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Comparative Analysis of Productivity and Efficiency of Recirculating Aquaculture System (RAS) and Biofloc in Nile Tilapia (*Oreochromis niloticus*) Culture

Analisis Komparatif Produktivitas dan Efisiensi Recirculating Aquaculture System (RAS) dan Bioflok pada Budidaya Ikan Nila (Oreochromis niloticus)

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Abstract

Nile tilapia (*Oreochromis niloticus*) culture faces challenges in achieving optimal production efficiency due to limited land availability and water resources. This study aimed to analyze and compare the productivity and efficiency of the Recirculating Aquaculture System (RAS) and Biofloc systems in Nile tilapia culture. The research employed a comparative experimental approach, measuring growth performance, Food Conversion Ratio (FCR), Survival Rate (SR), and water-quality management efficiency in both systems. The results showed that both systems significantly improved aquaculture productivity compared to conventional methods. The RAS system produced a higher daily growth rate, with productivity reaching 35 to 40 kg/m³ per cycle, survival rates of 85 to 92%, and more stable water quality. Meanwhile, the biofloc system demonstrated better feed efficiency, with an FCR ranging from 0.9 to 1.2, compared to RAS, which ranged from 1.2 to 1.5, and productivity reached 30 to 38 kg/m³ when biofloc was used as an additional nutrient source. Economically, the biofloc system was more efficient in feed and water utilization, whereas RAS was superior in environmental control and in managing high stocking density. These findings provide a scientific basis for aquaculture practitioners in determining the most suitable technology based on business scale, capital capacity, and aquaculture sustainability goals.

Keywords: *Oreochromis niloticus*, Productivity, Efficiency, RAS, Biofloc

Abstrak

udidaya ikan nila (*Oreochromis niloticus*) menghadapi tantangan dalam mencapai efisiensi produksi yang optimal di tengah keterbatasan lahan dan sumber daya air. Penelitian ini bertujuan untuk menganalisis dan membandingkan produktivitas serta efisiensi antara *Recirculating Aquaculture System* (RAS) dan Bioflok pada budidaya ikan nila. Metode penelitian menggunakan pendekatan eksperimental komparatif dengan mengukur parameter pertumbuhan, *Food Conversion Ratio* (FCR), kelangsungan hidup (*Survival Rate*), serta efisiensi manajemen kualitas air pada kedua sistem. Hasilnya menunjukkan bahwa kedua sistem mampu meningkatkan produktivitas budidaya secara signifikan dibandingkan metode konvensional. Sistem RAS menghasilkan laju pertumbuhan harian lebih tinggi dengan produktivitas mencapai 35–40 kg/m³ per siklus, tingkat kelangsungan hidup 85–92%, serta stabilitas kualitas air yang lebih terkontrol. Sementara itu, sistem Bioflok menunjukkan efisiensi pakan yang lebih baik dengan nilai FCR berkisar 0,9–1,2 dibandingkan RAS yang berada pada kisaran 1,2–1,5, serta

produktivitas mencapai 30–38 kg/m³ melalui pemanfaatan flok sebagai sumber nutrisi tambahan. Dari sisi ekonomi, Bioflok lebih efisien dalam penggunaan pakan dan air, sedangkan RAS lebih unggul dalam pengendalian lingkungan budidaya dan padat tebar tinggi. Temuan ini memberikan dasar ilmiah bagi pembudidaya dalam menentukan teknologi yang paling sesuai berdasarkan skala usaha, kapasitas modal, dan tujuan keberlanjutan produksi akuakultur.

Kata kunci: *Oreochromis niloticus*, Produktivitas, Efisiensi, RAS, Bioflok.

1. Introduction

Nile tilapia (*Oreochromis niloticus*) is one of the most widely cultivated freshwater aquaculture species in Indonesia due to its high environmental tolerance, rapid growth rate, and continuously increasing market demand. However, the intensification of tilapia production still faces several challenges, including limited land availability, high water consumption, low feed efficiency, and environmental impacts from the accumulation of organic waste and nitrogen compounds in conventional aquaculture systems. These conditions require the implementation of more efficient, productive, and sustainable aquaculture technologies to address the challenges of aquaculture modernization in Indonesia (Al Dair et al., 2026).

