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Production and business performance of *Anguilla bicolor* fingerlings in a recirculation system with different stocking densities

Kinerja produksi dan usaha *fingerling* ikan sidat *Anguilla bicolor* dalam sistem resirkulasi dengan padat tebar berbeda

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ABSTRACT

Eel (*Anguilla bicolor*) in the grow-out culture requires good fingerling seeds. Increasing the eel productivity can be done by increasing the stocking density, that should be balanced with good environmental and feed management. This study aimed to analyze the production and business performance of fingerlings in a recirculation system to increase the eel survival and growth rate. The study used a completely randomized design with three different stocking densities, namely 4 g/L (A), 5 g/L (B), and 6 g/L (C). The average weight of each fingerling was 20 ± 4.09 g, that was kept in a 1.5-m3 pond with a recirculation system. Feeding was performed two times a day using commercial feed with probiotic supplementation. The results showed that different stocking densities significantly affected feed conversion ratio, total biomass weight, and coefficient of variance. However, different stocking densities had no significant effect on survival rate, absolute weight growth rate, specific weight growth rate, and condition factor. The C treatment obtained the highest profit with an R/C ratio of 1.20 ± 0.03. The best production and cultivation performance of eel fingerling in a recirculation system with different stocking densities is found in treatment C (6 g/L).

Keywords: *Anguilla bicolor*, business performance, production performance, recirculation system, stocking density

ABSTRAK

Budidaya ikan sidat (*Anguilla bicolor*) pada segmen pembesaran memerlukan benih yang baik khususnya untuk benih *fingerling*. Upaya peningkatan produksi benih ikan sidat dapat dilakukan dengan peningkatan padat tebar yang diiringi dengan manajemen lingkungan dan pakan yang baik. Tujuan penelitian ini menganalisis kinerja produksi dan kinerja usaha pada pemeliharaan *fingerling* dalam sistem resirkulasi sehingga meningkatkan kelangsungan hidup dan pertumbuhan. Penelitian menggunakan rancangan acak lengkap yang terdiri atas tiga perlakuan padat tebar dengan tiga ulangan, yaitu padat tebar 4 g/L (A), 5 g/L (B), dan 6 g/L (C). *Fingerling* ikan sidat yang digunakan berbobot awal 20 ± 4,09 g/ekor, yang dipelihara dalam bak 1,5 m3 dengan sistem resirkulasi. Pakan diberikan dua kali sehari berupa pakan buatan komersial yang diberi probiotik. Hasil penelitian menunjukkan bahwa padat tebar berpengaruh nyata terhadap parameter rasio konversi pakan, laju pertumbuhan mutlak biomassa, dan koefisien keragaman bobot tetapi tidak berpengaruh nyata terhadap tingkat kelangsungan hidup, laju pertumbuhan mutlak bobot, laju pertumbuhan spesifik bobot, dan faktor kondisi. Hasil analisis kinerja usaha budidaya *fingerling* dengan padat tebar berbeda menunjukkan berbeda nyata dan sebanding dengan kinerja produksi. Perlakuan C memberikan keuntungan tertinggi dengan rasio R/C sebesar 1,20 ± 0,03. Kinerja produksi dan kinerja usaha budidaya *fingerling* ikan sidat (Anguilla bicolor) dalam sistem resirkulasi dengan padat tebar berbeda terbaik terdapat pada perlakuan C (6 g/L).

Kata kunci: *Anguilla bicolor*, kinerja produksi, kinerja usaha, padat tebar, sistem resirkulasi

INTRODUCTION

Eel (*Anguilla bicolor*) is a potential fishery commodity with high economic value and demand in local and foreign markets. Eel is widely distributed in Indonesian waters, so Indonesia has the potential to become an eel exporter (Affandi *et al*., 2013). Based on the Food and Agriculture Organization in 2017 and 2018, the world's eel production was 260,000 tons and 269,000 tons, respectively (FAO, 2020). BKIPM statistical data (2022) reported that the live eel exports in January-July 2022 reached 4,048 fish.

High demand for eels corresponds to the selling price of eels at IDR 350,000-450,000/kg with 250–300 g/fish (DJPB, 2018). The Central Statistics Agency of KKP (2021) also stated that the export value of Indonesian eels reached USD 16 million in 2020, then turned to USD 10 million in January-November, 2021 with China (63%), Japan (16%), and Vietnam (7%) as the importing countries. Eels are catadromous fish that live in fresh waters as adults and migrate to the sea for spawning. After spawning, the seeds (glass eels) will migrate around the river mouth.

The eel has several stages in its life cycle, namely egg, larvae (leptocephalus), glass eel, elver, yellow eel, and silver eel (Takeuchi *et al*., 2019; Cresci, 2020; Milosevic *et al*., 2022). Eel culture is divided into four stages: nursery I (glass eel rearing at 0.2 g/eel for two to three months to become elver at 2-3 g/eel), nursery II (seed rearing at 2-3 g/eel for three to four months to become 10 g/eel elver), nursery III (elver rearing at 10 g/eel for three to four months to become 20-50 g/eel fingerling), and grow-out (eel rearing at 20-30 g/eel for four to six months to reach the consumption size at > 200 g/eel) (Iskandar *et al*., 2021). Indonesia has abundant potential resources for eel seeds, which are scattered along the southern and eastern coasts of Java Island, west coast of Sumatra Island, east coast of Kalimantan Island, around the coast of Sulawesi Island, and the north coast of Papua (Iskandar *et al*., 2021). A cultivation system that has been implemented for eel fingerling grow-out rearing is the recirculation aquaculture system (RAS).

