

Effect of different diets on growth performance, a physiological response, and behavior of spiny lobster *Panulirus homarus* (Linnaeus, 1758)

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Abstract

This study aimed to know the effect of different feedings on growth performance, physiological responses, and behavioral changes of juvenile spiny lobsters. The experimental method used a completely randomized design with three treatments and four replications. There were three different feeds used as treatment, namely: flesh mussel (K), commercial fish feed (I), and commercial shrimp feed (U). Feed is given as much as 30% of body weight, five times per day at 6:30 am, 12:00 pm, 4:00 pm, 9:00 pm, and 2:00 am. The results showed that the commercial feeding of fish (I) significantly ($P < 0.05$) increased the survival rate and biomass of spiny lobster for 54.17% and 141.7 g, respectively. While fresh mussel give better growth and stress response, but had the lowest survival rate. The results of the physiological response test of lobster were more effective in suppressing lobster stress levels than other treatments ($P < 0.05$). The behavior of juvenile spiny lobsters showed a very striking color difference and reflex impairment scores, which indicated that the vitality of the treated juveniles (I) was better than the vitality of the treatments (K) and treatment (U). This study shows that commercial fish feed (I) is recommended for maintaining spiny lobsters in the juvenile phase, although it needs further maintenance by using an appropriate feed formulation to improve the growth performance of spiny lobsters.

Keywords: spiny lobster, feed, growth, physiological response

INTRODUCTION

Spiny lobster *Panulirus homarus* is an aquaculture commodity with high economic value and is in great demand in domestic and export markets. This increase in market demand impacts increasing the exploitation of lobsters in nature. In the long term, without good management, lobsters can be overfished. Lobster farming activities in floating net cages (KJA) are starting to develop both in Indonesia and in other countries. To ensure that lobster farming activities in KJA can sustainably occur, quality seed is needed and has the same size and sufficient amount.

Management of lobsters (*Panulirus* spp.) in the territory of the Republic of Indonesia has been stipulated in PERMEN KP No 16 of 2022, an amendment to PERMEN KP No 17 of 2021. The most crucial stage in lobster cultivation activities starts from the puerulus phase until it reaches a seed size 5 g per indiv. The main obstacle causing the low survival rate that has been known so far is the high rate of cannibalism and failure to molt. Efforts to obtain quality seeds while reducing the level of cannibalism and failure to molt require handling according to the behavior and habits of lobster seeds.

Of all the life phases of spiny lobsters, the post-puerulus to fry phase are a crisis phase, the mortality rate is very high, even reaching 95%. (Chau *et al.*, 2009; Thuy and Ngoc, 2004). Environmental factors and unsuitable feed influence the low productivity of lobsters. Lobsters are omnivores and, in nature, usually eat fresh food in the form of small fish and shellfish (Mahmudin *et al.*, 2016).

The growth and production of cultivated biota is influenced by several factors, one of which is feed. Growth and production can increase if the feed has a nutritional content that is in accordance with the needs of the cultivated aquatic organisms (Anggraini *et al.*, 2018). Mai and Tran (2022) stated that lobsters prefer fresh food to frozen food. However, the availability and nutritional value of fresh fishery products varies, are seasonal and excessive use can also cause environmental pollution and disease agents.

Various studies that examine stress levels have been carried out, are using hemolymph as an indicator to analyze total hemocytes and also hemolymph glucose levels. The total hemocyte count (THC) is a parameter that can be used as an indicator of stress in crustaceans (Arifin *et al.*, 2014; Adiyana *et al.*, 2014; Celi *et al.*, 2015; Pratiwi *et al.*, 2016). In addition, metabolic products such as hemolyzed glucose can be used to determine stress levels in crustaceans due to treatment in rearing, pollutants, handling, environmental changes, and post-transportation (Lorenzon *et al.*, 2007; Gulec and Aksu 2012; Bislimi *et al.*, 2013; Arifin *et al.*, 2014). Other parameters that can be used as a reference in determining the vitality and health level of lobsters are reflex or behavioral responses to indicators of vitality which are quick and easy to measure and have been shown to reliably correspond with prolonged whole body performance (James *et al.*, 2019; Stoner, 2012; Turnbull *et al.*, 2021). Reflex actions are consistent, involuntary and nearly instantaneous, and are independent of size, strength, motivation and gender (Turnbull *et al.*, 2021). When crustacean reflex responses are combined into a single score, it can provide an accurate indicator of crustacean vitality which is applicable to a variety of stressors (Stoner, 2012).

