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Optimisation of the Use of Cultivation System Technology to Increase Tilapia (*Oreocromis niloticus*) Production in Intensive Cultivation in the Era of Modernisation

Optimalisasi Penggunaan Teknologi Sistem Budidaya terhadap Peningkatan Produksi Ikan Nila (Oreocromis niloticus) pada Budidaya Intensif di Era Modernisasi

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Abstract

Tilapia (*Oreochromis niloticus*) is one of the main commodities in freshwater aquaculture because it is highly adaptable and easy to breed. In intensive aquaculture systems, production success is highly dependent on fish growth, which is closely related to feed availability and water quality. This study aims to analyze the effectiveness of modern aquaculture technologies, namely the biofloc system, aquaponics, and the Recirculating Aquaculture System (RAS), in supporting the success of tilapia aquaculture. The research was conducted in August 2025 at the Freshwater Aquaculture Center of the Sibolga College of Fisheries, North Sumatra. The research method used a completely randomised design with four treatments and three replicates. The results showed that the aquaponics technology (P3) produced the highest absolute weight growth (9.97±0.02 g), specific growth rate (4.26±0.00%/day), and absolute length (1.77±0.06 cm), followed by RAS (P2), control (P0), and biofloc (P1). The survival rate across all treatments ranged from 95.33% to 97.33%, indicating Tilapia's good adaptability to various farming systems. Water quality parameters were within optimal ranges: 29-30°C, pH 6.1-7.6, dissolved oxygen 4.5-5.0 mg/L, and ammonia 0.0001-0.0005 mg/L. The aquaponic system showed the most stable water quality with the lowest ammonia concentration (0.0001-0.0003 mg/L). This study demonstrates that aquaponic technology provides the best treatment for modernised intensive tilapia farming.

Keywords: Tilapia, Intensive Cultivation, Aquaponics, Biofloc, RAS

Abstrak

Ikan nila (*Oreochromis niloticus*) merupakan salah satu komoditas utama budidaya perikanan air tawar karena memiliki daya adaptasi tinggi dan mudah dipijahkan. Dalam sistem budidaya intensif, keberhasilan produksi sangat bergantung pada pertumbuhan ikan yang erat kaitannya dengan ketersediaan pakan dan kualitas air. Penelitian ini bertujuan untuk menganalisis efektivitas teknologi budidaya modern, yaitu sistem bioflok, akuaponik, dan Recirculating Aquaculture System (RAS) dalam mendukung keberhasilan budidaya ikan nila. Penelitian dilaksanakan pada Agustus 2025 di Balai Budidaya Perikanan Air Tawar Sekolah Tinggi Perikanan Sibolga, Sumatera Utara. Metode penelitian menggunakan Rancangan Acak Lengkap dengan empat perlakuan dan tiga ulangan. Hasil penelitian menunjukkan bahwa teknologi akuaponik (P3) menghasilkan pertumbuhan bobot mutlak tertinggi (9,97±0,02 g), laju pertumbuhan spesifik (4,26±0,00%/hari), dan panjang mutlak (1,77±0,06 cm), diikuti RAS (P2), kontrol (P0), dan bioflok (P1). Tingkat kelulushidupan pada semua perlakuan berkisar 95,33-97,33%, menunjukkan adaptabilitas ikan nila yang baik terhadap berbagai sistem budidaya. Parameter kualitas air berada dalam kisaran optimal, suhu 29-30°C, pH 6,1-7,6, oksigen terlarut 4,5-5,0 mg/L, dan amonia 0,0001-0,0005 mg/L. Sistem akuaponik menunjukkan kualitas air paling stabil dengan konsentrasi amonia terendah (0,0001-0,0003 mg/L. Penelitian ini membuktikan bahwa teknologi akuaponik memberikan perlakuan terbaik untuk budidaya intensif ikan nila di era modernisasi.

Kata kunci: Ikan Nila, Budidaya Intensif, Akuaponik, Bioflok, RAS

1. Introduction

Tilapia (*Oreochromis niloticus*) is one of the most widely cultivated freshwater fish commodities due to its high adaptability to unfavorable environments and ease of breeding (Zulhardi, 2020). It is distributed throughout tropical and subtropical regions. In addition, Tilapia is tolerant of low-oxygen conditions and can take oxygen directly from the air (Kordi, 2010). In intensive farming systems, fish growth largely determines production success, which is closely related to feed availability and water quality. Growth is an increase in weight and body size over time, which is influenced by internal factors (genetics and physiology) and external factors, particularly water quality and nutrient availability. In an effort to increase production, tilapia farming is carried out intensively, characterised by high stocking densities and high-protein feed (Setijaningsih & Gunadi, 2016).