The recirculation system reuses the water waste by recirculating it through the filter. This system applies a water drainage system, filtration, pumps for water circulation, aeration or oxygenation, and other water management components that can optimize the water quality for fish growth (Hutchinson *et al*., 2004). Filter in the RAS system contains mechanical or physical filter for water purification, biological filter to neutralize toxic ammonia into less toxic nitrate compounds in a process called nitrification (Samsundari & Wirawan, 2013), and chemical filters to absorb poisonous substances or compounds, can affect water quality. RAS is advantageous as farmers can control the culture conditions easier (water quality, feeding, and disease prevention) and can be performed with high stocking density.

However, RAS spends high costs that must be incurred and requires experienced human resources to handle the system. Also, when the contamination occurs, it will quickly spread throughout the system (Jacinda *et al*., 2021). Eel fingerling cultivation activities generally use a stocking density of 4 g/L (Swarni, 2019). Increasing the stocking density can be done to increase production and business performances of eel grow-out. Increasing the stocking density must be balanced with optimal environmental conditions and sufficient feeding to achieve maximum results.

Based on Harianto *et al*. (2014), the best results for elver eel stocking density were obtained at the highest stocking density, e.g. 4 g/L. This opens up opportunities to increase eel production with a stocking density higher than 4 g/L. The stocking density can increase the efficiency of land use and culture period. The stocking density of eel is much lower than the commonly used stocking density in other aquaculture commodities, such as vannamei shrimp (*Litopenaeus vannamei*) which reaches 50-75 g in intensive cultivation system.

Although the amount of production is higher, increased stocking density will be followed by a decreased growth performance, then the growth will stop when it reaches the maximum carrying capacity. High stocking densities in culture and a large amount of feed application cause high metabolic and feed waste exposure. These waste substances produce by-products such as ammonia, which will reduce the water quality and negatively affect cultured organisms. Therefore, further study regarding the increasing stocking density of eel fingerlings is necessary using a recirculation system to improve production and business performance.

MATERIALS AND METHODS

Experimental Design

This study used a completely randomized design with three treatments and three replications. The treatments were composed of different stocking density of fingerlings, namely 4 g/L (A), 5 g/L (B), and 6 g/L (C).

Tank Preparation

Nine fiber tanks (1×2×1) m^3 were used in this study, and each of which was placed randomly. Tanks were prepared by brushing, cleaning, and drying. Simultaneously, recirculation and aeration were also installed into the tanks. Installation for the recirculation system was carried out by preparing a submersible water pump, 80-L bucket as a filter container, and a series of connecting pipes.

The filter components used were physical, chemical, and biological filters. These filters included zeolite and active carbon as chemical filters, bio balls as biological filters, and synthetic cotton (dacron) as physical filters. For aeration system, blower, paralon pipes, hoses, and aeration stones were prepared and connected to one another. Each tank was installed with five aeration points.

Then, the tank was filled with water, disinfected with 5 mL/L chlorine, and aerated for 24 hours. After 24 hours, the water was replaced 100% and filled with water until 60 cm height. When the recirculation system was turned on, the water was pumped and flown through the pipes into the filter, then returned to the rearing tank. The layout and completeness of the tub are presented in Figure 1.

Fish stocking

The fingerlings with 20 ± 4.09 g/eel weight were obtained from *PT. Laju Banyu Semesta* (LABAS), Bogor, Indonesia. The fingerlings were acclimatized for 30 minutes in rearing tanks before being stocked into the test tanks. Fish were reared for 30 days in the experimental pond, Department of Aquaculture, Faculty of Fisheries and Marine Sciences, IPB University.

Feeding

Fish were fed after being fasted for 24 hours. Feeding was performed by applying artificial feed (pellets) with 50% protein content. This feed was mixed with 2 mL/L probiotic solution and stood for an hour before applying. Feeding was performed two times a day in the morning (08.00 WIB) and afternoon (17.00 WIB) by applying the feed to the eel at 2% of the eel biomass.

Water quality control

The water quality was controlled by taking the feed residue and metabolic waste each day to eliminate the solid waste from the system.

