Production performance of nursery graded eel *Anguilla bicolor bicolor* in recirculating aquaculture system

Kinerja produksi pendederan ikan sidat *Anguilla bicolor bicolor* hasil grading pada sistem resirkulasi

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ABSTRACT

The growth rate highly varies in nurseries of eel. Variations in size lead to competition in obtaining feed, this causes stunting of smaller fish. This situation leads to high production costs due to poor feed utilization efficiency. Grading needs to be done periodically to improve nursery production performance. Water quality is controlled by a recirculation system that can support production performance through the degradation of toxic compounds. This study aims to analyze the production and nursery performance of graded eel (*Anguilla bicolor bicolor*) that graded in the same batch in a recirculation system. Completely randomized design (CRD) consisting of three treatments with four replications was used in this research. The treatments included nursery of graded eels for 60 days in three groups of initial weight size, namely 0.35 ± 0.00 g (A); 0.50 ± 0.00 g (B); and 1.04 ± 0.00 g (C). There were 344 eels (A), 239 eels (B), and 116 eels (C) in each replication. The best nursery production performance was obtained in the treatment of 1.04 ± 0.00 g, and the best nursery business performance was obtained in the treatment of 0.50 ± 0.00 g.

Keywords: *Anguilla bicolor bicolor*, grading, production performance, recirculation system

ABSTRAK

Laju pertumbuhan ikan yang bervariasi merupakan kendala umum dalam manajemen budidaya ikan komersial. Laju pertumbuhan individu ikan sidat bervariasi tinggi. Persaingan individu ikan dalam memperoleh pakan, berimplikasi pada kinerja pertumbuhan individu yang berbeda. Pemanfaatan pakan didominansi oleh ikan yang berukuran lebih besar dalam suatu populasi. Kegiatan grading berdasarkan ukuran perlu dilakukan secara periodik untuk memperbaiki pertumbuhan dan kelangsungan hidup komoditas budidaya. Penelitian ini bertujuan untuk menganalisis kinerja produksi ikan sidat (*Anguilla bicolor bicolor*) berbagai ukuran (0.35 ± 0.00 g; 0.50 ± 0.00 g; dan 1.04 ± 0.00 g) pada sistem resirkulasi selama 60 hari masa pemeliharaan. Penelitian ini menggunakan rancangan acak lengkap (RAL) yang terdiri dari tiga perlakuan dengan empat kali ulangan. Perlakuan meliputi pendederan pada tiga kelompok ukuran bobot. Kelompok ukuran ikan uji diperoleh berdasarkan grading pada satu populasi ikan sidat di PT Laju Banyu Semesta yaitu 0.35 ± 0.00 g (A); 0.50 ± 0.00 g (B); dan 1.04 ± 0.00 g (C). Hasil penelitian menunjukkan bahwa kinerja produksi pendederan terbaik diperoleh pada ikan yang berukuran bobot awal 1.04 ± 0.00 g (C).

Kata kunci: *Anguilla bicolor bicolor*, grading, kinerja produksi, sistem resirkulasi

INTRODUCTION

Eel is an aquaculture commodity that posess high nutritional value. It is commonly used as food and benefit for human body which leads to eel as a sought-after commodity for global export markets. Eel meat contains of EPA 742 mg 100 g, DHA sebesar 1337 mg 100 g, and vitamin A about 4700 IU 100 g. Moreover, eel liver is rich in vitamin A about 15.000 IU 100 g-1, B1, B2, D, and E (Lukas *et al*., 2019). Global Eel production has increased from 251.491 tons in 2016, to 271.659 tons in 2019 (FAO 2021). It indicates that eel farming technology continues to develop. Recirculating aquaculture system is one of viable form of intensive aquaculture for eel production.

Eel farming requires access to good-quality water through a recirculating system (Affandi *et al*., 2013). The recirculating aquaculture system (RAS) represents a new way to farm fish using filters to clean the water and recycle it back into the fish tanks. The filtration system can degrade toxic compounds through physical, chemical, and biological filters. Two major sources of toxic compounds in aquaculture are uneaten feed and fecal materials, which can diminish water quality.

