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Production and business performance of tilapia *Oreochromis niloticus* larvae rearing in recirculation system with different stocking densities

Kinerja produksi dan usaha pendederan larva ikan nila *Oreochromis niloticus* pada sistem resirkulasi dengan padat tebar berbeda

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ABSTRACT

The increase in Nile tilapia (*Oreochromis niloticus*) production reflects a rise in fish consumption among the community. The provision of sufficient fry for ongrowing must accompany such a production boost. One way to achieve this is through intensification by increasing the stocking density of tilapia larvae during the nursery phase. This study aimed to analyze production performance and the economics of tilapia larva nursery in a recirculation system under different stocking densities. The experiment was carried out over 42 days using a completely randomized design with stocking density treatments of 5, 10, and 15 individuals per liter, each with five replicates. Differences in stocking density had a significant effect on absolute length growth rate (AGRL), specific length growth rate (SGRL), feed conversion ratio (FCR), and productivity. The 15 ind/L treatment yielded higher LPMP, SGR, and productivity than the other treatments, while showing the lowest FCR. It was concluded that the best production performance and economic return in a recirculating tilapia larva nursery system were achieved at 15 ind/L, delivering an annual productivity of 106,112 ind/m^3, a revenue-to-cost ratio of 1.54, and a payback period of 0.65 years.

Keywords: business analysis, fish tilapia, nursery, recirculation system, stocking density

ABSTRAK

Peningkatan produksi ikan nila (*Oreochromis niloticus*) merupakan gambaran peningkatan konsumsi ikan di masyarakat. Peningkatan produksi perlu diikuti dengan penyediaan benih yang mencukupi untuk pembesaran. Upaya yang dapat dilakukan adalah dengan intensifikasi melalui peningkatan padat tebar larva nila pada tahap pendederan. Tujuan penelitian ini adalah menganalisis kinerja produksi dan usaha pendederan larva ikan nila pada sistem resirkulasi dengan padat tebar berbeda. Penelitian dilakukan selama 42 hari menggunakan rancangan acak lengkap dengan perlakuan padat tebar larva ikan nila, yaitu 5, 10, dan 15 ekor/L dengan lima ulangan. Perlakuan perbedaan padat tebar berpengaruh nyata terhadap laju pertumbuhan mutlak panjang (LPMP), laju pertumbuhan spesifik panjang (LPSP), rasio konversi pakan (RKP), dan produktivitas. Perlakuan padat tebar 15 ekor/L menghasilkan LPMP, LPSP, dan produktivitas yang lebih tinggi daripada perlakuan lain, sedangkan nilai RKP menunjukkan nilai terendah. Penelitian menghasilkan kesimpulan bahwa kinerja produksi dan usaha terbaik pada pendederan ikan nila bersistem resirkulasi dihasilkan pada padat tebar 15 ekor/L dengan memberikan produktivitas sebesar 106.112 ekor/m^3 per tahun, *revenue/cost ratio* senilai 1,54, dan *payback* period yaitu 0,65 tahun.

Kata kunci: analisis usaha, ikan nila, padat tebar, pendederan, sistem resirkulasi

INTRODUCTION

Tilapia (*Oreochromis niloticus*) is one of the freshwater fish commodities in Indonesia and the world. The Food and Agriculture Organization states that total world production reached 4,571 million tons in 2020 and 5.3 million tons in 2022 (FAO, 2024). The Ministry of Marine Affairs and Fisheries reported that national tilapia aquaculture production was 1.172 million tons in 2020 and 1.364 million tons in 2023 (KKP, 2024). This represents an increase of 14.07%. Not only did production rise, but national fish consumption also grew by 4.73%, from 54.56 kg per capita in 2020 to 57.27 kg per capita in 2022 (KKP, 2022). National fish production is increasing to meet national food needs, with an increase in national fish consumption figures indicating an increasing pattern of fish consumption in society. This will increase business opportunities for consumer fish farmers, including tilapia fish farmers (Sharly, 2020).

Tilapia cultivation carried out by farmers has begun to apply intensive cultivation technology (high fish stocking density), such as recirculating aquaculture systems (RAS), since 2018 in several cities in Indonesia (KKP, 2018). Tilapia fingerlings can be produced in large quantities and of high quality if they are reared in accordance with good fish farming practices (CBIB), so that aquaculture activities can continue and the improvement of natural stocks of tilapia is always available. Marlida *et al.* (2022) explain that stocking density will affect the survival and growth of each fish species in different conditions; these circumstances impact the level of aquaculture production. In line with the statement of Schmittou (2024), that an increase in density will be followed by a decrease in growth (critical standing crop), so that at a specific density, the growth rate will stop because it has reached the point of environmental carrying capacity. To obtain optimal results, an increase in density must also be followed by an increase in carrying capacity. One way to increase the carrying capacity is by managing the cultivation environment through a recirculation system.

