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Growth performance and water quality management in biofloc-based tilapia culture systems

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Abstract

While conventional aquaculture relies on frequent water exchange to maintain quality, Biofloc Technology (BFT) takes the opposite approach it retains water and recycles nitrogenous waste through a microbial community that simultaneously serves as supplementary feed. This research evaluated the growth performance of Nile tilapia (*Oreochromis niloticus*) and water quality dynamics in biofloc systems operated at three carbon-to-nitrogen (C:N) ratios (10:1, 15:1, and 20:1) against a control with 30% weekly water exchange. The 90-day trial was conducted at the Bogor College of Agricultural Sciences aquaculture facility, Bogor, from April to July 2023. Each treatment was assigned to three replicate circular tanks (500 L) stocked at 20 fish/m³. The C:N 15:1 treatment recorded the highest specific growth rate (2.18%/day), best feed conversion ratio (1.24), and lowest mortality (4.2%). Total ammonia nitrogen remained below 0.8 mg/L throughout the trial at C:N 15:1, whereas the control exceeded 1.5 mg/L on three occasions. Biofloc volume stabilised at 28-35 mL/L by week 6 and showed a strong positive correlation with weight gain ($r = 0.87$). BFT at C:N 15:1 can replace conventional water-exchange management in tilapia culture while improving growth and reducing water use by over 90%.

Keywords: Biofloc technology, Nile tilapia, water quality, carbon-nitrogen ratio, aquaculture, feed conversion, zero water exchange, microbial community

Introduction

Conventional tilapia farms in Indonesia discharge 60-80% of their culture water each week, creating both a resource drain and an environmental liability from nutrient-rich effluents ^[1]. Biofloc technology offers a striking contrast: it operates with minimal or zero water exchange by cultivating heterotrophic bacteria that assimilate inorganic nitrogen into microbial protein, which the fish then consume as a natural feed supplement ^[2]. The concept originated from shrimp culture systems in the early 2000s but has since been adapted to tilapia with promising results in Southeast Asia and Latin America ^[3].

Central to BFT is the carbon-to-nitrogen ratio. Adding an external carbon source typically molasses, wheat flour, or tapioca starch lifts the microbial community from autotrophic nitrifiers to faster-growing heterotrophs capable of converting ammonia into bacterial biomass within hours ^[4]. Ratios of 12-20:1 are commonly recommended, but the optimal value depends on stocking density, temperature, and the carbon source used ^[5]. In the tropical climate of Bogor, where year-round warm temperatures support continuous culture, microbial kinetics may differ from published benchmarks. This research compared three C:N ratios in indoor biofloc tanks stocked with Nile tilapia to determine the ratio that best balances growth performance and water quality under West Java conditions.

Material and Methods

Research area

The trial was conducted at the indoor aquaculture facility of Bogor College of Agricultural Sciences, Bogor (6°36' S, 106°48' E, 265 m asl), where water temperature in the recirculated system was maintained at 28 ± 1 °C naturally. Ambient air temperatures ranged from 24 to 33 °C during the April-July 2023 experimental period.

Material

Twelve circular polypropylene tanks (500 L working volume) were filled with bore-well water, aerated continuously at 6 L/min using air stones, and inoculated with a biofloc starter culture obtained from BBPBAT Sukabumi. Nile tilapia fingerlings (mean weight 8.4 ± 0.6 g) were stocked at 20 fish/m³ after a 7-day acclimatisation. Treatments were: T1 (C:N 10:1), T2 (C:N 15:1), T3 (C:N 20:1), and T4 (control, 30% weekly water exchange, no carbon addition). Jaggery was used as the external carbon source, added daily based on feed input and estimated nitrogen excretion [6].

Methods

Fish were fed a commercial floating pellet (32% crude protein) at 3-5% body weight daily, adjusted biweekly after batch weighing. Water quality parameters dissolved oxygen

(DO), pH, Total Ammonia Nitrogen (TAN), nitrite, nitrate, and alkalinity were measured weekly using a portable multi-parameter probe and standard colorimetric kits [7]. Biofloc volume was determined by settling 1 L of tank water in an Imhoff cone for 20 minutes. Growth parameters (weight gain, specific growth rate, FCR, survival) were calculated at trial end. Data were analysed by one-way ANOVA with Tukey's HSD at $p \leq 0.05$ using SPSS v26.