In the nursery phase, the larvae size is not uniform (Lukas *et al*., 2017). It is caused by genetic factors, interactions, physical, chemical, and aquatic biology (Hirt-Chabbert *et al*., 2014). Size variations leads stunting in smaller eels (Król *et al*., 2019). According to Fekri *et al*. (2019) said that compensatory growth is defined as an increased growth rate following suffered a period of growth depression and returned to favorable conditions. Size variations of eel in nursery can be minimized through grading. Grading can reduce food competition that leads to uniform-sized fish. Compensatory growth is expected to occur in smaller eels. This condition can have a positive impact on production performance and increase the profits of the nursery business.

Aim

The present study aimed to analyse the production performance and nursery performance of graded eel in recirculating aquaculture system.

MATERIAL AND METHODS

The present study was conducted from May to July 2021 for 60 days at the Aquaculture Management Laboratory, Department of Aquaculture, Faculty of Fisheries and Marine Sciences, IPB University. A completely randomized design with three treatments and four replications were applied. The treatment includes the weight size of the graded eel. The eel was taken form Cimandiri, Sukabumi Regency, West Java. A glass eel stadia was used for test animal. The eels were reared for 3 months by Laju Banyu Semesta Company. The grading was divided into three weight measurements in the same batch. The weight size of the grading eel obtained was 0.35 ± 0.00 g (A); 0.50 ± 0.00 g (B); and 1.04 ± 0.00 g (C) respectively.

Research Procedures

The trials were conducted using aquarium size 80×44×40 cm. A total of 12 aquariums were filled with 60 L of water. Each aquarium unit was equipped with a top filter unit, three aeration points, and a shelter bundle in the form of raffia tassel. The top filter consisted of physical, chemical, and biological filters in the form of synthetic cotton (dacron), shell fragments, zeolite stone, and Nitrosomonas sp. and Nitrobacter sp. placed on biofoam. The aquariums was firstly cleaned and disinfection, top filter installation and aeration installation, water filling, and set up recirculation system. A total of 2 g/L eel or 120 g were stocked per aquarium. Eels were fed a commercial paste-shaped feed with a protein content of 50–52% and restricted to 4–5% (6.75–17.08 g) of the biomass per aquarium per day. Feeding was carried out in the morning (08.00 am) and afternoon (04.00 pm). the 20% of water exchange was performed every three days. The top filter was washed every 15 days, the dacron was washed every day, while the shell fragments, zeolite stone, and biofoam were rinsed with clean water every 15 days. Probiotics (*Bacillus* sp., *Nitrosomonas* sp., and *Nitrobacter* sp.) were added to rearing water once a week at a dose of 2 ml/L. Water physical-chemical parameters (temperature, pH, and dissolved oxygen) were measured in-situ in the morning and evening. Alkalinity, ammonia, nitrite, and nitrate variables were measured every 15 days. Biometric data was obtained by measuring individual weight, individual length, and fish biomass per aquarium every 15 days (day 0, 15, 30, 45, and 60). A total of 30 eels were used as samples per aquarium. A digital scale with an accuracy of 0.01 g and a ruler with an accuracy of 0.1 cm were used for biometric measurements.

Research parameters

Production parameters including amount of feed, mortality, weight, and length of fish, blood glucose, and water quality were measured for data collection. Production parameters were then calculated to obtain test parameters in the form of survival rate (TKH), absolute weight growth rate (LPMBb), specific weight growth rate (LPSBb), absolute biomass growth rate (LPMBm), feed conversion ratio (RKP), coefficient of weight variations (KKB), and condition factors (FK).

Data analysis

Microsoft Excel 2016 and Minitab version 19.0 through analysis of variance (ANOVA) and Kruskal-Wallis test were used for data analysis. A significantly different data was further tested with Tukey's test and Mann Whitney's test at 95% confidence interval. Water quality parameters and stress response were analyzed descriptively through the presentation of graphs and images.