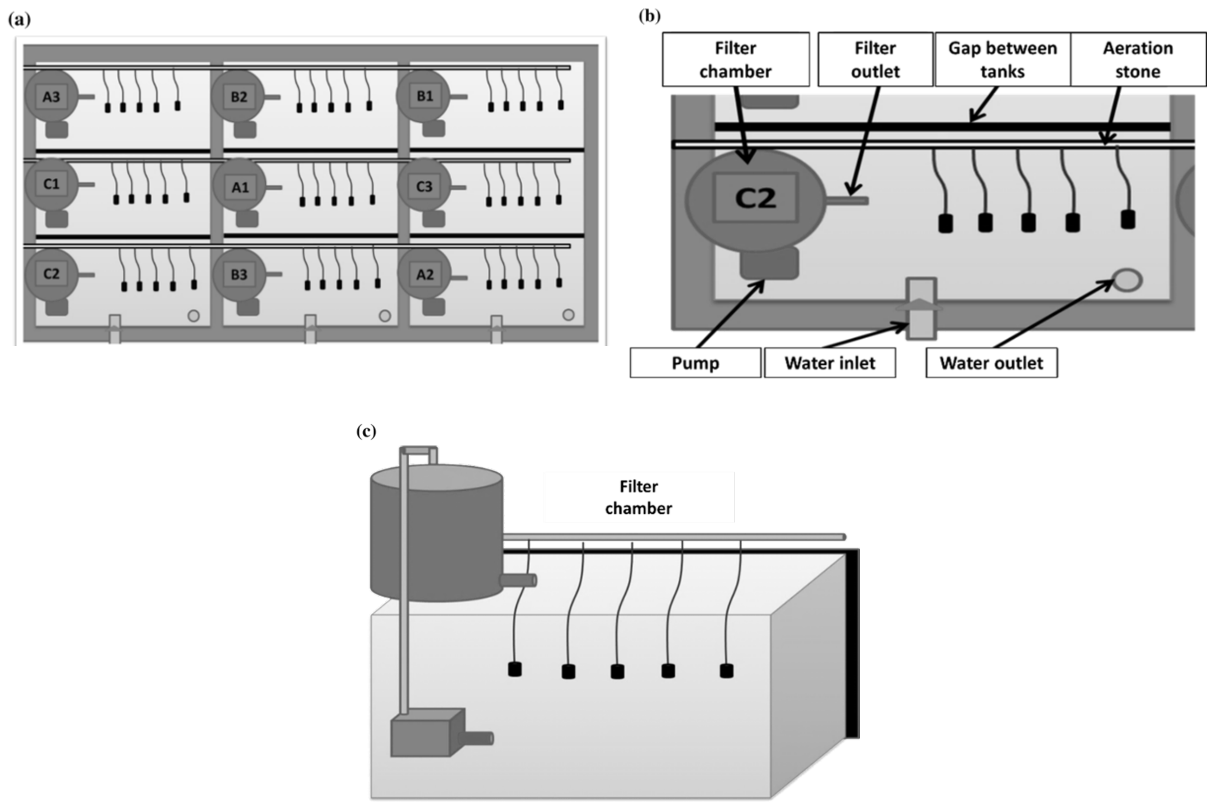

Figure 1. Fish rearing tank layout, (a) tank layout from above; (b) equipment in tank; (c) filter tank.

Moreover, the solid waste was also removed through mechanic filtration and dacron filter washing every seven days. Water was replaced by 30% every seven days to remove the dissolved nitrate accumulation.

Sampling and data collection

The data collected during the study included the number of dead fish, fish biometrics, fish blood glucose, and water quality. Biometric data were composed of individual weight and length, and biomass of each tank every 15 days (0, 15, and 30 days). The 30 individual samples were taken for biometric measurements per tank. The number of dead fish and feed intake were recorded every day and accumulated until the end of the study.

Fish mortality data were used to calculate the survival rate of eel. Biometric data and feed intake were collected to calculate the test parameters, namely growth, diversity coefficient, and feed conversion ratio. The water quality parameters in each tank, e.g. temperature, pH, and dissolved oxygen, were measured twice a day (morning and afternoon). Meanwhile, hardness, alkalinity, total ammonia-nitrogen (TAN), nitrite, and nitrate were measured once in 15 days. The water quality parameters during the study are presented in Table 1.

The fish blood glucose levels were measured once every 15 days. A fingerling from each tank was taken its blood with a syringe near the caudal fin base. The blood was dropped on the *glucotest* strip and put into the glucometer to read the blood glucose levels (Haq *et al*., 2022). In this study, the *glucometer* used was the Gluco DR Auto AGM 4000.

The fish behavior was observed based on the movement and feeding behavior. Fish movement was observed during checking and maintaining the tanks. Feeding behavior was observed during the feeding time.

Growth performance

Growth performance parameter was calculated based on the previous studies (Abo-Taleb *et al*., 2021; Pascon *et al*., 2021; Singh & Srivastava, 2021). The survival rate (SR) was determined by comparing the total living at the final rearing period and the total living fish at the initial rearing period. SR was calculated with the formula:

$$SR\ (\%) = \frac{Nt}{No} \times 100$$

Note:

SR = Survival rate (%)

No = Total of fish at the initial rearing period (fish)

Nt = Total of fish at the final rearing period (fish)

Biomass absolute growth rate

The biomass absolute growth rate is amount of the increased biomass divided by the rearing period. The biomass absolute growth rate was calculated with the formula:

$$BmAGR = \frac{(Bt - Bo)}{t}$$

Note:

BmAGR = Biomass absolute growth rate (g/day)

Bt = Biomass at the final rearing period (g)

Bo = Biomass at the initial rearing period (g)

t = Rearing period (day)

Table 1. Water quality parameters during the rearing period.

