Utilization of Locally Available Feeds to Develop Sustainable Blue Swimming Crab (*Portunus pelagicus*) Farming in Central Java

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Abstract

The popularity of the blue swimming crab (Portunus pelagicus) has led to significant overfishing. Aquaculture offers a potential solution to reduce fishing pressure, given that P. pelagicus is relatively easy to hatch, has high fecundity, a short larval duration, and rapid growth. However, knowledge about feed preferences and feed-use efficiency in P. pelagicus is limited. This study compared the effectiveness of three locally available feeds. A total of 160 juvenile P. pelagicus were divided into five repetitions across four diet groups: PPV (shrimp pellets + Perna viridis flesh, crude protein = 45 %), PAI (shrimp pellets + Acetes indicus, crude protein = 45 %), P100 (shrimp pellets, crude protein = 30%), and P150 (shrimp pellets at 150% of the dry matter requirement, crude protein = 45%, iso-protein to both PPV & PAI). The experiment consisted of three phases: a one-week pre-trial to determine feeding rates, followed by a six-week culture period (Period-1) and an eight-week culture period (Period-2). Body weight and survival were measured biweekly, feed amounts were adjusted accordingly, and costs were recorded. Survival rates and feed conversion ratios were similar across all diets. Crab growth was lower in Period-2 than in Period-1 across treatments. The specific growth rates for PPV, PAI, and P150 were comparable, while P100 resulted in lower growth. The cost of PPV was higher than that of PAI, P100, and P150, with the economic feed conversion ratio for P100 and P150 outperforming PPV and PAI. Shrimp pellets proved to be an efficient feed for the grow-out phase of blue swimming crabs, though pellet size should be matched to the crab's size.

Keywords: *Indonesia, crab juveniles, culture, growth, survival*

Introduction

Crab is an underutilized fishery commodity in Indonesia, contributing minimally to the country's total fish and aquatic product exports (FAO, 2020). However, crabs possess specific nutritional qualities (Liu and Chen, 2020) and a favourable market price. This is particularly true for the blue swimming crab (*Portunus pelagicus*), which has been overexploited in several fishing grounds across Indonesia (Hamid *et al.*, 2016). A restocking program was only recently initiated in Central Java (Ariyati *et al.*, 2017). In Indonesia, brackish-water aquaculture is largely dominated by extensive shrimp and milkfish farming, which carries a high risk of financial loss. Diversifying aquaculture to include blue swimming crab farming could better utilize brackish water ponds and reduce financial risks for farmers.

Blue swimming crabs are known for their short larval duration (Romano and Zeng, 2006), high fecundity (Romano and Zeng, 2008), ease of hatching (Walker, 2006) and rapid growth (Josileen and Menon, 2005). As carnivorous scavengers, they primarily prey on sessile or slow-moving benthic invertebrates (Patel *et al.,* 1979), with molluscs being their main food source. They can also consume other locally available food sources depending on their natural diet (Williams, 1982). Several studies have investigated the diets of *P. pelagicus* at different life stages, from zoea larvae to the C1 stage (Ikhwanuddin *et al.,* 2012, Sudaryono *et al.,* 2015; Rabby *et al.,* 2024), for juveniles (Josileen and Menon, 2005), and during grow-out (Chaiyawat *et al.,* 2009). It has been found that a diet consisting of 50% trash fish (with 69.5% protein, 9.3% lipid, 5.9% carbohydrate, and 14.1% ash) and 50% shrimp feed (with 37% protein, 4% lipid, 4% fibre, and 12% moisture) is suitable for rearing crab broodstock, resulting in higher weight gain compared to feeding with trash fish or shrimp feed alone (Oniam *et al.,*

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2012). Other diets used for rearing *P. pelagicus* include Ridley® shrimp feed (Romano and Zeng, 2006) and a combination of frozen *Artemia nauplii* and formulated Ridley® crumble feed (Romano and Zeng, 2007). However, there is limited information on the nutritional requirements for culturing *P. pelagicus* from juvenile to marketable size, unlike other commonly cultured crab species where such data is readily available. Understanding the feed preferences and efficiency of *P. pelagicus* is crucial before making recommendations to farmers considering blue swimming crab farming as an alternative to shrimp. The availability of stable, storable, and affordable feeds is a major requirement for successful aquaculture.

This study tested three locally available feeds/ingredients for the grow-out of *P. pelagicus* across four different diets. These diets were evaluated based on three criteria: (i) cost and availability of ingredients/feedstuffs, (ii) protein and fat levels, (iii) feed conversion ratios, and (iv) Fish-in Fish-out ratio. The subsequent chapters detail our methods and results, which are discussed in the context of sustainability.