RESULTS

The fish's growth performance is summarized in Table 1. No significant differences were observed in survival rate and coefficient variation of weight (P>0.05). The absolute growth rate increased as the initial weight of fish increased (P<0.05).Treatment C showed the highest specific growth rate, absolute biomass, and feed conversion ratio (P<0.05), meanwhile treatment A and treatment B were not statistically different (P>0.05). The results of water quality measurements are presented in Table 2. Most of the measured parameters (temperature, pH, dissolved oxygen, alkalinity, ammonia, nitrite, and nitrate) fluctuated within the optimal ranges for fish culture (Table 2). However, the lowest observed value of temperature and DO were below optimal (Table 2). The highest levels of ammonia and nitrite were found in treatment B, while the highest levels of nitrate were found in treatment C.

Table 1. Production performance of eel (*Anguilla bicolor bicolor*) obtained from grading after reared for 60 days using recirculating system.

Parameters	Initial weight treatments (g ind)		
	0.35 (A)	0.50 (B)	1.04 (C)
Survival rate (%)	86.63 ± 7.42[a]	89.54 ± 2.67[a]	93.97 ± 2.67[a]
Absolute growth rate (g day)	0.015 ± 0.00[2]c	0.023 ± 0.002[b]	0.059 ± 0.00[7]a
Specific growth rate (% day)	2.14 ± 0.12[b]	2.24 ± 0.08[b]	2.48 ± 0.1[4]a
Absolute biomass (g day)	4.23 ± 0.09[b]	4.88 ± 0.27[b]	6.31 ± 0.54[a]
Feed conversion ratio	1.05 ± 0.03[a]	1.06 ± 0.02[b]	0.96 ± 0.02[b]
Coefficient variation of weight (%)	10.45 ± 2.72[a]	12.55 ± 3.27[a]	11.46 ± 1.78[a]
Condition factor	1.29 ± 0.05[c]	1.49 ± 0.06[b]	2.16 ± 0.09[a]

*Values with different superscript in the same row indicate significant different in level of 5% (Tukey or Mann Whitney test).

Table 2. Water quality parameter of eel (*Anguilla bicolor bicolor*) obtained from grading after reared for 60 days using recirculating system.

Parameter	Treatments			
	0.35 (A)	0.50 (B)	1.04 (C)	Optimum ranges
Temperature (°C)	27.4–31,8	26.9–31.5	26.6–31.5	28–30 (Fekri *et al.* 2018)
pH	6.1–7.8	5.8–7.6	6.0–7.9	6.0–8.0 (Klau *et al*., 2020)
Dissolved oxygen (mg/L)	4.0–8.7	3.9–8.7	4.0–8.7	>4.0 (Suryono & Badjoeri 2013)
Alkalinity (mg/L)	56–140	60–124	64–92	50– 200 (Bhatnagar & Devi 2013)
Ammonia(mg/L)	0.0004–0.0595	0.0008–0.0935	0.0008–0.0582	<0.1 (Bhatnagar & Devi 2013)
Nitrite (mg/L)	0–0.50	0.02–0.59	0–0.41	<0.8 (Li & Liu 2013)
Nitrate (mg/L)	0.38–0.57	0.41–0.57	0.37–0.74	0–100 (Bhatnagar & Devi 2013)

The business analysis parameters are displayed in Table 3. The results demonstrated that treatment B showed higher revenue, profit and R/C ratio than treatment A (P<0.05), while PP and BEP price showed the opposite trend (P<0.05). Treatment C showed similar values of the mentioned parameters to those in the other treatments (P>0.05). In addition, treatment C had the lowest total cost and the highest HPP among all treatments (P<0.05).

The average weight and biomass of eel reared in 60 days of the culture period are shown in Figure 1 and Figure 2, respectively. Treatment C demonstrated the highest average weight and biomass at the end of the culture period and had a steeper increase trend than other treatments.

Table 3. Business analysis of eel (*Anguilla bicolor bicolor*) production obtained from grading after reared for 60 days using recirculating system.

