Original article DOI: 10.19027/jai.24.1.32-42

Performance of mud crab farming in natural seed-based apartment systems with various pre-transportation holding durations

Kinerja budidaya kepiting bakau sistem apartemen berbasis benih alam dengan berbagai lama penampungan pra-transportasi

Mira Atul Hayati, Irzal Effendi*, Yani Hadiroseyani, Tatag Budiardi

Department of Aquaculture, Faculty of Fisheries and Marine Science, IPB University, Bogor, West Java 16680, Indonesia

*Corresponding author: irzalef@apps.ipb.ac.id

(Received January 18, 2024; Revised March 6, 2024; Accepted September 17, 2024)

ABSTRACT

Farming mud crabs (*Scylla serrata*) in Indonesia generally use seeds from natural habitats, which are caught, held, and transported dry to the farming location. The crabs are held for several days while waiting for consumers. This study analyzed the impact of pre-transport holding times (one, three, and five days) with four replications and an average initial weight of 73.60 ± 12.53 g on the physiological condition and production performance of farming mud crabs in an apartment system. The crabs were transported dry from Muara Gembong, Bekasi Regency, West Java, to the IPB Fisheries and Marine Observation Station (IFMOS) Ancol, North Jakarta, DKI Jakarta, for three hours. The crabs were farming in apartment boxes with a recirculation system for 14 days. The results showed that the crabs experienced severe gill damage indicated by the lysis of gill cuticles and low survival rates, especially after five days of pre-transport holding. The crabs experienced stress in all treatments, as indicated by high glucose levels above 30 mg/dL. The best survival rate was found in the one-day pre-transport holding time, with a value of 87.50% at the holding location and 95% at the farming location. In conclusion, a one-day pre-transport holding time provides better physiological conditions and production performance for mud crab farming in an apartment system.

Keywords: crab, gills, natural catch, stress

ABSTRAK

Budidaya kepiting bakau (*Scylla serrata*) di Indonesia umumnya menggunakan benih dari alam, yang ditangkap, ditampung, dan kemudian di transportasi kering ke lokasi budidaya. Penampungan kepiting berlangsung beberapa hari sambil menunggu konsumen. Penelitian ini menganalisis dampak lama waktu penampungan pratransportasi (satu, tiga, dan lima hari) dengan empat ulangan dan bobot rata-rata awal 73,60 ± 12,53 g, terhadap kondisi fisiologi dan kinerja produksi kepiting bakau yang dibudidayakan dalam sistem apartemen. Kepiting di transportasi kering dari Muara Gembong, Kabupaten Bekasi, Jawa Barat, ke IPB fisheries and marine observation station (IFMOS) Ancol, Jakarta Utara, DKI Jakarta, selama tiga jam. Kepiting dibudidayakan pada boks apartemen dengan sistem resirkulasi selama 14 hari. Hasil penelitian menunjukkan bahwa kepiting mengalami kerusakan insang yang parah ditunjukkan dengan lisisnya kutikula insang dan tingkat kelangsungan hidup rendah, terutama setelah lima hari lama penampungan. Kepiting mengalami stres dalam semua perlakuan, yang ditunjukkan oleh tingginya kadar glukosa di atas 30 mg/dL. Tingkat kelangsungan hidup terbaik yakni pada lama waktu penampungan satu hari, dengan nilai 87,50% di lokasi penampungan dan 95% di lokasi budidaya. Kesimpulannya, lama waktu penampungan satu hari pratransportasi memberikan kondisi fisiologi dan kinerja produksi budidaya kepiting bakau sistem apartemen yang lebih baik.

Kata kunci: insang, kepiting, stres, tangkapan alam

INTRODUCTION

Mud crab (*Scylla serrata*) is a species of the Portunidae family and the Crustacean class that is very popular with the public, in addition to having a high protein value of 65.72% and 0.83% fat (Islam *et al*., 2022; Soares & Andiewati, 2022). Consuming mud crabs can also prevent cancer and increase endurance (Aswar *et al.*, 2023). In Indonesia, mud crab cultivation still relies on natural catches (Indarjo *et al*., 2020). Mud crab production in 2020, 2021, and 2022 was dominated by wild catches, respectively 62,106,626 tons, 44,844,514 tons, and 59,817,587 tons, while from cultivation, each amounted to 10,766,732 tons, 12,823,114 tons and 14,213,949 tons (KKP, 2022). According to PERMEN (2022), catching mud crabs for consumption may only be done when the carapace size is above 12 cm/pcs, and for cultivation purposes, it can be done with a minimum crab weight of 30 g/pcs.

Mud crabs live in the mangrove ecosystem not only as a habitat but also as a place for growing (nursery ground), spawning (spawning ground), and looking for food (Feeding ground) (Keenan, 1999; Tahmid, 2016). In Muara Gembong Bekasi, West Java, mud crabs are caught using folding traps (folding traps) with trash fish bait, and the folding traps are placed in the habitat of mud crabs, and this is by Naimullah *et al*. (2022). Wild-caught crabs are purchased by collectors to be stored before being transported (Parapat & Abdurrachman, 2019; Cheng *et al*., 2020). At the shelter, mud crabs are usually stored for up to one week to wait for buyers. During storage, the legs and claws of mud crabs are tied, and without feeding, this causes stress and death in crabs, according to Su *et al*. (2022).

The condition of the mud crabs is worsening because the transportation from the mud crab storage center to the cultivation center is quite far away. Transportation uses a dry system and baskets, and mud crabs' legs and claws are tied (Yasin, 2018). In dry live transportation, crabs will spend hours in the air, causing gill drying or changes in gill physiology, which can cause death and reduce transportation performance (Dong *et al*., 2019). Crab gills that experience drought have damaged lamellae (Sari *et al*., 2014), which is characterized by lysis of the gill cuticle (Zong-Ying *et al*., 2018), thus inhibiting the respiration process (Helfiani *et al*., 2023). In addition, exposure to air causes crab stress, which impacts glucose concentration (Santos & Keller, 1993).