One of the main obstacles in intensive aquaculture is stunted growth due to fluctuations in water quality. Unstable temperature changes, for example, can affect fish activity. Temperatures that are too low or too high can potentially reduce appetite, inhibit metabolism, and increase disease susceptibility (Siegers et al., 2019). To overcome this, it is necessary to optimise the use of modern aquaculture system technologies, such as biofloc, aquaponics, and Recirculating Aquaculture Systems (RAS) (Sinaga et al., 2025). The application of these technologies has been proven to maintain water quality stability, increase feed efficiency, and boost tilapia productivity.

In addition, modern aquaculture technology also supports the sustainability of intensive fisheries in the era of modernisation. This study aims to analyze the effectiveness of modern aquaculture technologies, namely biofloc, aquaponics, and the Recirculating Aquaculture System (RAS), in supporting the success of tilapia (*O. niloticus*) farming. The main focus of the study includes specific growth rate, growth, and water quality stability (temperature, pH, dissolved oxygen, and ammonia).

2. Material and Method

2.1. Time and Place

This study was conducted in August 2025 at the Freshwater Aquaculture Center of the Sibolga College of Fisheries, South Sibolga District, Sibolga City, North Sumatra Province.

2.2. Methods

The research method used was an experimental design with a completely randomised design (CRD) and one factor with four treatment levels. To minimize errors, each treatment was repeated three times. The treatments given were as follows:

P0 : Control
P1 : Biofloc Technology
P2 : Recirculating Aquaculture System Technology
P3 : Aquaponics Technology

2.3. Procedures

The initial preparation for the study involved cleaning 100-L buckets. After cleaning, the buckets were arranged and randomised according to the treatment. Next, each bucket was filled with 80 L of water and equipped with aeration and a filtration pump to supply oxygen and fiber to hold the water during the study.

In this study, the medium used was water sourced from a borehole. The water was placed in a storage tank and aerated. The water medium was allowed to settle for 3 days before being used as a test medium. The water was then distributed among the maintenance containers, with 80 L in each.

2.4. Parameter Measured

2.4.1. Absolute Weight Growth

Absolute weight growth is calculated using the formula according to Effendie (2002), as follows:

$$GR = Wt - Wo$$

Where :
GR = Absolute growth (g)

Wt = Average weight of fish at the end of the study (g)
Wo = Average weight of fish at the start of the study (g)

2.4.2. Absolute Length Growth

Absolute length measurements are calculated using the following formula (Effendie, 2002):

$$PM = Lt - Lo$$

Where:
PM = Absolute length (cm)
Lt = Average length at the end of the study (cm)
Lo = Average length at the start of the study (cm)

2.4.3. Specific Growth Rate

The specific growth rate of Tilapia was calculated using the formula according to Monentcham et al. (2010), namely:

$$SGR = ((\ln Wt - \ln Wo)/t)) \times 100$$

Where :
SGR = Specific growth rate (%/day)
Wt = Average weight of fish at the end of the study (g)
Wo = Average weight of fish at the start of the study (g)
T = Duration of the study (days)

2.4.4. Survival Rate

According to Effendie (2002), the survival rate can be calculated using the following formula:

$$SR = \frac{Nt}{No} x\ 100\%$$

Where:
SR = Survival rate (%)
Nt = Number of fish alive at the end of the study (tails)
No = Number of fish alive at the beginning of the study (tails)

2.4.5. Water Quality

The water quality parameters measured were temperature, pH, DO, and ammonia. Temperature and pH measurements were taken daily in the morning or afternoon. The instruments used were a thermometer and a pH meter. DO and ammonia measurements were taken three times: at the start of the study, after 15 days, and after 30 days of maintenance.

2.5. Data Analysis

The data obtained from the measurements were collected and tabulated. The data were first analyzed for homogeneity and then analyzed using analysis of variance (ANOVA). Suppose the treatment showed a significant difference ($P<0.05$). A Newman-Keuls post hoc test was performed to determine differences between treatments. The data obtained were presented in tabular and graphical form and discussed descriptively.