Parameter	Initial weight treatments (g ind)		
	0.35 (A)	0.50 (B)	1.04 (C)
Total cost (IDR)	397.010.122 ± 104.305[b]	398.378.911 ± 657.932[b]	401.501.261 ± 1.100.709[a]
Revenue (Rp)	708.002.785 ± 9.970.429[b]	783.737.775 ± 30.379.364[a]	746.212.475 ± 47.164.578[ab]
profit (IDR)	310.992.664 ± 98.667.100[b]	385.358.864 ± 29.755.40[8a]	344.711.215 ± 46.073.939[ab]
R/C *ratio*	1.78 ± 0.02[b]	1.97 ± 0.07a	1.86 ± 0.11[ab]
PP (year)	0.44 ± 0.01[a]	0.36 ± 0.0[3b]	0.40 ± 0.55[ab]
BEP price (IDR)	190.315.883 ± 1.729.730[a]	179.461.241 ± 3.830.408[b]	186.350.306 ± 7.027.856[ab]
HPP (IDR)	1.065.574 ± 14.697[a]	966.842 ± 36.494[b]	809.407 ± 49.173[c]

* Values with different superscript in the same row indicate significant different in level of 5% (Tukey or Mann Whitney test). R/C ratio = revenue/cost, PP = payback period, BEP = break even point, HPP = cost of goods manufactured.
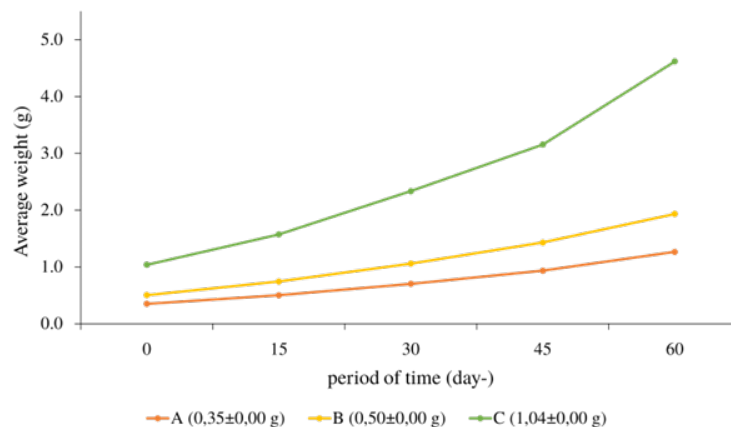

Figure 1. Average weight of eel (*Anguilla bicolor bicolor*) obtained from grading after reared for 60 days using recirculating system.
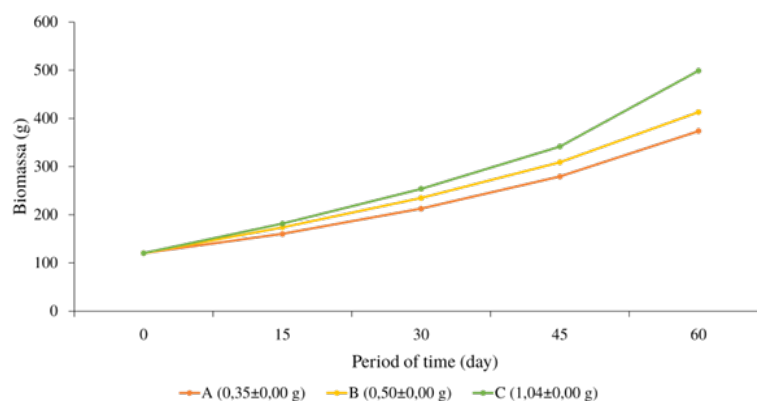

Figure 2. Biomass of eel (*Anguilla bicolor bicolor*) obtained from grading after reared for 60 days using recirculating system.

Treatment A had the lowest weight and biomass of eel and the most gentle increasing trend among all treatments. The level of blood glucose was displayed in Figure 3. Treatment A and B showed overall decreasing trends in the first 45 days, while treatment B showed more fluctuations. In the last 15 days of the culture period, the blood glucose levels increased in all treatments, in which treatment C demonstrated the highest value.