Glucose is the leading energy provider in crustaceans, so increased glucose concentrations indicate increased stress (Principe *et al*., 2019). Upon arrival at the cultivation location, the crabs are individually kept in an apartment system in each box arranged in tiers. The cultivated crabs come from natural catches and reservoirs (Gao *et al*., 2023). The crab apartment system is urban aquaculture, intensive cultivation in metropolitan areas with limited land and water resources (Benjamin *et al*., 2022; Haryanti *et al*., 2023). The apartment system is equipped with a recirculating aquaculture system (RAS) that can minimize water consumption (90-99% of water can be recycled) and control water quality using filters (Aich *et al*., 2020; Zhou *et al*., 2020; Kamali *et al*., 2022; Widiasa *et al*., 2023). Field observations: The selling price of mud crabs from fishermen to collectors is around IDR 15,000-20,000/kg (40-70g/pcs), from collectors to cultivators or markets around IDR 40,000/kg (40-70g/pcs).

The selling price of hard-shelled crabs on the market with a size of 125g/pcs is IDR 78,000/kg, and a size of 350g/pcs is IDR 185,000/kg. Mud crabs in their habitat are susceptible to stress due to poor environmental conditions that cause physiological stress for crabs (Pati *et al*., 2023). Physiological stress experienced by mud crabs, starting from the location of capture, storage, and transportation, can affect cultivation performance. Currently, comprehensive information regarding the impact of the duration of storage on the physiological condition and production performance of mud crabs has yet to be available. Therefore, further research is needed to analyze the impact of the duration of pre-transportation storage (one, three, and five days) on the physiological condition and production performance of mud crabs cultivated in the apartment system.

MATERIALS AND METHODS

Time and place of research

The research was conducted in February–April 2023 and consisted of several stages, from catching the shelter and dry transportation to rearing in the apartment system cultivation unit. The initial stock shelter for mud crabs was around Muara Gembong District, Bekasi Regency, West Java. Transportation was carried out from the shelter location to the cultivation location at the IPB fisheries and marine observation station (IFMOS) Ancol, North Jakarta, DKI Jakarta, with a total distance of 57 km, which took three hours using a four-wheeled vehicle. Post-transportation evaluation of mud crabs and water physicochemical measurements were carried out at the station. Gill physiology was analyzed at the Fish Health Laboratory and hemolymph glucose at the Fish Nutrition Laboratory. Both laboratories are in the Department of Aquaculture, Faculty of Fisheries and Marine Sciences, IPB University.

Experimental design

This study used a Completely Randomized Design (CRD) consisting of three treatments and four replications. The treatment in the study was the time required to store mud crabs after catching them, namely one, three, and five days. The mud crabs were captured at night, and the catch was stored in a separate basket for each treatment and replication.

Catching and storing mud crabs

Fishermen caught mud crabs using folding traps equipped with trash fish and then placed them at the fishing location in the Muara Gembong area. The caught crabs were immediately tied by the legs and claws to be sold to collectors and taken to the collection location. Mud crabs with a weight range of 43.86–97.99 and an average weight of 73.60 ± 12.53 g were collected in plastic baskets (48 × 35.5 × 16.5 cm3), as many as 10 in each basket with a total of 40 in each treatment. The crabs were not fed during the collection and were only sprinkled with sufficient water daily.

Mud crab transportation

After the holding period (one, three, and five days), the crabs were transported to the cultivation location (IFMOS Ancol) with a dry transportation system and using the same basket as during the holding. The crabs were not stacked in one basket. Transportation used four-wheeled vehicles because the distance was quite far. Namely, 57 km (three hours), the crabs were exposed to air during the trip. The temperature was measured during the trip using a max-min thermometer attached to the basket. The resulting transportation temperature was 30-36°C.

Acclimatization and spreading in apartment systems

Upon arrival at the cultivation location, the crabs were first sprinkled with water from the acclimatization container for 5-10 minutes before being put into a fiber tub for acclimatization to allow the crabs to adapt to the new environment. Post-transportation mud crabs were acclimatized in a tub filled with brackish water with a salinity of 10-15 ppt to adjust the salinity of the seed source with a water height of about 10 cm and aerated. Acclimatization was carried out by splashing the crabs before being put into the tub for about 30 minutes, then put into the tub for 1 hour by gradually increasing the salinity for 15 minutes until it reached 25 ppt as done by Hastuti *et al*. (2015).

Crabs were randomly spread in three fiber tanks without being removed from the transport basket. The diameter of the fiber tank was 1.5 m, and the height was 1 m; equipped with aeration, and each fiber tank contained 10 cm of seawater. After one hour, the crabs were weighed, and the ropes tied to the legs and claws were opened, then put into the apartment box to be maintained for two weeks by feeding trash fish in the form of yellow scads and satiation with a frequency of once a day, at five in the afternoon. During rearing, mud crabs were fed trash fish, namely yellow scads, with a frequency of once a day at five in the afternoon and an average feed of 10.49 g. The mud crab apartment system has a recirculating aquaculture system (RAS). The crab apartment box measuring 20×33×18 cm^3 is dark blue, made of polypropylene, and has a 220 mL/minute water discharge. The filters used in RAS are physical in the form of dacron (Dhewantara *et al*., 2021), bio-foam (Sari *et a*l., 2022), and sand filters (Prasetiawan *et al*., 2022), chemical filters in the form of ginger coral (Scabra *et al*., 2021) and ultraviolet (UV) (Samara *et al*., 2022), and biological filters in the form of bio balls (Amin *et al*., 2022).

Physical-chemical measurement of water

Water quality measurements were conducted daily, with a frequency of once a day, as long as the mud crabs were in the apartment system. The water quality measured was temperature, pH, dissolved oxygen (DO), salinity, and total ammonia nitrogen (TAN) (Table 1).