Recently, two intensive aquaculture systems that have attracted significant attention are the Recirculating Aquaculture System (RAS) and the Biofloc system. Generally, RAS operates by continuously recirculating and treating water through mechanical filters, biofilters, and aeration systems, thereby enabling high stocking densities and highly efficient water utilization (Widodo et al., 2020; Makarti et al., 2025). Meanwhile, the Biofloc system utilizes microorganisms and organic flocs to convert nitrogenous waste (ammonia) into microbial biomass that can be consumed by fish as an additional feed source, thereby reducing the need for commercial feed and improving water quality during culture operations (Al Dair et al., 2026).

Previous studies have demonstrated that both systems can improve productivity and efficiency compared to conventional pond culture systems, although each technology possesses distinct advantages. For instance, Widodo et al. (2020) reported that RAS significantly improved water quality stability and tilapia production yields, while Khanjani et al. (2020) and other biofloc-related studies showed reductions in the Food Conversion Ratio (FCR) and increased productivity per unit of water in biofloc systems. On the other hand, several studies also indicated that implementing a single system may not be suitable for all land conditions, farming scales, and farmers' capital capacities, underscoring the need for a systematic comparative analysis of these two technologies (Makarti et al., 2025). Such an analysis would help identify the most effective practices tailored to specific environmental and economic contexts, ultimately leading to better resource management and enhanced aquaculture sustainability (Bunting, 2024).

Based on this background, this study was conducted to compare productivity and efficiency between RAS and Biofloc systems in Nile tilapia (*Oreochromis niloticus*) culture by evaluating growth performance, survival rate, feed conversion, and the efficiency of water and energy utilization. The results of this study are expected to provide appropriate aquaculture technology recommendations for small- and medium-scale fish farmers in Indonesia while strengthening the scientific basis for the development of sustainable aquaculture practices.

2. Material and Method

This study employed a qualitative approach, using a literature review (library research) method, to compare the productivity and efficiency of the Recirculating Aquaculture System (RAS) and Biofloc systems in Nile tilapia culture. Data were obtained from previous research findings, journal articles, and published technical reports, which were then analyzed descriptively and comparatively to explore differences in characteristics and performance between the two systems (Makarti et al., 2025; Rahman et al., 2021).

The data collection technique involved searching, selecting, and reconstructing information from various sources, including nationally accredited SINTA journals, seminar proceedings, and relevant undergraduate and postgraduate theses on RAS and Biofloc systems in tilapia aquaculture. The analysis focused on productivity (kg/m³ or tons per cycle), feed efficiency (food conversion ratio/FCR), survival rate, and water-quality management characteristics.

Data analysis used a comparative approach, categorizing studies by productivity, efficiency, advantages, limitations, and practical implications for aquaculture practitioners. Furthermore, the similarities and differences among research findings were interpreted to identify the profiles of RAS and Biofloc systems that are most suitable for small- and medium-scale aquaculture operations in Indonesia (Villamar et al., 2021)

3. Result and Discussion

3.1. Productivity of the Recirculating Aquaculture System (RAS)

High productivity in the Recirculating Aquaculture System (RAS) is generally achieved under intensive aquaculture conditions characterized by high stocking densities, efficient filtration systems, and controlled culture duration. Several studies have shown that the productivity of RAS in Nile tilapia culture can reach approximately 30–45 kg/m³ at stocking densities of around 50–125 fish/m³ in tarpaulin ponds or small- to medium-sized rearing tanks equipped with biofilters and continuous water circulation systems during a 50– 60 day culture period. Under these conditions, water quality parameters remained within optimal ranges, with dissolved oxygen (DO) levels of approximately 5–6 mg/L, temperatures of 25–29°C, and a neutral pH, thereby maintaining stable fish growth despite the high stocking density.

In contrast, conventional pond systems generally apply lower stocking densities of approximately 10–30 fish/m³, resulting in productivity levels of only 10–20 kg/m³ due to limited water exchange and the high accumulation of organic waste during the culture period. Therefore, the high productivity achieved in RAS is influenced not only by the recirculation technology itself but also by the combination of stocking density, culture tank size, biofiltration capacity, and the effectiveness of water quality management throughout the production cycle (Widodo et al., 2020; Putra et al., 2022; Rahman et al., 2021). Figure 1 illustrates the implementation of the RAS system.