Fish density is important in the nursery because it will affect dissolved oxygen and ammonia in the rearing water. High fish densities result in reduced dissolved oxygen, while ammonia will increase due to the metabolic products of fish and feed residues. This condition is one of the environmental influences that can cause fish stress. This can inhibit fish growth because the energy used for growth is used to defend themselves from environmental influences (Sibarani *et al.,* 2015). An increase in stocking density will disrupt the physiological process and behavior of fish towards space, which in turn can reduce fish's health and physiological conditions. A further consequence of these conditions is decreased feed utilization, growth, and survival (Mile *et al.,* 2023). One of the efforts that can be made to prevent this occurrence is to use a recirculation system (Amin *et al.,* 2020).

The recirculation system is a system of filtering and cleaning water to be treated and can be reused without adding or reducing water (Bregnballe, 2015). Water reduction in the circulation system can be done if a physical filter system is used and media cleaning is done by reversing the circulation (backwash system) (Setyono *et al.,* 2021). Several main components are required in the RAS system, namely physical, chemical, and biological filters, aerators, temperature regulators, water pumps, and recirculation pumps (Jacinda *et al.,* 2021). RAS has the advantage of a more controlled cultivation environment and high stocking density, which can provide financial benefits for farmers (Permana *et al.,* 2019). The utilization of this recirculation system can create an optimal environment for fish growth. It can produce high productivity in a short cultivation time with low mortality and high survival rates (Badran *et al.,* 2024).

The problem experienced by tilapia nursery farmers is that productivity is still low due to low stocking densities. One tilapia larvae rearing farm in Bogor generally uses a stocking density of 2 ind/L. Pramesti (2024) mentioned that a stocking density that is too low will result in low productivity and less efficient use of production facilities. This is in line with the research results by Luz *et al.* (2012), which states that a stocking density of 2 tilapia ind/L with maintenance for 28 days results in a survival rate of 70.10%.

Then, in the research of Maharani and Fasya (2023), it was found that the stocking density of tilapia larvae of 5 ind/L with maintenance for 40 days obtained a survival rate of 100% so it is recommended to use a stocking density of 5 ind/L. However, stocking densities that are too high tend to produce low survival rates, so it is not necessarily that the amount of production increases by increasing stocking densities. Therefore, RAS technology is necessary to support high-density culture operations and achieve high productivity. Marlida *et al.* (2022) reported that tilapia larvae stocked at 15 ind/L and reared for 15 days showed a higher survival rate than other treatments, at 97.33%. Accordingly, further research is needed to determine the optimal stocking density using RAS technology over a 42-day rearing period to reach marketable fry size, thereby maximizing production and business profitability.

MATERIALS AND METHODS

Time and location

This research was conducted from February to April 2024 at the Aquaculture Management Laboratory, Department of Aquaculture, Faculty of Fisheries and Marine Science, Bogor Agricultural University.

Experimental design

This study used a completely randomized design with three larval stocking density treatments, and each treatment used five replicates. The stocking density treatments used were 5 ind/L (SD5), 10 ind/L (SD10), and 15 ind/L (SD15).

Procedure

The rearing containers were 50×30×35 cm^3 aquariums of 15 units cleaned and dried for 24 hours. After drying, the aquarium was filled with water to a height of 33 cm, and two aeration points were installed in each aquarium at the same speed. The study used a recirculation system with the aquarium as a container equipped with a pump with a water discharge of 100 L/h with an electric power of 8 watt. The pump circulated the water, which was then channelled to the filter for filtration. The filter used was placed at the top of the aquarium (top filter), which was filled with a physical filters in the form of dacron, biological filters in the form of bioballs as a substrate for growing bacteria, and chemical filters in the form of activated charcoal and zeolite, which functioned to absorb ammonia in the waters. The test fish used were nirvana black tilapia larvae (*Oreochromis niloticus*) with a length of 0.8 ± 0.2 cm and a weight of 0.009 ± 0.003 g. Before stocking, the fish were acclimatized in an aquarium for one day.