Sampling of hemolymph and gills of mud crabs

Hemolymph sampling was used to analyze the stress level of mud crabs through hemolymph glucose. Hemolymph samples of mud crabs were taken five times during the study, namely after capture in the shelter, with one crab in each treatment representing all repetitions in the treatment. Hemolymph after transportation was taken one hour after acclimatization and in the apartment system for five days once; four crabs were taken in each treatment, representing each repetition in the treatment. Gill samples of mud crabs were taken twice during the study, namely after capture in the shelter and at the end of rearing in the apartment system on the 14th day, with one crab in each treatment representing all repetitions in the treatment. Gill samples were taken on the 14th day to determine the physiology of the gills, which were improving or worsening during transportation until rearing in the apartment system.

The mud crab hemolymph sample was taken from the fourth moving leg. The hemolymph was carefully taken using a syringe (Qyli *et al.*, 2020). A 1 mL hemolymph sample was taken from each crab and put into a tube that had been labeled with a marker, then put into the freezer for further analysis at the end of the study at the Fish Nutrition Laboratory, Department of Aquaculture, FPIK, IPB. The mud crab gill sample was taken by first dissecting the mud crab; then the gills were put into Davidson's solution; after 24 hours, Davidson's solution was replaced with 70% alcohol solution so that the gill sample could last a long time and would be analyzed at the Fish Health Laboratory, Department of Aquaculture, FPIK, IPB.

Parameters

Stress response

The stress response of mud crabs was determined by observing the physiology of the gills and hemolymph glucose. The gills of crabs that experience stress due to poor environmental conditions have gill lamellae that experience epithelial damage, so the gills will be examined histologically to distinguish physiological changes in the gills of crabs that are not stressed and when stressed (Sari *et al.*, 2014). The histology procedure for crustacean gills refers to Lastriliah (2022). Hemolymph glucose examination was carried out by preparing a mixture of acetic acid and ortho-toluidine with a ratio of 94:6; the following procedure refers to Harianto (2014), and hemolymph glucose measurement refers to Hadiroseyani *et al.* (2016). The results of hemolymph glucose were converted into glucose levels in mg/100 ml Harianto (2014).

Production performance

The calculated mud crab production performance includes survival rate (SVR), weight change, and feed conversion ratio (FCR):

The survival rate was calculated based on (Huisman & Richter, 1987).

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

Note:
Nt = Number of live crabs at the end (pcs)
No = Number of live crabs at the beginning (pcs)

Weight changes are obtained from the average weight at the end of rearing (Effendi, 2016). The final weight of mud crabs is obtained from the average weight of crabs (g) at the end of the post-transportation evaluation in the apartment system. The final weight of mud crabs will determine the amount and price of crabs, which are usually expressed in 1 kg.

Feed conversion ratio (FCR) is a measure that states the amount of feed needed to produce 1 kg of meat (Saputra *et al.*, 2020). The calculation of FCR refers to (Goddard, 1996):

$$RKP = \frac{F}{Wt - W0}$$

Note:
F = Amount of feed consumption (g)
Wt = Biomass at the end of rearing (g)
Wo = Initial rearing biomass (g)

Physics-chemistry of water

The water physics and chemistry measured were temperature, pH, DO, salinity and TAN. The measured parameter values are presented in Table 1, and their suitability is by FAO (2011).

Data analysis

Production performance data were processed and analyzed using Microsoft Excel 2019 and SPSS version 26.0 for analysis of variance (ANOVA) with a 95% confidence interval. Treatments that showed significant differences ($P < 0.05$) were further analyzed using Duncan's advanced test. The results of hemolymph glucose data, gill physiology, water physics and chemistry were described descriptively.

RESULTS AND DISCUSSION

Results

Stress response

Gill physiology

The gills of mud crabs before and after treatment showed no healthy gills. The gills of mud crabs that had just been caught from the wild showed cuticles that had begun to wavy (Figure 1). The gills of mud crabs after being given treatment for the length of time of detention and having been transported and maintained for 14 days in the apartment system showed the most severe gill damage, namely on the fifth day of detention, which was indicated by rupture (lysis) of the gill cuticle (Figure 2C).

Hemolymph Glucose

The hemolymph response of mud crabs during the study ranged from 33.13 mg/dL–56.44 mg/dL. The hemolymph glucose value in the 5-day holding treatment at the beginning of the capture (H0) was 52.76 ± 0.00 mg/dL and continued to decrease until the end of the study in the apartment system (H14), which was 33.33 ± 0.92 mg/dL. The glucose response in the three-day

Table 1. Physicochemical characteristics of mud crab (*Scylla serrata*) culture water in an apartment system for 14 days to evaluate the survival of mud crabs after storage and transportation.

Water Physics-Chemistry	Measurement Results	Value Range (FAO 2011)	Measuring Instrument
Temperature (°C)	27,7 - 29	25-35	Thermometer
pH	7,3 - 8,3	7-9	pH meter
DO (mg/L)	4,7 - 7,7	>5	DO meter
Salinity (g/L)	21 - 26	10-30	Refractometer
TAN (mg/L)	0,16 -0,52	>3	Spectrophotometer

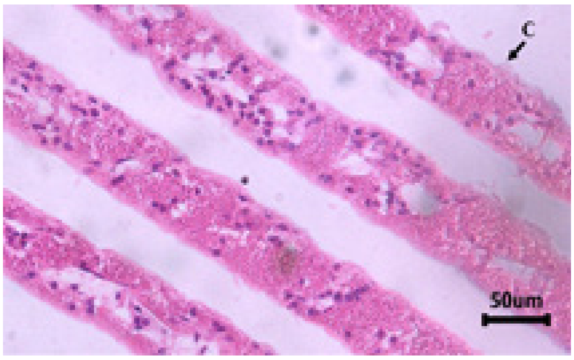

Figure 1. Histology of mud crab (Scylla serrata) gills on day 1 after capture, before being given the treatment of length of detention, (c) cuticle.

