Operational efficiency of feeding in Mud Crab fattening culture *Scylla serrata* in recirculating aquaculture system (RAS) apartment system

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Abstract. Mud crabs (*Scylla serrata*) are highly valued aquaculture commodities in the international market. However, feeding operations in mud crab culture using a Recirculating Aquaculture System (RAS) are often inefficient, increasing labor time and operational costs. This study aimed to evaluate the operational efficiency of feeding *S. serrata* once, twice, and three times per day by assessing production performance and conducting a business analysis in a RAS apartment system. A completely randomized design was used with three feeding frequency treatments (one, two, and three times daily), each with three replicates. Parameters observed included survival rate, absolute weight gain, carapace length and width growth, molting frequency and percentage, feed consumption, feed conversion ratio (FCR), feed utilization efficiency, and labor efficiency. Results showed that feeding frequency had no significant effect on survival rate, growth parameters, molting performance, or feed utilization efficiency. However, feeding twice per day produced the highest profit (IDR 5,342,008) and a labor efficiency of 1.08%. These findings indicate that feeding twice daily optimizes both biological performance and economic returns in mud crab fattening using a RAS apartment system.

1 Introduction

Mud crabs (*Scylla serrata*) are among the most valuable crustacean species in global aquaculture due to their high market demand and export potential. Indonesia, one of the major producers of mud crabs, contributes significantly to international markets such as China, the United States, Japan, and the European Union. Despite this, approximately 81% of Indonesia's crab production still relies on wild catches, indicating limited aquaculture-based supply and the need to increase cultured production [1]. To meet rising demand while promoting sustainable practices, the development of effective mud crab aquaculture systems has become increasingly important.

Conventional pond culture systems, although widely practiced, face several challenges including large land requirements, poor water quality control, and high cannibalism rates among crabs [2]. To address these limitations, the Recirculating Aquaculture System (RAS) "apartment" system has been introduced as an innovative approach for mud crab fattening. This system enables intensive culture within a controlled environment, reduces land use, and minimizes cannibalism by housing crabs individually [3–4]. However, despite these advantages, the efficiency of feeding operations in RAS systems remains a key constraint. Feeding in mud crab culture is labor-intensive because crabs must be fed individually, increasing operational costs and time requirements.

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Efficient feed management is essential not only for improving growth and survival but also for enhancing labor productivity and overall economic performance in aquaculture. Previous studies have shown that feeding frequency can influence growth and feed conversion efficiency in crustaceans, yet the relationship between feeding operations and labor efficiency in mud crab culture has not been comprehensively evaluated [5–6]. Therefore, this study aims to analyze the operational efficiency of feeding mud crabs once, twice, and three times per day by evaluating production performance and conducting a business analysis within the RAS apartment system. The findings are expected to provide insights into optimizing feeding management strategies for sustainable and profitable mud crab farming.

2 Method

2.1 Site location and time

The study was carried out between October 2023 and January 2024. The study was conducted at the RAS apartment system mud crab culture business development unit of the IPB Fisheries and Marine Observation Station (IFMOS), Ancol, North Jakarta, DKI Jakarta. Collectors in Keramat Village, Pakuhaji District, Tangerang Regency, Banten, provided the seeds. Water quality assessments were conducted in the Aquaculture Environment Laboratory and the Fish Nutrition and Feed Technology Division Laboratory, Department of Aquaculture, FPIK, IPB University.

2.2 Experimental design

A Completely Randomized Design (CRD) was employed in the trial, with three replications for each of the three treatments: one, two, and three times daily feeding. In the RAS apartment system, the effects of feeding crabs once, twice, and three times a day were compared using these three treatments.

2.3 Culture techniques

2.3.1 Rearing preparation

Synthetic sponge cleaning is used to remove food residue, moss, and excrement from the apartment boxes used as mud crab rearing containers. It takes one to two days to clean the rearing containers. The rearing containers are rinsed with new water to get rid of germs and parasites. The RAS apartment system consisted of 90 individual rearing boxes (30 cm × 33 cm × 15 cm each) arranged vertically in stacked modules. Each box contained 7–8 L of rearing water, giving a total system capacity of approximately 720 L. The system operated continuously with an aeration system and a filtration unit consisting of physical (synthetic cotton, biofoam, Japanese filter mats), chemical (UV sterilizer), and biological (bioballs, crushed coral, kaldness) filters. The water flow rate was maintained at 1.5 L min^{-1}, and the water exchange rate was approximately 10% per day to maintain optimal water quality (Fig. 1).