Discussion

For statistically significant results, the treatment showed no significant effect on the TKH parameter ($P>0.05$). The mortality observed in treatments A, B, and C during the 60-day rearing was caused by the high stocking density and water temperature fluctuations. The high stocking density has implications on oxygen and space in the rearing tank. The more eel in the tank, the more oxygen diffusion and space are required (Lukas *et al*., 2019). The growth of a fish population affected by the density, physiological processes, behavior, health, growth rate, and survival rate. The increase of fish size without followed by the increase of water volume leads to higher density. Consequently, the amount of dissolved oxygen and space are not favourable condition for optimum growth performance.

The lowest average weight was obtained from group A among other groups. The average weight of groups B and C were 0.35 ± 0.00 g, hence, the number of fish in each aquarium has the largest quantity (A=344 fish, B=239 fish, and C=116 fish). Urbina and Glover (2013) stated that smaller fish require more oxygen, compared to larger fish. The survival of fish is also influenced by fluctuated temperature. The optimum temperature for eel juvenile growth ranged from 28 to 30 °C (Fekri *et al*., 2018). The temperature of the rearing water during ranged from 26.6 to 31.8 °C. The temperature fluctuations of the rearing media adversely effect on the survival rate and productivity of eel (Lukas *et al*., 2019).

Growth can be defined as an increase in volume and weight in unit time. The grading treatment showed a significant effect ($P<0.05$) on the growth rate parameters (LPMBb, LPSBb, and LPMBm). The grading treatment has positive implications on the growth rate. The results showed that each individual fish in treatment C received more and more evenly distributed feed than individual fish in other treatments. Because the number of individuals in groups A and B is higher than group C. This is indicated that the growth is closely related to the amount of feed consumed.

The feed conversion ratio is the ratio of the amount of feed and the amount of fish meat in units of weight produced (Anti *et al*., 2018). The feed used by individual fish in group C was more efficient, resulting in greater biomass production during the rearing period. The higher the biomass, the higher growth performance of eel (Harianto 2014). The groups A and B have high number of
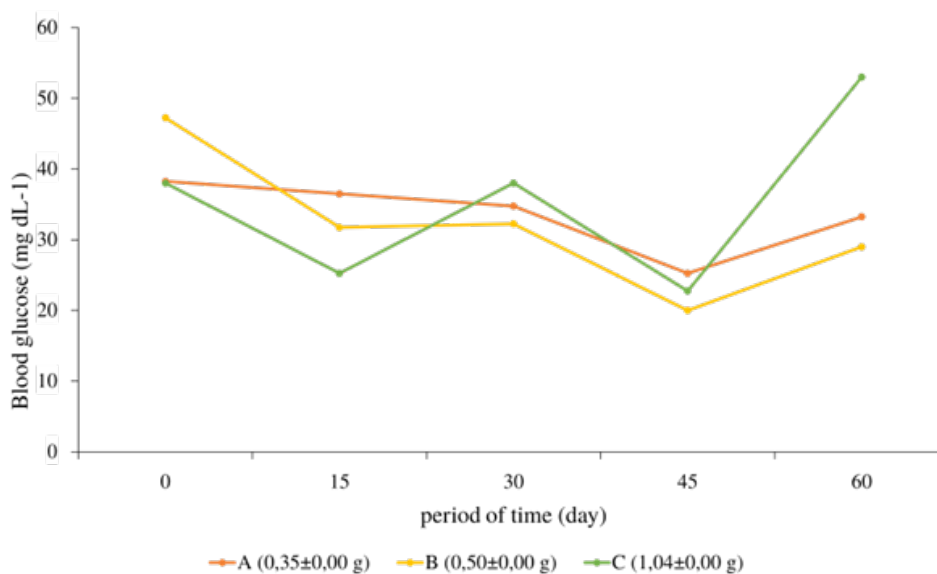

Figure 3. Blood glucose of eel (*Anguilla bicolor bicolor*) obtained from grading after reared for 60 days using recirculating system.

fish. However, the size tends to be smaller. Rather than using energy for growth, the fish allocates more their energy for maintenance (Saputra *et al*., 2016). Energy for the maintenance of group A and B fish is influenced by density and the amount of energy used for competing feed and oxygen consumption. on the on contrary, the group C with fewer individuals has more energy which can be allocated for growth.