The research on developing formulated diets for lobsters has been carried out for over 30 years (Sudewi *et al.*, 2021). However, there still needs to be more information on research results related to rearing juveniles after puerulus so that they are ready to be cultivated in floating net cages. Besides that, giving the correct type of feed will encourage faster growth and survival. Therefore, in this study, we wanted to examine the effect of using different feeds, namely, the provision of artificial feed (shrimp pellets and fish pellets) and fresh flesh mussel feed on the growth performance, physiological response, and behavior of juvenile spiny lobster reared in controlled tanks at land-based nursery.

MATERIALS AND METHODS

The research was conducted for eight weeks at the land-based nursery of Lampung Main Center for Marine Aquaculture, Teluk Pandan District, Pesawaran Regency, Lampung Province, Indonesia.

The spiny lobster *P. homarus*, 360 post-puerulus juvenile with an average weight of 0.2-0.4 g and an average length of 2.3 ± 0.12 cm was from the coast of the West Coast of Lampung. The juvenile was acclimated for two weeks the experiment done to get used to pellet feed. The study used a completely randomized design (CRD), with three treatments and four replications. Three different feed treatments were chopped fresh green mussels (*Perna viridis*) (K), commercial fish pellets from Kaio brand type 6 (I), sizing 1.010-1.310 mm and commercial shrimp pellets from Beryl brand type 2 A (U), sizing 0.7-1.0 mm. Twelve plastic containers were used as rearing media sizing 70 cm x 45 cm x 35 cm, equipped with a water flow through of 3 liters/minute and aeration to supply oxygen. The plastic containers are placed in a closed seawater laboratory, and lighting is provided on a 12:12 light dark cycle.

The spiny lobster density was 30 indiv per container, with weights ranging from 0.2-0.4 g per indiv. Feeding was five times per day at 6:30 am, 12:00 pm, 4:00 pm, 9:00 pm, and 2:00 am, at 30% of body weight. Other supporting facilities used during the study were shelters made of cast cement and pieces of waring made of ribbons (Figure 1). Preparation of experimental diets Feed preparation is done every three days by weighing according to the dose given and then putting it into a colored plastic cup as a treatment marker. To prepare mussel meat feed (*P. viridis*), first

separate the mussel meat from the shell furthermore, the meat is finely chopped and the size is adjusted to your needs. The feed that has been weighed is stored in the refrigerator. The nutritional content of the feed used in the study is shown in Table 1.

Growth performance and survival rate parameters, measured every two weeks, and the sample used was 20% of the biomass, were enumerated using the following equations:

$$\text{Weight gain} = (\text{Final weight (g)} - \text{Initial weight (g)})$$

$$\text{Absolute Growth rate} = \frac{\text{Final weight (g)} - \text{Initial weight (g)}}{\text{Day}}$$

$$\text{Total Length} = (\text{Carapace length (cm)} + \text{Abdominal length})$$

$$\text{Total length gain} = (\text{Final length (cm)} - \text{Initial length (cm)})$$

$$\text{Specific growth rate (SGR)} = \frac{(\ln \text{ final weight} - \ln \text{ initial weight}) \times 100}{\text{experiment duration}}$$

$$\text{Survival rate (SR)} = \frac{\text{Final individu lobster}}{\text{Initial individu lobster}} \times 100$$

The lobster biomass production parameter is the total weight multiplied by the population at the end of the rearing period. The rate of biomass production can be calculated using the formula Zonneveld *et al.* (1991):

