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Original Article

Carrying capacity of 4 ppt saline water on the production performance and water quality profile of Nile tilapia (*Oreochromis niloticus*) at different densities

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Abstract: Increased density in fish farming can reduce the space for fish movement. The increase in density should be followed by considering the carrying capacity, which includes using an iso-osmotic environment, in this case, 4 ppt salinity. The purpose of this study is to analyze the use of 4 ppt salinity at different densities on production performance, water quality, physiological responses, and cost analysis in Nile tilapia. The experimental method was performed using Nile tilapia measuring 4.53±0.04 cm and an average weight of 1.45±0.03 g in each different density treatment, namely the control treatment of 1000 fish m^{-3}, A 1250 fish m^{-3}, B 1500 fish m^{-3}, and C 1750 fish m^{-3}, given a salinity 4 ppt with research parameters, including production performance parameters, water quality, and stress response. The results showed that the use of 4 ppt salinity in Nile tilapia can support the success of treatment C with a density of 1750 fish m^{-3}, with water quality that is still in the optimal range for Nile tilapia and a survival rate of 95.6% with an average length of 6.6 cm, so that treatment C has the highest profit of IDR 51,500.00.

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Introduction

Nile tilapia (*Oreochromis niloticus*) is a significant commodity in Indonesia, characterized by its substantial economic value and widespread public preference. The production volume of tilapia has been experiencing an annual increase, with aquaculture production reaching 1,356,654.06 tons in Indonesia in 2022 (KKP, 2022). The global demand for fish has risen, highlighting the importance of fish as a source of nutrition. Despite the increased production, only approximately 50% of the community's demand is currently being met (Arie and Dejee, 2013). The rising demand for tilapia has necessitated the production of tilapia fish seeds, highlighting the need for an optimal method to maximize tilapia fish seed yield.

The maximum aquaculture production is subject to various influencing factors, including the enhancement of the carrying capacity of the environment. In aquaculture systems, carrying capacity is crucial for determining optimal stocking density. This concept pertains to the maximum number of fish that can be sustained within a system without adversely affecting water quality or fish health (Tidwell and Allan, 2001). In this regard, effective density management is essential to optimize production while maintaining the quality of the fish culture environment.

Environmental quality is a critical determinant of the success of tilapia aquaculture, as it significantly influences growth rates (Aliyas et al., 2016). Salinity serves as a key indicator of water quality, impacting osmotic pressure; an increase in salinity corresponds to an increase in osmotic pressure (Maulana et al., 2013). Optimal fish growth is observed under iso-osmotic conditions (Yuliani et al., 2018). A salinity level of 4 ppt is conducive to favorable growth and a survival rate exceeding 95% because it provides an iso-osmotic environment for tilapia (Romadhoni, 2012). Iso-osmotic conditions in tilapia are achieved when the ion concentration in the blood matches that of the surrounding environment. Consequently, the energy expenditure for osmoregulatory processes is minimized owing to the equilibrium between body fluids and the external environment, allowing the

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Table 1. Nile tilapia density treatment at 4 ppt salinity.

Treatment	Density (fish m^{-3})	Description
K (Control)	1000	Standard optimal density according to SNI
A	1250	Medium density with 4 ppt salinity
B	1500	High density with 4 ppt salinity
C	1750	Very high density with 4 ppt salinity

remaining energy to be allocated for growth (Anggoro et al., 2013).

The use of iso-osmotic media in aquaculture has been proposed as a strategy to alleviate stress in fish reared under high-density conditions. Iso-osmotic media, which match the osmotic pressure of fish bodily fluids, are believed to help reduce the osmoregulatory workload on fish, thereby supporting better homeostasis even under stressful conditions. High-density aquaculture environments often expose fish to chronic stress, compromising their health, growth, and productivity (Siddik et al., 2020; Ciji and Akhtar, 2021). An increase in stocking density necessitates consideration of the carrying capacity, which includes the implementation of an iso-osmotic environment, specifically at a salinity of 4 ppt. Consequently, research is required to ascertain the optimal density level for tilapia culture in iso-osmotic media, which not only promotes fish growth and survival but also preserves the quality of the culture environment. Therefore, the purpose of this study is to analyze the use of 4 ppt salinity at different densities on production performance, water quality, physiological responses, and cost analysis in Nile tilapia (*Oreochromis niloticus*). The findings of this study could contribute to enhancing the efficiency and sustainability of Nile tilapia aquaculture.

Materials and Methods

Materials and research design: The Nile tilapia fry, with an average length of 4.53±0.04 cm and a weight of 1.45±0.03 g, were obtained from farmers in Bekasi, Indonesia. The rearing process was conducted in a salinity of 4 ppt, achieved using Sea salt at a rate of 1 ppt h^{-1}, equivalent to 100 g h^{-1} for each replicate. The experimental design was a completely randomized design (CRD) with four stocking density treatments: 1000 (control), 1250, 1500, and 1750 fish m^{-3}. Each treatment consisted of three replicates, all in a constant salinity of 4 ppt, as detailed in Table 1.

Experimental procedure: A total of 12 aquarium units (100×40×50 cm^3) were prepared as tilapia rearing containers, which were previously washed with clean water and filled with reservoir water that had been allowed to stand for three days until it reached a volume of 100 L (25 cm depth). Maintenance was conducted indoors, and each aquarium was equipped with three aerators. Nile tilapia were acclimatized for three days before being stocked at different densities for each treatment: K (1000 fish), A (1250 fish), B (1500 fish), and C (1750 fish), following the standard density of I (1 fish L^{-1}) (SNI, 1999; Alfia et al., 2013).