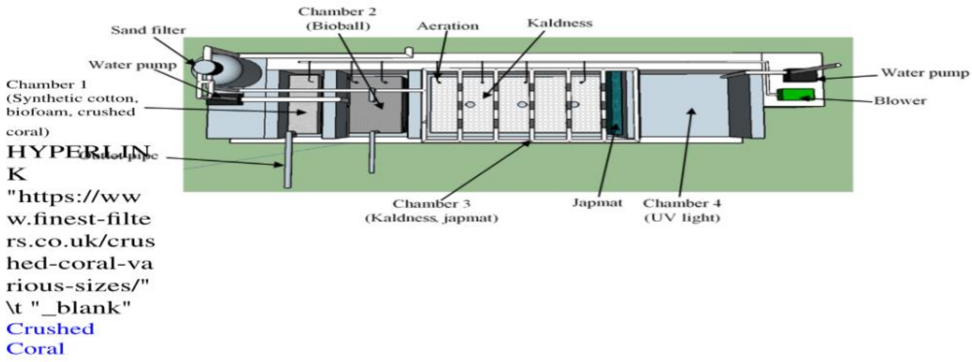

Fig. 1. Physical, chemical, and biological filter design for a recirculating aquaculture system in an apartment box for cultivating mud crabs (*Scylla serrata*).

2.3.2 Mud crab selection and acclimation

Crab selection is carried out at the crab collector's location in the village Keramat, Pakuhaji District, Tangerang Regency, Banten. Mud crab criteria which is chosen among others. Healthy mud crab with complete bodies. No spots are black or barnacles that stick to the crab's body [2]. Live crabs are also characterised by their reactions, which fasten when the foot is withdrawn and the eye, which actively move if disturbed. Gender is also observed from the external shape of the body. Male crabs are characterised by genitals that are triangular in shape and slightly pointed and attached to the part of their stomach. The crab female is characterised by an organ of his gender, which has a relatively wide triangular shape, and the front part is somewhat blunt [5] (Fig. 2). The type of mud crab was used in this research. There were 23 male mud crabs and 67 female mud crabs.

2.3.3 Mud crab rearing

Crabs are transported to the culture location using a dry transportation system. A receptacle used for transportation is a basket sized 75 cm × 42 cm × 32 cm. The time required from the transportation location to the culture location is 1-1.5 hours. The container for acclimatising mud crab is a round fibre tank. Fibre tank for acclimatisation is filled with a mixture of seawater and freshwater by adjusting the salinity of the source seed to 10-15 g/L and giving aeration. Crabs that arrive in the location are entered into the basket with a concentrated spread of 15 crabs/basket and left for 10-15 minutes. The crab is splashed with water, rearing, and left alone for 10-15 minutes. Crab acclimatised in a tub fibre round, which has been filled with rearing water to a height of 8-10 cm for 1-2 hours. The optimal salinity for mud crab is 25-30 g/L, and the temperature range is 27-28°C. Crab was acclimatised to the condition of the claw and foot road. Still bound, the bond is released after the acclimatisation process is finished. The initial size of the crab was measured using a digital scale. The length and width of the carapace were measured. Average weight of a beginning mud crab is 140.3±2.83 g, average carapace length 59.98±0.51 cm, and average carapace width 81.72±3.33 cm. Crabs were kept in apartment boxes randomly, each block (G, H, I) containing 90 crabs (Fig. 3).

Fig. 2. Morphological differences between male mud crabs (left) and female (right).

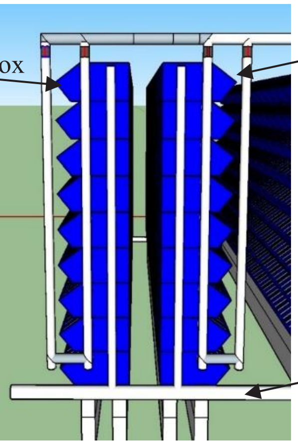

Fig. 3. RAS system apartment box design for mud crab (*Scylla serrata*) culture.