Materials and Methods

The effectiveness, efficiency, and sustainability of three locally available feedstuffs by measuring the Specific Growth Rate (SGR) were evaluated, Survival Rate (SR) of *P. pelagicus*, feed cost per gram of body weight gain, and the Fish-in/Fish-out (FIFO) ratio. Observations included feeding rate and behaviour, growth and mortality measurements, Feed Conversion Ratio (FCR) calculations, and diet cost analysis over a 15-week experiment with 5 repetitions. The experiment consisted of a one-week pre-trial period, a first period of six weeks (Period-1), and a second period of eight weeks (Period-2).

Diets

Three locally available feeds were used: shrimp pellets, flesh of *Perna viridis*, and whole *Acetes indicus*. Shrimp pellets, which contain high protein levels (30%), are widely used by pond farmers. *P. viridis* and *A. indicus* are easily collected in coastal zones and seasonally grow in ponds. These two are also part of the natural diet of *P. pelagicus* (Williams, 1982; Chande and Mgaya, 2004). The nutritional values of these diet ingredients were measured beforehand through proximate analysis of 100 gr of *P. viridis* flesh, whole *A. indicus*, and shrimp pellets (Table 1.).

The PPV and PAI treatments consisted of a combination of pellets and fresh feed at each feeding, while the P100 treatment contained 100% shrimp pellets (size: 1,5x1,5x3 mm), and the P150 treatment involved 1.5 times the quantity of P100 (Table 2.). The PPV, PAI, and P150 diets were balanced for crude protein (CP) content in dry matter (approximately 45% CP/DM), while P100 had about two-thirds of this CP level (Table 2.). P100 served as the control for the recommended feeding level, while P150 tested the usefulness of providing supplementary CP. The amount of ingredients (wet weight) per diet was calculated using Formula (1).

Research design

Twenty circular tarpaulin tanks (diameter 1.6 m) were filled with filtered brackish water (25 ppt) to a height of 0.5 m. The tanks were continuously aerated and protected using a shading/mosquito net. During rainy days, the tanks were covered with plastic to prevent a drop in salinity. Gracilaria was added to the tanks to provide shelter for the crabs. Attempts to add plastic separation walls within the tanks for additional shelter proved unsuccessful due to the material's unsuitability. The tanks were cleaned weekly, with about 10–20% of the water renewed after cleaning with filtered brackish water from the nearby mangrove area.

$$Amount\ WW\ ingredient = \frac{BW\ crab * Feeding\ rate * \%\ of\ ingredie\!\!:}{\%\ DM\ ingredient} \quad (1)$$

where 'Amount WW of ingredient' is the wet weight of the ingredient per diet (g.d^{-1}); BW is the body weight of crabs; 'feeding rate' is derived from a pre-trial experiment (see section 2.3); '% of ingredient in diet' is derived from CP balancing calculations in Excel (Table 2.); and '% DM ingredient' is the dry matter content of the ingredient.

The pre-experimental period used 160 juvenile *P. pelagicus* with weights and sizes below the commercial minimum standards. The juveniles, weighing 15.9±4.8 g and with carapace widths measuring 4.9±5.1 cm, were collected using commonly used traps and acclimatized in the tanks for two weeks approximately. After the adaptation period, the crabs were grouped into four size classes and distributed across 20 tanks, ensuring similar mean body weight and sex composition in all tanks. Consequently, each tank contained 7 crabs (4 females, 3 males) of different size classes with a total body weight of 15 to 17 g at the start of Period-1. For Period-2, crabs in the same treatments were randomized and stocked similarly at a lower density of 5 crabs (3 females and 2 males) per tank. The densities were based on previous experiments by a team that used a range of stocking densities (Ariyati *et al.,* 2017). This reduction in stocking density followed the findings of Oniam and Arkronrat (2013), which indicated that cannibalism increases due to size differences after 30–45 d of culture (DoC). Dead crabs (or their residues) were removed daily.

Pre-trial experiment

Before the experiment, the crabs were starved for one day. To estimate the optimal feed quantity, we monitored how many shrimps pellets the crabs would consume during a one-week pre-experimental period. At the start of the pre-experiment, the crabs were fed 4% dry matter (DM) of their body weight, divided over two daily feedings. The feed was distributed across approximately seven different locations in the tanks. The quantity was increased by 1 percentage point per day (*e.g.,* first to 5%) if the crabs consumed all the feed. If a substantial amount of feed remained, the quantity was decreased by 1 percentage point (*e.g.*, first to 3%). The optimal feeding rate was determined to be 5% DM of the total body weight per tank.

