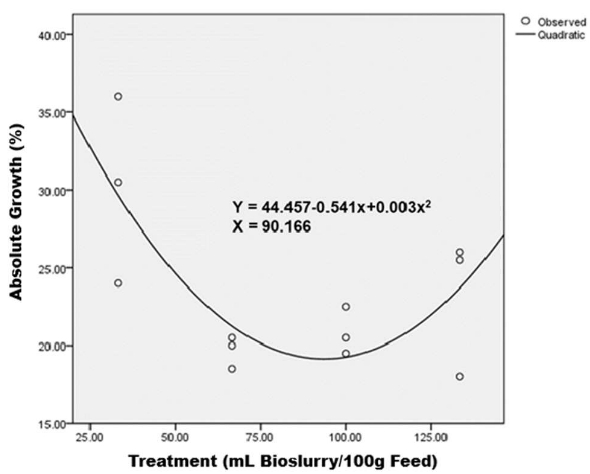

Fig. 4: Quadratic relationship between liquid bioslurry concentration in feed and absolute growth of Nile tilapia (*O. niloticus*).

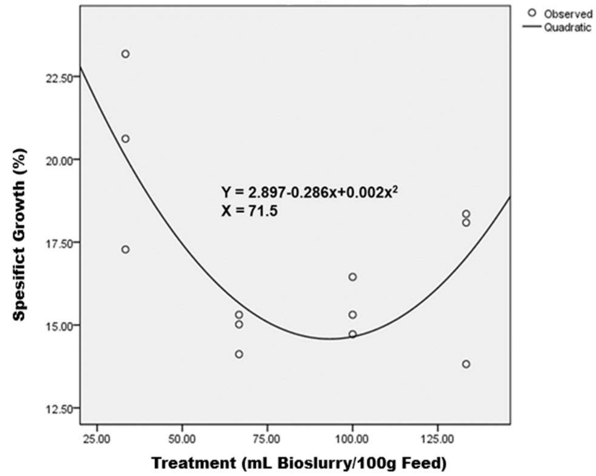

Fig. 5: Quadratic relationship between liquid bioslurry concentration in feed and specific growth rate of Nile tilapia (*O. niloticus*).

Fig. 4 and 5 illustrate the quadratic relationship between the concentration of liquid bioslurry in feed and the growth performance of Nile tilapia (*O. niloticus*). Based on the curve patterns in Fig. 4 and 5, it can be seen that increasing bioslurry concentration initially leads to a decline in tilapia growth rates, reaching the lowest point at concentrations around 75–100mL per 100g of feed. However, beyond this point, growth rates begin to increase again as the concentration of bioslurry continues to rise.

This pattern indicates that the response of Nile tilapia to liquid bioslurry application is non-linear, possibly due to stress or physiological disturbances at moderate concentrations, followed by adaptation or improved nutrient utilization at higher bioslurry concentrations. At low concentrations, growth remains relatively high, likely because the fish are not yet significantly affected by the bioslurry addition. In contrast, at higher concentrations, the fish appear to adapt and utilize the available nutrients more effectively, resulting in enhanced growth. The results of the polynomial regression analysis showing the quadratic relationship between bioslurry concentration and both absolute and specific growth of Nile tilapia (*O. niloticus*) are presented in Fig. 6 and 7.

Fig. 6 illustrates the quadratic relationship between liquid bioslurry concentration in feed and feed efficiency in *O. niloticus*, based on the regression model: $Y = 65.745 + 0.78x - 0.005x^2$. The x-axis represents varying concentrations of liquid bioslurry (mL/100g feed), while the y-axis indicates feed efficiency values. Data points represent observed values, and the curved line shows the predicted trend from the quadratic regression model. The parabolic curve opens downward, indicating that feed efficiency increases with bioslurry concentration up to an optimal level, then declines beyond this point.

The curve's peak occurs at x = 78.7mL/100g feed, representing the optimal concentration for maximizing feed efficiency. This suggests that incorporating liquid bioslurry at approximately 78.7mL per 100g of feed yields the highest feed efficiency. However, exceeding this concentration may lead to reduced efficiency, potentially due to nutrient overload or inhibitory substances in the bioslurry that impair digestion or metabolic processes. This finding aligns with studies such as Tabassum et al. (2021), which report that probiotic supplementation in tilapia diets exhibits an optimal dose threshold. Beyond this threshold, performance including feed efficiency declines. Similar patterns have been observed with varying incubation durations of probiotics affecting growth responses in tilapia (Ndobe et al. 2021; Prasetyo et al. 2024).

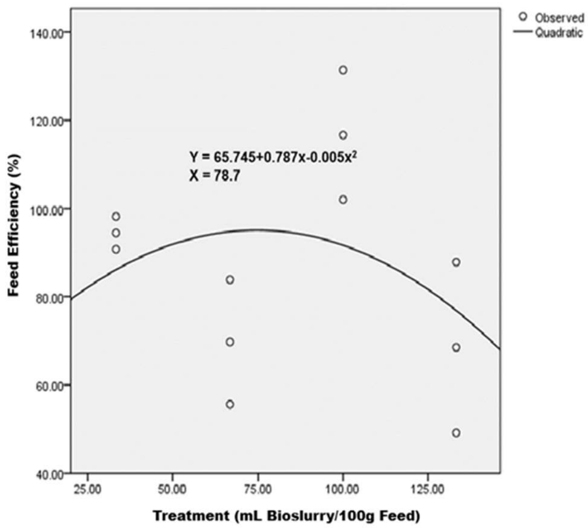

Fig. 6: Quadratic relationship between liquid bioslurry concentration in feed and feed efficiency of Nile Tilapia (*O. niloticus*).