Crab given feed fish trash in a restricted way, 5-10% from the biomass crab. Type fish trash, which is fish *Selaroides leptolepis*. Fish was purchased from Muara Angke Fish Market, Jakarta North. Giving fish trash done with chopping fish so that it is more easily consumed, and weighing as much as ± 6 g/crab, then given to the mud crab with stainless steel tongs to prevent the hand from being hit by a crab's pincers. Fresh fish was stored as feed in the freezer for seven days to prevent the growth of bacteria that cause decay, which can cause damage to the feed.

2.3.4 Sampling

The crab census is carried out every 14 days with 90 crabs. The measurements taken were weight, carapace length, carapace width, and completeness of body organs. Measurements were taken using digital scales with an accuracy of 0.01 g and a vernier calliper with an accuracy of 0.1 cm. Mud crabs are observed every four hours to determine which ones are molting. Crabs immediately after molting are weighed and recorded. Harvest target crab sized 250-400 g with a rearing time range of 30 days. Water quality management is maintained by siphoning off the remaining feed. Moreover, other waste accumulates before feeding—leftover feed cleaned in the morning (07.00 WIB). Water quality parameters consisting of temperature, pH, salinity, and dissolved oxygen (DO) were measured twice a day, namely in the morning (09.00 WIB) and afternoon (17.00 WIB). Total ammonia Nitrogen (TAN), nitrite, nitrate, and alkalinity are measured every 7 days in the Laboratory Aquaculture Environment and Laboratory of Nutrition and Feed Technology Division, Aquaculture Department, IPB University.

2.4 Parameter test

Parameters observed during rearing include production performance, water quality, and business analysis. The production performance parameters measured consist of labor efficiency, survival rate, absolute weight growth, carapace length growth, carapace width growth, molting time, number and percentage, feed consumption, feed conversion ratio (FCR), and feed utilization efficiency.

$$\text{Labor efficiency (\%)} = \frac{Amount\ of\ feed\ given\ (kg)}{Amount\ of\ labor\ time\ (hours/day)} \times 100 \quad (1)$$

$$\text{Survival rate (SR, \%)} = \frac{Final\ number\ of\ crab\ (crab)}{Initial\ number\ of\ crab\ (crab)} \times 100 \quad (2)$$

$$\text{Absolute weight growth (AWG, \%)} = \frac{Final\ average\ weight\ (g) - Initial\ average\ weight\ (g)}{Time\ of\ rearing\ (Day)} \quad (3)$$

Carapace length growth is the difference between the final carapace length and the initial carapace length during the rearing period. Carapace width growth is the difference between the final carapace width and the initial carapace width during the rearing period. Molting time can be defined as the length of time it takes for a mud crab to shed its shell during the rearing period. Molting time is calculated from the first day the crab molts during the rearing period. Molting time for mud crabs is checked every four hours.

$$\text{Percentage of molting (\%)} = \frac{Final\ number\ of\ crab\ molting\ (Crab)}{Initial\ number\ of\ crab\ molti\ (Crab)} \quad (4)$$

The amount of feed consumption (g) is calculated from the total feed given, minus the total remaining feed that is not consumed during the rearing period.

$$\text{Feed conversion ratio (FCR)} = \frac{Amount\ of\ feed\ consumption\ (g)}{\left(Final\ biomass\ of\ crab\ (g) - Initial\ biomass\ of\ crab\ (g)\right) + Biomass\ of\ death\ crab\ (g)} \quad (5)$$

$$\text{Feed utilization efficiency} = \frac{Final\ average\ weight\ (g) - Initial\ average\ weight\ (g)}{Amount\ of\ feed\ consumption\ (g)} \times 100 \quad (6)$$

The water quality parameters measured consisted of temperature, pH, dissolved oxygen (DO), salinity, total ammonia nitrogen (TAN), nitrate, nitrite, and alkalinity (Table 1).

Table 1. Water quality parameters of mud crab (*Scylla serrata*) rearing media in Recirculating Aquaculture System (RAS) apartment boxes for 30 days of rearing.