The study began with sampling 30 fish in each aquarium to measure their length and weight. The feed given during the rearing period was commercial in the form of flour with 40-42% protein, 6% fat, 3% crude fiber, 12% ash content, and 10% moisture content. Feed is given three times daily in the morning, afternoon, and evening at satiation. Water quality management was done by removing 5-10% of the dirt at the bottom of the aquarium every three days, providing continuous aeration, and cleaning the physical filter once a week. Temperature, pH, and dissolved oxygen (DO) parameters were measured daily. Alkalinity, total ammonia nitrogen (TAN), nitrite, and nitrate parameters were measured every two weeks. The observed water quality parameters and their measuring devices are listed in Table 1.

Data collection was conducted during the study. The data collected were production performance parameters, water quality, and business performance. Production performance parameters observed included fish mortality, weight, length, and feed amount. Fish weight and length measurements were carried out on a sample of 30 fish per aquarium every 14 days. Fish weight was measured using a digital scale with an accuracy of 0.001 g, while length was measured using a crossbar with an accuracy of 0.1 cm. The number of dead fish and feed was recorded daily and accumulated every 14 days. Water quality parameters such as temperature,

Table 1. Parameters and measuring instruments for water quality in tilapia fingerlings reared for 42 days in the recirculation system.

Parameters	unit	Methods
Temperature	°C	APHA, ed 2550-Temperature
pH	-	APHA, ed 4500-pH
Dissolved Oxygen	mg/L	APHA, ed 4500-Oxygen
Hardness	mg/L	APHA, ed 2340-Hardness
Alkalinity	mg/L	APHA, ed 2320-Alkalinity
Total Ammonia Nitrogen	mg/L	APHA, ed. 21, 2005,4500-NH_3-F
Nitrite	mg/L	APHA, ed. 21, 2005,4500-NO2-B
Nitrate	mg/L	APHA, ed. 21, 2005,4500-NO3-B

pH, and DO were measured daily, while alkalinity, TAN, nitrite, and nitrate were measured every 14 days (Table 1).

Test parameters

The test parameters in the study consisted of production and business performance. These parameters determined the best stocking density in tilapia rearing with a recirculation system. Data on fish mortality, feed consumption, length, and sampling weight were processed to produce production performance as test parameters. Production performance parameters include survival rate, absolute growth rate, specific growth rate, length coefficient of variation, feed conversion ratio, productivity, and stress response. Business performance is assessed through business analysis, which is an important component in starting to build a business. Business analysis is conducted to analyse various aspects, including investment cost analysis, fixed costs, variable costs, total costs, revenue, profit, R/C, and payback period (PP).

Data analysis

The collected data were processed and analysed according to the research objectives. Data on production performance parameters, including survival rate, absolute growth rate of length, specific growth rate of length, specific growth rate of weight, absolute growth rate of weight, coefficient of variation of length, coefficient of variation of weight, feed conversion ratio, and productivity, were analysed at a 95% confidence interval. If there was a significant difference, it was followed by the Duncan test. Water quality parameters were analysed with repeated-measure analysis to explain changes in water conditions during rearing, presented in tables or figures. Business performance was analysed descriptively to explain the condition of the business by presenting it in tabular form. Data analysis used Microsoft Excel 2021, Origin 2024, and SPSS 26.0 software.

RESULTS AND DISCUSSION

Result

The results of the study include survival rate (SR), absolute growth rate in length (AGRL), specific growth rate in length (SGRL), absolute growth rate in weight (AGRW), specific growth rate in weight (SGRW), feed conversion ratio (FCR), coefficient of variation in length (CVL), coefficient of variation in weight (CVW), and productivity which are production performance parameters are presented in Table 2. Temperature, pH, dissolved oxygen, alkalinity, hardness, TAN, ammonia, nitrite, and nitrate are water quality parameters observed during the study and are listed in Table 3. Blood glucose observed as a stress response parameter is described in Figure 4. Table 2 stated that the values of SR, AGRW, SGRW, CVL, and CVW between the treatment groups were not significantly different (P>0.05). SR values ranged from 85.68-88.43%, AGRW

Table 2. Production performance of tilapia fingerlings reared for 42 days in a recirculation system with different stocking densities.

Parameters[1)]	Stock density treatment		
	SD5	SD10	SD15
SR (%)	85.68 ± 9.21[a]	86.20 ± 5.08[a]	88.43 ± 1.07[a]
AGRL (cm/day)	0.042 ± 0.003[b]	0.048 ± 0.004[a]	0.048 ± 0.003[a]
SGRL (%/day)	2.59 ± 0.11[b]	2.76 ± 0.22[ab]	2.83 ± 0.09[a]
AGRW (g/day)	0.009 ± 0.002[a]	0.010 ± 0.002[a]	0.010 ± 0.002[a]
SGRW (%/day)	8.69 ± 0.54[a]	9.26 ± 0.58[a]	9.09 ± 0.38[a]
FCR	2.36 ± 0.52[b]	1.46 ± 0.27[a]	1.88 ± 0.24[ab]
CVL (%)	11.33 ± 2.01[a]	15.43 ± 3.27[a]	14.23 ± 4.33[a]
CVW(%)	54.10 ± 26.70[a]	78.25 ± 20.92[a]	67.14 ± 23.99[a]
Productivity (ind/m^3 year)	34,272 ± 3,682[c]	68,960 ± 4,065[b]	106,112 ± 1,286[a]