Parameter	Unit	Method/measuring tool	Measurement period
Temperature	°C	Thermometer	Everyday
pH	-	pH-Meter	Everyday
Dissolved oxygen	mg/L	DO-meter	Everyday
Hardness	mg/L	Titrimeter	Every 15 days
Alkalinity	mg/L	Titrimeter	Every 15 days
Total ammonia nitrogen	mg/L	APHA/spectrophotometer	Every 15 days
Nitrite	mg/L	APHA/ spectrophotometer	Every 15 days
Nitrate	mg/L	APHA/spectrophotometer	Every 15 days

Absolute growth rate

Absolute growth rate (AGR) is the difference in average individual weight from the initial to final rearing period. AGR was calculated with the formula:

$$AGR = \frac{(Wt - Wo)}{t}$$

Note:
AGR = Absolute growth rate (g/day)
Wt = Average weight at the final rearing period (g)
Wo = Average weight at the initial rearing period (g)
t = Rearing period (day)

Specific growth rate

The specific growth rate (SGR) is a percentage of logarithmic fish weight daily increase. SGR was calculated with the formula:

$$SGR\ (\%/day) = \left[\sqrt[t]{\frac{Wt}{Wo}} - 1\right] \times 100$$

Note:
SGR = Specific growth rate (%/day)
Wt = Average weight at the final rearing period (g)
Wo = Average weight at the initial rearing period (g)
t = Rearing period (day)

Feed conversion ratio

Feed conversion ratio denotes the feed intake required (kg) to produce 1 kg of fish biomass. FCR was calculated with the formula:

$$FCR = \frac{pa}{Bt - Bo + Bm}$$

Note:
FCR = Feed conversion ratio
Pa = Feed intake (g)
Bt = Fish biomass at t-day (g)
Bo = Fish biomass at the initial period (0 day) (g)
Bm = Dead fish biomass (g)

Coefficient of variance

The coefficient of variance is a size variation in fish weight unit. Coefficient of variance can be calculated as:

$$CV = \frac{s}{y} \times 100$$

Note:
CV = Coefficient of variance (%)
s = Standard deviation
y = Sample average

Condition factor

Condition factor (CF) is used to express the correlation of length and weight linear curve. Condition factor can be calculated with the formula:

$$FK = W \times L^{-2} \times 100$$

Note:
CF = Condition factor
W = Average weight (g)
L = Average length (cm)

Stress Response Analysis

The stress response was observed in blood glucose levels and behavior during rearing. The stress response as measured by blood glucose levels was carried out to determine the stress level of the fish based on the blood condition. Blood glucose could describe the physiological response of the fish body when maintaining homeostasis to changes. The behavior of eels was observed visually through the movements when maintaining the tanks, namely cleaning the tank, checking the filters and water quality.

Response was observed based on the movement speed, thus could be classified as active and passive movement (Aliza *et al*., 2014; Sinaga *et al*., 2021). Eel feeding behavior was also observed based on the appetite after feeding (Prasetio *et al*., 2017; Arianto *et al*., 2018). Behavior observation criteria are listed in Table 2.

Business analysis

Business analysis was determined to obtain the business efficiency of eel culture, especially

Table 2. Eel fingerling (*Anguilla bicolor*) behavior observation criteria during rearing.

Behavior	Criteria
Movement	Passive movement (no reaction against the outer movement) or active movement (responsive against the outer movement, schooling)
Appetite	Appetite loss, low appetite, or high appetite

in the nursery segment. The parameters used in this analysis contained investment costs, total costs, revenues, profits, cost of production (HPP), revenue cost ratio (R/C ratio) and total costs, and payback period (PP).

Total Cost

The total cost is the sum of variable and fixed costs in a year. The total cost was obtained by the formula:

$$\text{Total cost} = \text{Fixed cost} + \text{Variable cost}$$

Revenues

Revenue is the amount of money obtained from selling the product for a year. Revenue was obtained by the formula:

$$\text{Revenues} = \text{Total production} \times \text{selling price}$$

Profit

Profit determines the components of input and output in an effort to obtain profit, namely the difference between revenue and total costs. Business is classified as profitable, if the difference between revenue and total costs is positive. Profit was obtained by the formula:

$$\pi = TR - TC$$

Note:
π = Profit
TR = Total revenue
TC = Total cost

Revenue-cost ratio

The revenue-cost ratio (R/C Ratio) determines the ratio of income earned to the total costs incurred. Each cost value used can provide a number of revenues as benefits. R/C Ratio was obtained by the formula:

$$\frac{R}{C} = \frac{TR}{TC}$$

If the value of:
R/C > 1, then the business is classified as profitable
R/C = 1, then the business is at the breakeven point
R/C < 1, then the business suffers loss

Payback period

The payback period was analyzed to determine the payback period for all capital invested in a business. Payback period was obtained by the formula:

$$\text{Payback period} = \frac{\text{investment cost}}{\text{profit}}$$

Break Even Point

The breakeven point (BEP) is a condition when the income received equals the costs incurred. This situation indicates that the business is in a breakeven position, neither making a profit nor experiencing a loss. There are two types of BEP that are used as parameters, namely price BEP and unit BEP. Price BEP is the business breakeven point based on the minimum amount of money that must be obtained, while unit BEP is based on the minimum number of products that must be sold in one year of production. Price BEP and unit BEP were obtained by the formula:

$$\text{Price BEP} = \frac{\text{fixed cost}}{1 - \frac{\text{variable cost}}{\text{production}}}$$

$$\text{Unit BEP} = \frac{\text{fixed cost}}{\text{Price per unit} - \frac{\text{variable cost}}{\text{revenue}}}$$

Data Analysis

The production and business performance parameters were analyzed for variance with a 95% confidence level. If they have a significant effect, the Tukey test was applied. The water quality and stress response parameters were analyzed descriptively by presenting them on tables or pictures. Data analysis was carried out with Microsoft Excel 2020 and Minitab 18.