Main experiment

Circular plastic tarpaulin tanks were set up in a semi-outdoor hangar. To minimize the impact of environmental variability, the four treatments were randomly assigned to tanks through a randomized block design (Figure 1.).

Table 1. Nutritional composition of diet ingredients.

	Shrimp pellets	*Perna viridis*	*Acetes indicus*
Dry matter (%/DM)	88.0	17.8	16.5
Crude protein	30.0	51.8	68.3
Lipids	3.9	6.4	12.6
Carbohydrates	37.3	0.2	3.6
Ash	9.5	13.5	13.8
Total	80.7	71.9	98.3

Table 2. Nutritional profiles of the four balanced diets

	PPV	PAI	P100	P150
% Shrimp pellets	30	60	100	150
% *Perna viridis*	70	0	0	0
% *Acetes indicus*	0	40	0	0
Total crude protein level (%/DM)	45.3	45.3	30.0	45.0
Total lipid level (%/DM)	5.7	7.4	3.9	5.8

The daily diets of PVV and PAI derived from these calculations are: PPV: 30% Shrimp pellets + 70% flesh of *Perna viridis* (Asian green mussel); PAI: 60% Shrimp pellets + 40% *Acetes indicus* (Jawla paste shrimp).

Figure 1. The tanks for rearing blue swimming crab

The two rows of tanks located near the outside were assigned to a different block than the three rows with most tanks inside. From the start of the main experiment, crabs were fed 5% DM of their body weight, twice daily. Before weighing, fresh feeds were prepared by removing the flesh from the shells of *P. viridis* and cleaning *A. indicus* of other debris or species. Weekly portions were prepared and stored them in cold storage. The feeds were mixed daily with pellets according to the treatment protocols and immediately fed to the crabs. The feed was distributed across seven locations in the tanks to prevent competition. The quantity of feed was adjusted to the number of crabs daily and to the body weight once every two weeks. Any feed refusals were monitored daily.

The tanks were cleaned twice a week, with partial water replacements using filtered brackish water (salinity > 26 ppm) sourced from a nearby mangrove area. When water quality issues arose, part or all of the tank water was replaced. The water level was replenished every two days.

Temperature and dissolved oxygen (DO) levels were monitored twice a day using a YSI® Pro20 water quality checker. pH was checked once daily with a HANNA® HI98129 pH meter, and salinity was measured daily using an ATAGO® PAL-06S refractometer. Ammonia, nitrite, and phosphate levels were measured weekly by sending 350 ml water samples in insulated boxes to the Fisheries and Marine Science Laboratory at Diponegoro University.

Measurements and calculations

All crabs were individually weighed every two weeks using an A&D®HL-100 electronic scale with a precision of 0.01 g. The specific growth rate (SGR) was calculated using Formula (2).

$$SGR\ (\%\ per\ day) = \frac{ln(BWt) - ln(BWo)}{T}\ x\ 100 \quad (2)$$

where SGR is the specific growth rate (% body weight gain per day), BW_t is the final body weight (g), BW_o is the initial body weight (g), and T is the duration of the experiment (days) (Busacker *et al.,* 1990). SR was calculated for each tank during weighing using Formula (3).

$$SR\ (\%) = \frac{Nt}{No}\ x\ 100 \quad (3)$$

where SR is the survival rate (%), N_t is the number of crabs at sampling time t, and N_o is the initial number of crabs stocked (Busacker *et al.,* 1990). The feed conversion ratio (FCR) and economic feed conversion ratio (eFCR) were calculated per tank on a dry matter basis using Formula **Error! Reference source not found.** and Formula (4), respectively.

$$FCR = \frac{Feed\ dry\ matter\ consumption\ (g)}{Body\ weight\ gain\ (g)} \quad (4)$$

$$eFCR = \frac{Total\ feed\ given\ (g)}{Body\ weight\ gain\ (g)} \quad (5)$$

The feed costs per gram of gain per tank were calculated using Formula (6) by Gebhart (n.d) and the Fish-in/Fish-out ratio was calculated using Formula (7) by Jackson (2009).

$$Feed\ costs\ per\ gram\ of\ BW\ gain = FCR\ x\ costs\ per\ gram\ of\ feed\ (in\ wet\ w \quad (6)$$

$$FIFO = \frac{Level\ of\ fishmeal\ in\ the\ diet + Leve}{Yield\ of\ fishmeal\ from\ wild\ fish + Yiel} \quad (7)$$

Data analysis

Data were statistically analysed using SPSS version 26. First, normality was assessed using the Homogeneity of Variances test. If normality was confirmed, growth, SR, FCR, eFCR, and FIFO across the four treatments were analysed by Univariate Analysis of Variance, considering the two blocks. In cases of significant differences, post hoc comparisons were made using Duncan's multiple range test. Statistical significance was set at *P*< 0.05.

