Effectiveness of a nanofiltration membrane-based recirculation system on growth and survival of asian redtail catfish (*Hemibagrus nemurus*) under various retentate treatments

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Abstract. Recirculated Aquaculture Systems (RAS) is an efficient, stable, and easily controllable method of aquaculture. By utilizing nanofiltration, these systems improve water quality in the pond, which in turn promotes better fish growth. The purpose of this study is to assess the optimal management of retentate flow in rearing systems utilizing nanofiltration membrane technology, aimed at improving the growth performance and survival rate of Asian redtail catfish. The research follows a Completely Randomized Design (CRD) with one factor, five treatment levels and three repetitions. The treatment levels are as follows: P_1 = discarding 40% of the retentate, P_2 = discarding 50% of the retentate, P_3 = discarding 60% of the retentate, P_4 = discarding 70% of the retentate, and P_5 = discarding 80% of the retentate. The best results were obtained in P_2, with an average absolute weight growth of 6.45±0.42 g, absolute length growth of 4.79±0.19 cm, specific growth rate of 4.82±0.19%, feed efficiency of 77.35±1.08%, feed conversion ratio of 1.29±0.01, survival rate of 90.62±3.12%, and water quality within the rearing media suitable for Asian redtail catfish growth and survival. The glucose levels observed during the study ranged from 47 to 61 mg dL^{-1}.

1 Introduction

The Asian redtail catfish (*Hemibagrus nemurus*) is a freshwater species valued for its significant economic importance and wide market appeal. Valued for its premium-quality meat, this species typically commands a higher price than other freshwater fish. Fresh fish is sold for 75,000 to 100,000 IDR kg^{-1}, while smoked products fetch prices of 250,000 to 400,000 IDR kg^{-1}. However, intensive aquaculture practices often involve high stocking densities, which can result in rapid water quality degradation due to the buildup of metabolic waste and uneaten feed, ultimately hindering the fish's growth [1]. Recirculated Aquaculture System (RAS), commonly known as a recirculating system, is an aquaculture approach that efficiently utilizes water while maintaining stability and control. This system

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involves recycling water through various filters and components to enhance its quality, allowing it to be reused in the cultivation process [2]. The implementation of RAS technology improves the carrying capacity of the cultivation medium by enabling precise control over water quality. This technology is water-efficient and environmentally friendly, promoting both the survival and growth of fish [3].

Various studies have shown that nanofiltration (NF) membranes hold great promise in a range of fish farming applications. NF technology can efficiently concentrate and recycle nutrients from aquaculture waste, providing a viable solution to the problem of nutrient excess in aquaculture wastewater [4]. These membranes are effective at retaining dissolved contaminants, foul-smelling compounds, and inorganic substances, making them ideal for removing unwanted materials in recirculating aquaculture systems (RAS) [5]. However, membrane technology still faces the challenge of fouling on the pores and surface of the membrane. Fouling is a significant issue because it reduces flux values, necessitating frequent membrane cleaning or replacement, which increases operational and maintenance costs [6]. The fouling phenomenon is highly complex and influenced by many factors, making the fouling mechanism not yet fully understood. Treating retentate from nanofiltration is expected to help create an optimal recirculation system for fish farming with lower operational costs.

The treatment of different retentates is necessary because retentate, which is the by-product of the nanofiltration process, can have a significant impact on water quality in aquaculture systems [7]. If not properly managed, the accumulation of retentate can increase the concentration of organic matter, minerals, and other dissolved substances that may negatively affect the environmental conditions for fish. Each level or method of retentate treatment can produce different effects on water quality parameters including levels of dissolved oxygen levels, pH, and ammonia concentration, which ultimately influence fish growth, survival, and health. One of the main reasons why retentate is reused in aquaculture systems is to improve the overall efficiency of water and resource utilization. Reusing retentate allows for a reduction in wastewater discharge, making recirculation systems more water-efficient and environmentally friendly. In the context of aquaculture, where large volumes of water usage are a major concern, retentate treatment strategies that enable its reuse can help reduce operational costs while supporting the sustainability of the aquaculture industry [8]. Additionally, reusing retentate can help maintain certain nutrient concentrations that may be beneficial for fish, as long as the retentate is properly treated to remove harmful components such as ammonia or excess organic matter. With proper management, reused retentate can maintain a water quality balance that supports fish growth without the need for large-scale water replacement. By applying different retentate treatments, this study aims to understand how these variations impact the microenvironment in the recirculation system. This is crucial because each type and amount of retentate can have different effects on the aquatic environment, which in turn influences the physiological performance of the fish.