3. Result and Discussion

3.1. Growth Rate

Table 1 shows that differences in cultivation technology yield research results, and the application of various cultivation technologies significantly affects the absolute weight growth of Tilapia. It can be seen that aquaponics technology (P3) produced the highest absolute weight of 9.97±0.02 g, followed by Recirculating Aquaculture System technology (P2) at 9.52±0.03 g, control (P0) at 9.20±0.04 g, and biofloc technology (P1) at 8.28±0.02 g. Based on the study's results, Table 1 shows that different cultivation technologies affect Tilapia growth rate.

The high absolute weight in aquaponics technology is due to the system's ability to create synergy between fish and plant cultivation, in which fish metabolic waste, rich in nitrogen and phosphorus, is converted by nitrifying bacteria into nutrients that plants can absorb (Shobihah et al., 2022). This process removes toxic compounds, such as ammonia, from the water and creates optimal environmental conditions for fish growth. Well-maintained water quality in aquaponics systems supports efficient fish metabolism, allowing energy to be allocated maximally to growth. This aligns with the opinion of Mukti & Biswas (2019), who stated that high antinutrient content can reduce the digestibility and absorption of nutrients. Tilapia growth with aquaponics technology can increase every week.

RAS technology ranks second in terms of absolute weight. The recirculation system enables strict control of water quality parameters, including temperature, pH, dissolved oxygen, and ammonia concentration (Fauzia & Suseno, 2020). Effective mechanical and biological filtration in RAS helps maintain stable environmental conditions. However, the slightly lower weight compared to aquaponics may be due to higher fish density in RAS systems, which can increase competition for feed and social stress.

Table 1. Growth rate of Tilapia

Treatment	Parameters		
	Absolute Weight (g)	LPS (g%/day)	Length Absolute (cm)
P0 (Control)	9.20±0.04[b]	3.76±0.01[b]	0.97±0.06[a]
P1 (Biofloc Technology)	8.28±0.02[a]	3.90±0.00[c]	0.93±0.06[a]
P2 (Recirculating Aquaculture System Technology)	9.52±0.03[c]	3.68±0.01[a]	1.37±0.06[b]
P3 (Technology aquaponics)	9.97±0.02[d]	4.26±0.00[d]	1.77±0.06[c]

The control treatment (conventional farming) showed moderate results. Although not as optimal as modern technologies, traditional farming can still produce acceptable growth because Tilapia has a good tolerance for variations in water quality. However, limitations in environmental control and waste management meant that its performance was not as good as that of more sophisticated systems. Biofloc technology showed the lowest absolute weight, which was quite surprising considering that this system should provide additional nutritional benefits from microorganisms. These results may be due to several factors: first, oxygen competition between fish and microorganisms in the floc, which can cause hypoxic stress in fish; second, the possible instability of the biofloc system during the study period, which may have affected water quality consistency; third, the adaptation of fish to biofloc conditions, which may take longer (Liana et al., 2024).

A different pattern was observed for the LPS parameter, with aquaponics technology continuing to show the highest value (4.26±0.00 %/day), followed by biofloc (3.90±0.00 %/day), control (3.76±0.01 %/day), and RAS (3.68±0.01 %/day). The high LPS in aquaponics indicates optimal feed conversion efficiency and good physiological conditions of the fish. Despite its low absolute weight, the high LPS in biofloc technology indicates that this system has the potential for rapid growth, but may require further optimization in system management and maintenance duration (Yusup et al., 2025). Microorganisms in flocs can provide additional nutrients in the form of high-quality microbial protein, thereby supporting a relatively good growth rate.

The absolute length parameter shows a pattern consistent with absolute weight, with aquaponics producing the greatest length growth (1.77±0.06 cm), followed by RAS (1.37±0.06 cm). In contrast, the control and biofloc show results that are relatively similar (0.97±0.06 cm and 0.93±0.06 cm, respectively). Good length growth in aquaponics and RAS indicates optimal fish morphology development, which is important for final product quality. Based on this study's results, aquaponics technology shows the best overall performance for tilapia farming. This system not only promotes optimal fish growth but also adds value through plant production. However, implementing aquaponics requires a relatively high initial investment and adequate technical expertise.