Table 3. Initial and final body weights (BW) and survival rates (SR) of male and female crabs

Sexe	Sample size	Initial BW (g)	Body weight (g)		Survival rate (%)	
			Period 1	Period 2	Period 1	Period 2
F	60	16.5±4.9[a]	55±17[a]	62±15[a]	65±34[a]	35±17[a]
M	40	15.3±4.8[a]	62±23[a]	64±14[a]	73±34[a]	19±15[a]
Mean	50	15.9±4.8	59±20	63±15	69±34	27±16

Includes means and standard deviations. Superscript letters indicate significant differences (P < 0.05).

Results and Discussion

No significant differences were found among the diets in terms of water quality parameters, including ammonia, nitrite, nitrate, phosphate, temperature, pH, salinity, and dissolved oxygen. However, salinity levels in all tanks gradually decreased during Period-2 due to the rainy season affecting the water source. During both periods, the shrimp pellets offered to the crabs had a crude protein (CP) level of 30%, with a size of 1.8 x 2.0 mm, the largest available from the selected brand. After approximately seven weeks, larger crabs struggled to grasp and ingest the pellets. Non-used pellets were removed but not weighed. Later in the experiment, crabs were observed consuming algae from the tank bottom. There were no significant differences in final weight and SR between male and female crabs (Table 3.). The high standard deviation observed in both sexes and parameters was attributed to the small sample size.

Growth

The mean initial weight at week 0 ranged from 15.6±1.8 g to 16.3±1.2 g. The mean final weights at week 14, from highest to lowest, were 70.1±7.5 g for P150, 68.4±14.8 g for PPV, 64.2±7.4 g for PAI, and 55.9±6.1 g for diet P100 (Figure 2.). Growth in the P100 group slowed significantly once crabs reached 55–60 g, compared to the other three treatments.

The mean SGR during Period-1 was 2.3±0.2%.d^{-1}, while in Period-2, it was nearly 0. The overall SGR was 1.3±0.1%.d^{-1}. The SGR difference between P100 and the other three diets was primarily observed during Period-2 when crabs in the P100 group barely gained weight (Figure 3.).

Diet significantly affected SGR during Period-1 but not during Period-2. No significant block effects or interactions between diet and block were observed. The Duncan test did not identify any diet as significantly superior.

The SGRs observed in this study (2.3%.d^{-1} for Period-1 and 1.3%.d^{-1} overall) were lower than those reported in previous studies, such as 3.9%.d^{-1} in earthen ponds (Oniam *et al*., 2010), 4.8% to 7.9%.d^{-1} on diets with different dietary organic acids (Sukor *et al*., 2016), and 4.2%.d^{-1} for juveniles fed pellets or fish processing waste (Ariyati *et al*., 2017). However, Tina and Darumas (2014) reported lower SGRs (0.2–1.3%.d^{-1}) when feeding juveniles with cheaper diets. The low SGR in our study may be due to the small pellet size used in Period-2, resulting in lower growth compared to Period-1 (Figure 2.).

Additionally, slower growth during Period-2 may be attributed to the crabs reaching sexual maturity (Josileen and Menon, 2005), as seen in mud crabs where SGR decreased from 0.03%.d-1 at a body weight of about 10 g to 0.01%.d^{-1}at a body weight of over 22 g (Marasigan, 1999). Reduced salinity could have also negatively impacted crab performance, similar to findings in previous studies where salinity significantly affected the growth and survival of juvenile blue swimming crabs (Romano and Zeng, 2006).