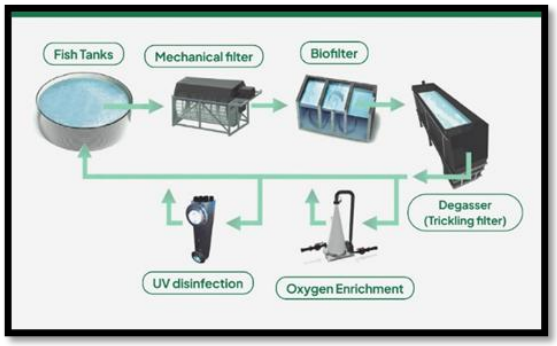

Figure 1. Examples of the Application of RAS in the Media
Source: agtech.folio.com

3.2. Productivity of the Biofloc System

The Biofloc system also demonstrates competitive productivity in Nile tilapia culture, particularly through the utilization of heterotrophic microorganisms that convert organic waste into nutrient-rich flocs. Biofloc productivity generally ranges from 25 to 40 kg/m³, slightly lower than that of RAS but still significantly higher than conventional aquaculture systems. The primary advantage of the Biofloc system lies in its feed efficiency, as the flocs serve as an additional nutrient source that supports fish growth while reducing the dependence on commercial feed. This system also enables high stocking densities with minimal water usage.

However, the productivity of the Biofloc system is strongly influenced by the stability of the carbon-to-nitrogen (C/N) ratio, aeration management, and suspended solids control. Poor management practices may lead to the accumulation of organic matter, resulting in decreased water quality and reduced productivity. Nevertheless, the Biofloc system remains an intensive aquaculture technology that is more economical and adaptive for small- to medium-scale aquaculture farmers (Paul et al., 2024). Figure 2 presents an example of the Biofloc system implementation.

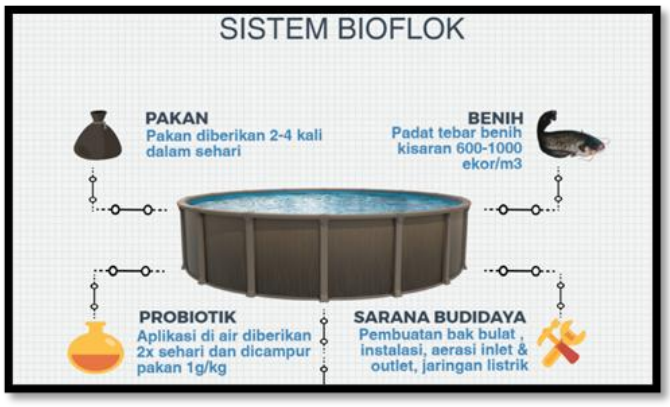

Figure 2. Example of biofloc system implementation
Source: kolambioflok.com

Table 1. Comparison of productivity among RAS, biofloc, and conventional systems

No.	Aquaculture System	Productivity (kg/m³)	Performance Description	Main Advantages	References
1	RAS	30–40	High productivity through optimal water quality control	High stocking density, environmental stability	Setyono et al. (2021)
2	RAS	25–35	Biomass increased significantly compared to conventional systems	Effective biological filtration	Sopiandi et al. (2022)
3	RAS	28–38	Faster growth and a high survival rate	Low ammonia levels, stable DO	Nurhariati et al. (2021); Yulianti & Sari (2022)
4	RAS	30–45	High production in limited land areas	Space and water efficiency	Rusman et al. (2023)
5	RAS	27–36	Stable water quality improved harvest yield	Suitable for modern intensive aquaculture	Wijayanti et al. (2024)
6	Biofloc	28–40	Low FCR and competitive growth performance	Feed and water efficient	Makarti et al. (2025); Wahidin et al. (2024)
7	Biofloc	24–32	High survival rate with lower production costs	Zero water exchange	Sugiarto (2021)
8	Conventional	10–20	Low productivity	Simple management	Rachmawati et al. (2015)
9	Conventional	12–18	Slower growth rate	Low initial investment cost	Prasetyo et al. (2019)
10	Conventional	15–22	Fluctuating water quality	Easy to implement	Nugraha et al. (2023)
11	Conventional	10–15	High FCR and higher mortality	Traditional system	Widodo et al. (2020)