During the 30-day rearing period, the fish were fed PF-800 commercial feed three times daily (at 08:00, 13:00, and 20:00 local time) *ad libitum*, with weight and length data collected weekly, five times in total. Water quality was maintained by flushing and replacing 75% of the water every three days, and daily salinity levels were monitored using a refractometer. A salinity of 4 ppt was achieved by adding 400 g of sea salt to each aquarium. In-situ water quality parameters, including pH, temperature, salinity, and DO, were recorded daily, while ex-situ parameters such as nitrite, nitrate, TAN, alkalinity, and hardness were analyzed weekly. Blood glucose testing was conducted on days 0, 18, and 30 using five fish samples per replicate, which were slowly bled via injection in the linea lateralis and then analyzed with a digital glucose test kit using a measuring strip before returning the fish to the aquarium.

Growth performance parameters

Feed conversion ratio (FCR): The FCR was calculated at the end of the study. The FCR is used to determine the total feed used to form fish biomass at

Table 2. Water quality test methods and tools.

Parameter	Method	Instrument
Salinity (ppt)	SNI 7644:2010	Refractometer
Temperature (°C)	SNI 6989.23-2005	Thermometer
pH	SNI 6989.11-2019	pH meter
DO (mg L^{-1})	SNI 06-6989.14-2004	DO meter
Nitrite (mg L^{-1})	APHA 2012	Spectrophotometer (543 nm)
Nitrate (mg L^{-1})	APHA 2012	Spectrophotometer (410 nm)
TAN (mg L^{-1})	Zhou and Boyd 2016	Spectrophotometer (630 nm)
Alkalinity (mg L^{-1} as $CaCO_3$)	APHA 2012	Titration apparatus
Hardness (mg L^{-1} as $CaCO_3$)	APHA 2012	Titration apparatus

DO = dissolved oxygen, TAN = total ammonia nitrogen.

harvest. FCR was calculated using the equation of FCR = $F / (B_t - B_0)$ (Effendie, 1997; Ihsanudin et al., 2014), where F is the total feed provided (g), B_t is the final biomass (g), and B_0 is the initial biomass (g).

Specific growth rate (weight and length): The specific growth rate of weight (SGRW) was calculated to determine the percentage of fish weight gain every day. The SGRW was calculated using the formula of $SGRW = [(W_t - W_0)^{1/t} - 1] \times 100$ (Effendi, 2009; Wijayanti et al., 2019), where W_t is the final average weight (g), W_0 is the initial average weight (g), and t is the duration of the rearing period (days). The specific growth rate of length (SGRL) was calculated to determine the percentage of fish length increase every day. The SGRL was calculated using the equation of $SGRL = [(L_t - L_0)^{1/t} - 1] \times 100$ (Effendi, 2009; Wijayanti et al., 2019), where L_t is the final average length (cm), L_0 is the initial average length (cm), and t is the duration of the rearing period (days).

Absolute growth rate (weight and length): The absolute growth rate of weight (AGRW) is the difference between the final and initial weights during rearing. The AGRW can be calculated using the formula of AGRW = $(W_t - W_0) / t$ (Zonneveld et al., 1991), where W_t is the final average weight (g), W_0 is the initial average weight (g), and t is the duration of the rearing period (days). The absolute growth rate of length (AGRL) is the difference between the final and initial lengths during maintenance. AGRL can be calculated using the formula AGRL = $(Lt - L_0) / t$ (Zonneveld et al., 1991), where L_t is the final average length (cm), L_0 is the initial average length (cm), and t is the duration of the rearing period (days).

Survival rate (SR): SR was calculated to determine the percentage of the total number of fish that survived until the end of rearing. The SR was calculated using the equation of SR (%) = $N_t / N_0 \times 100$ (Haliman and Adijaya, 2005), where N_t is the final number of fish (individuals), and N_0 is the initial number of fish (individuals).

Stress response: Glucose levels were measured to assess the stress levels in Nile tilapia reared at different densities. Blood glucose levels were measured at the beginning, middle, and end of rearing using a blood glucose test meter (Autocheck). Glucose levels were measured in five fish per replicate directly at the research site.

Water quality: In situ water quality measurements were performed directly at the research site, including salinity, temperature, and pH, which were measured every day, and DO, which was measured every 7 days. Ex situ water quality measurements were performed in the laboratory, and the parameters measured included nitrite, nitrate, TAN, alkalinity, and hardness. The methods and tools used are listed in Table 2.

Cost analysis: A cost analysis was conducted to compare the costs incurred and benefits obtained for each treatment. The data included the total initial density, total final density, average length (cm), selling price, and amount of feed (kg) (Emilyasari et al., 2023).

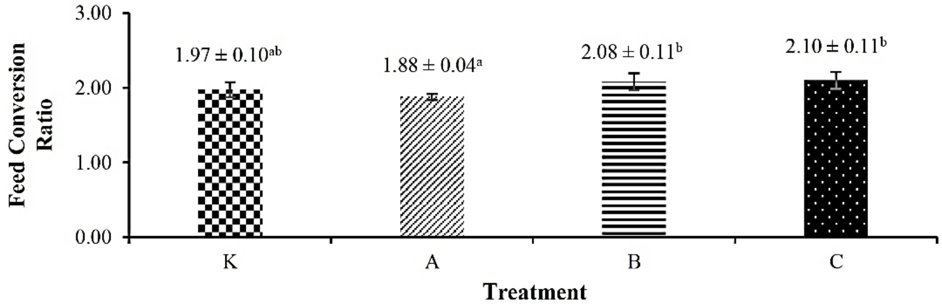

Figure 1. Feed conversion ratio of Nile tilapia (*Oreochromis niloticus*) in the control treatment (1000 fish m^{-3}), A (1250 fish m^{-3}), B (1500 fish m^{-3}), and C (1750 fish m^{-3}).