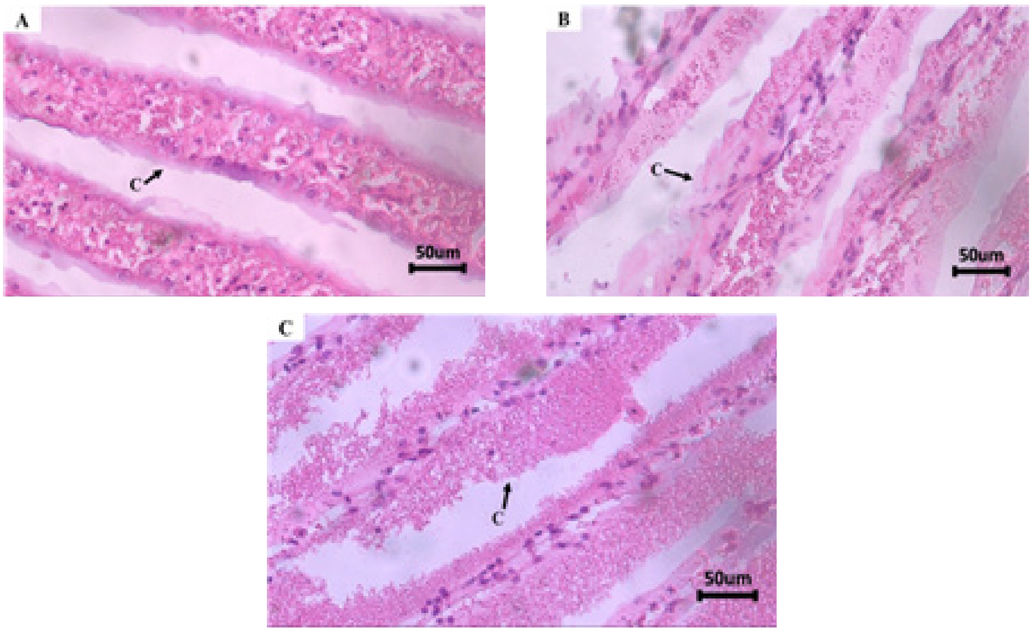

Figure 2. Histology of mud crab (*Scylla serrata*) gills on the 14th day after transportation with different storage period treatments: (A) 1 day storage period before transportation, (B) 3 days storage period before transportation, (C) 5 days storage period before transportation, (c) cuticle.

holding treatment and the 1-day holding treatment continued to fluctuate from the beginning of the capture (H0) until the end of the study in the apartment system (H14) (Figure 4).

Production Performance

The percentage of daily mortality of mud crabs during the holding period (one, three, and five days) in Muara Gembong is presented in Table 2. The holding of mud crabs at the beginning of the capture (H0) did not experience mortality in all treatments. Mortality began to occur on the first day after capture. The highest total mortality until the end of the holding was in the five-day holding treatment of 50%.

The percentage of daily mortality of mud crabs during 14 days of rearing in the apartment system after being given different treatments of

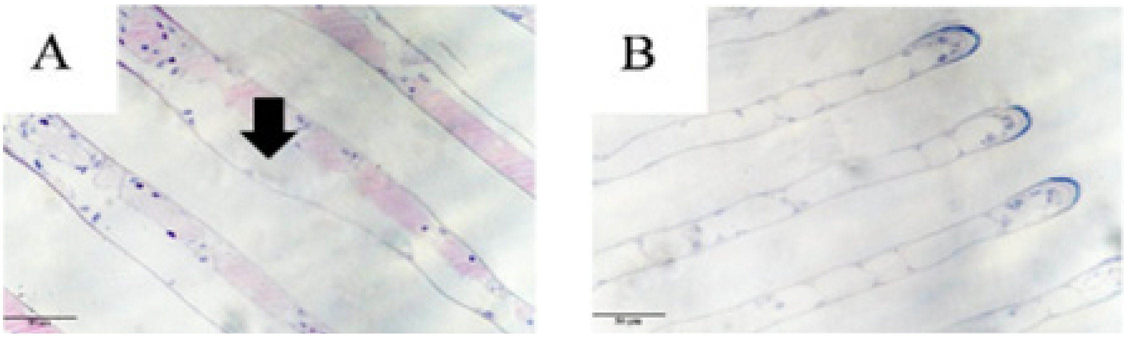

Figure 3. Histology of the gills of the mud crab *Scylla paramamosain* (A) Cuticle disorders in the gills of the mud crab, (B) Normal cuticle in the gills of the mud crab (Zhang *et al*., 2023).

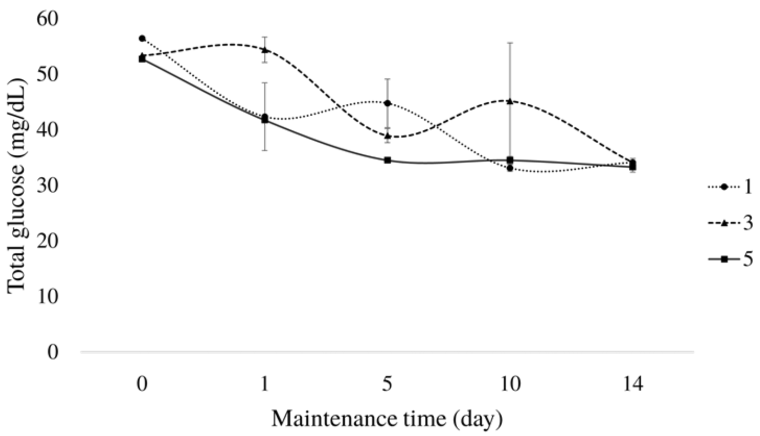

Figure 4. Hemolymph glucose of mud crabs (*Scylla serrata*) after capture, acclimatization, and rearing in apartment boxes with various storage time treatments (one, three, and five days).