The weighted coefficient of variation parameter (KKB) is used to interpret the level of data uniformity. A low coefficient value indicates high data uniformity (Harianto *et al*., 2014). The KKB value at the end of the rearing period in all treatments was less than 20%. According to Baras *et al*. (2011), the value of coefficient of variation is higher than 20%. This indicates a low level of uniformity. The uniformity of weight size is highly affected by the grading treatment at the beginning of rearing period.

Condition factor (FK) can be defined as the physical and biological circumstances of the fish. This is closely related to the relationship between length and weight of fish. The other interactions also play important part in determining the condition factor such as feeding conditions, parasitic infections and physiological factors. Condition factors in aquaculture business have a commercial role to determine the quality and quantity of fish meat that can be consumed (Ahlina *et al*., 2016). There was a significant difference (P<0.05) between treatments. According to Ujjania *et al*. (2012) the condition factor value 1 indicates environmental quality and feed utilization at a good level. Faradonbeh *et al*. (2015) stated that the condition factor varies for each fish species that live in different tanks or environments. This occurs due to several factors such as the intensity of obtaining feed and the size of the fish. The use of feed and the different growth patterns in individual fish in each treatment were considered to be the cause of the varying condition factor values.

Blood glucose describes the physiological response of fish to environmental changes. High blood glucose values indicate a stress response in fish (Harianto *et al*., 2021). The lowest blood glucose was observed on day 45th of treatment B about 20 mg/dL, while the highest blood glucose was observed on day 60th of treatment C (53 mg/dL). The range of blood glucose levels obtained was not much different from that of Scabra *et al*. (2015) with a range of blood glucose levels of 25–54.3 mg/dL. Blood glucose levels of 31.92

± 4.29 mg/dL were obtained in the production performance of high stocking density of eel (4 g/L) with a survival rate of 100% (Harianto *et al*., 2014). According to Driedzic *et al*. (2013), blood glucose levels have different values for each fish size and fish activity. The increase of blood glucose in treatment C was caused by the low dissolved oxygen in the rearing tank. The value of dissolved oxygen (DO) during the rearing period tends to decrease (8.7–4 mg/L). The size of the fish continues to grow. Nevertheless, it did not followed by the stable dissolved oxygen levels. According to Saputra *et al*. (2016) metabolic activity is directly proportional to respiration as an energy extraction process. Therefore, the dissolved oxygen plays important role in the stress response of eels.

Recirculating aquaculture system is one of the factors that play a important role in maintaining water quality during rearing period. Ammonia is excreted by fish through the gills, metabolic waste in the form of feces, and uneaten feed. This nitrogen compound in certain limits can be toxic to fish. RAS system improves water quality and more efficient in using water (Almeida *et al*., 2020).

Fish are poikiotherms. It is known as an organism whose body temperature varies according to the temperature of its environment. An increase in water temperature can increase appetite which has implications on growth rate (Harianto *et al*., 2014). Water temperature affects the performance of nitrifying bacteria, such as *Nitrosomonas* sp. and *Nitrobacter* sp. Low temperature conditions have an impact on the decreasing performance of nitrite reformation to nitrate, while the performance of bacteria to convert ammonia to nitrite is not affected. Higher nitrite accumulation interfere fish production performance. According to Fekri *et al*. (2018), the optimum water temperature support the growth and survival of eel ranges from 28 to 30°C.

The pH value is influenced by several factors including turbidity, dissolved CO2, salinity, decomposition of organic matter, and individual density. The optimum pH value for eel cultivation is 6.0–8.0 (Klau *et al*., 2020). The decrease in the pH value of the media during rearing period was caused by an increase in CO2 level and fish stock density along with the growth of biomass in each treatment. Carbon dioxide reacts with water to release H+ ions.