RESULTS AND DISCUSSION

Results

The study results for production performance are shown in Table 3. The stocking density treatment had no significant effect on the survival rate, absolute growth rate, specific growth rate, and condition factor (P>0.05). The C treatment showed the best absolute growth rate of biomass, while the A treatment showed the highest value in feed conversion ratio and coefficient of variance (P<0.05). The water quality condition for 30 days is shown in Table 4.

The temperature is quite optimal for fingerling maintenance, e.g. 26.0-27.9 °C. The pH value was 6-7.7 and included in the optimal category. The dissolved oxygen content remained optimal, namely 5.1-5.9 mg/L. The hardness values were 32.03-128.13 mg/L, while the alkalinity was 8-96 mg/L.

TAN levels were 0.32-2.52 mg/L, while nitrite was 0.04-0.43 mg/L and nitrate was 0.57-0.95 mg/L. Based on the fingerling behavior observation for 30 days, fingerlings had a high appetite and tended to school when eating. In addition, fingerlings had active movements, tended to swim to the tank base when there was a stimulus from the environment, such as falling objects or tank management. Graphs of average weight growth and fingerling biomass for each treatment are presented in Figures 2 and 3.

Based on Figure 2, the average fingerling weight in all treatments after 30 days of rearing was increased. The A treatment (4 g/L) obtained the highest average weight gain of 28.38 g on the 30th day, followed by C treatment (6 g/L) which obtained an average weight growth of 26.69 g on the 30th day. The B treatment (5 g/L) obtained the lowest average weight growth of 23.28 g on the 30th day. Based on Figure 3, the fingerling biomass in all treatments increased from the initial to the 30th day of rearing. The highest biomass on the 30th day of rearing was found in the C treatment (6 g/L) and the lowest was in the A treatment (4 g/L). Growth rate in B treatment (5 g/L) was stable from 15th for 30th day.

Based on Figure 4, the blood glucose level of fingerling eels in all treatments was relatively stable between 52.67–75.33 mg/dL. The A treatment (4 g/L) had an increased blood glucose

Table 3. Production performance of eel fingerling (*Anguilla bicolor*) in recirculation system with different stocking density for 30 days.

Parameter	Stocking density treatment		
	A	B	C
SR (%)	97.86 ± 0.70^{a}	98.89 ± 0.34^{a}	97.12 ± 1.15^{a}
BmAGR (g/day)	0.27 ± 0.03^{a}	0.23 ± 0.03^{a}	0.21 ± 0.04^{a}
SGR (%)	1.13 ± 0.10^{a}	0.99 ± 0.13^{a}	0.90 ± 0.17^{a}
AGR (g/day)	21.52 ± 1.79^{c}	45.11 ± 2.01^{b}	64.11 ± 8.22^{a}
FCR	3.54 ± 0.23^{a}	2.34 ± 0.20^{b}	1.84 ± 0.18^{b}
CV (%)	24.21 ± 2.69^{a}	21.76 ± 0.69^{a}	18.60 ± 0.94^{b}
CF	3.46 ± 0.06^{a}	3.53 ± 0.05^{a}	3.53 ± 0.08^{a}

Note: A = 4 g/L, B = 5 g/L, C = 6 g/L; stocking density, SR = survival rate; AGR = absolute growth rate; SGR = specific growth rate; BmAGR = biomass absolute growth rate; FCR = feed conversion ratio; CV = coefficient of variance; CF = condition factor.

Table 4. Water quality condition of eel fingerling *(Anguilla bicolor)* rearing media for 30 days.

Parameter (unit)	Stocking density treatment						Optimal value
	A		B		C		
	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet	
Suhu (^{o}C)	26-27.9		26-27.9		26,1-27,9		25-30 (Coffill-Rivera *et al*., 2023)
pH	6-7.7		6-7.6		6-7,7		6,0-8,0 (Harianto *et al*., 2021)
Dissolved oxygen (mg/L)	5.2-5.9		5.1-5.9		5,2-5,9		>3 (Rahmawati *et al*., 2015)
Hardness (mg/L)	36.04-120.12	36.04-116.12	36.04-124.12	32.03-112.11	44,04-128,13	36.04-120.12	20-150 (Stickney, 1979)
Alkalinity (mg/L)	8-36	12-80	8-96	8-88	12-48	12-40	30-500 (Harianto *et al*., 2021)
TAN (mg/L)	1.31-1.71	0.32-1.71	1.40-1.85	0.77-1.40	1.76-2.52	0.72-2.03	<1 (Idris, 2014)
Nitrite (mg/L)	0.08-0.39	0.11-0.33	0.05-0.4	0.06-0.34	0.04-0.43	0.06-0.38	<1,0 (Samsundari & Wirawan, 2013)
Nitrate (mg/L)	0.77-0.84	0.69-0.86	0.72-0.90	0.73-0.87	0.57-0.95	0.58-0.90	<100 (Bhatnagar & Devi, 2019)

level on the 15th day at 76.67 mg/dL and decreased on the 30th day at 52.67 mg/dL. The B (5 g/L) and C (6 g/L) treatments had low blood glucose level gaps on the 15th for 30th day, which tended to be stable. The fingerling nursery business analysis under different stocking densities was calculated