Note: SR=Survival rate, AGRL= Absolute growth rate of length, SGRL= Specific growth rate of length, AGRW= Absolute growth rate of weight, SGRW= Specific growth rate of weight, FCR= Feed conversion ratio, CVL= Coefficient of variation of length, CVW= Coefficient of variation of weight. *Mean values (±standard deviation) followed by different superscript letters in the same row indicate significantly different results at the 5% test level (Duncan test). *SD= Stocking density: SD5= 5 ind/L, SD10= 10 ind/L, SD15= 15 ind/L.

ranged from 0.009-0.010, CVL ranged from 11.33-15.43%, and CVW ranged from 54.10-78.25%.

The production performance parameters of AGRL, SGRL, FCR, and productivity between treatments obtained significantly different results (P<0.05). Statistical analysis and Duncan's test are listed in Appendices 2 and 3. AGRL of treatments SD10 and SD15 were not significantly different, but were higher than treatment SD5. SGRL of treatment SD15 showed the highest value, while the lowest value was shown by treatment SD5. FCR in treatment SD10 showed the lowest value, while the highest value was shown by treatment SD5. Treatment SD15 showed productivity with the highest value, then by treatment SD10, while treatment SD5 showed the lowest value.

Fish mortality occurred throughout the rearing period, with a decreasing trend with increasing length of rearing. Figure 1 shows that the survival rate in treatment SD15 decreased significantly until day 14, then remained relatively stable until day 42. The survival rate in treatments SD5 and SD10 continued to decline during rearing. All treatments' average length of tilapia larvae increased during the 42-day rearing period (Figure 2). Treatments SD5, SD10, and SD15 had relatively similar lengths at the beginning of rearing 0.90 ± 0.01 cm. A significant increase in growth was observed from day 0 to day 42. Treatment SD10 and SD15 produced the highest average length at the end of rearing, which was 2.91 cm.

The average weight of tilapia larvae increased during the 42-day rearing period. Treatments SD5, SD10, and SD15 had the same average weight at the beginning of rearing 0.009 ± 0.001 g. A significant increase in weight was observed from day 0 to day 42. Treatments SD10 and SD15 produced higher average weights at the end of rearing than treatment SD5. The average blood glucose value of all treatments was 69.50 mg d/L and did not differ significantly between treatments (P>0.05). The average blood glucose in treatment SD5 was 67.00 mg d/L, treatment SD10 was 69.25 mg d/L, and treatment SD15 was 72.25 mg d/L.

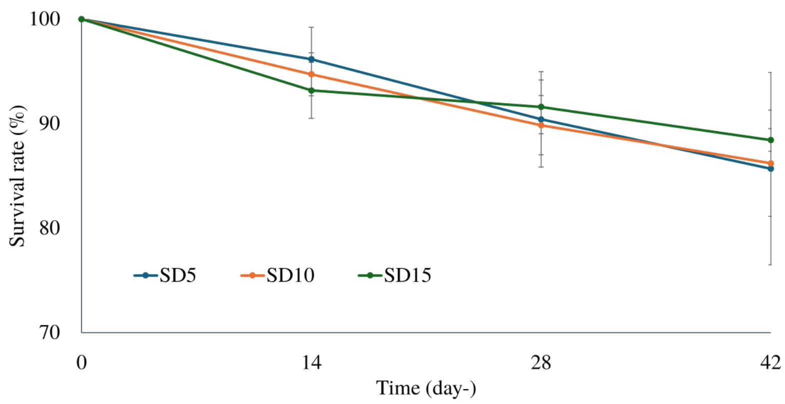

Figure 1. Survival of tilapia reared for 42 days in a recirculation system with different stocking densities. Note: *SD= Stocking density: SD5= 5 ind/L, SD10= 10 ind/L, SD15= 15 ind/L.