Table 2. Percentage of daily mortality of mud crabs (*Scylla serrata*) during the detention period in Muara Gembong District, Bekasi Regency, West Java.

Storage period after capture (days)	Percentage of mortality (%) on day-					
	0*	1	2	3	4	5
1	0	12,5				
3	0	22,5	12,5	0		
5	0	20	15	0	15	0

Note: *Initial capture of mud crabs (H0) in the Muara Gembong District, Bekasi Regency, West Java habitat.

the length of detention in Muara Gembong is presented in Table 3. On the first day of crabs in the apartment system, crabs in all treatments did not experience death. The death of mud crabs began to occur on the second to the fifth day, while there were no more crab deaths on the sixth to the 14th. The highest total death was on the five days of detention at 17.5%.

The results of production performance during the storage and cultivation period of mud crabs in the apartment system are listed in Table 4. During the storage period, the results showed that different storage periods of mud crabs had a significant effect on the survival of mud crabs, with the highest value of 87.50 ± 9.57% in the one-day storage period and the lowest in the five-day treatment of 50.00 ± 0.00%. Changes in mud crabs during the storage period were not significantly different between one day and three days but were significantly different from the five-day storage period.

The different durations of mud crab storage during the storage period in Muara Gembong affected the production performance during 14 days of rearing in the apartment system. The results showed that the survival rate of mud crabs for one day and five days was significantly different, but both were not significantly different from three-day storage; the highest survival rate was 95 ± 5.77% for one-day storage, and the lowest for five-day storage, which was 82.50 ± 5.00%. The weight changes of mud crabs for one day and three days were not significantly different but were significantly different for five-day storage. The feed conversion ratio significantly differed between treatments, with the lowest value at one day of storage of 15.85 ± 0.65.

Discussion

Gills are one of the most essential organs in an organism because they are the primary site of ion transport and water movement (Malik & Kim, 2021). In addition, gills are involved in the innate immunity of crustaceans because they are directly exposed to the external aquatic environment and affect the survival of mud crabs (Bao *et al*., 2019; Song *et al*., 2021). Crabs obtain dissolved oxygen by breathing air directly or using residual moisture in the carapace (Lardies *et al*., 2011). The water in the carapace will evaporate over time so that the crab does not get enough oxygen, which causes severe stress (Schvezov *et al*., 2019). The results of the study showed that the gills of mud crabs had begun to experience damage at the beginning of capture, and the damage became worse after the crabs were stored for a long time and were exposed to direct air during transportation to the cultivation location (Figures 1 and 2).

Weiner *et al*. (2021) stated that in healthy crab gills, the gill lamellae are covered by cuticles and separated by hemolymph spaces or heme channels, while in sick crab gills, there are visible

Table 3. Percentage of daily mortality of mud crabs (*Scylla serrata*) during 14 days of rearing in the RAS apartment system at the treatment of length of detention (one, three, and five days).

Duration of pre-transportation shelter (days)	Percentage of deaths (%) on the day													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	0	2.5	0	2.5	0	0	0	0	0	0	0	0	0	0
3	0	2.5	2.5	0	5	0	0	0	0	0	0	0	0	0
5	0	2.5	7.5	7.5	0	0	0	0	0	0	0	0	0	0

Table 4. Survival rate, weight change, and feed conversion ratio of mud crab (*Scylla serrata*) during the holding period and 14 days of maintenance.

Activity (location)	Test parameter	Duration of Containment (days)		
		1	3	5
Containment (Muara Gembong)	Survival rate (%)	87.50 ± 9.57[c]	65.00 ± 5.77[b]	50.00 ± 0.00[a]
	Weight change (g)	-0.43 ± 0.33[b]	-1.47 ± 0.45[b]	-3.07 ± 1.05[a]
Rearing (IFMOS, Ancol)	Survival rate (%)	95.00 ± 5.77[b]	90.00 ± 8.16[ab]	82.50 ± 5.00[a]
	Weight change (g)	7.18 ± 0.77[b]	6.21 ± 0.55[b]	4.26 ± 0.83[a]
	Feed conversion ratio	15.85 ± 0.65[a]	18.68 ± 0.99[b]	27.58 ± 0.62[c]

Note: [1]Values shown are the mean and standard deviation, different letters in the same row indicate significant differences (P<0.05).

cuticle disorders (Figure 3A). Kim and Kwak (2022) explained that healthy crab gills have a straight cuticle structure (Figure 3B). Zong-Ying *et al*. (2018) said that the gill cuticles in unhealthy crabs are wavy or broken (Figures 1, 2, 3A). In addition to causing gill damage, exposure to air during long-term transportation and poor environments also causes crab stress (Dong *et al*., 2019; Lorenzo *et al*., 2020).

Hemolymph glucose is the leading energy provider for cell metabolism, especially brain cells. Brain activity will be optimal when the energy supply from glucose is continuously available. Glucose in target cells is related to insulin performance and is greatly influenced by the hormone cortisol (Hastuti *et al*., 2016). Dhewantara *et al*. (2021) explained that under stress conditions, the hormone cortisol inhibits insulin performance so that the glucose content in the blood increases because glucose cannot enter the cells. The high hemolymph glucose value is caused by stress and the crab's activity when maintaining body stability, which requires a lot of energy. The hemolymph glucose value of mud crabs describes the response and level of stress; namely, the higher the hemolymph glucose value, the higher the crab's stress level, and vice versa, the lower the hemolymph glucose value, the crab's stress level also decreases (Hastuti *et al*., 2019).