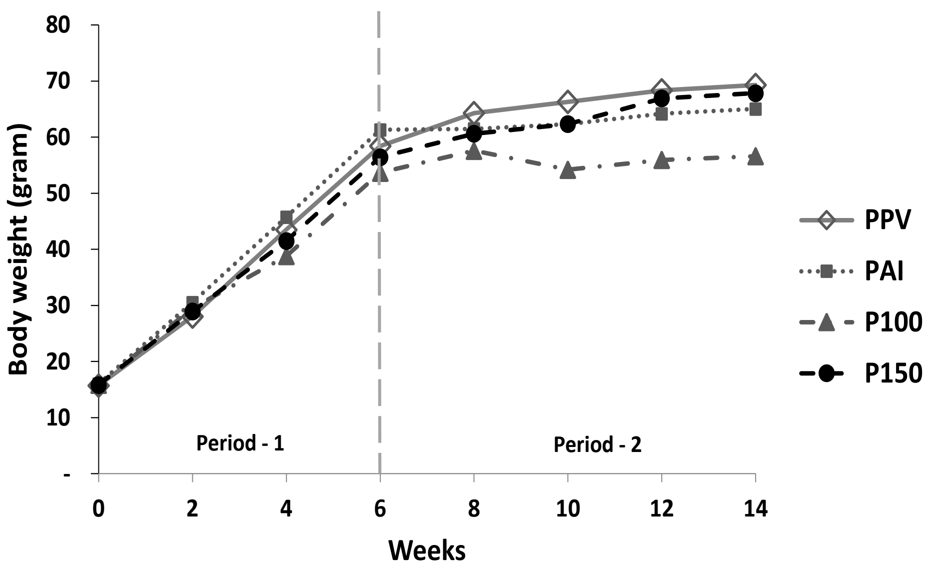

Figure 2. Mean body weight of crabs for each diet over a 14-week period.

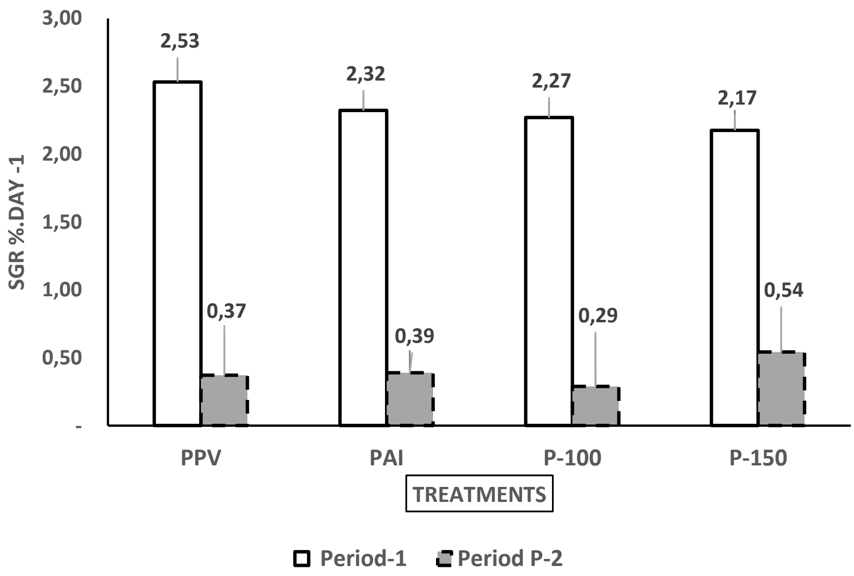

Figure 3. Specific growth rate of crabs by diet and period.

The differences in SGR between diets may be due to variations in feed type, protein and lipid levels, and feeding quantities. Blue swimming crabs are known to consume a wide variety of organisms (Sumpton and Williams, 2002; Chande and Mgaya, 2004) which may influence their ability to utilize different nutrient sources. *P. pelagicus* is flexible with its diet, with local food availability being a major factor influencing its diet rather than size-related dietary changes (Williams, 1982).

The influence of feed type aligns with findings by Chaiyawat *et al.* (2009), who reported that male blue swimming crabs fed live blue mussels (62% CP) grew faster than those fed chopped fish (69% CP), moist pellets (46% CP), or red seaweed (9% CP). Similarly, Alaminos and Domingues (2007) found that juvenile spider crabs (*Maja brachydactyla*) fed fresh mussels showed higher growth rates than those fed shrimp pellets. For Chinese hairy crab (*Eriocheir sinensis*) juveniles, Mu *et al*. (1998) reported an optimal dietary protein level of 39%, whereas Chen *et al.* (1994) found that protein levels of 47–54% resulted in the best growth. The diets in this study (PVP, PAI, and P150) were balanced at 45% CP, close to the optimal range, while diet P100, with 30% CP, may explain its lower performance during Period-2, despite similar SGR in Period-1.

Lipid levels in the diets ranged from 3.9% to 7.4% (dry matter basis), within the acceptable range for crabs. Crustaceans require significant lipid intake, especially before moulting (Dall *et al.,* 1990). However, lipid levels above 10% can lead to inefficient utilisation and reduced growth (Cuzon and Guillaume, 1997). the diets in this experiment remained well below this threshold. Nonetheless, during Period-2, the crabs selectively consumed *Acetes indicus*, which contained 12.6% lipid. The energy provided by P100 was sufficient for crabs weighing 50–60 g, but inadequate for larger crabs.