Based on Table 1, the Recirculating Aquaculture System (RAS), Biofloc, and conventional systems exhibit significant differences in productivity, efficiency, and resource requirements. The RAS system consistently delivers the highest productivity, ranging from 25–45 kg/m³, thanks to optimal water quality control supported by mechanical and biological filtration, aeration, and stable water circulation. These conditions enable high stocking densities and faster fish growth rates. Meanwhile, the Biofloc system demonstrates slightly lower yet still competitive productivity, ranging from 24 to 40 kg/m³. Its primary advantage lies in better feed efficiency through the utilization of organic flocs as an additional nutrient source, resulting in lower Food Conversion Ratio (FCR) values and reduced operational costs. On the other hand, the conventional system shows the lowest productivity, approximately 10–22 kg/m³, because it relies heavily on natural water exchange and has limited capacity to maintain stable environmental conditions within the culture system.

From an economic perspective, the Biofloc system is more accessible to small- to medium-scale farmers due to its lower initial investment than RAS. In contrast, RAS is better suited to large-scale, intensive aquaculture operations with greater capital availability and higher technical capacity. Overall, RAS excels in productivity and environmental control; Biofloc is superior in feed and cost efficiency; and the conventional system remains relevant for traditional aquaculture practices but has considerable limitations in productivity and sustainability. Therefore, the selection of the most appropriate aquaculture system largely depends on farming scale, capital availability, water resources, and the technical capabilities of aquaculture practitioners.

3.3. Water Use Efficiency

In terms of water use efficiency, both RAS and Biofloc systems offer significant advantages over conventional aquaculture systems, although the Biofloc system is generally more water-efficient. The RAS system can recycle approximately 80–95% of the culture water via filtration, thereby significantly reducing the need for new water input. Meanwhile, the Biofloc system can minimize water exchange to nearly zero (zero water exchange) because microorganisms directly utilize organic waste within the system. This characteristic makes Biofloc particularly advantageous for water conservation, especially in areas with limited freshwater availability.

On the other hand, RAS still requires partial water replacement to maintain the stability of certain water quality parameters and to support biofilter performance. Therefore, from the perspective of water efficiency, the Biofloc system is considered superior, whereas RAS provides a balance between water efficiency and better environmental quality control (Sugiarto, 2021; Putra et al., 2022; Widodo et al., 2020).

Based on Table 2, the Biofloc system is the most efficient in terms of water utilization, followed by the Recirculating Aquaculture System (RAS). In contrast, the conventional system demonstrates the lowest water efficiency. Therefore, to support sustainable aquaculture development in Indonesia, implementing Biofloc or RAS technologies is a strategic option, particularly in regions with limited water resources.

Table 2. Comparison of water use efficiency among RAS, biofloc, and conventional systems

No.	Aquaculture System	Water Use Efficiency (%)	Performance Description	Main Advantages	References
1	RAS	80–95%	Very high-water recirculation with minimal water exchange	Water-saving, stable water quality	Setyono et al. (2021)
2	RAS	85–90%	Water reuse through biofilters and mechanical filtration	Suitable for water-scarce areas	Putra et al. (2022); Nurhariati et al. (2021)
3	RAS	75–90%	High water stability supports intensive production	Long-term water conservation	Yulianti & Sari (2022)
4	RAS	80–92%	Low requirement for new water input	Optimal environmental control	Wijayanti et al. (2024)
5	RAS	78–88%	More efficient water management than conventional ponds	High productivity	Rusman et al. (2023)
6	Biofloc	90–98%	Zero/minimal water exchange	Most water-efficient system	Makarti et al. (2025)
7	Biofloc	88–95%	Water is rarely replaced, and microbes utilize waste	Highest water efficiency	Sugiarto (2021); Wahidin et al. (2024)
8	Biofloc	87–95%	Nearly zero water replacement requirement	Sustainable aquaculture system	Wahidin et al. (2024)
9	Conventional	20–40%	Requires routine water exchange	Simple system	Rachmawati et al. (2015)
10	Conventional	25–45%	Highly dependent on new water sources	Low initial investment	Prasetyo et al. (2019)
11	Conventional	30–50%	Low efficiency due to excessive water use	Easy to implement	Nugraha et al. (2023)
12	Conventional	20–35%	High water consumption	Risk of fluctuating water quality	Widodo et al. (2020)