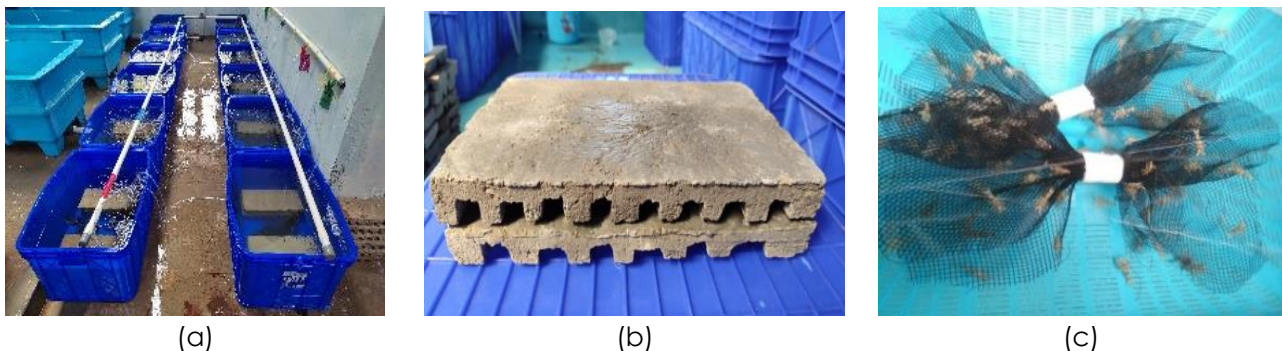


Figure 1. Setup of the research (a) The rearing containers sizing of 70 cm x 45 cm x 35 cm; (b) Shelter made of cast cement; (c) Shelter made of a piece of waring in the form of a ribbon

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$$BM = (Wt \times Nt)$$

Note: BM = Biomass Production (g); Wt = Total weight of individu lobster contained in the cultivation container (g); Nt = a total individu lobster.

$$\text{Feed conversion ratio (FCR)} = \frac{\text{Feed intake (g)}}{\text{Weight gain (g)}}$$

Parameters of the coefficient of variation size were measured at the end of the study. The coefficient of variation is a statistical measure that helps measure the spread of various data around the mean.

Table 1. The nutritional content of the feed used in the study

	Treatment		
	Mussel (K)	Fish (I)	Shrimp (U)
Nutritional Content	Protein: 21,9% Lipid: 14,5% Ash: 4,3% Carbohydrate: 18,5% Water: 40%	Protein: Min 50% Lipid: Min 6% Ash: Max 15% Crude fiber: Max 3% Calcium: Min 2.0% Fosfor: Min 1.5%	Protein: Min 36% Lipid: Min 6% Ash: Max 15% Crude fiber: Max 4% Water: Max 12%
Source	Eshmat <i>et al.</i> (2014)	Listed on packaging	Listed on packaging

$$\text{Coefficient of variation (CV\%)} = \frac{\text{Standar deviation}}{\text{Mean}} \times 100$$

The water quality parameters such as; temperature, pH, DO, salinity, ammonia, and nitrite which are measured 3 times a week were analyzed descriptively.

Behavioral analysis

Lobster behaviour observed every day by directly the activities and habits, then reported descriptively, and at the end of the research the vitality of the lobster produced is also observed one by one and grouping them according to the treatment. According to Spanoghe and Bourne (1997); Stoner (2012); Turnbull *et al.* (2021). Vitality on lobster can be assessed visually, with a score

of reflex impairment on a scale of 1-5, namely (1 = dead; 2 = limp tail, no escape response, and no response to touch or handling; 3 = limp tail, some responses for handling and touch, slight leg movement; 4 = mostly alert, tail held upright; 5 = alert with assertive escape behavior).

Physiological response

The physiological response parameters observed were total hemocyte count (THC) and hemolymph glucose levels. Specifically for these two parameters using a comparison or control, namely lobsters that are kept free with various feed combinations. Lobster hemolymph sampling was carried out on the 60th day of the study.

The hemolymph sample was taken using a 1 mL syringe that has been rinsed with 10% citric acid anticoagulant, taken from the leg of the back road near the lobster's abdomen, dripped into the hemacytometer, covered with a glass slide and then observed under a light compound microscope (400 x). microscope. Total haemolymph cells (THCs) was counted and calculated using the formula of Abdollahi-Arpanahi *et al.* (2018) :

$$\text{THCs/ml} = (\text{cells counted} \times \text{dilution factor} \times 1000 / \text{volume of grid (0.1 mm)})$$

Statistical analysis

The statistical analysis of one way analysis of variance (ANOVA) and continued with Duncan's test at 95% confidence was performed in SPSS (version 22). The differences were considered statistically significant at the level of $P \leq 0.05$.