In aquaculture research, recirculation systems using nanofiltration membranes have not been extensively explored, particularly in the context of freshwater fish species like *Hemibagrus nemurus*. Moreover, most studies on recirculation systems focus solely on water quality without specifically measuring the impact of varying retentate concentrations on fish growth and survival. This highlights the need for more in-depth investigations into how retentate generated from the nanofiltration process can affect aquaculture performance. This study aims to fill that gap by evaluating the effectiveness of a nanofiltration membrane-based recirculation system regarding the growth and survival of *Hemibagrus nemurus* under varying retentate treatments. The study offers fresh perspective on the potential use of nanofiltration technology in aquaculture and demonstrates how variations in retentate concentration can influence water quality, fish growth, and overall health.

2 Research Method

2.1 Time and place

This research was carried out over a period of 56 days, from April to June 2024. The study occurred in several laboratories, including the Experimental Fish Maintenance Unit at the Fish Hatchery and Experimental Pond Unit of the Faculty of Fisheries and Marine Sciences, University of Riau. Additional facilities included the Fish Cultivation Technology Laboratory; the Laboratory of Parasites and Fish Diseases for physiological observation of the test fish; and the Chemical Oceanography Laboratory of the Department of Marine Science.

2.2 Materials and equipment

The main materials utilized in this research were juvenile Asian redtail catfish (*H. nemurus*), obtained from fish farms in Kampar, measuring 3 and 4 cm long, totaling 1,300 individuals. The feed was a commercial type, specifically HiPro 9, with a protein content of 38%.

2.3 Research methods

The research method applied is a Completely Randomized Design (CRD) with a single factor, five levels of treatment, and three replications. The treatment in this research refers to the results of Assidiqi's research [9]. The treatments in this study involved discarding 40%, 50%, 60%, 70%, and 80% of the retentate.

2.4 Observed parameters

The variables assessed in this study encompass water quality parameters, including temperature [10], pH [10], dissolved oxygen (DO) [11], CO_2 [11], ammonia (NH_3) [11], nitrite (NO_2) [12], nitrate (NO_3) [12], Total dissolved solids [13] and Total Suspended Solid [14]; physiological responses such as blood glucose levels [15]; and the growth performance of Asian redtail catfish, which includes measurements of absolute length growth [15], specific growth rate [16], feed efficiency [16], feed conversion ratio [16] and survival rate [17].

2.5 Data analysis.

The data regarding ammonia, nitrite, nitrate, blood glucose levels, absolute weight growth, absolute length growth, specific growth rate, feed conversion ratio, feed efficiency, and survival rate of Asian redtail catfish were analyzed using a Completely Randomized Factorial Design. An analysis of varianece (ANOVA) with an F-test conducted to determine the effect of treatments on each measured variable. The analysis wa performed using SPSS software version 25.0. When $p<0.05$, a Newman-Keuls post hoc test was applied to identify significant differences between treatments. Data regarding temperature, pH, dissolved oxygen, and CO2 were analyzed using descriptively methods.

3 Results and Discussion

3.1 Water Quality.

The water quality observations for each treatment are displayed in Table 1.

Table 1. Results of water quality observations across all treatments over the 56-day study period.

Parameters	Treatment				
	P_1	**P_2**	**P_3**	**P_4**	**P_5**
Suhu (°C)	26.3 – 29.6	26.8 – 28.6	26.2 – 30.5	26.4 – 30.7	26.5 – 29.8
pH	6.4 – 7.5	6.3 – 7.4	6.5 – 7.5	6.2 – 7.5	6.0-7.0
DO (mg L^{-1})	3.86 – 6.35	3.91 – 6.16	3.40 – 6.32	4.07 – 7.08	3.81-5.69
CO_2 (mg L^{-1})	2.5 – 5	2.5 – 4	2.5 – 5	2.5 – 6	2.5-4
Amonia (mg L^{-1})	0.054 – 0.127	0.040 – 0.127	0.032 – 0.127	0.059 – 0.127	0.063-0.226
Nitrite (mg L^{-1})	0.088 – 0.719	0.077 – 0.719	0.176 – 0.719	0.116 – 0.719	0.084-0.186
Nitrate (mg L^{-1})	0.067 – 5.658	0.059 – 0.658	0.106 – 0.658	0.097 – 0.658	0.105-0.631
TSS (mg/L)	29 - 36	29 - 37	28 - 31	28 - 33	29-39
TDS (ppm)	31 - 84	31 - 51	31 - 69	31 - 90	31-94