Further research is needed to determine the optimal protein-to-energy ratio, essential amino acid profile, and HUFA content for blue swimming crabs. Additionally, it is important to evaluate the effects of anti-nutritional factors, particularly when using plant-based materials, and to assess the inclusion of nutrients like calcium, especially before or after moulting. While incorporating these factors could potentially benefit crab growth, as suggested by Alaminos and Domingues (2007), it may increase the FIFO ratio and reduce the overall sustainability of aquaculture practices.

Survival rate

During Period-1 (7 crabs.m^{-2}), the SR was higher than in Period-2 (5 crabs.m^{-2}), where mortality nearly doubled (Figure 4.). In Period-2, one tank with diet P150 recorded no mortality, but the mean SR was close to 40%, significantly lower than the 77% average in Period-1. The main limitation of our study was the low number of crabs due to the limited tank size, leading to relatively high standard deviations in SR parameters. This may explain why few significant differences were found.

Diet significantly affected the SR of crabs during Period-1 but not during Period-2. For both periods, the block effect and the interaction between diet and block were not significant. The Duncan Test did not reveal any treatment as superior or inferior.

The mean SR (43%) was higher than that recorded for *P. pelagicus* reared in ponds (Oniam *et al.,* 2010) but lower than that for *P. pelagicus* individually reared in containers (Sukor *et al.,* 2016). Our results were comparable to those of red king crab (*Paralithodes camtschaticus*) juveniles (Daly *et al.,* 2009) and mud crab (Triño *et al.,* 1999). The SR may be optimised by using lower stocking densities, as shown by Ariyati *et al*. (2017) where the survival rate of blue swimming crablets stocked at 40 ind. m^{-2} was higher than those stocked at 60 and 80 ind. m^{-2}. Additionally, practical considerations like production costs can be reduced by determining the optimal stocking densities for each crab stage and implementing preventative measures to reduce mortality due to cannibalism, such as adding different types of substrates for hiding, other than.

Feed conversion ratio and cost

The feed cost and eFCR of the crab's diets differed significantly, though FCR_{DM} did not (Tabel 4.). For all three parameters in both periods, the block effect and the interaction between diet and block were not significant. The eFCRs of the mixed diets (PPV and PAI) were poor (8.6 $g.g^{-1}$) compared to those of the pellet diets (P100 and P150), but only P150 (5.7 $g.g^{-1}$) was significantly better than the first two (Table 4.). The FCRs of PPV and PAI were roughly identical, while that of diet P100 was worse, and that of P150 was intermediate.

The feed cost of PPV (55±10 IDR g^{-1}) was significantly higher than those of PAI (28±6 IDR g^{-1}), P100 (18±3 IDR g^{-1}) and P150 (27±10 IDR g^{-1}). Among these, the cost of P100 was about two-thirds of PAI and P150, but the standard deviations for P150 and, to a lesser extent, PAI were high.

The eFCR and feed costs were significantly different (P<0.05) between the diets (Table 6.), underscoring the importance of these costs (Figure 5.). Despite lower survival and higher cost, the eFCR of diet P150 was slightly better than that of diet P100, even when the P150 feeding level was ad libitum. The high FCR of diet PAI, which had a similar cost to P150, may be due to the low intake of frozen *Acetes indicus*, which might also have affected the eFCR. The lower

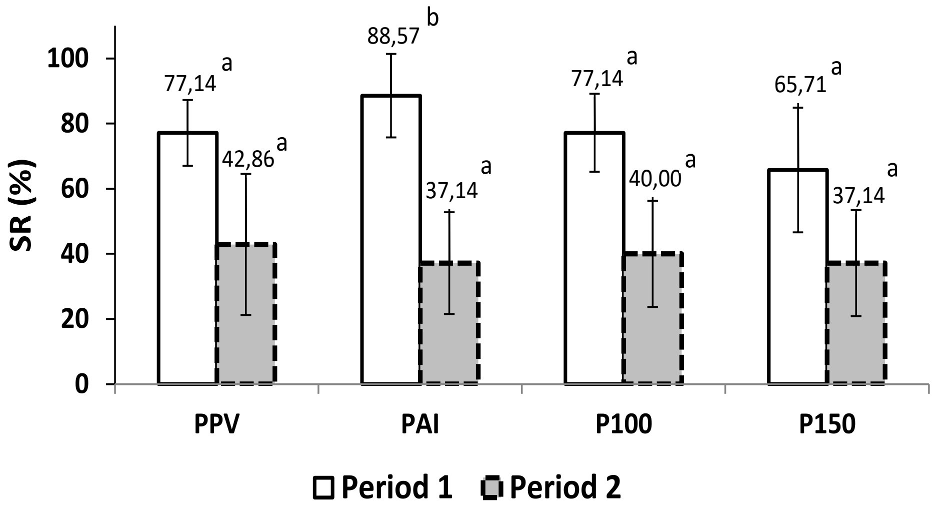

Figure 4. Mean survival rate (SR) of crabs for each diet across periods.