RESULTS AND DISCUSSION

The growth index of juvenile spiny lobsters with different feed treatments is shown in Table 2. The diet with flesh mussels (K) had better growth performance when compared to the other two treatments (I and U), but no significant difference was observed in the parameters of the specific growth rate (SGR) and total length gain to the fish pellet fed treatment (I) (Table 2). On the growth rate parameter, treatment K; (0.037 ± 0.0028), the treatment I; (0.030 ± 0.0006), and treatment U; (0.021 ± 0.0011), then total length gain, treatment K; (1.59 ± 0.11 cm), the treatment I; (1.52 ± 0.09 cm) and treatment U; (1.22 ± 0.14 cm). The specific growth rate parameter, treatment K (3.16 ± 0.09 g), was not significantly different from treatment I (3.07 ± 0.16 g), and then treatment U (2.62 ± 0.15 g) was significantly lower with both treatments K and I.

Based on the results of growth performance measurements (growth rate, total length, and specific growth rate) showed that the treatment of diet flesh mussels resulted in the best growth when compared to artificial feeding treatment I and U. Irvin *et al.* (2015) reported the results of his research that lobsters fed diets that did not contain fresh ingredients showed lower growth rates than all treatments. This suggests that including fresh ingredients in the feed can enhance the growth of juvenile lobsters because fresh ingredients contain high levels of chemo-attractants that promote feeding responses in crustaceans. Furthermore, fresh food is softer in texture, which may suit the mouth parts of juvenile lobsters that still need to develop. Argus sea lobsters need animal protein as a source of energy in addition to tissue growth. Adult rock lobsters experience a decrease in body weight if the protein content in their diet is less than 60% dry weight.

Adiyana *et al.* (2014) reported that feeding trash fish as much as 4% of the lobster weight resulted in a specific growth rate of 0.96-1.32%, whereas in a study by Anggraini *et al.* (2018), feeding trash fish as much as 5% of the weight of the tested biota resulted in a specific growth rate of 0.88%. Compared with the research results obtained in this study, it is still better to suspect this as an effect of the percentage of feed in this study that was given a more significant amount of 30% per day. Cox and Davis (2006) reported that juvenile lobsters fed with a feed percentage of 100% body weight per day at dusk significantly increased growth over 28 days of rearing.

Table 2. Absolute growth rate, total length gain, coefficient of variation size (CV), specific growth rate (SGR), survival rate (SR), biomass, and feed conversion ratio (FCR) of juvenile spiny lobster *Panulirus homarus*

Parameters	Mussel (K)	Fish (I)	Shrimp (U)
Initial weight (g)	0.40±0.02	0.34±0.03	0.34±0.03
Final weight (g)	2.65±0.18 ^a	2.17±0.01 ^b	1.64±0.07 ^c
Weight gain (g)	2.25±0.17 ^a	1.83±0.04 ^b	1.3±0.07 ^c
Absolute growth rate (g/day)	0.037±0.0028 ^a	0.030±0.0006 ^b	0.021±0.0011 ^c
Initial length (cm)	2.41±0.05	2.29±0.05	2.28±0.05
Final length (cm)	4±0.10	3.82±0.06	3.50±0.09
Total length gain(cm)	1.59±0.11 ^a	1.52±0.09 ^a	1.22±0.14 ^b
CV (%)	21.19±6.39 ^a	13.61±2.43 ^b	17.82±2.49 ^{ab}
SGR (%/day)	3.16±0.09 ^a	3.07±0.16 ^a	2.62±0.15 ^b
SR (%)	34.17±4.19 ^b	54.17±4.19 ^a	40.83±9.18 ^b
Biomass (g)	104.4±0.54 ^b	141.7±0.29 ^a	77.82±0.28 ^c
FCR	17.26±2.84 ^a	20.14±2.48 ^a	19.02±2.16 ^a

Regarding the coefficient of variation size, the data obtained showed that the best percentage of similarity in size was obtained in treatment I, namely 13.61±2.43, followed by similarity in size in treatment U 17.82±2.49, and finally, in the K treatment, namely 21.19±6.39. From the statistical test results, treatment I was significantly different (P<0.05) from treatment K but not significantly different from treatment U, and treatment U was not significantly different (P>0.05) from treatment K. This showed around 79-97 % of the size of the lobster seeds harvested have relatively the same weight. Suwoyo *et al.* (2014) reported the results of their research that the diversity of shrimp at harvest had a coefficient of variation between 12.7-14.6%; this indicated that around 85% of the size of the shrimp harvested had relatively the same weight. The percentage similarity in size of shrimp is an indicator of the quality of fry and shrimp produced at harvest.