The highest mortality during the holding period was on the first day after capture in all treatments, and the highest total mortality during the holding period was on the five-day treatment of 50% (Table 2). Crab mortality during the holding period occurred because the crabs were stressed due to capture and handling (Tavares *et al*., 2022). The results of the study stated that mud crabs that were held for a long time produced poor-quality crab seeds, which impacted the performance of mud crab cultivation. This was proven by the fact that during the crab cultivation in the apartment system, daily crab mortality continued from day 2 to day 5 (Table 3), with the highest total mortality being during the five-day holding period of 17.5%. On the 6th to 14th day, the crabs did not experience any deaths because the crabs had adapted to the environment. The high survival rate explains that the commodity can adapt well to its environment (Oktari *et al*., 2022).

The crabs caught by fishermen that have been tied, then stored or collected without water media for more than three days will worsen the quality of the crabs and cause death in mud crabs (WWF, 2023). The decrease in the weight of mud crabs during the storage period is caused by the crabs being tied during storage so that they cannot find food, and dehydration occurs in mud crabs due to storage without water (WWF, 2023). After the storage period, the crabs experienced an increase in weight until the end of the evaluation in the apartment system. RKP is obtained to determine the level of nutritional performance consumed by a commodity (Chaikaew *et al*., 2019). Pasi *et al*. (2022) explained that a low RKP value indicates that the feed consumed is utilized efficiently for growth.

CONCLUSION

The one-day pre-transportation holding period provides better physiological conditions and production performance of mud crab cultivation in the apartment system.

REFERENCES

Aich N, Nama S, Biswal A, Paul T. 2020. A review on recirculating aquaculture systems challenges and opportunities for sustainable aquaculture. Innovative Farming 5: 17–24.

Amin AA, Pramudia Z, Yanuar AT, Susanti YAD, Okuda H, Kurniawan A. 2022. Analisis *Environment-DNA* (E-DNA) untuk estimasi jumlah total bakteri pada air kolam dengan sistem *Recirculating Aquaculture System* (RAS). REKAYASA 15: 368–374. (In Indonesian).

Aswar A, Limi MA, Slamet A. 2023. Preferensi konsumen terhadap pemilihan kepiting bakau (*Scylla* sp.) di kawasan pesisir Teluk Kendari. Journal of Social Science Research 3: 9737–9743. (In Indonesian).

Bao J, Xing Y, Jiang H, Li X. 2019. Identification of immune-related genes in gills of Chinese mitten crabs (*Eriocheir sinensis*) during adaptation to air exposure stress. Fish and Shellfish Immunology 84: 885–893.

Bejamin EO, Ola O, Buchenrieder GR. 2022. Feasibility study of a small-scale recirculating aquaculture system for sustainable (Peri-) urban farming in Sub-Saharan Africa: A Nigerian perspective. Land 11: 1–19.

Chaikaew P, Rugkarn N, Pongpipatwattana V, Kanokkantapong V. 2019. Enhancing ecological-economic efficiency of intensive shrimp farm through in-out nutrient budget and feed convertion ratio. Sustainable Environment Research 29: 1–11.

Cheng CH, Ma HL, Deng YQ, Feng J, Chen XL, Guo ZX. 2020. Transcriptome analysis and histopathology of the mud crab (*Scylla paramamosain*) after air exposure. Comparative Biochemistry and Physiology Part C: Toxicology & Pharmacology 228: 108652.

Dhewantara YL, Rahmatia F, Usman RS. 2021. The effectiveness growth of males and females crabs (*Scylla Serrata*) in recirculation system. Journal of Aquaculture Science 6: 24–37.

Dong Z, Mao S, Chen Y, Ge H, Li X, Wu X, Liu D, Zhang K, Bai C, Zhang Q. 2019. Effect of air-exposure stress on the survival rate and physiology of the swimming crab *Portunus trituberculatus.* Aquacultue 500: 429–234.

Effendi I. 2016. Budidaya intensif udang vaname *Litopenaeus vannamei* di laut: Kajian lokasi, fisiologi dan biokimia [Dissertation]. Bogor (ID): Institut Pertanian Bogor.

[FAO]. 2011. Mud Crab Aquaculture: A Practial Manual. Rome, Italy: FAO.

Gao W, Yuan Y, Huang Z, Chen Y, Cui W, Zhang Y, Saqib HSA, Ye S, Li S, Zheng H, Zhang Y, Ikhwanuddin M, Ma H. 2023. Evaluation of the feasibility of harvest optimisation of soft-shell mud crab (*Scylla paramamosain*) from the perspective of nutritional values. Foods 12: 1–16.

Goddard S. 1996. Feed Management in Intensive Aquaculture. New York. Amerika Serikat: Chapman and Hall.

Hadiroseyani Y, Sukenda S, Surawidjaja EH, Utomo NBP, Ridwan Affandi. 2016. Survival rate of transported ricefield eels, *Monopterus albus* (Synbranchidae), in open and closed system at water salinity level of 0 and 9 g L^{-1}. AACL Bioflux 9: 759–767.

Harianto E. 2014. Kinerja produksi ikan sidat (*Anguilla marmorata*) ukuran 7 g dengan kepadatan tinggi pada system resirkulasi melalui kajian fisiologis [Thesis]. Bogor (ID): Institut Pertanian Bogor.

Haryanti, Iskandar, Rizal A, Aliah RS, Sachoemar SI. 2023. Urban farming aquacultue as an alternative business for food anf economic security during the COVID-19 pandemic-Case study in the sub-urban area of Jakarta, Indonesia. Polish Journal of Environmental Studies 32: 4023–4036.

Hastuti YP, Affandi R, Millaty R, Nurussalam, Tridesianti S. 2019. The best temperature assessment to enhance growth and survival of mud crab *scylla serrata* in resirculating system. Jurnal Ilmu dan Teknologi Tropis 11: 311–322.