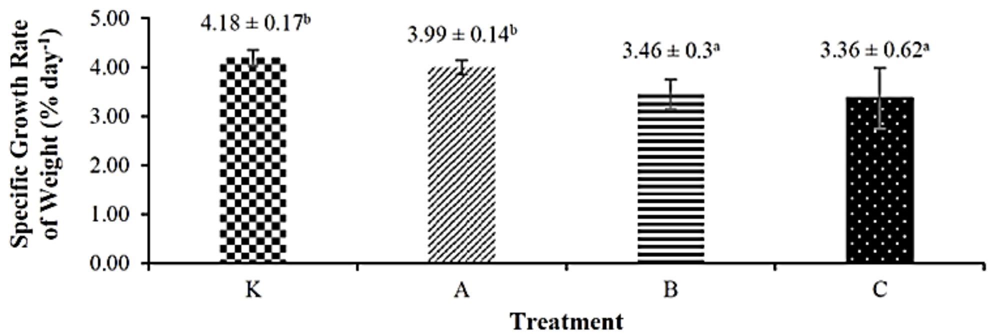

Figure 2. Specific growth rate of Nile tilapia weight (*Oreochromis niloticus*) in the control treatment (1000 fish m^{-3}), A (1250 fish m^{-3}), B (1500 fish m^{-3}), and C (1750 fish m^{-3}).

Data analysis: The data were processed in graphical form using Microsoft Excel 2019. IBM SPSS 26.0 software was used for data testing using analysis of variance (one-way ANOVA) with a 95% confidence interval. Further tests were done using Duncan's test to determine the differences in each treatment.

Results

Growth performance

***Feed conversion ratio (FCR)*:** The FCR during rearing showed that treatment A was significantly different from treatments B and C, but not significantly different from treatment K. Treatment A had the lowest average of the other treatments. The FCR of 1.88±0.04 in treatment A means that 1.88 kg of feed is needed to produce 1 kg of fish (Fig. 1).

***Specific growth rate (weight and length)*:** The specific growth rate of weight (SGRW) during the study showed that treatment A was not significantly different from treatment K, but was significantly different from treatments B and C. The highest SGRW was found in treatment K at 4.18±0.17% day^{-1}, and the lowest was in treatment C at 3.36±0.62% day^{-1} (Fig. 2). Specific growth rate of length (SGRL) during the study showed that treatment A was significantly different from treatments B and C but not significantly different from treatment K. The treatment C (2.34±0.29% day^{-1}) had the lowest SGRL from other treatments, and the highest value was obtained in treatment K (3.21±0.05% day^{-1}) (Fig. 3).

***Absolute growth rate (weight and length)*:** AGRW during the study showed that treatment A was significantly different from treatments B and C but not significantly different from treatment K. Treatment C (0.082±0.014 g day^{-1}) had the lowest results among the treatments, and the highest value was observed in treatment K (0.119±0.006 g day^{-1}) (Fig. 4).

The absolute growth rate of length (AGRL) during the study showed that treatment A was significantly different from treatments B and C, but not significantly different from treatment K. The highest AGRL was recorded in treatment K (0.086±0.001 cm day^{-1}), followed by treatment A (0.081±0.003 cm day^{-1}), and the lowest value was found in treatment C (0.067±0.006 cm day^{-1}) (Fig. 5).

***Survival rate*:** SR during the study showed that

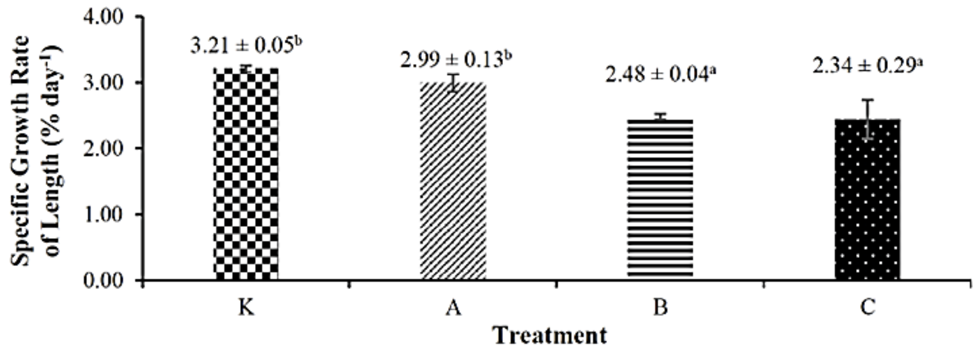

Figure 3. Specific growth rate of Nile tilapia length *(Oreochromis niloticus)* in the control treatment (1000 fish m^{-3}), A (1250 fish m^{-3}), B (1500 fish m^{-3}), and C (1750 fish m^{-3}).

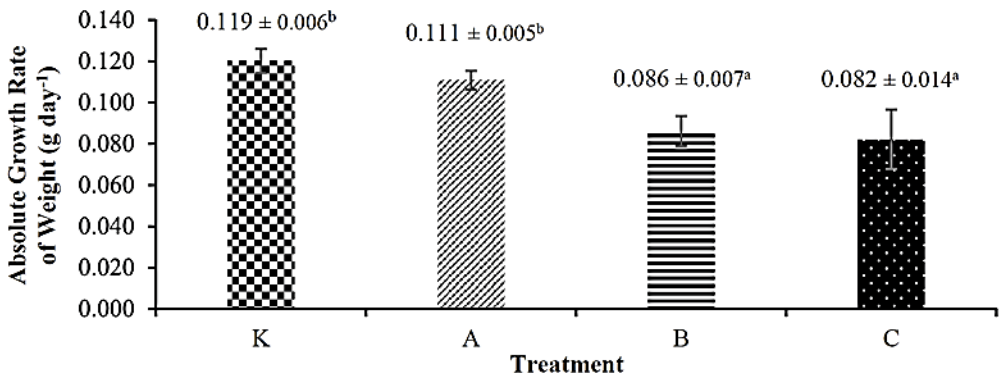

Figure 4. Absolute growth rate of Nile tilapia weight (*Oreochromis niloticus*) in the control treatment (1000 fish m^{-3}), A (1250 fish m^{-3}), B (1500 fish m^{-3}), and C (1750 fish m^{-3}).