In the survival rate parameter, the best survival rate was obtained in treatment I (54.17%), which was significantly different from the two treatments. Treatment U (40.83%) and treatment K (34.17%) were not significantly different. The survival results obtained are by the opinion of Sudewi *et al.* (2020), in his research found that the highest survival was found in lobsters fed pellets. At the same time, low survival was obtained from lobsters that were given fresh feed. Smith *et al.* (2005) reported experiments on *Panulirus ornatus* with an average initial weight of 2.5±0.19 g for eight weeks of rearing, lobsters fed pellets had a high survival rate (79±4.5%) and responded to an increase in the content of crude protein in feed and then the lobsters fed flesh mussels grew and survived relatively well during the first four weeks of the experiment, but their growth and survival decreased abruptly over the 5-8 week period. Barclay *et al.* (2006) reported that lobsters fed frozen thawed mussels consistently grew slower for an overall growth period of 0 to 12 weeks. Survival of lobsters fed shellfish was significantly worse than those fed pellets during the final 9 to the 12-week phase of the experiment, with mortality mainly occurring during molting.

The low survival rate obtained in the K treatment was thought to be due to the effect of feeding flesh mussels, which stimulated their instincts, or the cannibalistic nature of lobster seeds to do cannibalism. According to Pratiwi *et al.* (2016), high mortality is generally caused by cannibalism. Cannibalism appears in healthy lobsters, while the prey is weak because they are in moderate condition or after molting. Physically, post-molting lobsters have soft carapace characteristics, are pale white, and emit an aroma that attracts predators (Setyono, 2006). AS *et al.* (2021) state that cannibalism occurs in small lobsters and lobsters undergoing molting. When the molting process is taking place, the lobster will emit a distinctive aroma that can attract the

attention of other lobsters, causing cannibalism because when the outer shell is released, the lobster will look weak and have no body armor, which eventually causes the lobster to be easily preyed upon by other lobsters.

Spiny lobster of biomass parameter in the treatment (I) showed the highest yield of 141.7 ± 0.29 g, and then treatment (K) yielded a biomass of 104.4 ± 0.54 g, and finally, treatment (U) produced a biomass of 77.82 ± 0.28 g. The treatment I produced significantly different biomass from the two treatments ($P < 0.05$). While the K treatment and U treatment also produced significantly different biomass. The biomass value indicates that the spiny lobster can utilize the feed provided. The high final biomass in the fish pellet feed treatment (I) is presumably because the fish pellet feed, besides having a distinctive feed aroma, also has the highest protein content compared to the other two feed treatments.

According to Widaksi *et al.* (2014), protein is the primary energy valuable source for the growth of aquatic organisms. Feeding with inappropriate protein content will reduce the growth of these organisms. Organs and tissues will use Makasangkil *et al.* (2017) to state that digested proteins form new proteins that function for growth or replace existing proteins as a maintenance function. In addition, feeding with the right type, amount, and frequency will support growth and prevent cannibalism (Richards *et al.*, 2013).

Feed conversion (FCR) is the ratio between the amount of feed used and the weight of the seeds produced. The value of the lobster seed feed conversion ratio during the study for each treatment was K; 17.60 ± 2.85 , Treatment I; 20.14 ± 2.48 , and U treatment; 19.02 ± 2.16 . The statistical test results showed that the FCR of the lobsters was not significantly different between the three treatments ($P > 0.05$). Several factors affect feed conversion efficiency: feed type, lobster age, body size, feeding level, salinity, and temperature (Adiyana *et al.*, 2014). Riani *et al.* (2012) state that the feed conversion value is inversely proportional to the weight gain value, so the lower the value, the more efficient the biota is in utilizing the feed it consumes for growth.