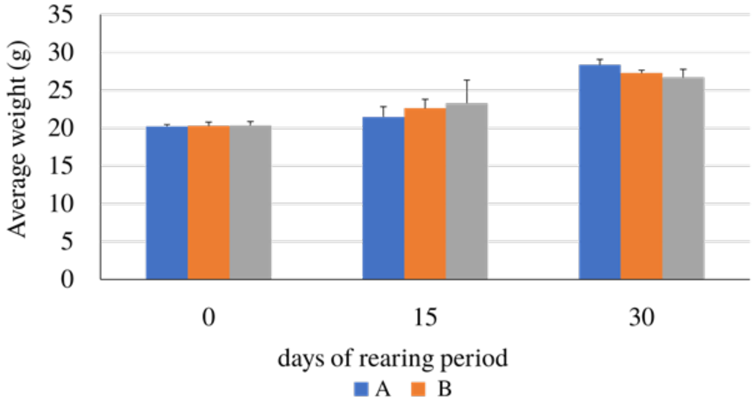

Figure 2. Average weight of eel (*Anguilla bicolor*) fingerling at A (4 g/L), B (5 g/L), and C (6 g/L) treatments in 30 days of rearing.

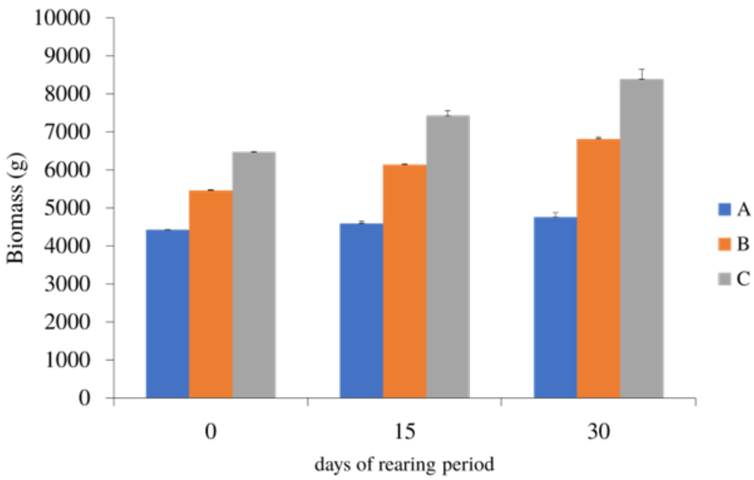

Figure 3. The eel fingerling (*Anguilla bicolor*) biomass at A (4 g/L), B (5 g/L), and C (6 g/L) treatments in 30 days of rearing.

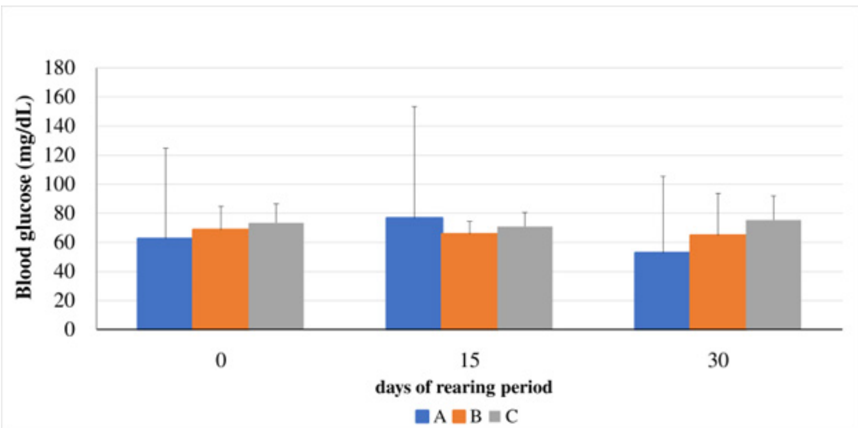

Figure 4. Blood glucose of eel fingerlings at A (4 g/L), B (5 g/L), and C (6 g/L) treatments in 30 days of rearing.

based on the business assumptions presented in Table 5. The profit value of eel fingerling culture with A (4 g/L), B (5 g/L), and C (6 g/L) stocking density treatments is positive, that can be classified as profitable.

Discussion

A high SR value means that eels can adapt to their rearing environment. Different stocking densities had no effect on SR may occur due to the use of a recirculation system, good water quality management, and sufficient amount of feed for all fish. In addition, eels could presumably adapt to the environment with well-maintained water quality by applying the recirculation system. High mortality rate is commonly proportional to the increased stocking density, due to cannibalism and competition for space and oxygen requirements.

This can cause fish to experience stress, inhibiting the metabolic rate and reducing the fish health condition. Stress can also be caused by the environment, such as water quality changes. Based on the growth performance analysis results, different stocking densities provide a significant difference in weight growth rates, i.e. AGR and SGR. The highest AGR and SGR values were obtained from the A treatment (4 g/L) at 0.272 g/day and 1.128%/day, respectively.

The SGR and AGR increase on low stocking density. This condition occurs due to the low space competition level. When there is a space competition, individuals that are unable to compete will have their growth disrupted. In contrast, wider space and sufficient feed will help fish grow optimally (Alfia *et al*., 2013). BmAGR obtained a significant difference among stocking density treatments ($p<0.05$).

The highest BmAGR was obtained from the C treatment (6 g/L). Eels tended to school, that affected their appetite and feeding behavior. Eels will be triggered whenever other eels begin consuming the feed (Affandi, 2013), so the weight of most individual will be easier to increase and the biomass will increase. BmAGR obtained a significant difference among stocking density treatments ($p<0.05$). Different stocking density had a significant effect ($p<0.05$) on FCR.