Description: P_1 = discarding 40% of the retentate, P_2 = discarding 50% of the retentate, P_3 = discarding 60% of the retentate, P_4 = discarding 70% of the retentate, and P_5 = discarding 80% of the retentate

Table 1 shows that after 56 days of maintenance, the dissolved oxygen (DO), temperature, pH, CO_2, total suspended solids (TSS), total dissolved solids (TDS), ammonia, nitrite, and nitrate in each treatment were within the optimal range for the survival of Asian redtail fish. Radona et al. [18] found that the ideal temperature for maintaining Asian redtail fish is between 27-30°C. Kordi and Ghufran [19] suggested that a pH range of 6.5 to 8.5 and a DO level of 3-7 mg L^{-1} are optimal for their cultivation. Setiadi et al [20] reported that ammonia levels between 0.20-0.72 mg L^{-1}, nitrite levels between 0.11-0.72 mg L^{-1}, and nitrate levels between 0.10-1.23 mg L^{-1} are conducive to their growth and survival. The ideal carbon dioxide concentration to support fish life is less than 5.0 mg L^{-1}, although higher levels, above 10 mg L^{-1}, can be tolerated if oxygen levels are sufficient [21]. Putra et al. [22] noted that Asian redtail fish can tolerate TSS values between 100-350 ppm and TDS values between 250-850 ppm.

Suspended solids (TSS) consist of particles like silt and fine sand that contribute to water turbidity [23]. Total Dissolved Solids (TDS) quantity is the concentration of dissolved substances in water, encompassing both organic and inorganic materials. Both TSS and TDS are critical factors that can degrade water quality, leading to physical, chemical, and biological changes [24]. Nanofilters are effective in reducing TSS and TDS levels in water due to their extremely small pore size, typically around 1 nanometer. This small pore size enables them to filter out small molecules and ions. By capturing particles larger than the pore size, nanofilters can significantly lower TSS levels, while also reducing TDS by removing most dissolved substances such as calcium and magnesium ions, as well as heavy metals.

3.2 Growth Performance of Asian redtail catfish.

The findings from the observations on the growth performance of Asian redtail catfish for each treatment are displayed in Table 2.

Table 2. Growth performance of Asian redtail catfish across all treatments during the study

Parameters	Treatment				
	P_1	P_2	P_3	P_4	P_5
AWG (g)	4.82±0.45^b	6.45±0.42^c	3.63±0.20^a	3.49±0.16^a	3.00±0.16^a
ALG (cm)	4.34±0.19^a	4.79±0.19^b	4.23±0.27^a	4.20±0.16^a	3.97±0.16^a
SGR (%)	4.46±0.24^b	4.82±0.19^b	3.88±0.27^a	3.83±0.27^a	3.21±0.27^a
FE (%)	72.72±1.50^b	77.35±1.08^c	64.57±2.01^a	65.05±1.57^a	60.04±1.57^a
FCR	1.37±0.03^b	1.29±0.01^a	1.54±0.04^c	1.53±0,03^c	1.75±0.03^c
SR (%)	84.37±3.12^b	90.62±3.12^c	77.08±1.80^a	77.08±1.80^a	71.4±1.80^a

Description : AWG = Absolute weight growth, ALG = Absolute length growth, SGR = specific growth rate, FE = Feed efficiency, FCR = Feed Conversion Ratio, SR = Survival Rate

Based on Table 2, the highest values for absolute length, absolute weight, and specific growth rate were recorded in P_4, while the lowest values were observed in P_5. The results of the Analysis of Variance (ANOVA) test indicate that the recovery percentage significantly impacts the growth of absolute weight and absolute length in Asian redtail fish reared in a recirculation system with nanofilter technology ($P<0.05$). Assiddiq [9] noted that nanofilters help break down organic matter such as food leftovers and fish waste, thereby preserving water quality in aquaculture systems. Low ammonia levels can enhance the appetite of Asian redtail fish, leading to faster weight gain. Maintaining good water quality in the rearing environment is crucial for improving fish appetite and reducing stress, thus promoting optimal growth [25].