Table 4. Economic feed conversion ratio (eFCR), feed conversion ratio (FCR), and costs per gram of body weight gain for each diet.

Diet	FCR (g g^{-1})	eFCR (g g^{-1})	Cost (IDR g^{-1})
PPV	2.9±0.4^{a}	8.6±1.5^{b}	54±10^{b}
PAI	3.1±0.5^{a}	8.6±1.7^{b}	28±6^{a}
P100	3.7±0.3^{a}	6.6±0.6^{a}	18±3^{a}
P150	3.4±0.8^{a}	5.7±1.4^{a}	27±10^{a}
Mean	3.3±0.5	7.4±1.3	32±7

Includes means and standard deviations. Superscript letters indicate significant differences (P < 0.05).

eFCR (calculated using feed wet weight) of the diet containing *P. viridis* could be attributed to the low DM content of the green mussel (17.8%). Consequently, a larger amount was needed to achieve the same weight, which also explains the higher costs for the green mussel diet compared to the pure shrimp pellet diet. The time spent preparing the diets was not included in the cost; however, if accounted for, it would further increase the cost of diet PPV due to the time-consuming process of removing the shell from the green mussel flesh.

The FCR observed in this study (2.9±0.4 and 3.7±0.3 gDM g^{-1}) was within the ranges found in mud crabs fed formulated pelleted diets under laboratory and pond conditions by Catacutan (2002) and Triño *et al*. (2001): 3.2–4.2 and 2.1–3.0, respectively. However, the results were worse than the FCRs found for the Chinese mitten crab: 1.8–2.3 (Jiang *et al*., 2013), juvenile *Portunus trituberculatus*: 1.1–1.4 (Huo *et al.,* 2014), 1.5–2.9 (Unnikrishnan and Paulray, 2010), and 1.5–2.0 (Zhao *et al.,* 2015). The FCR range in this experiment was narrower than that found for *Chiromanthes bidnes* and *C. maipoensis*: 0.98 to 6.8 (Ravichandran *et al.,* 2006).

Fish-In/Fish-Out (FIFO)

Diet significantly affected the crab's FIFO. The block effect and the interaction between diet and block were not significant. The mean FIFO ratio ranged between 0.74±0.3 (P150) and 1.13±0.1 (PAI) (Figure 6.). The FIFO ratio of the mixed diets (PPV and PAI) was significantly higher than that of the pellet diets (P100 and P150). Although P150 used 1.5 times more shrimp pellets compared to P100, the FIFO ratio was almost the same, with no significant difference: 0.76±0.1 for P100 and 0.74±0.3 for P150.

The FIFO ratio of diets containing either *Perna viridis* or *Acetes indicus* was higher than that of diets containing only shrimp pellets. Fish processing waste is not locally available due to high demand from the feed industry, and the slaughter of other animals is also rare in Indonesia. Using fresh seafood is not a sustainable practice for aquaculture; however, the observation that crabs ingest algae suggests a potential new source of crude protein. For sustainable aquaculture, research on local feed ingredients should focus on algae such as *Chlorella* spp., *Dunaliella* spp., *Haematococcus* spp., *Scenedesmus obliquus*, and *Spirulina* spp. (Yaakob *et al.,* 2014; Derwenskus and Holdmann, 2016). While most have high protein content, sun- or air-drying can reduce this level more than centrifuge drying, making these algae less viable for farmers.