RAS technology can be a good alternative, especially for intensive farming with strict environmental control. Although its growth is slightly lower than that of aquaponics, RAS offers greater flexibility and can be implemented in a wider range of locations. Biofloc technology has significant potential but requires further research to optimise systems, especially in oxygen management and microbial stability. With technological improvements, biofloc could become a cost-effective solution for tilapia farming.

3.2. Survival Rate

Based on the research results, the survival rate of Tilapia ranged from 95.33 to 97.33%, as shown in Figure 1.

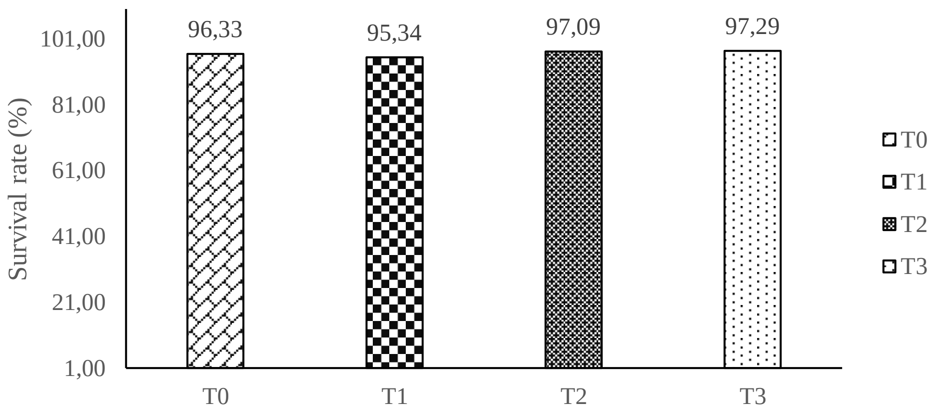

Figure 1. Survival rate of Tilapia

Survival rates ranging from 95.33 to 97.33% indicate that all tested aquaculture technologies provide environmental conditions that support Tilapia survival. The relatively narrow range of survival rates across treatments indicates that factors related to aquaculture technology influence growth more than mortality. The high survival rate in all treatments shows that Tilapia are highly adaptable to various farming systems. This aligns with Tilapia's characteristics as a species tolerant of environmental variation and with good disease resistance.

3.3. Water Quality

Water quality is one of the most critical factors in supporting fish growth and survival (Karimah & Samidjan, 2018). The water quality parameters measured during the study were temperature, pH, dissolved oxygen (DO), and ammonia (NH_3). The measurement results for each water quality parameter are shown in Table 2.

Table 2. Water quality measurement

Treatment	Parameters			
	Temperature(°C)	pH	DO (mg/L)	NH_3 (mg/L)
P0 (Control)	29-30	6,1-7,6	4,5-5,0	0,0002-0,0005
P1 (Biofloc Technology)	29-30	6,4-7,6	4,5-4,9	0,0001-0,0004
P2 (RAS)	29-30	6,3-7,4	4,5-4,9	0,0002-0,0005
P3 (Technology aquaponics)	29-30	6,3-7,6	4,5-5,0	0,0001-0,0003

Table 2 shows that the temperature range (29–30°C) in all treatments is still suitable for tilapia cultivation at 25–32°C. The pH value ranged from 6.1 to 7.6, with the best stability in RAS (P2) and aquaponics (P3), in accordance with the requirements of Tilapia (6.5–8.5). However, the control (P0) tended to be lower (6.1), which could reduce feed efficiency. The dissolved oxygen level (4.5–5.0 mg/L) remains within the minimum limit for optimal growth (≥4 mg/L), and the greater stability in P2 and P3 reflects the effectiveness of filtration and circulation. Meanwhile, ammonia concentrations were very low (0.0001–0.0005 mg/L), well below the toxic threshold of ≤0.05 mg/L. The lowest values in biofloc (P1) and aquaponics (P3) systems indicate their ability to utilize nitrogen waste through microbial activity and plant absorption. Overall, the water quality across all treatments remains suitable for tilapia cultivation, with the best conditions in the aquaponics system (P3), followed by RAS (P2), biofloc (P1), and control (P0).

4. Conclusions

This study demonstrates that cultivation technology significantly affects Tilapia growth performance. Aquaponics technology showed the best results, followed by RAS, control, and biofloc. The high survival rate in all treatments shows that Tilapia can adapt well to various cultivation systems. The selection of aquaculture technology should consider not only biological aspects but also economic, technical, and environmental sustainability factors.

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