Parameter	Measurement tool	Time
Salinity (g/L)	Refractometer	Every day
Temperature (°C)	Thermometer	Every day
pH	pH meter	Every day
DO (mg/L)	DO meter	Every day
TAN (mg/L)	Spectophotometer	Every 7 days
Nitrite (mg/L)	Spectophotometer	Every 7 days
Nitrate (mg/L)	Spectophotometer	Every 7 days
Alkalinity (mg/L)	Titration	Every 7 days

The business analysis consisted of investment cost, variable cost, fixed cost, total cost, total revenue, profit, cost of good sold, revenue/cost ratio, payback period, and break-even point.

$$\text{Total cost (TC, IDR)} = \text{Fixed cost (IDR)} + \text{Variable cost (IDR)} \tag{7}$$

$$\text{Total revenue (TR, IDR)} = \text{Number of production (Crab)} \times \text{Selling price (IDR)} \tag{8}$$

$$\text{Profit (IDR)} = \text{TR (IDR)} - \text{TC (IDR)} \tag{9}$$

$$\text{Cost of good sold (CGS, IDR)} = \frac{Total\ cost\ (IDR)}{Number\ of\ production\ (Crab)} \tag{10}$$

$$\text{Revenue/cost (R/C) ratio} = \frac{Total\ revenue\ (IDR)}{Total\ cost\ (IDR)} \tag{11}$$

$$\text{Payback period (Year)} = \frac{Investment\ cost\ (IDR)}{Profit\ (IDR)} \tag{12}$$

$$\text{Break-even point (BEP) unit (Crab)} = \frac{Fixed\ cost\ (IDR)}{Selling\ price\ (IDR) - \frac{Variable\ cost\ (IDR)}{Number\ of\ production\ (Crab)}} \tag{13}$$

$$\text{Break-even point (BEP) price (IDR)} = \frac{Fixed\ cost\ (IDR)}{1 - \frac{Variable\ cost\ (IDR)}{Total\ revenue\ (IDR)}} \tag{14}$$

2.5 Data analysis

Data were analyzed using Microsoft Excel 2019 and SPSS software version 26. Test parameters were analyzed using Analysis of Variance (ANOVA) with a 95% confidence interval, and if there was a significant effect, Duncan's test was continued. Business performance analysis is carried out based on assumptions obtained from the results of production performance in the research. Analysis of the water quality of the rearing media and costs was carried out descriptively through table. The number of production cycles carried out in one year is 12. The number of workers employed is one person. The business analysis was conducted on softshell and non-softshell crabs.

3 Result

3.1 Production performance

The allocation of working time workers spend cultivating mud crabs in RAS apartment boxes for 30 days of rearing, with once-daily feeding is 141 hours, twice-daily 171 hours, and three times-daily 201 hours (Table 2). More frequent feeding will affect the number of molting times, so the harvest of soft-shelled crabs will be more frequent and require more working time. In the research conducted, only one worker was used, so the workload received is heavier. Labor efficiency for feeding once, twice, and three times daily in mud crab (*Scylla serrata*) culture is presented in Table 3. Labor efficiency for once-daily feeding was 0.78%, twice-daily 1.08%, and three times-daily 1.53% (Table 3). Labor efficiency in feeding showed a significant increase with more frequent feeding. At once-daily feeding, labor efficiency only reached 0.78%. However, when fed twice daily, efficiency increased to 1.08%. The highest efficiency was achieved with three times-daily feeding, namely 1.53%. This indicates that frequent feeding allows labor to work more effectively and productively, optimising their time to achieve better productivity.

Table 2. Labor load on feeding one, two, and three times a day in the cultivation of mangrove crabs(*Scylla serrata*) in RAS apartment boxes for 30 days of rearing.

Sub-activities	**Feeding frequency (times/day)**		
	1	**2**	**3**
	Working hours (Hours)		
Container preparation (apartment box, RAS filter, acclimatization)	1	1	1
Filter system setup and water filling	2.5	2.5	2.5
Crab apartment and filter system cleaning	2.5	2.5	2.5
Mud crab seed selection	1	1	1
Mud crab seed transportation	2	2	2
Mud crab acclimatization	3	3	3
Measurement of carapace length, width, and weight	2	2	2
In-situ water quality check	30	30	30
Ex-situ water quality check	30	30	30
Siphoning	30	30	30
Mud crab feeding	30	60	90
Mud crab molting check	6	6	6
Mud crab census	4	4	4
Harvesting soft-shell crabs	1	1	1
Post-harvest	1	1	1
Total work time allocation (hours)	141	171	201
Feed consumption (kg/30 days)	1.1	1,8	3,1
Working hours (30 days)	141	171	201
Number of workers (persons/day)	1	1	1
Labor efficiency (%)	0.8	1.1	1.5

Table 3. Production performance of mud crab (*Scylla serrata*) rearing media in Recirculating Aquaculture System (RAS) apartment boxes for 30 days of rearing.