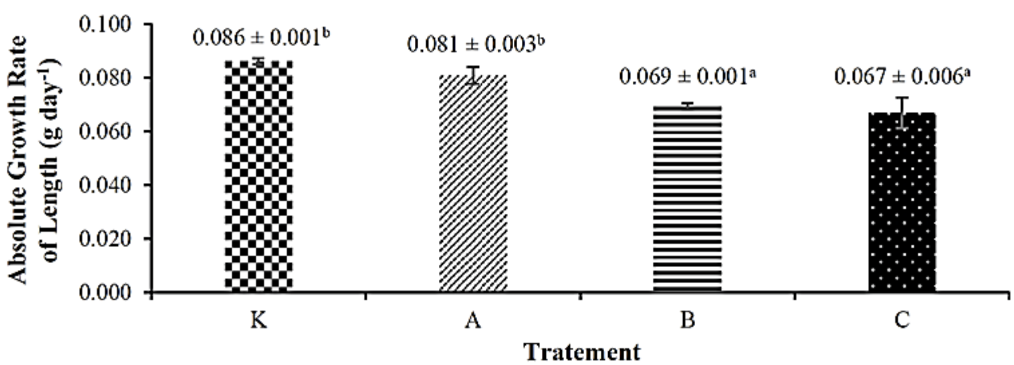

Figure 5. Absolute growth rate of length (AGRL) Nile tilapia length (*Oreochromis niloticus*) in the control treatment (1000 fish m^{-3}), A (1250 fish m^{-3}), B (1500 fish m^{-3}), and C (1750 fish m^{-3}).

treatment A was significantly different from treatments B and C, but not significantly different from treatment K. The SR decreased with increasing density for each of the treatments. The lowest SR was observed in treatment C at a density of 1750 fish m^{-3} (95.62±1.75%), while the highest was in treatment K at 100% (Fig. 6).

Stress response**:** The average blood glucose levels during the study are shown in Figure 7. The overall average glucose level was 40.72 mg dL^{-1}. The lowest blood glucose was in treatment C (38.29 mg dL^{-1}), and the highest was in treatment K (45.5 mg dL^{-1}).

Water quality

Temperature**:** The temperature values ranged from 28.92 to 29.25°C (Fig. 8). The highest average temperature was recorded in treatment C (29.25°C), and the lowest one in treatment K (28.92°C). The temperature during Nile tilapia rearing was within the range of optimal quality standards.

Dissolved oxygen (DO): The DO values in this study ranged from 5.17 to 5.63 mg L^{-1} (Fig. 9). The highest

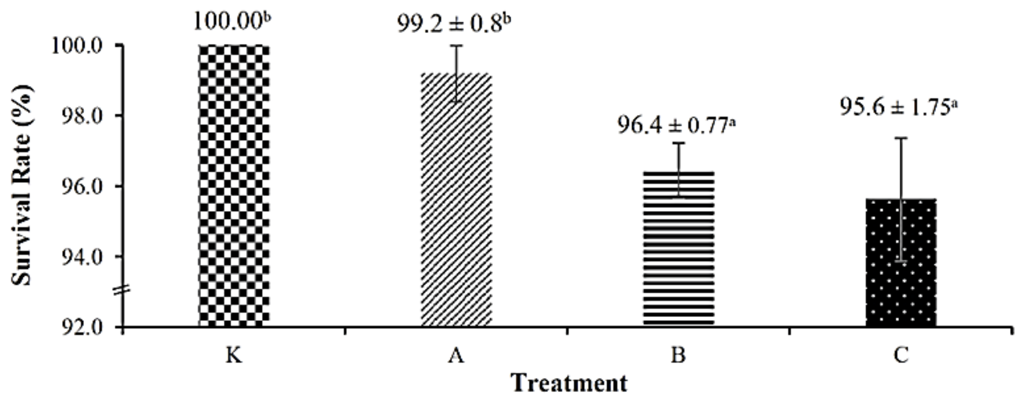

Figure 6. Survival rate of Nile tilapia (*Oreochromis niloticus*) in the control treatment (1000 fish m^{-3}), A (1250 fish m^{-3}), B (1500 fish m^{-3}), and C (1750 fish m^{-3}).

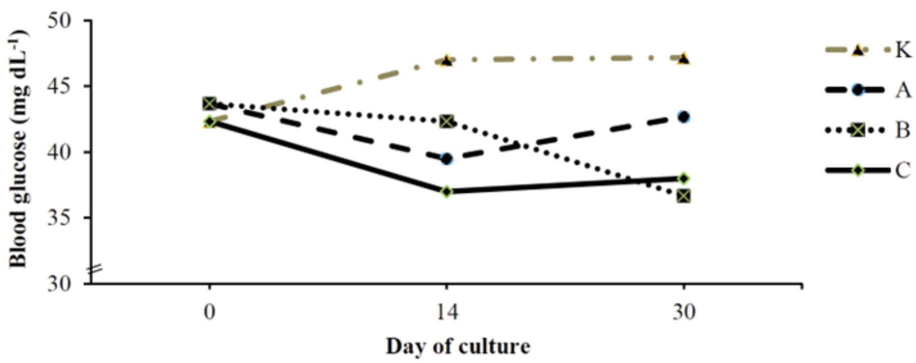

Figure 7. Blood glucose of Nile tilapia (*Oreochromis niloticus*) in the control treatment (1000 fish m^{-3}), A (1250 fish m^{-3}), B (1500 fish m^{-3}), and C (1750 fish m^{-3}).