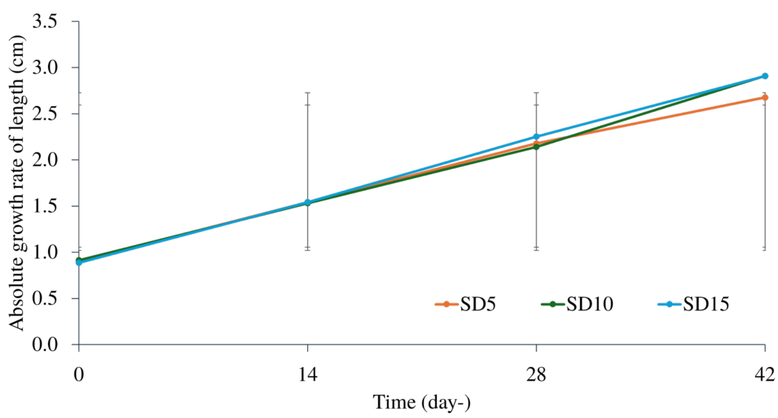

Figure 2. The average length of tilapia reared for 42 days was in the recirculation system with different stocking densities. Note: *SD= Stocking density: SD5= 5 ind/L, SD10= 10 ind/L, SD15= 15 ind/L.

Table 3 presents data on water quality parameters of tilapia rearing production in the recirculation system for 42 days. Data on water quality parameters in all treatments showed decent values to support the production performance of the test fish, especially survival and growth. The performance of the tilapia nursery business with different stocking densities in the recirculation system is shown in the business analysis in Table 4. The highest profit obtained during one year

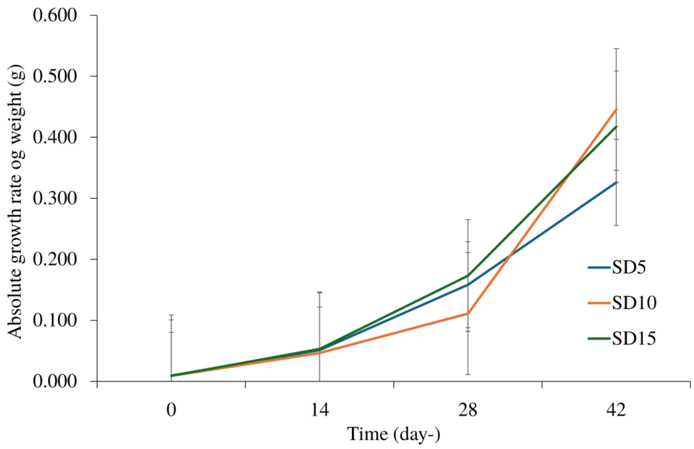

Figure 3. The average weight of tilapia was reared for 42 days in the recirculation system with different stocking densities. Note: *SD= Stocking density: SD5= 5 ind/L, SD10= 10 ind/L, SD15= 15 ind/L.

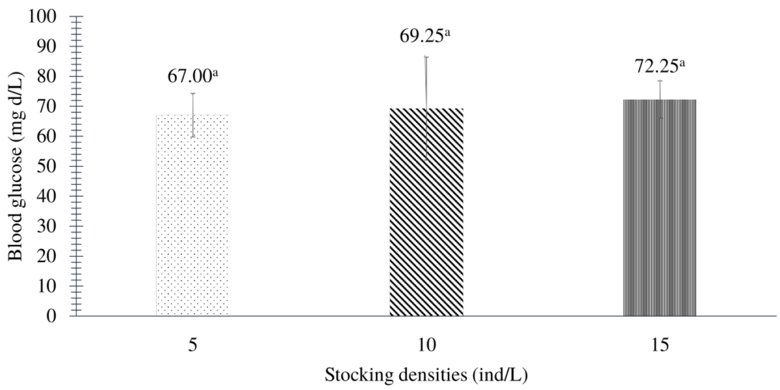

Figure 4. Blood glucose of fish reared for 42 days in the recirculation system with different stocking densities.

Table 3. Water quality of tilapia fingerlings reared for 42 days in a recirculation system with different stocking densities.

Parameters	Stock density treatment			Recommendation value[*)]
	SD5	SD10	SD15	
Temperature (°C)	28.4 ± 0.028[a]	28.3 ± 0.176[a]	28.4 ± 0.032[a]	28–33[1)]
pH	7.8 ± 0.176[a]	7.7 ± 0.176[b]	7.7 ± 0.032[ab]	6.5–9.0[2)]
Dissolved Oxygen (mg/L)	6.4 ± 0.111[a]	6.4 ± 0.119[a]	6.0 ± 0.486[a]	>5.0[2)]
Hardness (mg/L)	17.80 ± 2.17[a]	17.80 ± 2.59[a]	15.60 ± 1.14[a]	75–150[3)]
Alkalinity (mg/L)	120.72 ± 11.643[a]	127.13 ± 3.941[ab]	131.93 ± 4.769[b]	50–200[2)]
Ammonia (mg/L)	0.304 ± 0.139[a]	0.268 ± 0.211[a]	0.504 ± 0.269[a]	<0.20[4)]
Nitrite (mg/L)	0.069 ± 0.045[a]	0.845 ± 0.126[a]	0.200 ± 0.037[a]	<0.7[2)]
Nitrate (mg/L)	0.089 ± 0.084[a]	0.845 ± 0.126[b]	0.885 ± 0.147[b]	1.0–4.5[3)]