Parameter	**Feeding frequency (times/day)**		
	1	**2**	**3**
Survival rate (%)	60.00 ± 20.00^{a}	73.33 ± 20.82^{a}	66.67 ± 15.28^{a}
Absolute weight growth rate (g/day)	0.33 ± 0.21^{a}	0.64 ± 0.05^{a}	0.67 ± 0.53^{a}
Carapace length growth (cm)	1.79 ± 0.71^{a}	2.85 ± 0.38^{a}	2.41 ± 1.23^{a}
Carapace width growth (cm)	1.60 ± 0.53^{a}	2.62 ± 0.13^{a}	2.33 ± 1.23^{a}
Amount of feed consumption (g)	368.30 ± 83.51^{a}	617.67 ± 314.24^{ab}	1,026.70 ± 345.25^{b}
Molting percentage (%)	6.67 ± 5.77^{a}	16.67 ± 5.77^{a}	16.67 ± 5.77^{a}
Feed conversion ratio	3.49 ± 0.83^{a}	3.00 ± 0.33^{a}	3.56 ± 0.73^{a}
Feed utilization efficiency	2.94 ± 1.77^{a}	3.58 ± 1.57^{a}	2.25 ± 1.82

Feeding once, twice, and three times a day showed no significant differences (P>0.05) in survival rate, absolute weight growth rate, carapace length growth, carapace width growth, percentage of molting, and feed conversion ratio. The amount of feed consumption parameter showed significant differences (P<0.05). Better results in survival rate, carapace length width growth, molting percentage, feed conversion ratio, and feed utilization efficiency were obtained in the 2 times/day feeding frequency treatment, while the highest absolute weight growth rate and feed consumption were obtained in the 3 times/day feeding frequency treatment. Table 3 shows the results of mud crab production performance in the RAS apartment box for 30 days of rearing.

Table 4. Time and number of molting (crab/day) of mud crabs (*Scylla serrata*) when fed once, twice, and three times a day during culture in RAS apartment boxes for 30 days of rearing.

Feeding (times/ day)	**Day of rearing (day)**														
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
1	0	0	0	0	0	0	0	0	0	0	0	0	0	■	0
2	0	0	■	0	0	0	0	■	0	0	0	0	0	0	0
3	0	0	■	0	0	0	0	0	0	0	0	0	0	0	0
Feeding (times/ day)	Day of rearing (day)														
	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1	0	0	0	0	0	0	0	0	0	■	0	0	0	0	0
2	0	■	0	0	■	0	■	0	0	0	0	0	0	0	0
3	0	0	0	0	■	■	■	0	0	0	0	0	0	0	0

Molting observations conducted every four hours showed that feeding two and three times a day resulted in the same number of molts, namely 5, and feeding once a day resulted in the fewest molts, namely 2 (Table 4). More frequent feeding can increase the molting frequency in crabs. However, this also increases the workload for workers, as more frequent feeding requires extra time and attention. Furthermore, the molting period requires intensive care, as crabs are more vulnerable and require optimal environmental conditions. However, with efficient scheduling and good management, increasing the molting frequency can increase productivity and yields in the long term, although it requires more labor in the short term. Based on Table 5, the water quality of the mud crab (*Scylla serrata*) culture media in the RAS apartment box for 30 days was within the optimal range for mud crab culture.

Table 5. Water quality of the mud crab (*Scylla serrata*) rearing media during 30 days of culture in RAS apartment boxes.

Parameter	**Range of values**	**Optimum values [6]**
Temperature (°C)	27.8 – 29.4	25 – 35
pH	7.0 – 8.3	7 – 9
Dissolved oxygen (mg/L)	6.2 – 7.8	≥ 5
Salinity (g/L)	25 – 33	25
Nitrate (mg/L)	0.253 – 1.886	< 10
Nitrite (g/L)	0.045 – 1.723	< 10
Total ammonia nitrogen (g/L)	0.01 – 0.47	< 3
Alkalinity (g/L)	54.67 – 97.33	> 80