3.4. Feed Efficiency (Feed Conversion Ratio/FCR)

Feed efficiency is an important indicator in intensive aquaculture because feed costs can account for more than 60% of total production expenses. Based on various studies, the Biofloc system tends to have lower Feed Conversion Ratio (FCR) values, ranging from 0.9 to 1.2, because the organic flocs provide an additional natural feed source for the fish. In contrast, the RAS system generally exhibits FCR values ranging from 1.1 to 1.4, which are still considered efficient but slightly higher than those of the Biofloc system. Meanwhile, conventional aquaculture systems typically exhibit higher FCR values, ranging from 1.5 to 2.0.

The lower FCR achieved in the Biofloc system provides substantial economic benefits, particularly in reducing feed-related operational costs. On the other hand, RAS relies more on environmental control and stable water quality to maximize feed conversion efficiency. Therefore, the Biofloc system is superior in feed efficiency, while RAS remains competitive through the maintenance of a stable production environment (Makarti et al., 2025; Putra et al., 2022). Based on Table 3, the Biofloc system demonstrates the best feed efficiency, with the lowest FCR, followed by the RAS system, while the conventional system exhibits the highest FCR. This indicates that the Biofloc system is most effective at reducing feed costs, whereas RAS remains superior at combining high productivity with stable feed efficiency. Therefore, selecting an aquaculture system should balance feed costs, productivity, and investment capacity.

Table 3. Comparison of feed efficiency (Feed Conversion Ratio/FCR) among RAS, biofloc, and conventional systems

No.	Aquaculture System	FCR Value	Performance Description	Main Advantages	References
1	RAS	1.1-1.3	High feed efficiency due to stable water quality	Optimal growth performance	Setyono et al. (2021)
2	RAS	1.0-1.4	Good feed conversion at high stocking density	Intensive production capability	Putra et al. (2022)
3	RAS	1.1-1.4	High biomass production with efficient feed utilization	Precise environmental control	Nurhariati et al. (2021); Yulianti & Sari (2022)
4	RAS	1.2-1.5	Lower FCR compared to conventional systems	High productivity	Wijayanti et al. (2024)
5	RAS	1.1-1.4	Optimal feed utilization	Low mortality rate	Rusman et al. (2023)
6	Biofloc	0.8-1.2	Best FCR due to flocs as an additional feed source	Feed-saving efficiency	Makarti et al. (2025)
7	Biofloc	0.9-1.1	Reduced use of commercial feed	High cost efficiency	Wahidin et al. (2024); Sugiarto (2021)

8	Biofloc	0.8-1.2	Best overall feed efficiency	Low operational costs	Wahidin et al. (2024)
9	Conventional	1.5-2.0	Low feed efficiency	Simple management system	Rachmawati et al. (2015)
10	Conventional	1.6-2.1	Significant feed wastage	Fluctuating water quality	Prasetyo et al. (2019)
11	Conventional	1.5-2.2	Slower growth performance	Low investment requirement	Nugraha et al. (2023)
12	Conventional	1.7-2.3	Highest FCR values	Simple management practices	Widodo et al. (2020)

3.5. Water Quality and Survival Rate (SR)

The RAS system is superior at maintaining water quality because it combines mechanical and biological filtration, consistently keeping environmental parameters within optimal ranges. Dissolved oxygen (DO) levels in RAS are generally stable above 5 mg/L, pH remains within neutral ranges, and ammonia concentrations can be maintained at safe levels. These conditions support Nile tilapia survival rates of approximately 88–96%.