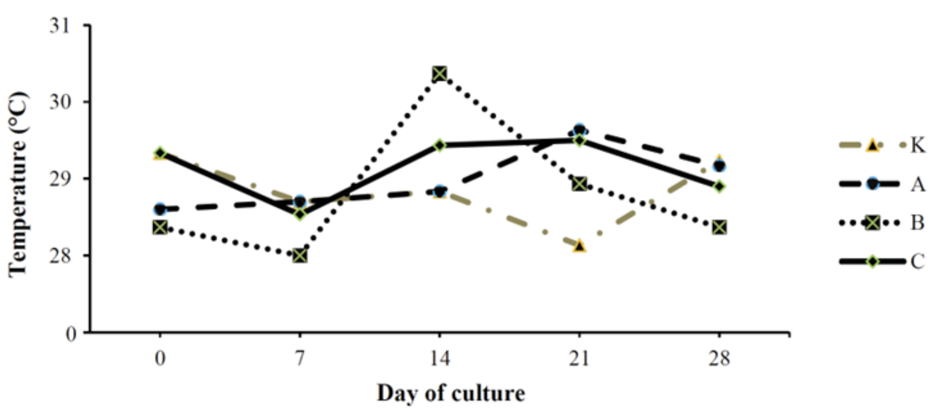

Figure 8. Temperature value of Nile tilapia (*Oreochromis niloticus*) rearing water in the control treatment (1000 fish m^{-3}), A (1250 fish m^{-3}), B (1500 fish m^{-3}), and C (1750 fish m^{-3}).

average DO value was in treatment K, with a value of 5.63 mg L^{-1}. DO levels during tilapia rearing fluctuate wildly and exhibit different patterns between treatments, but remain within the range of optimal quality standards.

***PH*:** The pH values ranged from 6.9 to 7.5 (Fig. 10). The highest average pH value was in treatment C (7.5), and the lowest average pH was in treatment K (6.91). The pH levels during Nile tilapia rearing exhibited different patterns in each treatment, but remained within the optimal quality standards range.

***Nitrite*:** The nitrite content during the study period ranged from 0.097-0.548 mg L^{-1} with an average of 0.365 mg L^{-1} (Fig. 11). The nitrite content during the study period fluctuated wildly and exhibited the same pattern in each treatment from the beginning of stocking to the final week of the study.

***Nitrate*:** The nitrate content ranged from 0.550 to 1.14

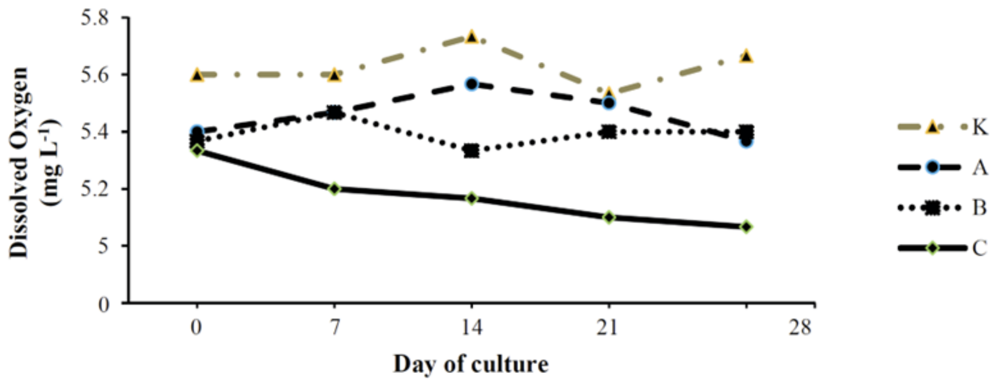

Figure 9. DO value of Nile tilapia (*Oreochromis niloticus*) rearing water in the control treatment (1000 fish m^{-3}), A (1250 fish m^{-3}), B (1500 fish m^{-3}), and C (1750 fish m^{-3}).

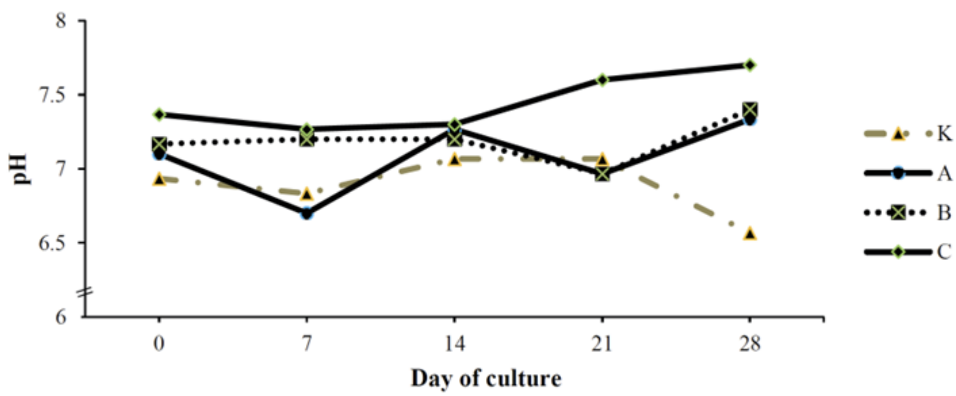

Figure 10. pH of Nile tilapia (*Oreochromis niloticus*) rearing water in the control treatment (1000 fish m^{-3}), A (1250 fish m^{-3}), B (1500 fish m^{-3}), and C (1750 fish m^{-3}).

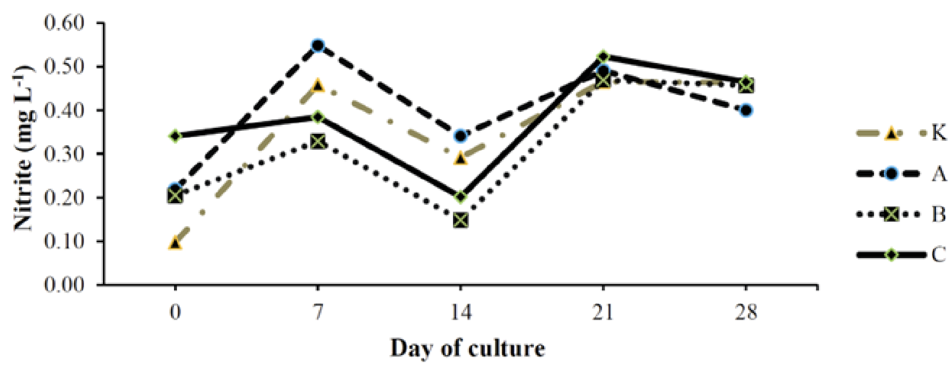

Figure 11. Nitrite of Nile tilapia (*Oreochromis niloticus*) rearing water in control treatment (1000 fish m^{-3}), A (1250 fish m^{-3}), B (1500 fish m^{-3}), and C (1750 fish m^{-3}).

mg L^{-1}, with an average of 0.858 mg L^{-1} across all treatments (Fig. 12). The lowest nitrate content was recorded on day 0 in treatment C at 0.55±0.1 mg L^{-1}, and the highest on day 21 in treatment A (1.146±0.01 mg L^{-1}). The nitrate content in each treatment exhibited the same pattern from the beginning of the study to the final week.