The assumptions for the mud crab business, based on feeding once, twice, and three times daily in RAS apartment boxes, are shown in Table 6. Based on the basic business assumptions, calculations of investment costs, fixed costs, variable costs, and income for mud crabs were obtained when fed one, two, and three times a day. An analysis of the mud crab business, feeding one, two, and three times a day in culture in RAS apartment boxes, can be seen in Table 7. Mud crab culture in the RAS apartment with twice-daily feeding yielded the highest profit of IDR 5,342,008, with a revenue/cost ratio of 1.09, meaning that every 1 rupiah of total costs incurred will generate a profit of 0.09 rupiah, and a payback period of 13.25 years. The 13.25-year payback period indicates that the income from the culture business is not high enough compared to the initial investment costs. Low income, high operational costs, and a significant initial investment could cause this. The payback period can be reduced by increasing income through market development and product diversification, reducing operational costs through efficiency and negotiation with suppliers, and improving production efficiency with better health and nutrition management. In addition, wiser investment management and increasing business scale to achieve economies of scale can also help accelerate returns.

Table 6. Assumptions for mud crab culture with one, two, and three feeding times daily in RAS apartment boxes during 30 days of rearing (12 production cycles/year).

Business Assumptions	Feeding (times/day)		
	1	2	3
Initial number of crabs (crab)	300	300	300
Initial crab weight (g)	135	135	135
Initial biomass (kg)	40.50	40.50	40.50
Number of workers (persons)	1	1	1
Working hours (hours)	141	171	201
Survival rate of soka and non-soka (%)	60	73.33	66.67
Survival rate of non-soka (%)	53.33	56.66	50.00
Survival rate of soka (%)	6.67	16.67	16.67
Mortality (%)	40	27	33
Weight increase of soft-shelled crabs (%)	46.31	62.56	64.38
Weight increase of non-soft-shelled crabs (%)	5.48	4.20	4.13
Weight increase of dead crabs (%)	1.37	1.58	7.69
Price of soft-shelled crabs (IDR/kg)	150,000	150,000	150,000
Price of non-soft-shelled crabs (IDR/kg)	120,000	120,000	120,000
Price of dead crab (IDR/kg)	70,000	70,000	70,000

Table 7. Analysis of mud crab culture using one, two, and three feeding times daily in RAS apartment boxes.

Parameter	Feeding Frequency (times/day)		
	1	2	3
Investment cost (IDR)	70,760,400	70,760,400	70,760,400
Fixed Cost (IDR)	14,714,433	14,714,433	14,714,433
Variable Cost (IDR)	41,887,080	43,467,120	44,715,360
Total Cost (IDR)	56,601,513	58,181,553	59,429,793
Revenue (IDR)	53,715,100	63,523,561	62,430,398
Profit (IDR)	-2,886,413	5,342,008	3,000,605
R/C ratio	0.5	1.09	1.05
Payback period (years)	-	13.25	23.58
BEP price (IDR)	66,823,294	46,604,139	51,855,824
BEP softshell crab unit (kg)	59	97	111
BEP non-softshell crab unit (kg)	340	211	210
BEP dead crab (kg)	245	98	143
Cost of Goods Sold (IDR/kg)	1,193,416	441,774	446,255
Cost of Goods Sold (IDR/kg)	207,038	202,735	344,095
Cost of dead crabs (IDR/kg)	287,225	436,493	234,867

4 Discussion

Feeding frequency is one of the most critical factors affecting production efficiency, feed utilization, and labor management in aquaculture. In this research, feeding mud crabs (*Scylla serrata*) once, twice, and three times per day did not significantly affect survival rate, growth parameters, or feed conversion ratio (FCR). However, feeding twice daily yielded the best combination of biological performance, feed utilization efficiency, and profitability. This indicates that optimizing feeding schedules can enhance overall culture performance without increasing feed costs or labor requirements unnecessarily. The number of workers is related to working hours in a business.