Palatability

We observed that crabs fed the PAI or PVV diets preferred fresh food over frozen *A. Indicus* and *V. viridis*. The leftovers of the six daily portions of the PAI and PVV diets stored in a freezer were relatively high compared to those from the first day and the P100 and P150 diets. This may have influenced

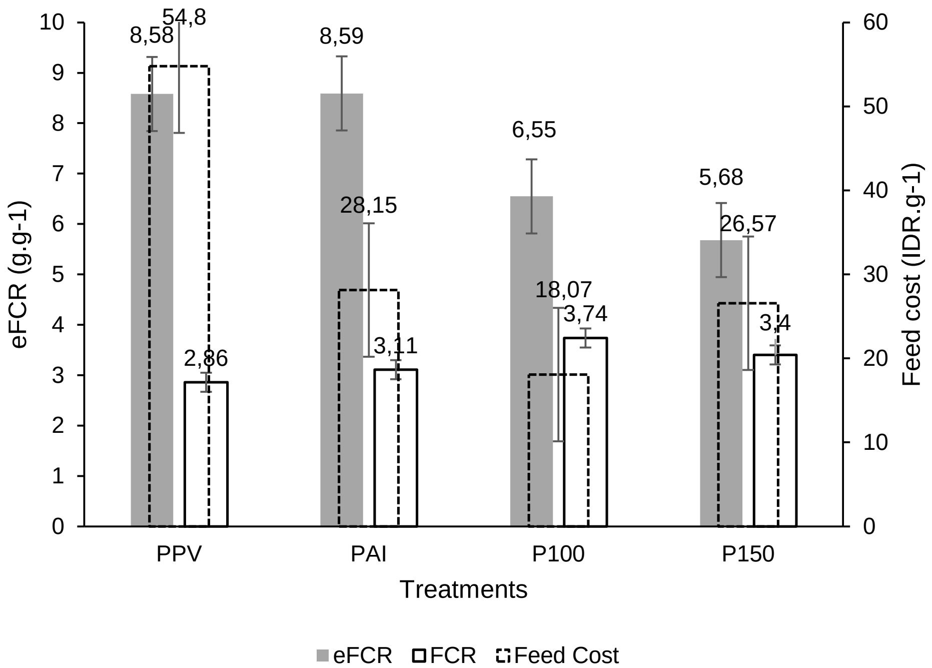

Figure 5. Economic feed conversion ratio (eFCR), feed conversion ratio over dry matter content (FCR), and feed costs.

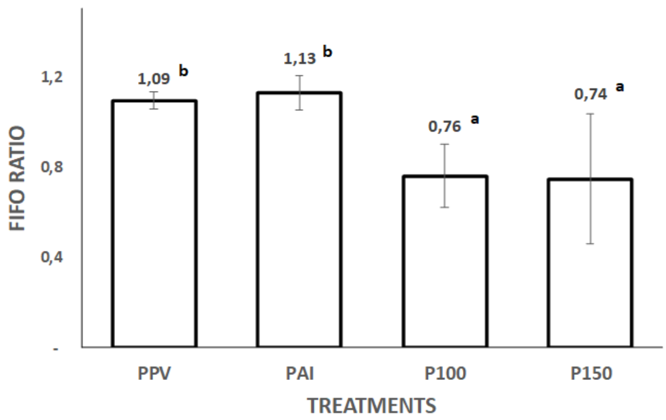

Figure 6. Mean and standard deviation of the fish-in/fish-out (FIFO) ratio for each diet.

intake over the six days, consequently affecting growth, FCR, and eFCR for the PAI and PVV diets. For convenience, we prepared feed portions for a week in advance and stored them in a freezer. However, freezing may have affected palatability and consequently, the growth of crabs fed the PAI diet; thus, we recommend avoiding this practice.

The observed difficulty in ingesting small pellets may have affected the measured FCR. The pellet size should be adapted to the size of the crab, ensuring the crabs can find and grab the pellets. The pellets should sink slowly and be durable in water. The use of feeding trays, like those used for shrimp, is not recommended due to the aggressiveness of crabs. When raising crabs in cages, these cages should touch the bottom of the water body. Pellets can be used in brackish water pond farming, provided the aforementioned requirements are met.

Conclusion

Both mixed diets with either *Perna viridis* or *Acetes indicus* were effective for the growth and survival of blue swimming crabs, but the eFCR was poor due to the high cost and low palatability after freezer storage. A diet of shrimp pellets providing 30% protein was sufficient to support the growth of blue swimming crabs weighing less than 40–50 g. Considering the good eFCR, FIFO, and overall performance of diet P150, which provided close to 45% CP and performed similarly to the mixed diets (PPV and PAI), this diet could be an efficient starting point for sustainable blue swimming crab farming. Further research is needed to reduce cannibalism during moulting and to meet calcium requirements after moulting, for instance, by identifying appropriate supplements and replacement levels for pellets and optimizing distribution practices. The low ingestion of small pellets may have affected growth and eFCR. The pellet size should be matched to the crab's size, with pellets designed to stay intact in water and sink slowly so the crabs can easily find and grab them.

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