The highest feed efficiency was observed in treatment P_2 at 77.35%, while the lowest was in P_5 at 60.04%. According to the ANOVA test, rearing Asian redtail fish with varying recovery rates in a recirculating system equipped with nanofiltration technology significantly impacts feed efficiency ($P<0.05$). High feed efficiency indicates that the fish utilize feed effectively, leading to optimal growth, whereas low feed efficiency suggests that more feed is needed for weight gain, as only a small portion of the feed's energy contributes to growth. Therefore, higher feed efficiency reflects a better response to the feed, resulting in faster fish growth [26].

The highest feed conversion ratio for Asian redtail fish was observed in treatment P_5 at 1.75, while the lowest was in P_2 at 1.29. The feed conversion ratio measures the quantity of feed required to generate one kilogram of fish weight and acts as a measure of the efficiency with which fish use the feed they consume. According to Kong et al. [27], several factors can influence this ratio, including poor feed quality—such as feed that easily disintegrates or has an unpleasant odor, which can lead to uneaten feed. ANOVA test results indicated that rearing Asian redtail fish with varying retentate recovery percentages in a recirculating system equipped with nanofiltration technology significantly impacts the feed conversion ratio of Asian redtail fish ($P<0.05$).

The survival rate of Asian redtail fish ranged from 71% to 90%, which is considered good. The ANOVA test results revealed that varying the recovery percentages of Asian redtail fish seeds in a rearing medium using a recirculation system with nanofiltration technology significantly impacts their survival rate ($P<0.05$). This treatment resulted in a higher survival rate compared to the findings of Sari et al [28], which ranged 69,90% to 87,20%. The enhanced survival rate can be attributed to the recirculation system equipped with nanofiltration technology, which ensures that water quality remains within optimal parameters for the growth and survival of Asian redtail fish. As stated by Smejkal et al [29], a fish's capacity to adjust to its surroundings is also essential for its survival. In this study, the survival rate of Asian redtail fish was deemed satisfactory, as survival rates above 50% are classified as good, 30-50% as moderate, and below 30% as poor.

3.3 Glucose of Asian redtail catfish

The findings of the blood glucose observations for Asian redtail catfish (*H. nemurus*) are shown in Table 3.

Table 3. Results of blood glucose observations in Asian redtail catfish across all treatments

Treatment	Blood Glucose (mg dL^{-1})		
	Day-0	Day-28	Day-56
P_1	31± 0.00	35± 1,00^{ab}	51 ± 2.00^{b}
P_2	31± 0.00	37± 0,56^{c}	47 ± 1.53^{a}
P_3	31± 0.00	36± 1,00^{bc}	53 ± 3.51^{b}
P_4	31± 0.00	34± 0,56^{a}	58 ± 2.52^{c}
P_5	31± 0.00	37± 1,00^{c}	61 ± 1.53^{c}

Table 3 presents the blood glucose levels belonging to the Asian redtail catfish (Hemibagrus nemurus), which are still within the typical range for freshwater fish. The results of the Analysis of Variance (ANOVA) test indicated different retentate treatments in a rearing medium employing a recirculation system using nanofiltration technology significantly affect the blood glucose levels in the fish ($P<0.05$). The blood glucose levels in the catfish ranged from 47 to 61 mg dL^{-1}. Giri et al. [30] reported that the highest glucose levels are often associated with a decreased metabolic rate, which causes the fish to remain passive and maintain higher blood glucose levels compared to initial conditions. Yuan and Tao [31] found that the highest glucose levels were observed in treatments with the highest rates of cannibalism. The mechanism behind changes in blood glucose levels in fish begins with stress-related signals detected by receptor organs, which are then transmitted to the hypothalamus in the brain via the nervous system. The hypothalamus subsequently directs chromaffin cells to secrete catecholamine hormones through sympathetic nerve fibers. These catecholamines activate enzymes involved in the breakdown of glycogen stores, leading to an increase in blood glucose levels [32].

4 Conclusions

During the 56-day maintenance period, the most effective retentate treatment in the recirculation system with nanofiltration membranes for Asian redtail catfish was discarding 40% of the retentate. The best results were achieved with this treatment (P_2), which included an average absolute weight growth of 6.45±0.42 g, absolute length growth of 4.79±0.19 cm, specific growth rate of 4.82±0.19%, feed efficiency of 77.35±1.08%, feed conversion ratio of 1.29±0.01, and a survival rate of 90.62±3.12%. The water quality within the rearing media was suitable for the growth and survival of Asian redtail catfish. Additionally, glucose levels observed during the study ranged from 47 to 61 mg dL^{-1}.

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