Labor efficiency is a concept that describes how efficiently labor is used to achieve production goals. Feeding frequencies of one, two, and three times daily can affect labor efficiency. Optimising technician work schedules appropriately and efficiently can reduce workloads and increase productivity. Optimising technician work schedules and mapping work processes aims to increase productivity and effectiveness in mud crab culture. A structured work schedule and a clear division of tasks and responsibilities allow for more efficient use of work time. The process flow for each work stage must be clear to guide technicians in minimising errors in cultivating activities. Work time spent by labor covers various stages of the culture process, from cleaning the crab apartment and filter, acclimatisation, initial sampling, feeding, maintenance, daily quality checks, to harvesting and post-harvest. Optimising work time can be achieved by increasing efficiency at each stage of the culture process, thereby increasing the productivity of soft-shelled crab culture using the apartment system. Workforce skills are crucial because they can help workers perform better and produce higher-quality output. Aquaculture activities require high skill levels and are closely related to work experience. Due to their complexity, closed-cage crab culture systems require highly skilled workers [8].

The survival rate results obtained during the study were influenced by several factors, such as the mud crabs' water quality, feed, age, and adaptability. This is also supported by research conducted by Fatihah *et al*. [9] that factors such as molting, water quality, and shelter influence the survival rate of crabs. Mud crabs were raised for 30 days using an apartment system. The apartment system has the advantage of reducing cannibalism in mud crabs, thus affecting the survival rate of mud crabs [10]. Growth is influenced by two factors: internal and external. Internal factors include heredity, sex, age, disease resistance, and the crab's ability to utilise food. External factors include food, physical and chemical conditions of the water, food quantity and quality, and movement space. One external factor that significantly impacts growth is food availability [11]. The growth of carapace length and width is related to the molting process in mud crabs. This is because the number of crabs that experience molting is minimal and the crabs used for the study were adult crabs with an average weight of 140.3 ± 2.83 g. Mud crabs (*Scylla serrata*) have a discontinuous growth pattern, namely rapid growth only occurs during molting, and growth becomes very slow after molting. Suryani *et al*. [12] stated that molting rarely occurs in adult crabs weighing above 70 g.

Molting is unavoidable in crustaceans, including mud crabs. Internal and external factors influence the molting process in mud crabs. Internal factors include age, size, and sex, while external factors include light, temperature, and food availability. One factor that causes mud crab mortality is failure in the molting process. The molting process in mud crabs requires sufficient energy from consumed food and suitable environmental conditions. The molting process in mud crabs involves several stages: premolt, ecdysis, molting, postmolt, and intermolt. The critical phase of the molting process is the ecdysis stage. At this stage, mud crabs shed their old exoskeletons and increase their water absorption. This process requires significant energy and an optimal environment, making mud crabs susceptible to molting failure [13].

Feed acts as an energy provider that drives growth. Efforts are made to provide sufficient feed for the optimal growth of mud crabs. Feed availability significantly impacts crab growth and survival. Feed consumption can be defined as the amount of food consumed by crabs during culture. Factors influencing feed consumption include the size or stage of the mud crab, appetite, feed nutritional quality, feeding frequency, environmental conditions, mortality rate during culture, and feed availability. Underfeeding can inhibit crab growth and molting, while overfeeding can cause water pollution due to the accumulation of leftover feed at the bottom of the water [11]. The feed conversion ratio (FCR) is the ability of mud crabs to convert feed into meat. The lower the FCR, the better the feed quality. The FCR reflects how efficiently the consumed feed is converted into biomass in the crab's body. A higher FCR indicates low feed quality and poor feed utilisation efficiency [14]. The FCRs of mud crabs obtained during maintenance with feeding once, twice, and three times daily were 3.49 ± 0.83, 3.00 ± 0.33, and 3.56 ± 0.73, respectively. The high FCR value occurs because the growth of mud crabs is not linear and only occurs during molting. Feed utilisation efficiency is an organism's capacity to utilise feed for optimal metabolism and growth [13]. Uneaten feed will rot, affecting the quality of the rearing environment and disrupting the crab's appetite. Rotting feed releases ammonia (NH_3), which can disrupt the survival of mud crabs. Stress factors in crabs can also reduce feed utilisation efficiency, resulting in limited energy for survival and growth and increasing the risk of mortality. Feed quality can be assessed by the feed utilisation efficiency value, which states that the lower the feed utilisation efficiency value, the lower the quality of the feed consumed [15].