Note: [*)]Luo *et al.* (2013), [2)]Boyd (2020), [3)]Bhatnagar & Devi (2019), [4)]Ariyanto *et al.* (2019). *Mean values (±standard deviation) followed by different superscript letters in the same row indicate significantly different results at the 5% test level (Duncan test). *SD= Stocking density: SD5= 5 ind/L, SD10= 10 ind/L, SD15= 15 ind/L.

of production was in treatment SD15, worth Rp 92,323,279. Based on the PP, COGS, and R/C values, it is stated that treatment SD15 is still feasible and profitable to continue, while treatments SD5 and SD10 are not profitable.

Discussion

Survival rate in this study produced the same SR between treatments. This is due to the water quality, which is still within the tolerance limit for fish survival and growth. Stocking density that is too low can also make fish unsafe because they cannot form shoals for self-defense (Chambel *et al.,* 2015). Aeration provided in this study during maintenance plays a role in increasing dissolved oxygen to provide a comfortable environment and reduce stress levels in fish during growth (Abd El-Hack *et al.,* 2022). This can be seen in the high stocking density (15 ind/L), which does not cause excessive stress in tilapia.

The pH of the environment influences the degree of survival. Boyd (2020) states that the optimal pH for tilapia rearing ranges from 6.5 to 9.0. The pH value affects the gills' structure and enzyme activity, affecting the oxygen consumption level. If oxygen consumption levels decrease, energy production will decrease, and energy requirements for biosynthetic activities will also decrease. Furthermore, this can cause the osmoregulation and excretion system to be disrupted, the body's osmotic pressure becomes non-ideal, and the fish can experience death (Wang *et al.,* 2023).

Alkalinity describes water's capacity to neutralize acid (acid neutralizing capacity, ANC) (Bintoro & Abidin, 2016). Alkalinity is also interpreted as a buffer capacity for changes in water pH. During maintenance, alkalinity is still within the normal range. According to Boyd (2020), the optimal alkalinity to support the life and growth of fish is between 30 and 500 mg/L. The study's results during 42 rearing days showed that the length growth rate showed significantly different values (P<0.05) between treatments.

In contrast to the length growth rate, the weight growth, although decreased in the high stocking density treatment (SD15), did not significantly affect the daily weight growth rate. This is due to the negative allometric length-weight relationship, where length growth is faster than body weight gain (Muttaqin *et al.,* 2016). Thus, differences in stocking density only have a significant effect on length growth, but do not have a significant effect on daily weight growth rate. Research for 42 days of maintenance showed significantly different results (P<0.05) on the

Table 4. Business analysis of tilapia fingerlings reared for 42 days in a recirculation system with different stocking densities.

Component	Stock density treatment		
	SD5	SD10	SD15
Investment cost (IDR)	60,146,200	60,146,200	60,146,200
Fixed cost (IDR)	125,772,273	125,772,273	125,772,273
Variable cost (IDR)	23,077,088	34,307,808	46,487,008
Total cost (IDR)	148,849,361	160,080,081	172,259,281
Total production	342,720	689,600	1,061,160
M production (ind)	292,454	542,485	799,407
L production (ind)	50,266	147,115	261,753
M seed price (IDR/ind)	200	200	200
L seed price (IDR/ind)	400	400	400
Revenue (IDR)	78,597,120	167,342,933	264,582,560
Profit (IDR)	(70,252,241)	7,262,852	92,323,279
Break even point (IDR)	178,049,942	158,207,098	152,580,599
Break even point (unit)	1,870,937	778,068	546,324
Cost of goods sold (IDR)	434	232	162
Payback period (year)	-	8.28	0.65
Revenue/cost.	0.53	1.05	1.54

Note: *SD= Stocking density: SD5= 5 ind/L, SD10= 10 ind/L, SD15= 15 ind/L.

feed conversion ratio (FCR) parameter. The high intensity of competition for feed in treatment SD5 affects the performance of feed protein utilization for growth. The feed used by fish in treatment SD10 is more efficient, so the individual weight produced during maintenance is better.