Hastuti YP, Affandi R, Safrina MD, Faturrohman K, Nurussalam W. 2015. Optimum salinity for growth of mangrove crab *Scylla serrata* seed in recirculation systems. Jurnal Akuakultur Indonesia 14: 50–57.

Hastuti YP, Nadeak H, Affandi R, Faturrohman K. 2016. Optimum pH determination for mangrove crab *Scylla serrata* growth in controlled container. Jurnal Akuakultur Indonesia 15: 171–179.

Helfiani, Saputra F, Rousdy DW. 2023. Prevalence and intensity of ectoparasites on mud crab (*Scylla serrata*) in Teluk Pakedai District, Kubu Raya Regency. Jurnal Biologi Tropis 23: 530–540.

Huisman EA, Richter CJJ. 1987. Reproduction, growth, health control and aquacultural potential of the African catfish, *Clarias gariepinus* (Burchell 1822). Aquaculture 63: 1–14.

Indarjo A, Salim G, Zein M, Septian D, Bija S. 2020. The population and mortality characteristic of mangrove crab (*Scylla serrata*) in the mangrove ecosystem of Tarakan City, Indonesia. Biodiversitas Journal of Biological Diversity 21: 3856–3866.

Islam T, Saha D, Bhowmik S, Nordin N, Islam S, Ujjaman Nur AA, Begum M. 2022. Nutritional properties of wild and fattening mud crab (*Scylla serrata*) in the south-eastern district of Bangladesh. Heliyon 8: e09696.

Kamali S, Ward VCA, Ricardez-Sandoval L. 2022. Dynamic modeling of recirculating aquaculture systems: Effect of management strategies and water quality parameters on fish performance. Aquacultural Engineering 99: 102294.

Keenan CP. 1999. Aquaculture of the mud crab, genus *Scylla,* past, present, and future. ACIAR Proceedings No.78. In: Keenan, C.P., Blackshaw, A. (Eds.), mud crab aquaculture and biology, *Proceedings of an International Scientific Forum,* Darwin, Australia, 21–24 April 1997. Australian Centre for International Agricultural Research, Canberra, Australia. 9–13.

Kim W, Kwak I. 2022. EDCs trigger immune-neurotransmitter related gene expression, and cause histological damage in sensitive mud crab *Macrophthalmus japonicus* gills and hepatopancreas. Fish and Shellfish Immunology 122: 484–494.

[KKP] Kementerian Kelautan dan Perikanan. 2022. Statistik Kelautan Perikanan. https://statistik.kkp.go.id/home.php?m=prodikan&i=2#panel-footer. [19 March 2023].

Lardies MA, Munoz JL, Paschke KA, Bozinovic F. 2011. Latitudinal variation in the aerial/aquatic ratio of oxygen consumption of a supratidal high rocky-shore crab. Marine Ecology 32: 42–51.

Lastriliah M. 2022. Keberadaan Penyakit Pada Pembesaran Lobster (*Panulirus* spp.) di Keramba Jaring Apung PT. Saibatin Perikanan Indonesia, Lampung [Thesis]. Bogor (ID): Institut Pertanian Bogor.

Lorenzo RA, Tapella F, Romero MC. 2020. Transportation methods for Southern king crab: From fishing to transient storage and long-haul packaging. Fisheries Research 223: 105441.

Malik A, Kim C. 2021. Role of transportome in the gills of chinese mitten crab in repsonse to salinity change: A mate-analysis of RNA-Seq datasets. Biology 10: 1–27.

Naimullah M, Lan KW, Ikhwanuddin M, Amin-Safwan A, Lee WY. 2022. Unbaited light-emitting diode traps performance for catching orange mud crabs. Journal of Marine Science and Technology (Taiwan) 30: 48–62.

Oktari LD, Swasta IBJ, Martini NND. 2022. Effect of different probiotics on survival and growth rate of tilapia seed (*Oreochromis niloticus*). Berkala Perikanan Terubuk 50: 1481–1487.

Parapat ER, Abdurrachman. 2019. Analisis pendapatan dan efisiensi pemasaran kepiting bakau di Kecamatan Seruway Kabupaten Aceh Tamiang. Jurnal Penelitian Agrisamudra 6: 54–60. (In Indonesian).

Pasi RY, Koniyo Y, Lamadi. 2022. Pemberian pakan yang berbeda pada budidaya kepiting bakau (*Scylla* sp.) dengan sistem crab ball di tambak. Jurnal Vokasi Sains san Teknologi 2: 7–12. (In Indonesian).

Pati SG, Paital B, Panda F, Jena S, Saho DK. 2023. Impacts of habitat quality on the physiology, ecology, and economical value of mud crab *Scylla* sp.: A Comprehensive Review. Water 15: 1–39.

[PERMEN] Peraturan Menteri Kelautan dan Perikanan Republik Indonesia. 2022. Perubahan atas peraturan menteri kelautan dan perikanan nomor 17 tahun 2021 tentang pengelolaan lobster (*Panulirus* spp.), kepiting (*Scylla* spp.), dan rajungan (*Portunus* spp.) di wilayah negara Republik Indonesia https://www.regulasip.id/book/19766/read#:~:text=DAN%20RAJUNGAN%20(Port-,PERATURAN%20MENTERI%20KELAUTAN%20DAN%20PERIKANAN%20REPUBLIK%20INDONESIA%20NOMOR%2016%20TAHUN,.)%2C%20DAN%20RAJUNGAN%20(Port&text=KP.&text=a.&text=b. [8 January 2024].

Prasetiawan NR, Kurniasih RA, Mulyadi U, Setiawan A, Ma'muri, Bramawano R, Widyanto SW, Kuncoro A, Wisnugroho, Yusharto T, Sudrajat R. 2022. Sistem penyangga kehidupan dan pemeliharaan ikan pada kolam sentuh akuarium publik. Jurnal Aquatik 5: 82–90. (In Indonesian).