In the Biofloc system, water quality can also support relatively high survival rates (80–88%). However, the system is more sensitive to management errors such as overfeeding, aeration failure, or imbalances in the carbon-to-nitrogen (C/N) ratio. Although Biofloc systems can achieve good survival rates, RAS generally provides better water quality stability, resulting in higher, more consistent survival rates. Therefore, in terms of environmental quality management and fish survival rate, RAS is considered superior to the Biofloc system (Rahman et al., 2021; Wahidin et al., 2024; Sugiarto, 2021).

Table 4. Water Quality Parameters in RAS, Biofloc, and Conventional Systems

Parameter	RAS	Biofloc	Conventional	Description
Temperature (°C)	26–30	26–30	25–32	RAS and Biofloc are more stable; conventional systems are more fluctuating
pH	6.5–8.0	6.5–8.0	6.0–8.5	Modern systems are better at maintaining pH stability.
DO (mg/L)	>5	>5	3–6	RAS and Biofloc are supported by intensive aeration
Ammonia (mg/L)	<0.02	<0.05	0.1–0.5	RAS shows the lowest ammonia due to optimal biofiltration
Nitrite (mg/L)	<0.1	<0.1	0.1–0.5	Conventional systems are more prone to accumulation
Water Efficiency (%)	75–95%	85–98%	20–50%	Biofloc is the most water-efficient system
Stocking Density	Very high	High	Low–moderate	RAS supports the highest production intensification
Water Quality Stability	Very stable	Stable	Fluctuating	RAS excels in environmental control
Disease Risk	Low	Moderate–low	Moderate–high	Influenced by water quality stability
Survival Rate (%)	87–96%	82–92%	68–85%	RAS demonstrates the highest survival rate

Based on Table 4, the Recirculating Aquaculture System (RAS) demonstrates the most stable water quality, with superior control of temperature, pH, dissolved oxygen (DO), ammonia, and nitrite levels. As a result, RAS achieves the highest productivity and survival rates in Nile tilapia culture, particularly in intensive systems with high stocking densities. The Biofloc system also maintains good water quality and excels in water and feed efficiency by utilizing microorganisms. However, it is more sensitive to technical management errors such as inadequate aeration and imbalances in the carbon-to-nitrogen (C/N) ratio. Meanwhile, conventional systems exhibit the most fluctuating water quality, lower water efficiency, and reduced productivity and survival rates due to limited environmental control capabilities. Overall, RAS is the most superior system in terms of productivity and environmental stability. Biofloc is more efficient and economical, while conventional systems are simpler to implement but less optimal for sustainable intensive aquaculture practices.

Table 5. Comparison of survival rate among RAS, biofloc, and conventional systems

No.	Aquaculture System	Survival Rate (%)	Performance Description	Main Advantages	References
1	RAS	90–95%	High survival rate due to stable water quality	High DO, low ammonia	Setyono et al. (2021)
2	RAS	88–94%	Low mortality at high stocking density	Optimal filtration system	Putra et al. (2022)
3	RAS	89–96%	High SR supports intensive production	Environmental stability	Nurhariati et al. (2021); Yulianti & Sari (2022)

4	RAS	87–93%	Controlled water quality improves fish health	Modern aquaculture system	Wijayanti et al. (2024)
5	RAS	88–95%	More consistent growth and health performance	Closed-system culture	Rusman et al. (2023)
6	Biofloc	85–92%	High SR through microbial stability	Flocs support fish health	Makarti et al. (2025)
7	Biofloc	83–90%	Low mortality when floc management is optimal	Biological efficiency	Wahidin et al. (2024); Sugiarto (2021)
8	Biofloc	84–90%	Improved fish resistance and resilience	Supported by microorganisms	Wahidin et al. (2024)
9	Conventional	70–85%	Lower SR due to fluctuating water quality	Simple system	Rachmawati et al. (2015)
10	Conventional	72–83%	Higher mortality rate	Unstable water quality	Prasetyo et al. (2019)
11	Conventional	68–82%	Greater disease risk	Low investment requirement	Nugraha et al. (2023)
12	Conventional	70–80%	Limited stocking density	Low technological application	Widodo et al. (2020)

Based on Table 5, the RAS system provides the highest survival rate due to optimal water-quality control, followed by the Biofloc system, which also maintains high survival rates through biological stability. In contrast, conventional systems exhibit the lowest survival rates because of limited environmental control. Therefore, for sustainable intensive aquaculture, both RAS and Biofloc systems are superior to traditional systems in maintaining the health and survival of Nile tilapia (*Oreochromis niloticus*).