TAN (Total Ammonia Nitrogen)**:** The average ammonia content during the study was 0.513 mg L^{-1}. The lowest ammonia content occurred on day 0 in treatment K at 0.037±0.019 mg L^{-1}, and the highest occurred on day 21 in treatment A at 1.02±0.15 mg L^{-1}. The ammonia content in treatments A, B, and C exhibited the same pattern from the beginning of the study to the final week. Treatment K increased at the beginning of stocking until day 14, but decreased on day 21 (Fig. 13).

Alkalinity**:** The average alkalinity during the study

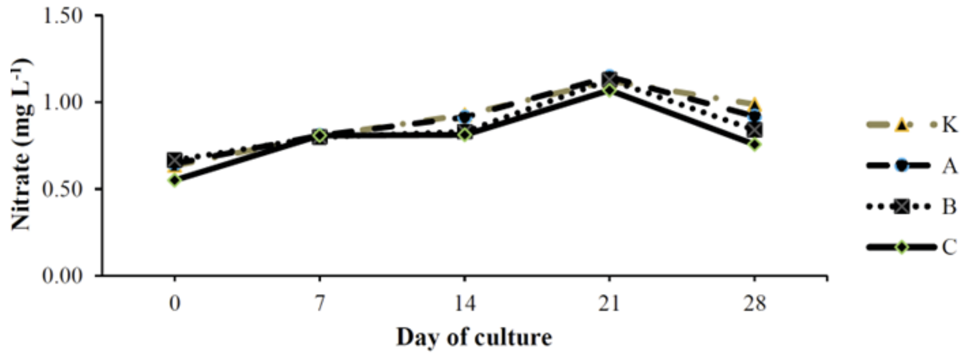

Figure 12. Nitrate of Nile tilapia (*Oreochromis niloticus*) rearing water in the control treatment (1000 fish m^{-3}), A (1250 fish m^{-3}), B (1500 fish m^{-3}), and C (1750 fish m^{-3}).

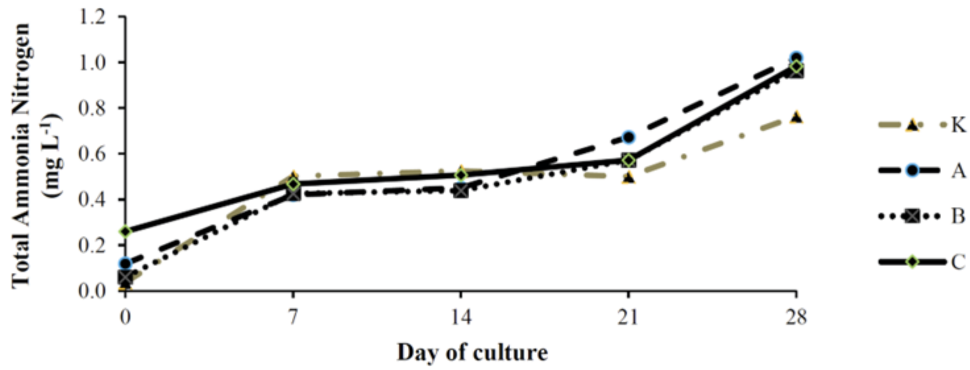

Figure 13. Total ammonia nitrogen of Nile tilapia (*Oreochromis niloticus*) rearing water in control treatment (1000 fish m^{-3}), A (1250 fish m^{-3}), B (1500 fish m^{-3}), and C (1750 fish m^{-3}).

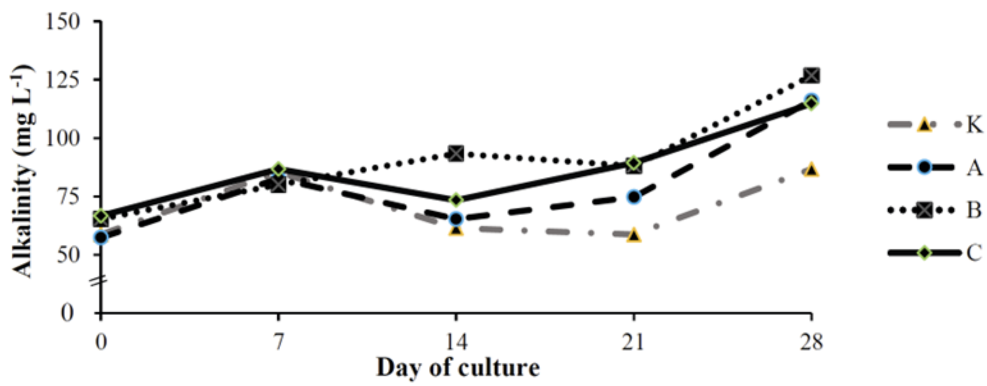

Figure 14. Alkalinity of Nile tilapia (*Oreochromis niloticus*) rearing water in the control treatment (1000 fish m^{-3}), A (1250 fish m^{-3}), B (1500 fish m^{-3}), and C (1750 fish m^{-3}).

was 81.53 mg L^{-1}. The lowest alkalinity content occurred on day 0 in treatment A at 57.33±4.61 mg L^{-1}, and the highest occurred on day 28 in treatment A at 126.66±14.04 mg L^{-1}. The alkalinity content of each treatment increased by the end of the study (Fig. 14).