Principe SC, Augusto A, Costa TM. 2019. Point-of-care testing for measuring haemolymph glucose in inveterbrates is not a valid metod. Conservation Physiology 7: 1–11.

Qyli M, Aliko V, Fagglo C. 2020. Physiological and biochemical responses of Mediterranean green crab, *Carcinus arstuarii,* to different environment stressors: Evaluation of hemocyte toxicity and its possible effects on immune response. Comparative Biochemistry and Physiology Part C: Toxicology & Pharmacology 231: 108739.

Samara RW, Iskandar, Liviawaty E, Grandiossa R. 2022. The effect of the different types plants on the recirculating aquaculture system (RAS) on the growth performnace of carp seed (*Cyprinus carpio*). Jurnal Perikanan dan Kelautan 12: 20–33.

Santos EA, Keller R. 1993. Crustacean hyperglycemic hormone (CHH) and the regulation of carbohydrate metabolism: Current perspectives. Comparative Biochemistry and Physiology Part A: Physiology 106: 405–411.

Saputra F, Thahir MA, Mahendra, Ibrahim Y, Nasution MA, Efianda TR. 2020. The effectiveness of different probiotic composition in aquaponic technology to optimize growth rate and conversion feed of snakehead fish (*Channa* sp.). Jurnal Perikanan Tropis. 7: 85–97.

Sari AHW, Risjani Y, Marhendra APW. 2014. Efek konsentrasi sublethal fenol terhadap *Total Haemocyte Count* (THC) dan histologi isang kepiting bakau (*Scylla serrata*). The Journal of Experimental Life Science 2: 82–88. (In Indonesian).

Sari WP, Zaidy AB, Haryadi J, Krettiawan H. 2022. Effectivity of filter types in recirculation system on the water quality and the growth of *Pangasionodon hyphophthalmus.* Jurnal Penyuluhan Perikanan dan Kelautan 16: 205–219.

Scabra AR, Marzuki M, Setyono BDH, Dininiarti N, Mulyani LF. 2021. Aplikasi teknologi mikrobubble pada petani ikan nila di Desa Bayan. Jurnal Pengabdia Perikanan Indonesia 1: 36–43. (In Indonesian).

Schvezov N, Lovrich GA, Tapella F, Gowland-Sainz M, Romero MC. 2019. Effect of the temperature of air exposure on the oxidative stress status of commercial male southern king crab *Lithodes santolla*. Fisheries Research 212: 188–195.

Soares DCDC, Andiewati S. 2022. Pemberian pakan jenis berbeda terhadap pertumbuhan dan kelulushidupan kepiting bakau (*Scylla serrara*). Jurnal Aquatik 5: 217–223. (In Indonesian).

Song Y, Wu M, Pang Y, Song X, Shi A, Shi X, Niu C, Cheng Y, Yang X. 2021. Effects of melatonin feed on the changes of hemolymph immune parameters, antioxidant capacity, and mitochondrial functions in Chinese mitten crab (*Eriocheir sinensis*) caused by acute hypoxia. Aquaculture 535: 736374.

Su M, Zhang Xiaojun, Yuan J, Zhang Xiaoxi, Li F. 2022. The role of nsulin-like Ppeptide in maintaining hemolymph glucose homeostasis in the Pacific white shrimp *Litopenaeus vannamei.* International Journal Molecular Sciences 23: 3268.

Tahmid M. 2016. Kajian Ekologi-Ekonomi Kepiting Bakau (*Scylla serrata* – Forsskal, 1775) di Ekosistem Mangrove Teluk Bintan Kabupaten Bintan [Thesis]. Bogor (ID): Institut Pertanian Bogor.

Tavares CPS, Zhou M, Vogt EL, Model JFA, Vinagre AS, Silva UAT, Ostrensky A, Schott EJ. 2022. High prevalence of CsRV2 in cultured *Callinectes* danae: Potential impacts on soft-shell crab production in Brazil. Journal of Invertebrate Pathology 190: 1–12.

Weiner AC, Roegner ME, Watson RD. 2021. Effect of a chemical dispersant (Corexit 9500A) on the structure and ion transport function of blue crab (*Callinectes sapidus*) gills. Comparative Biochemistry and Physiology, Part C Toxicology & Pharmacology 247: 109070.

Widiasa IN, Susanto H, Ting YP, Suantika G, Steven S, Khoiruddin K, Wenten IG. 2023. Membrane-based recirculating aquaculture system: Opportunities and challenges in shrimp farming. Aquaculture 579: 740224.

[WWF] World Wide Fund for Nature. 2023. BMP Kepiting Bakau Panduan Penangkapan dan Penanganan. https://www.wwf.id/upload/2023/09/2023_BMP_Kepiting_Bakau_Final.pdf. [12 September 2023].

Yasin H. 2018. Kepiting Bakau: Dinamika Molting. Yogyakarta, Indonesia: Plantaxia.

Zhang K, Zhang w, Li R, Lu J, Chen Q, Hu H, Yin F, Mu C, Song W, Wang C. 2023. Dynamic distribution of *Mesanophrys* sp. And tissue enxyme activities in experimentally infected mud crab *Scylla paramamosain.* Fishes 8: 1–12.

Zhou J, Li N, Wang H, Wang C, Mu C, Shi C, Liu L, Li R, Ye Y, Song W. 2020. Effects of salinity on growth, nutrient composition, fatty acid composition and energy metabolism of *Scylla paramamosain* during indoor overwintering. Aquaculture Research 51: 1834–1843.

Zong-Ying Y, Yi-Liu Z, Kum H, Li-Shuo L, Hong-Gui C, Feng-Xiang Z, Xiang-Le Y. 2018. Etiological and hsitopathological study on hepatopancreatic necrosis syndrome in *Eriocheir sinensis.* Acta Hydrobiologica Sinica 42: 17–25.