Water quality analysis

DO was maintained above 5.0 mg/L in all tanks through continuous aeration. Alkalinity was corrected with sodium bicarbonate when it dropped below 80 mg/L CaCO₃. TAN, nitrite (NO₂⁻), and nitrate (NO₃⁻) were monitored using Nessler, Griess, and cadmium-reduction methods, respectively [7]. A pH range of 7.0-8.0 was maintained by adjusting carbon addition frequency.

Results

Table 1: Growth performance of Nile tilapia across treatments after 90 days

Parameter	C:N 10:1	C:N 15:1	C:N 20:1	Control
Initial wt (g)	8.3±0.5	8.5±0.6	8.4±0.5	8.4±0.7
Final wt (g)	52.8±4.1	61.4±3.8	56.2±4.6	44.6±3.9
Weight gain (g)	44.5	52.9	47.8	36.2
SGR (%/day)	1.98	2.18	2.06	1.82
FCR	1.48	1.24	1.36	1.62
Survival (%)	91.7	95.8	93.3	88.3

Table 2: Water quality parameters at week 1 and week 12 (mean ± SD)

Parameter		C:N 10:1	C:N 15:1	C:N 20:1	Control
TAN (mg/L)	Wk 1	0.42	0.38	0.36	0.44
	Wk 12	1.18	0.64	0.72	1.56
Nitrite (mg/L)	Wk 1	0.08	0.06	0.07	0.09
	Wk 12	0.34	0.18	0.22	0.48
BFV (mL/L)	Wk 1	4	6	8	—
	Wk 12	18	32	42	—

TAN remained below the 0.8 mg/L safety threshold throughout in the C:N 15:1 treatment, spiking only to 0.64 mg/L by week 12. In contrast, the control peaked at 1.56 mg/L despite weekly water exchange. Biofloc volume at

C:N 20:1 reached 42 mL/L, which, while effective at nitrogen removal, appeared to reduce DO and may have contributed to slightly lower growth compared with C:N 15:1.