***Hardness*:** The average hardness content during the study was 135.4 mg L^{-1}. The lowest hardness content was observed on day 7 in treatment A at 100.1±30.23 mg L^{-1}, and the highest was recorded on day 21 in treatment C at 173.5±25.742 mg L^{-1}. The hardness content fluctuated in each treatment during the study period(Fig. 15).

***Cost analysis*:** A cost analysis was conducted to determine the benefits of each treatment after 30 days of maintenance. The cost analysis during maintenance is presented in Table 3. A cost analysis was performed for each treatment. Treatment K had the highest price per head, amounting to IDR 549.57, while the lowest was in treatment C, at IDR 475.50. Treatment C had the highest profit of IDR 51,500.00, while the lowest

Table 3. Cost analysis during maintenance.

Description	Treatment			
	K	A	B	C
Initial stocking density (fish)	300	375	450	525
Final stocking density (fish)	300	372	434	502
Mean length (cm)	7.1	6.9	6.6	6.6
Selling price (IDR)	IDR 700	IDR 600	IDR 600	IDR 600
Total feed (kg)	2.135	2.350	2.530	2.920
Total expenditure (IDR)	IDR 164,870	IDR 192,100	IDR 218,560	IDR 249,640
Price per fish (IDR)	IDR 594.57	IDR 512.27	IDR 485.69	IDR 475.50
Profit (IDR)	IDR 30,130	IDR 31,100	IDR 41,720	IDR 51,500

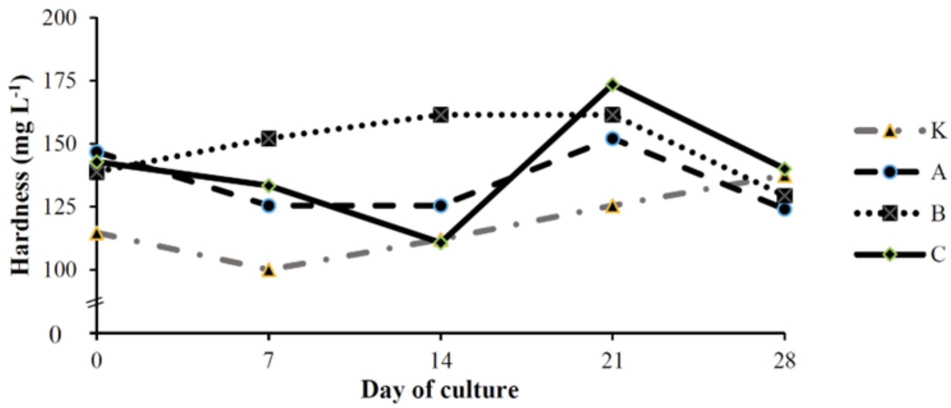

Figure 15. The hardness of Nile tilapia (*Oreochromis niloticus*) rearing water in the control treatment (1000 fish m^{-3}), A (1250 fish m^{-3}), B (1500 fish m^{-3}), and C (1750 fish m^{-3}).

profit was in treatment K, at IDR 30,130.00. Higher profits between treatments were attributed to the high density and survival rates.

Discussions

The feed conversion ratio, as determined by the results of this study, ranged from 1.88±0.04 to 2.1±0.11. The higher the density, the higher the conversion value, as evidenced by treatment C (2.1). The conversion values of treatments C and A were not significantly different because they remained within the tolerance limits of optimal density and were supported by good water quality conditions, ensuring that the concentration of body fluids in the environment was optimal. The higher FCR in treatments B and C was due to the digested feed used to defend itself against environmental pressure resulting from high density, which reduced the energy available for growth (Nugroho et al., 2013). This is directly proportional to the specific growth rate data for weight and length, which yield the same results: a decrease in each treatment. The value of SGRW ranged from 3.01±0.62 to 4.36±0.17% day^{-1}, and the SGRW in Nile tilapia was still within normal conditions, with the highest SGRW observed in treatment K at 4.36%. The value of SGRW was higher than that reported by Nugroho et al. (2013), who used densities of 1000, 1500, and 2000 fish m^{-3} in tilapia with a charcoal filter recirculation system. When the environment is optimal, fish exhibit optimal endurance, and their energy is focused on growth.

Overall, the survival rate in each treatment remains high, with values above 80% (SNI 7550:2009). Treatment K had a 100% survival rate. This is due to the wide space available for fish to move, resulting in little to no competition. Another case in treatment C, which had a survival value of 95.6%, was influenced by the increasingly narrow space, which put pressure on the fish, resulting in a decrease in the fish's immune system until death (Nugroho et al., 2013).

The average glucose level during the study was 40.72 mg dL^{-1}. The lowest average blood glucose value was found in treatment C, which was 38.29 mg dL^{-1}. Normal or healthy fish have glucose levels of approximately 40-90 mg dL^{-1} (Cahyanti and Awalina, 2022). Treatments B and C had an average below 40 mg dL^{-1}, and it is suspected that the fish experienced hypoglycemia (low blood glucose levels) (Lestari et al., 2023). This is caused by the use of glucose as an energy source to adapt to dense environments.

The in situ water quality measurements conducted during the study showed optimal ranges. The temperature during the study ranged from 28.92 to 29.18°C, i.e., still optimal for Nile tilapia growth (SNI 7550:2009). Water temperature plays a crucial role in fish survival, as it affects various physiological processes, including respiration rate, feed efficiency, growth, behavior, and reproduction of cultured fish (Samsundari, 2013). Temperature can affect oxygen consumption in fish, as well as the solubility of oxygen in water. Specifically, the higher the water temperature, the lower the oxygen solubility. Additionally, at high temperatures, the biological activity of microorganisms increases, leading to enhanced activity that consumes more oxygen and results in decreased oxygen levels in the water (Mu'minin et al., 2022).