A lower FCR value indicates that the amount of feed intake is efficiently utilized by fish for growth and flesh formation. Conversely, the greater FCR value, the less efficient feed utilization in fish, thus requiring more feed to produce 1 kg of fish. The best FCR value was obtained in C treatment (6 g/L) at 1.836. The highest RKP value was found in A treatment (4 g/L) at 3.54. High FCR was caused by the underutilized feed by eels, so the nutrients were less absorbed by the fish body and were defecated as feces (Arief *et al*., 2016).

Based on Swarni (2019), the FCR value in fingerling rearing with probiotic-supplemented

Table 5. Business analysis of eel fingerling (*Anguilla bicolor*) nursery rearing with different stocking densities in 30 days of rearing.

Parameter	Stocking density treatment		
	A	B	C
Investment cost (Rp)	65,002,000	65,002,000	65,002,000
Variable cost (Rp)	2,752,596,000 ± 26,317,653	3,389,735,500 ± 8,250,589	4,003,922,000 ± 16,303,152
Fixed cost (Rp)	217,365,000	217,365,000	217,365,000
Total cost (Rp)	2,966,312,000 ± 26,877,787[c]	3,603,451,000 ± 8,250,589[b]	4,220,638,000 ± 16,303,152[a]
Revenue (Rp)	3,013,000,000 ± 9,643,651[c]	4,090,000,000 ± 30,789,609[b]	5,034,000,000 ± 156,920,362[a]
Profit (Rp)	46,688,000 ± 17,243,847[c]	486,549,000 ± 38,686,181[b]	813,362,000 ± 140,620,792[a]
BEP (Rp)	2,427,800,977 ± 173,643,631[b]	1,231,304,466 ± 59,883,261[a]	1,040,271,518 ± 119,307,465[a]
BEP (unit)	4856 ± 347[b]	2463 ± 120[a]	2081 ± 239[a]
HPP (Rp)	491,404 ± 2,884[c]	439,876 ± 4,289[b]	418,581 ± 11,633[a]
PP (year)	1.06 ± 0.09[b]	0.13 ± 0.01[a]	0.08 ± 0.02[a]
R/C	1.02 ± 0.01[c]	1.14 ± 0.01[b]	1.20 ± 0.03[a]

Note: Different superscript letters in the same line show a significant difference (Tukey $P<0.05$). Data without superscript letters showed no significant difference. Breakeven point (BEP), cost of production (HPP), payback period (PP), R/C Ratio (R/C).

feed and 4 g/L stocking density was obtained at 3.75–9.54. Probiotics can produce enzymes that help accelerate the decomposition of complex compounds into simpler compounds, thus can be digested easily. High digestibility causes eels to absorb feed nutrients more easily and the growth will be faster. CV shows the uniformity level in fish weight at the final rearing. The smaller CV value, the greater uniformity level of fish weight (Harianto *et al*., 2020).

The CV values among treatments were significantly different ($P<0.05$). The lowest CV value was found in C treatment (6 g/L) at 18.601%. Eel fingerlings that have a relatively larger body weight tend to be more capable of gaining more feed, so they can grow quickly, while smaller eels tend to be less competitive in gaining feed, thus slower to utilize feed and their growth is also slower (Fekri *et al*., 2015). The A treatment has the highest values for SGR and AGR, but showing the lowest value in BmAGR parameter. This was presumably because all eel fingerlings in A treatment did not receive the same amount of feed and did not experience a similar weight growth among the individuals, thus CV and FCR values were also higher than B and C treatments.

High FCR value in A treatment could cause improper feed utilization for fish growth as not all fish gained sufficient feed. In contrast, C treatment had the highest BmAGR value, while showing the lowest SGR, AGR, FCR, and CV values. This was presumably because all eel fingerlings in C treatment received the same amount of feed with high uniformity growth level, which increased the biomass, so the feed was utilized properly and produced a low FCR value. CF means the fatness of fish (Ahlina *et al*., 2016), which indicates the physiological condition of fish, influenced by intrinsic factors (gonadal development and fat deposition) and extrinsic factors (food availability and environmental pressure). CF is obtained from the relationship between the length and weight of the fish.

The CF value of the study results was insignificantly different ($p>0.05$). High CF value indicates that the fish is in growing state or gonadal development state, while low FK value indicates that the fish gains insufficient food or due to the presence of other unsuitable factors for supporting fish growth (Aisyah *et al*., 2017). Condition factor at 0-2 indicates a less flattened fish body (Sudarno *et al*., 2018). Eel is known to have a non-flattened body. Blood glucose describes the physiological response in organisms when maintaining homeostasis within the body and outside the body (environment).

Elevated blood glucose (hyperglycemia) is an initial stress indicator, because blood glucose level is highly sensitive to stress. The higher blood glucose level, the higher stress level in fish (Harianto *et al*., 2014). The blood glucose measurement during the study was 52-75 mg/dL in all treatments. The blood glucose level was still within normal limits, namely 40-90 mg/dL (Fekri *et al*., 2018). The highest blood glucose value was found in A treatment on the 15th day of rearing up to 76.67 mg/dL.