The relationship between feeding efficiency and growth can also be linked to molting behavior. Since *S. serrata* exhibits discontinuous growth through molting, feed management directly influences the energy available during the premolt stage. Feeding twice per day appears sufficient to sustain metabolic demands while maintaining stable water quality, reducing stress that can disrupt molting success. This finding supports Suryani et al. [12], who emphasized that molting frequency and success rate are highly sensitive to feeding management and environmental stability. The crab will feed after 6 hours, and its body will harden in less than 24 hours. Mud crabs can molt 20 – 25 times during their lifetime. Each molt increases the size of the mud crab along with its weight [11]. Feeding too frequently can limit the digestive tract's capacity to digest food, thus affecting the rate of gastric emptying. If the feed and energy from the previous feed are not used up before new feed is provided, most of the feed is uneaten and is excreted as faeces.

Mud crab culture using the apartment system employs a closed system using recirculating aquaculture.Compared to previous studies, this research uniquely integrates biological performance, labor efficiency, and financial analysis within a controlled RAS apartment system. Previous research primarily focused on growth and FCR in open or pond systems [4; 14]. By applying a recirculating and compartmentalized system, this research demonstrates that feeding management not only affects feed utilization but also determines economic feasibility under intensive rearing conditions. The RAS apartment system offers stable water quality, reduced cannibalism, and efficient space utilization, making it a promising model for sustainable soft-shell crab production.

Filters are a crucial element in the recirculation system. The physical filters used include synthetic cotton, sand filters, biofoam, and Japanese filter mats (japmat). Dacron filters out water-soluble particles. Sand filters function to filter non-aqueous materials such as algae or other types of algae found in the maintenance water. Biofoam is a foam that filters coarse dirt. Japanese filter mats (japmat) filter dirt so that it is not carried back to the maintenance water container. The chemical filter used is UV (ultraviolet) light. UV light kills bacteria, so the water is sterile. The biological filters used are bioballs, Crushed coral, and kaldness. Bioballs function as a habitat for bacteria and filter dirt. Crushed coral functions to stabilise water pH and decompose ammonia (NH_3). Kaldness functions as a nitrification medium.

The best temperature for mud crab culture is 29 °C, because this temperature impacts feed conversion, survival, physiological response, and specific growth rate of mud crabs [4]. During culture, DO values range from 6.2 to 7.8 mg/L. This value indicates that dissolved oxygen during the culture period is in the optimum range of ≥ 5 mg/L [6]. The range of salinity values for mud crabs during the 30-day culture period ranges from 25 to 33 g/L. This range is within the optimal range for mud crab growth. This is supported by research conducted by Hastuti [7], which found that the best salinity for mud crabs is 25 g/L, because this salinity has the best impact on the growth and survival of mud crabs. The range of nitrate values during the maintenance period is 0.253 – 1.886 mg/L. This value is within the normal range of <10 mg/L [6]. The range of nitrite values during the maintenance period is 0.045 – 1.723 mg/L. This value is within the normal range of <10 mg/L [6]. Total ammonia in the mud crab culture environment is the main result of nitrogen waste from aquatic organisms [4]. The range of TAN values during the maintenance period is 0.01 - 0.47 mg/L. This value is within the safe limit of <3 mg/L [6]. The range of alkalinity values during the rearing period was 54.67 – 97.33 mg/L.

In this research, feeding twice per day produced the highest profit (IDR 5,342,008) with an R/C ratio of 1.09, indicating feasible business performance. More frequent feeding (three times daily) increased labor time and operational costs without proportionate gains in growth, resulting in lower profit margins. Labor productivity and feeding management are major determinants of profitability in mud crab aquaculture. Optimizing labor schedules through efficient feeding routines can thus enhance both technical and economic outcomes. The business is profitable and feasible if the R/C ratio is >1. Conversely, if the R/C ratio is = 1, the business is considered to have reached break-even, meaning revenue and costs are equal, with no profit or loss. If the R/C ratio is less than one, the business is experiencing a loss.

5 Conclusion

Feeding frequency did not significantly affect the survival rate, growth rate, or molting performance of Scylla serrata cultured in the RAS apartment system. However, feeding twice per day resulted in the most efficient combination of biological and economic outcomes. This treatment produced a feed conversion ratio (FCR) of 3.00 ± 0.33, a labor efficiency of 1.08%, and the highest profit of IDR 5,342,008 per production cycle. In contrast, once-daily feeding led to reduced profitability, while three-times-daily feeding increased labor costs without improving growth performance. These results demonstrate that optimizing feeding frequency to twice daily enhances operational efficiency, reduces labor workload, and improves the economic feasibility of mud crab fattening in a recirculating aquaculture system.

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Data availability statement

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

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