Fig. 7 depicts the quadratic relationship between bioslurry concentration and the body protein content of Nile tilapia, modeled by the equation: $Y = 78.430 + 0.211x - 0.001x^2$. The graph demonstrates that increasing bioslurry concentration initially enhances protein deposition in fish tissues, likely due to improved nutrient bioavailability and probiotic activity. However, beyond a concentration of x = 105.5mL/100g feed, protein content begins to decline. This turning point suggests that while moderate bioslurry levels improve fish body protein, excessive concentrations may induce stress or reduce protein assimilation. These findings reinforce the concept that optimal dosing is critical for maximizing the nutritional benefits of bioslurry and that overuse may compromise fish health and nutrient composition (Tabassum et al. 2021).

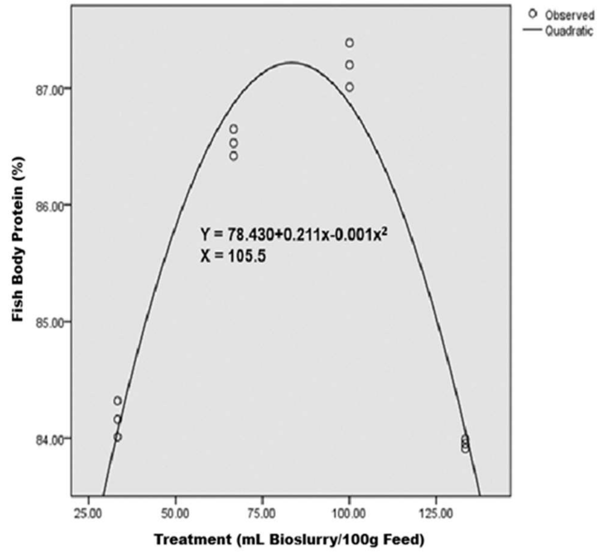

Fig. 7: Quadratic relationship between liquid bioslurry concentration in feed and body protein content of Nile Tilapia (*O. niloticus*).

Fig. 8 presents water quality conditions throughout the cultivation period in the FNC, ensuring that environmental parameters remained within acceptable limits for tilapia culture.

Based on the heat map and dendrogram visualization of water quality shown in Fig. 8, it can be seen that water quality monitoring was carried out over a 60-day period in a Nile tilapia (*O. niloticus*) aquaculture system using FNC, measuring five water quality parameters: temperature, pH, ammonia, nitrate, and dissolved oxygen (DO). The data visualization using heat maps and hierarchical cluster analysis (HCA) provides insight into the relationship patterns among these parameters throughout the observation period.

The analysis shows that temperature had the highest values, as reflected by the dominant yellow-white gradient on the heat map, indicating relatively high and variable temperatures during the rearing period. On the other hand, ammonia and nitrate concentrations tended to remain stable and low, indicated by consistently dark blue coloring across the observations, suggesting that the system maintained optimal conditions without the accumulation of nitrogenous waste that could be harmful to the fish. The pH and DO parameters also fluctuated but remained within stable conditions.

Fig. 8: Water quality conditions in floating net cages (FNC) during the rearing of *O. niloticus.*

The cluster analysis revealed that water quality parameters could be grouped into two major clusters. The first cluster consisted of nitrate, ammonia, and DO, which are closely related to fish metabolism and leftover feed in the water. The second cluster included pH and temperature, which are more influenced by external environmental factors such as solar radiation and photosynthetic activity. This indicates that temperature fluctuations do not directly affect nitrogen concentrations in the water but can influence pH and DO levels through biological processes such as respiration and algal photosynthesis.

Overall, the monitoring results demonstrate that the Nile tilapia culture system in the FNC maintained optimal water quality, with low concentrations of ammonia and nitrate (Santeri et al. 2021; Fujaya et al. 2022) and pH and DO levels within a range that supports fish growth (Yonarta et al. 2023). Proper temperature management is crucial for maintaining water quality balance, as excessive temperature fluctuations can cause stress in fish.

Conclusion

The addition of liquid bioslurry to the feed of Nile tilapia (*O. niloticus*) cultured in floating net cages (FNCs) had a significant effect on growth performance and body chemical composition. The treatment with a dose of 100mL per 100g of feed (treatment C) resulted in the highest absolute growth, best feed efficiency, and optimal body protein content. Regression analysis indicated that the optimal dose of liquid bioslurry ranged between 95 and 105mL per 100g of feed. These findings suggest that liquid bioslurry has strong potential as an environmentally friendly, cost-effective feed supplement that supports circular economy principles, particularly by utilizing livestock waste to enhance aquaculture sustainability. Furthermore, all treatments maintained water quality within acceptable ranges for Nile tilapia farming in open waters.

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Data Availability: All the data is available in the article.

Ethics Statement: No ethical approval was required for this study.

Author's Contribution: AM and SZ created the research concept, methodology, and wrote the manuscript. SZ and AS collected and analyzed the data, contributed to the development of the methodology. AM and KK visualized the data and performed language editing. All authors have reviewed, assessed, and approved the final manuscript.

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