High blood glucose level was thought due to low stocking density, whereas eels preferred living in large schools. Glucose is very important to meet the high energy requirement due to stress. Stressful fish will divert energy from normal metabolic processes into energy that can activate physiological systems to deal with stress (Djauhari *et al*., 2019). The use of a recirculation system in fish culture has many advantages, including saving water use and suppressing or minimizing the ammonia content. The use of zeolite as a chemical filter has several functions, i.e. reducing the ammonia levels through the absorption process.

Zeolites can absorb ammonium ions excreted by fish, so the water quality can be maintained well (Skleničková *et al*., 2020). Bioballs used as filter media are served as a place for beneficial bacteria to grow and help filter the water taste. The use of activated carbon or activated charcoal functions as chemical filters can absorb toxic substances and purify the water that passes through them (Sahetapy *et al*., 2021). Temperature is one of the important water quality parameters that affect the survival rate and growth of fish. Temperature affects the fish metabolism rate, whereas the higher water temperature, the higher secretion of digestive enzymes.

Therefore, the metabolic rate will increase and fish will tend to have a high appetite and the growth rate will also increase. Drastic changes in temperature can cause stress and even death in fish (Fekri *et al*., 2018). The temperature level during the study for all treatments was 28.3-31.7 °C. Temperature conditions that exceed 30°C or below 10°C can reduce or eliminate mucus on the eel body (Suryono & Badjoeri, 2013). pH is the degree of acidity in a solution or liquid.

Based on the study results, the pH was measured at 5.6-8. The optimal pH range for eel culture is 6-8 (Harianto *et al*., 2021). The pH condition can affect the fish physiology, including the osmoregulation process, the gill structure, and enzymatic activity in gills, thus affecting the oxygen consumption level. A low pH value will cause the dissolved oxygen content to decrease, which causes fish to lack oxygen and decreases their metabolic rate. High pH value will cause a high level of unionized ammonia content in the water, which becomes toxic and can be easily absorbed into the fish body, so it can cause mass fish death.

Increased water temperature will cause an increased oxygen requirement, as metabolic processes require oxygen. Dissolved oxygen (DO) parameter shows the amount of oxygen dissolved in water. The DO content in all treatments was 4.5-7.2 mg/L. Eels can live in water with DO content of 3-5 mg/L, but the oxygen content in the water should be stable above 5 mg/L to increase the productivity level (Rahmawati *et al*., 2015). The alkalinity is water capacity to neutralize acidic and basic condition (pH), called a buffer (Carstensen & Duarte, 2019).

The alkalinity level in this study was 8-96 mg/L. A good alkalinity level to support fish growth is 30-500 mg/L (Harianto *et al*., 2021). Alkalinity content in water is also needed by beneficial bacteria in water such as nitrifying bacteria. Low alkalinity causes the beneficial bacteria to not grow optimally (Yunarty *et al*., 2022). TAN is ammonium (NH_4) and ammonia (NH_3) combination.

If the two compounds are separated, ammonia becomes very dangerous for fish, while ammonium is relatively safer. The maximum level of TAN in water is 1 mg/L (Idris, 2014). The measurement results showed that TAN level in this study was 0.32-2.52 mg/L. High TAN is generally caused by the high decomposition of organic matter, feed residue, feces, and dead organisms. The higher stocking density, the higher TAN content in the waters. High stocking density will also cause an increased ammonia concentration and a decreased water quality, which will affect the stress level and appetite in fish (Alfia *et al*., 2013).

Nitrite (NO_2^-) in natural waters can be found in a smaller amount than nitrate and is unstable when oxygen is present. According to Samsundari and Wirawan (2013), the maximum level of nitrite in water is commonly 1.0 mg/L. Nitrite content in this study was 0.04-0.43 mg/L. If the nitrite content in the water is excessive, the fish blood ability to bind oxygen will reduce, because nitrite will react more strongly and bind more easily with hemoglobin, causing the fish to lack oxygen and can cause death. Nitrate (NO_3^-) is the main form of nitrogen and the main source of nutrients for microalgae and aquatic plants.

Nitrate dissolves easily in water due to unstable and non-toxic to aquatic organisms. The concentration of nitrate in this study was 0.57-0.95 mg/L. The tolerable nitrate concentration in fish is 0-100 mg/L (Bhatnagar & Devi, 2019). Business analysis showed a significantly different effect (P<0.05) among treatments. Based on the calculation results in Table 5, the best variable costs, total costs, revenues, the profits are found in the C treatment.

This is because C treatment causes the seed cost and feed cost to become expensive and affects variable costs and total costs. High stocking density in C treatment has high growth rate, low FCR, and high SR, which leads to an increased production level, thereby increasing revenues and profit. The highest amount of production in C treatment will put the business at a breakeven point with a smaller price and production quantity (price and unit BEP). A business is said to be feasible and profitable if the R/C value is greater than 1 (R/C>1). The greater R/C value, the more profitable business conducted (Hasdinar *et al*., 2017).

The R/C values for A, B, and C treatments were 1.02, 1.14, and 1.20, respectively. Therefore, the eel fingerling nursery culture with different stocking densities is still profitable to conduct. This value is almost similar to Fitriani (2021), who reported that eels reared at 4 g/L stocking density had an R/C value of 1.05-1.26. The PP value for C treatment is 0.08, which means that the business will return on investment after 0.08 years (about a month). This study also suggests a tendency to increase production performance, followed by business performance improvement.

CONCLUSION

The production and business performance of eel (*A. Bicolor*) fingerling culture in recirculation system with different stocking densities provide the best stocking density treatment of 6 g/L.

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