The coefficient of variation in length (CVL) and weight (CVW) describes the variation in size (length and weight) of fish; the lower the value obtained, the more successful fish production activities are (Astari *et al.,* 2021). The coefficient of variation in length in commercial fish farming, especially in seed sales, dramatically affects the selling price of fish. The more uniform the seed, the higher the selling price (Sharly, 2020). The coefficient of length variation in this study (Table 1) is still below 25% so it can be considered uniform (Pedrini *et al.,* 2022). The coefficient of variation of weight is above 25%. This occurs because the at-satiation feeding method allows the fish only to get the desired feed. Thus, this study's difference in stocking density is still within the tolerance range of fish feasibility in competing for space and feed.

Productivity is the ratio between output and input (Iswitardiyanti, 2021). In this study, the best productivity value was at a stocking density of 15 ind/L. This stocking density cannot be said to be maximized because productivity still tends to increase as stocking density increases. An increase in stocking density can increase productivity due to increased production (Astari *et al.,* 2021). Blood glucose is a parameter that can describe the physiological response in animals when maintaining homeostasis in response to a change that occurs. Blood glucose is determined by stress. Higher blood glucose levels indicate increased stress levels due to the treatment (Hanafi *et al.,* 2023).

At very high stress levels, a rapid increase in blood glucose and persistence at high levels will be followed by death (Hanafi *et al.,* 2023). Blood glucose levels obtained in this study were not much different from the results of Bashar *et al.* (2021), which ranged from 65-77 mg d/L. The difference in stocking density used is still within the tolerance limits of tilapia larval rearing. Water quality parameters measured during the study were still within the tolerance range of tilapia production performance (Table 3). The use of a recirculation system is a factor that plays a role in maintaining water quality during maintenance. The recirculation system is sequentially composed of physical filter components in the form of dacron, chemical filters in the form of activated charcoal and zeolite, and biological filters in the form of bioballs. The physical filter applied is synthetic cotton, which functions as a filter for feed residue, metabolic waste, and dirt suspended in the rearing medium.

The physical filter is placed at the beginning (pre-filter) before the water enters the chemical or biological filter, because large particles suspended in water are effectively processed through physical filters (Rahman, 2022). Charcoal filters function to remove chlorine, sediment, odors, and organic compounds (Lembang & Kuing, 2021). The addition of bioballs and zeolites in the recirculation system can suppress ammonia concentrations in waters to increase the growth and survival of selais (*O. hypophthalmus*) (Gunawan *et al.,* 2020). Zeolite functions to absorb ammonia in water so that levels can be lowered. Bioballs in the filter function as a place for nitrifying bacteria to attach. Under aerobic conditions, nitrifying bacteria will convert ammonia (NH_3) into nitrite (NO_2^-) and further convert it into nitrate (NO_3^-). Thus, ammonia levels in the media during 42 days of maintenance showed excellent values for the survival and growth of the test fish.

According to Ariyanto *et al.* (2019), good ammonia levels to support tilapia survival are less than 0.2 mg/L. According to Wahyuningsih and Gitarama (2020), the accumulation of waste in the maintenance water can reduce the filter's performance in the recirculation system, so water remediation is needed. Therefore, regular water changes were carried out during this study. Water change is one way to remove or reduce aquatic waste, such as ammonia, by adding new water (Sitompul *et al.,* 2021). This resulted in no opportunity for bacteria to conduct the nitrification process, so ammonia was not oxidized to nitrite. The range of nitrite in this study is still within the tolerance value of tilapia larvae, which is 0-0.44 mg/L.

Based on Xu *et al.* (2022), a nitrite value <0.7 is the standard limit for fish farming. Nitrite is an intermediate product of the nitrification process by aerobic bacteria. This compound is lethal to aquatic animals because it can attack the gills, blood circulation, and other vital organs in high concentrations. Nitrate compounds are less harmful to fish than ammonia and nitrite. The nitrate value obtained is still within the 0-1.44 mg/L tolerance range. Tolerance of nitrate value for fish is 0-100 mg/L (Bhatnagar & Devi, 2019). Nitrate is the result of the conversion of nitrite compounds by *Nitrobacter* sp. High nitrate concentrations can cause nitrate toxicity, so denitrifying bacteria are needed to reduce nitrate to nitrogen gas (Maulianawati & Lembang, 2022).