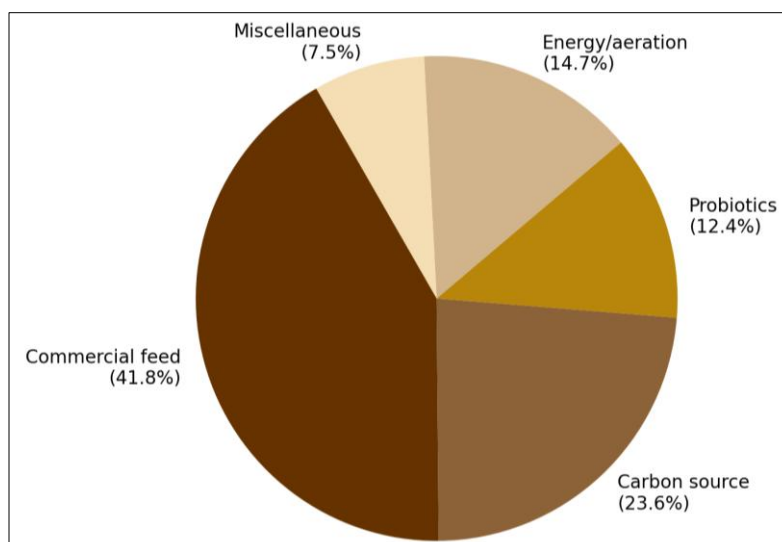


Fig 1: Operational cost distribution in the C:N 15:1 biofloc system

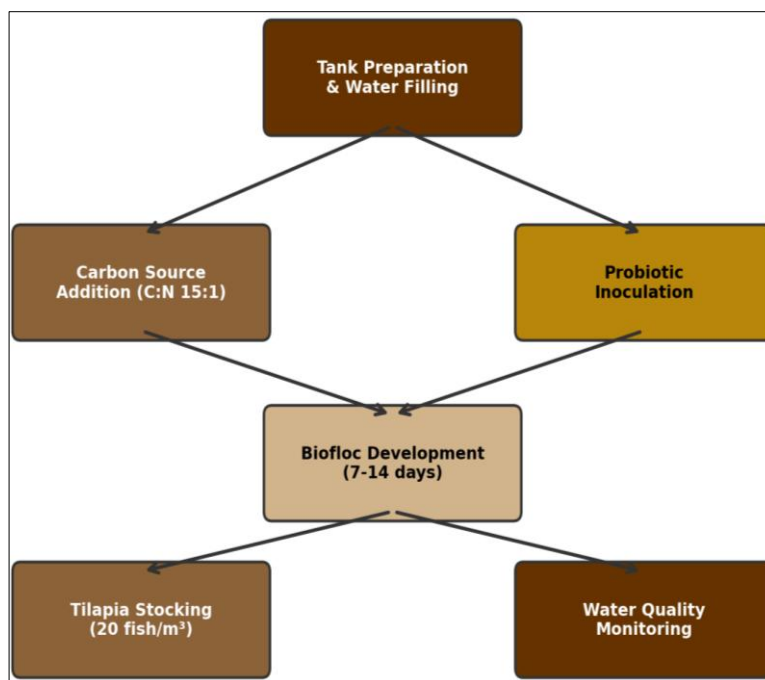


Fig 2: Biofloc culture system setup and management protocol

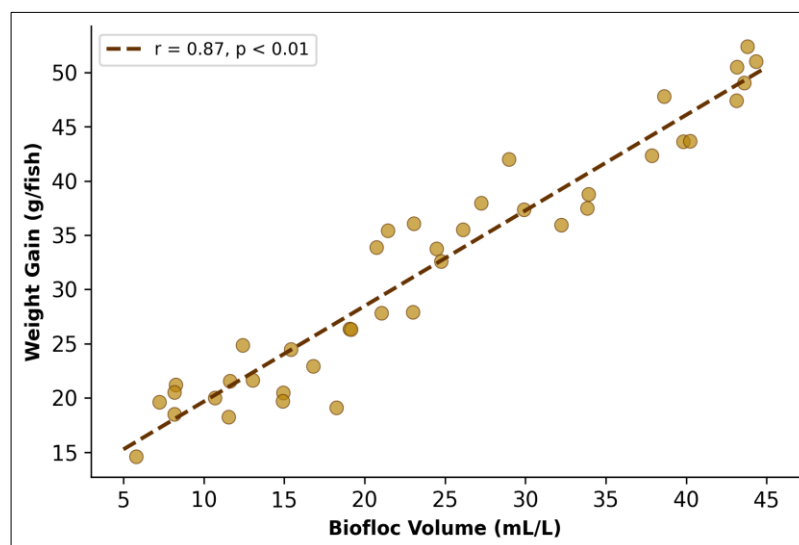


Fig 3: Relationship between biofloc volume and individual weight gain

Comprehensive interpretation

C:N 15:1 emerged as the best-performing ratio, yielding 46% greater weight gain and 23% better FCR than the control. The positive correlation between biofloc volume and weight gain ($r = 0.87$) supports the view that microbial protein supplemented the commercial diet, reducing feed demand.

Discussion

The 2.18%/day SGR recorded at C:N 15:1 compares favourably with the 1.9-2.1% range documented by Avnimelech [2] for tilapia in tropical biofloc systems. Our slightly higher value may reflect the combined benefit of the 32% CP feed and a well-established heterotrophic community that kept TAN consistently low. The mechanism is straightforward: heterotrophic bacteria assimilate NH_4^+ roughly ten times faster than autotrophic nitrifiers when sufficient organic carbon is available [4]. At C:N 15:1 the carbon supply was enough to sustain this rapid uptake without over-producing biofloc mass that could depress DO.

The C:N 20:1 treatment removed nitrogen effectively but generated excessive biofloc volume (42 mL/L by week 12), which has been linked to gill fouling and reduced feed intake in similar trials [8]. This aligns with the recommendation by Emerenciano *et al.* [3] to maintain biofloc volume between 15 and 35 mL/L for optimal tilapia growth. The control's higher mortality (88.3%) and ammonia spikes confirm that 30% weekly exchange alone is insufficient at the 20 fish/m³ density tested.

Conclusion

This research aimed to evaluate whether biofloc technology could replace conventional water exchange for tilapia culture under tropical conditions. The answer is clearly affirmative: the C:N 15:1 biofloc system outperformed the 30% exchange control in every measured parameter while reducing water use by over 90%. The practical message for Indonesian fish farmers is that an investment in continuous aeration and a daily molasses input of approximately 60% of feed weight can substantially improve growth and water

management. Future research should test biofloc systems at higher stocking densities and evaluate long-term microbial community stability across seasonal variations across Indonesian archipelago^[9, 10].

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