The chemical filter component in the form of shell fragments in the RAS system functions

to maintain the pH value of the water. Shellfish shells contain calcium carbonate ($CaCO_3$) compounds which are alkaline to waters (Rizki *et al*., 2020). Calcium carbonate reacts with carbonic acid (H_2CO_3) which the fusion of carbon dioxide with water, calcium bicarbonate compounds ($Ca(HCO_3)_2$) are then produced from the reaction (Meetei *et al*., 2020). The degree of acidity of the water will decrease compared to normal conditions without shellfish filtration.

The role of dissolved oxygen can affect the fish appetite and metabolic processes. Not only consumed by the test fish, but also oxygen is consumed by nitrifying bacteria as an energy source in addition to carbon. According to Suryono and Badjoeri (2013), the optimum dissolved oxygen concentration for the survival of eels is greater than 4 mg/L.

Alkalinity refers to chemical measurement of a water's ability to neutralize acids (pH). Alkalinity acts as a buffer capacity. The shell filtration component of the RAS system supports the alkalinity value by preventing fluctuations in water pH during rearing period. The high content of CO_2 in water decline the alkalinity value. According to Bhatnagar and Devi (2013), the optimum range of water alkalinity in fish farming is 50–200 mg/L. Water alkalinity value which is less than 20 mg/L can cause stress to cultivated commodities. Water quality parameter below the threshold lead fish to lose appetite, weak and death (Affandi *et al*., 2013).

Ammonia (NH_3) is a nitrogen compound resulting from metabolism of protein. It is excreted through the gills, urine and feces. Ammonia is formed as uneaten feed or fecal material in rearing water decomposes. Ammonia (NH_3) has a higher lethality than ammonium ion (NH_4^+) (Mercante *et al*., 2018). Oxygen consumption in fish tissue can be affected by the value of ammonia. High concentrations of ammonia can damage the gills and inhibit oxygen transport by the blood. Bhatnagar and Devi (2013) suggest that a good ammonia concentration to support fish survival is less than 0.1 mg/L.

According to Li and Liu (2013), a normal limits of nitrite level for intensive fish farming systems should be below 0.8 mg/L. This compound is lethal to aquatic animals because it can attack the gills, blood circulation, and other vital organs in high concentrations. However, nitrate compounds (NO_3^-) tend to be less harmful to fish than ammonia and nitrites. Tolarable nitrate level for fish is 0–100 mg/L (Bhatnagar & Devi, 2013).

Nitrate is the result of the conversion of nitrite compounds (NO_2^-) by the bacteria *Nitrobacter* sp.

Physical filters are designed to eliminate solid particulate material such as uneaten feed, metabolic waste from the rearing water. The physical filter is placed at the beginning (prefilter) before the water enters the chemical or biological filter, because large particles suspended in the water are effectively processed through the physical filter. Chemical filters play a role in binding the rest of the metabolism in the form of nitrogen compounds that are toxic to fish. Zeolite is effectively used in flowing water systems such as recirculation systems. Hence, water quality can optimally support fish survival (Priono & Satyani, 2012). Biological filters are used by remodel bacteria as a place to live. Nitrifying bacteria are added through the addition of probiotics to the rearing water, namely *Nitrosomonas* sp. and *Nitrobacter* sp. The presence of nitrifying bacterial colonies in the recirculation system supports the performance of reorganizing toxic nitrogen compounds (Jacinda *et al*., 2021).

Business analysis of eel nursery production used assumptions and adjusted to the results of the study. The survival rate, biomass, amount of feed consumption, and the amount of probiotic needs refer to the results of the study. Nonetheless, scale up was carried out according to the assumptions used. The nursery production of eel is assumed to have six cycles in one year. A total of 100 aquariums for each treatment with the assumption that the water volume is 100 L per aquarium. The stocking density of eels used for production activities is 2 g/L or 200 g per aquarium. Feeding in the form of pasta is given at rate of 4-5% of body weight.

CONCLUSION

The production performance and the best nursery performance of eel *Anguilla bicolor bicolor* graded from recirculating system were obtained at initial weight of 1.04 ± 0.00 g and 0.50 ± 0.00 g, respectively. Grading activities need to be carried out periodically in eel cultivation. Further research is required to analyze the production performance of stadia elver eel and fingerling in the recirculation system.

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