Growth is always related to the amount of feed given and water quality in the rearing container because temperature affects appetite and metabolism (Cao *et al.,* 2024). The temperature in the rearing medium during the study ranged from 26.7-31.1°C. According to Hepher and Pruginin (1981), this value is still within the tolerance range for tilapia growth, which is 25-32°C. The degree of acidity (pH) describes the mineral salt content in water and indicates the condition of acidic, neutral, or alkaline waters (Lembang & Kuing, 2021). According to Boyd (2020), the value of acidity is in the proper range, which ranges from 6.6 to 9.0. The pH value is influenced by turbidity, dissolved CO_2, salinity, organic matter breakdown, and individual density (Rahman, 2022).

The pH value during the study ranged from 6.7 to 8.4. This value is still within the tolerance limit of tilapia rearing because it is supported by using zeolite filters that play a role in maintaining pH stability. This is because zeolite is negatively charged, so it can balance ions by binding H^+ ions in the water and preventing a drastic decrease in pH (Heriyani & Mugisidi, 2016). Dissolved oxygen (DO) is required for the breathing process of cultured biota, growth metabolism, and aerobic oxidation of organic and inorganic waste. RAS technology increases the DO value due to good water quality, resulting from the filtration process of aquaculture wastewater.

The filtration process will reduce aquaculture waste, such as feed residue and fish metabolic waste. The aquaculture waste can reduce oxygen levels because the aerobic oxidation process of bacteria uses oxygen to break down the waste. Therefore, dissolved oxygen in the water becomes low. The recirculation system also distributes dissolved oxygen in the waters to maintain stability. High oxygen is vital for tilapia growth because it is needed in the metabolic process. Lack of oxygen will cause fish to experience stress because the brain does not get enough oxygen. The worst situation is causing death due to the absence of oxygen for the respiratory process (Siegers *et al.,* 2019).

The results of DO measurements during 42 days of maintenance were 3.1-7.7 mg/L. Based on these results, the DO value is still optimal for tilapia cultivation. Hardness is a value that states the amount of minerals in water, such as magnesium and calcium (Sitanggang & Amanda, 2019). The hardness in this study was at the optimal value of 72.07 and 156.16 mg/L.

Alkalinity values during maintenance ranged from 4 to 40 mg/L. This value is still within the tolerance range for tilapia life, which ranges from 30-500 mg/L (Boyd, 2020). The alkalinity value during maintenance also indicates that the condition of the maintenance media is still stable. Waters containing more than 20 mg/L of alkalinity indicate that the waters are relatively stable against acid and alkaline changes, so the buffer capacity is more stable (Boyd, 2020). Alkalinity is closely related to the pH of the waters; an increase in alkalinity and a decrease in free CO2 tend to be followed by an increase in pH.

Tilapia nursery production business is oriented towards the length produced at harvest as the final product. The tilapia seed production business analysis uses assumptions and is adjusted to the study results. Hepher and Pruginin (1981) suggested stocking density is the fish biomass per unit volume. Under good conditions and adequate feed, an increase in density will be accompanied by an increase in yield (Budiardi *et al.,* 2011). Investment costs and fixed costs incurred for all stocking density treatments were similar.

The 15 ind/L stocking density treatment has the highest variable costs because each production component's needs vary depending on the number of fish stocked. Different stocking densities will produce different fish sizes and selling prices, so the revenue generated in each treatment is also different. The difference in variable costs will undoubtedly affect the total costs in each stocking density treatment. The 15 ind/L stocking density treatment resulted in the highest revenue because the fish production at the end of rearing was higher than the other treatments.

The business analysis in Table 4 shows that treatment SD15 obtained the highest profit of Rp92,323,279 per year. R/C is used to see how far each rupiah value of costs in business activities can provide a certain amount of revenue (Budiardi *et al.,* 2011). Business activities are declared profitable if they have an R/C value >1, so treatment SD15 can be said to be profitable with a value of 1.54. This is in accordance with Budiardi *et al.* (2011), who state that the R/C value of more than 1 indicates that the rearing business is still feasible and financially profitable.

PP in treatment SD15 is 0.65 years, a relatively fast time to return the capital spent at the beginning of business activities. Based on research on tilapia farming in Sari (2022), the results of business analysis found a profit of Rp 47,888,000 with PP and R/C values of 0.6 years and 1.5. Then, in the research of Vinasyiam *et al.* (2022) on tilapia rearing, a profit of IDR 43,989,000 was obtained with R/C and PP values of 2.29 and 6.27 years. Based on some of these studies' R/C value and payback period, the best business performance analysis on tilapia rearing production is in treating stocking density of 15 ind/L.

CONCLUSION

The best production and business performance in tilapia (*Oreochromis niloticus*) larvae rearing with a recirculation system was produced at a stocking density of 15 fish/L.

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