Rosariawari et al. (2019) stated that dissolved oxygen plays an important role as an indicator of water quality because it facilitates the reduction and oxidation processes of organic (feces and feed residues) and inorganic materials. Oxygen levels during the current study ranged from 5.17 to 5.63 mg L^{-1}. The levels observed met the quality standards for oxygen in Nile tilapia aquaculture. Wijayanti et al. (2019) reported that the optimal DO concentration for Nile tilapia growth is at least 3 mg L^{-1}. Dissolved oxygen is the main factor limiting fish survival and is necessary for the ammonia oxidation process (Ajitama, 2017). DO can influence the pH value; lower DO levels are associated with more alkaline pH, while higher DO levels tend to make the water more acidic. As dissolved oxygen levels decrease, organisms in the water struggle with respiration, resulting in increased CO_2 production. This excess CO_2 reacts with water to form carbonic acid (H_2CO_3), which releases hydrogen ions (H^+), causing a decrease in pH (Dauhan et al., 2014).

The degree of acidity (pH) determines primary productivity, and based on SNI 7550:2009, the quality standard value for Nile tilapia rearing ranges from 6.5 to 8.5, indicating that the pH content during the study was within the normal range. This range is still very feasible for the growth and survival of 4 cm tilapia fry (Situmorang et al., 2022). However, when DO is low, the respiration process in fish decreases, leading to lower CO_2 levels. As CO_2 levels decrease, the pH tends to become alkaline, and this is in line with the results of the current study in treatment C, where the treatment produced the lowest DO and alkaline pH values. An increase in pH will also increase the concentration of ammonia (NH_3), which is known to be very toxic to fish, and a decrease in pH can increase the concentration of NH_4^+, which is relatively non-toxic (Bayu and Sugito, 2018).

High fish densities cause DO levels to decrease, and the ammonia content in the water increases due to fish metabolic waste and feed residues. Increasing density is indirectly related to increased metabolic waste and feed residue, which in turn increases the level of ammonia in the culture system and the rate of ammonia oxidation. The tolerable and suitable ammonia concentration for fish survival is less than 1 mg L^{-1} (Asnawi, 1984; Scabra et al., 2022). In the current study, the ammonia content remained within normal limits, with an average value of 0.513±0.041 mg L^{-1}. The level of ammonia toxicity depends on several factors, including fish species, salt content, the acclimatization process, and the duration and intensity of ammonia exposure in fish. (Irianto, 2005).

High ammonia concentrations increase nitrite and nitrate levels through the oxidation of ammonia by Nitrosomonas and the oxidation of nitrite by Nitrobacter. (Izzati, 2011). The nitrite toxicity level in tilapia is 5 mg L^{-1}, and in most cases, it should remain below 1 mg L^{-1} (Wahyuningsih, 2015). The results of the current study are feasible for tilapia aquaculture, with an average value of 0.365 mg L^{-1}. Adding chloride as sodium chloride (NaCl) prevents the buildup of nitrite. Cl ions and nitrite ions compete to be absorbed in the gill epithelium, which can decrease nitrite absorption and allow the enzyme methemoglobin reductase to convert methemoglobin back into hemoglobin (Irianto, 2005). The final result of the nitrification process is nitrate. Farmed fish can withstand nitrate levels in water up to 40 mg L^{-1}, but the best growth occurs below 10 mg L^{-1} (Juliyanti et al., 2016). Nitrate threshold value in PP. No. 82 of 2001 for freshwater fish farming was 10 mg L^{-1}; therefore, the results of the present study were still within the normal range.

Alkalinity, or the capacity of water to neutralize acids, also affects the water body and functions as a pH buffer. Nile tilapia can grow and develop well in water environments with low or neutral alkalinity (Karimah et al., 2018). The optimum alkalinity levels for fish farming range from 30 to 500 mg L^{-1} (Effendi, 2003). The alkalinity levels during the present study ranged from 57 to 126 mg L^{-1}, indicating that the alkalinity levels during the study were within the normal range. The pH value, which tends to be stable, supports the alkalinity results, which also tend to be stable, as confirmed by the findings of Nurchayati et al. (2021), who stated that alkalinity is inversely related to acidity (pH).

Water hardness refers to the presence of dissolved magnesium and calcium salts (Irianto, 2005). The dominant causes of hardness are Ca^{2+} and Mg^{2+}, especially Ca^{2+}, so the meaning of hardness is limited as a property/characteristic of water, which describes the concentration of the sum of Ca^{2+} and Mg^{2+} ions expressed as C_aCO_3 (Nababan et al., 2015). Based on Limbaugh et al. (2021), water hardness levels ranging from 150 to 2000 mg L^{-1} $CaCO_3$ are safe for gill integrity. In contrast, exposure to 3000 mg L^{-1} $CaCO_3$ induces morphological changes in the gills, specifically an increase in interlamellar cell mass as an adaptive response to protect the lamellae from calcium-induced irritation. However, this protective modification can reduce the functional surface area of the gills, thereby limiting ion exchange efficiency and potentially affecting the fish's overall physiology. If the total alkalinity and total hardness are too low, they can be increased through the addition of lime (Sitanggang and Amanda, 2019). The type of lime that is usually used is quicklime (C_aCO_3), employing dry lime directly sown to the entire bottom of the pond; otherwise, the lime is soaked, and then the water from the lime soak is spread over the entire surface of the pond bottom (Arie and Dejee, 2013). The results of the current study showed that the hardness values were still within the optimal range.

A cost analysis was performed for each treatment. Treatment K had the highest price per head at IDR 549.57, while treatment C had the lowest at IDR 475.50. Treatment C also yielded the highest profit at IDR 51,500.00, whereas treatment K had the lowest profit at IDR 30,130.00. The higher profits in certain treatments were due to the high density and survival rate values.

Conclusion

A salinity of 4 ppt can support the success of treatment C with a density of 1750 fish m^{-3}, a survival rate of 95.6%, water quality within the optimal range, normal blood glucose levels, and the highest profit of IDR 51,500.00.

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