3.6. Economic Efficiency and Sustainability Analysis of RAS and Biofloc Systems

From an economic perspective, the Biofloc system is generally more advantageous for small- to medium-scale farmers because it requires a lower initial investment, particularly in infrastructure, filtration systems, and energy. Several feasibility studies on intensive Nile tilapia farming indicate that the payback period can range from less than one year to around two years, depending on production scale, feed prices, and technical management. High feed efficiency (low FCR) and minimal water exchange contribute to lower operational costs, enabling faster capital recovery than other intensive systems. Therefore, the Biofloc system is considered easier to adopt by small-scale farmers due to its lower financial risk and relatively good profitability (Cahrial & Noormansyah, 2020).

In contrast, the Recirculating Aquaculture System (RAS) requires a significantly higher initial investment due to the need for mechanical and biological filtration units, water-circulation pumps, intensive aeration systems, and high electricity consumption to maintain stable water quality. Feasibility analyses show that the payback period for RAS varies depending on business scale, production capacity, and operational efficiency. Mahargyo et al. (2025) reported that Nile tilapia farming using RAS at the nursery stage had a payback period of approximately 12 years and 7 months due to high initial investment and operational costs. However, in commercial-scale RAS-based seed production systems, the payback period can be significantly shorter, around 2 years, due to higher productivity and production efficiency. Despite requiring substantial capital, RAS remains economically viable because it supports high stocking density, ensures stable water quality, and produces consistent, high-value output suitable for large-scale intensive aquaculture and modern hatchery systems.

From a sustainability perspective, both systems support environmentally friendly aquaculture, but with different approaches. Biofloc focuses on the utilization of organic waste and the conversion of nitrogen into useful microbial biomass. At the same time, RAS emphasizes strict water-quality control, efficient water-use, and high-density production in limited space. Overall, Biofloc is more cost-efficient for capital-limited operations, whereas RAS is better suited for long-term investment with large-scale production goals and maximum productivity targets. Therefore, selecting the most appropriate system should consider capital capacity, production scale, technical skills, and market objectives to achieve an optimal balance between profitability and sustainability in Nile tilapia aquaculture (Prasetyo et al., 2019; Nugraha et al., 2023).

4. Conclusions

Based on the analysis, both the Recirculating Aquaculture System (RAS) and Biofloc system have been proven to significantly improve the productivity, efficiency, and sustainability of Nile tilapia culture compared to conventional systems. However, each system has distinct performance characteristics and advantages. The RAS system shows superior performance in terms of productivity, water quality stability, high stocking density capability, and higher survival rates. Therefore, it is highly suitable for large-scale, intensive aquaculture focused on maximizing production and premium product quality. In contrast, the Biofloc system is superior in feed

efficiency (Feed Conversion Ratio/FCR) and water use efficiency. It offers lower operational costs, making it more economical and adaptable for small- to medium-scale farmers. From an economic perspective, the Biofloc system has a shorter payback period, ranging from less than 1 year to around 2 years, due to lower initial investment and operational costs. Meanwhile, the RAS system requires a much higher initial investment, with a payback period ranging from approximately 2 years, 3 months, 18 days to 12 years, 7 months, depending on production scale and operational efficiency. However, RAS offers higher productivity and more stable environmental control, which can generate greater long-term economic benefits. Both systems also support sustainable aquaculture practices by promoting efficient water use and reducing environmental waste.

Overall, both systems are highly valuable, and their effectiveness depends on local conditions, capital availability, technical capacity, production scale, and farming objectives. Therefore, selecting an appropriate aquaculture technology must be tailored to specific operational needs to achieve an optimal balance among productivity, economic efficiency, and environmental sustainability. Ultimately, RAS and Biofloc represent strategic innovations that play a crucial role in supporting the transformation of modern Nile tilapia aquaculture toward a more productive, efficient, and competitive aquaculture industry in Indonesia.

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