Lobster growth depends on feed availability and lobsters' ability to utilize or digest the feed. The feed conversion value in this study was quite significant, ranging from 17.60-20.14. Compared with the results of Slamet *et al.* (2020), which range from 3-3.20, with a feeding rate of 5% of body weight per day. However, the feed conversion results obtained were not much different from the results of a study reported by Pratiwi *et al.* (2016), that the FCR of lobsters during the maintenance period was in the *individual compartment system* (ICS) treatment for 60 days of maintenance, the feed given was fresh trash fish with the percentage of feed given was 3-4% per day, resulting in a control treatment of 15.61 ± 0.10 , fair ICS treatment 22.71 ± 1.72 , triangular ICS treatment 23.74 ± 0.91 , and tube ICS treatment of 25.50 ± 0.42 , with statistical test results showing lobster FCR between tube ICS, triangular ICS, and square ICS were not significantly different ($P > 0.05$).

The results of direct observation of research activities carried out are changes in the morphology and behavior of lobster seeds that are different from the three treatments, namely the change in body color produced. Body color is one of the parameters that can affect the sale value of lobsters. Compounds that can increase the color of lobsters are carotenoids, especially astaxanthin. Measures of whole-body performance (including survival, nutritional state, and state of health) are a practical approach to determining organismal performance but can be slow to react and require monitoring over some time (Barclay *et al.*, 2006).

Behavioral indices

Through direct observation of research activities that have been carried out, there are changes in the morphology and behavior of lobster seeds that are different from the three treatments, namely the change in body color produced. In treatment K, the lobster seeds produced had a reddish body color and had quite active movements but were still less responsive when compared to the seeds produced from treatment I. Meanwhile, in treatment I, the lobster

seeds produced were bluish and had movement, which was very active and responsive compared to treatment K and treatment U. In treatment U, the seeds produced were pale white, less active, and unresponsive to touch. The performance of the lobster seeds can be seen in the image (Figure 2).

The following observation of seed behavior was in one month of maintenance, visually more lobster seeds were in the shelter warning (Figure 1C), but entering the second month of maintenance, lobster seeds preferred a shelter made of cement castings (Figure 1B), and the molting process occurred at night as evidenced by the large amount of shells floating on the surface of the rearing tank water in the morning.

The research results obtained related to the vitality of lobster seeds produced with different feeding treatments, concerning the results of research by Spanoghe and Bourne (1997), Stoner (2012), and Turnbull *et al.* (2021). (Table 3). Based on the seed vitality indicators presented in Table 3, in treatment K, there were 11 individuals in category 3 and 25 individuals in category four, and only five individuals in category 5, while in treatment I, there were five individuals in category 4. and there were 60 individuals in category 5, and in treatment U, there were 35 individuals in category 2 and 14 individuals in category 3. In general, the best seed vitality performance was obtained in treatment I followed by treatment K, and lastly, treatment U.

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Based on the seed vitality indicators presented in table 3, in treatment K, there were 11 individuals in category 3 and 25 individuals in category 4, and only 5 individuals in category 5, while in treatment I, there were 5 individuals in category 4. and there were 60 individuals in category 5, and in treatment U, there were 30 individuals in category 2, 14 individuals in category 3 and 5 individuals in category 4. In general, it can be concluded that the best seed vitality performance was obtained in treatment I followed by treatment K, and lastly, treatment U. Reflex impairment scores significantly correlated with fry vitality Reflex and behavioral measures are valuable indicators of vitality and mortality in the commercial trade in crustacean species (James *et al.* (2019); Stoner. (2012); Turnbull *et al.* (2021)).

Observation of other parameters of lobster seed behavior is that in one month of reared, visually, more lobster seeds are in the shelter netting. However, in the second month of maintenance, lobster seeds prefer shelter made of cement castings. The molting process occurs at night, as evidenced by many shells floating on the water surface of the rearing container in the morning. According to Chau *et al.* (2009), during the nursery phase, molting juveniles are most vulnerable to cannibalism, and this risk is reduced if the shelter is present. The type of shelter that provides the best shelter is made of black, folded netting material.

From observations during research activities, when viewed from the five times the frequency of feeding, the period between 4.00 pm and 9.00 pm is the best hour of feeding when viewed from the response to eating and the absence of leftover feed at the time of the next feeding.

Spiny lobsters are nocturnal, actively starting foraging activities before sunset, increasing at night, and reducing their activity before sunrise (Permana *et al.*, 2016). Based on daily observations of the remaining feed in the tank after morning feeding, lobsters can consume feed more than once daily to meet their daily energy needs. Thomas *et al.* (2003) reported that feeding once a

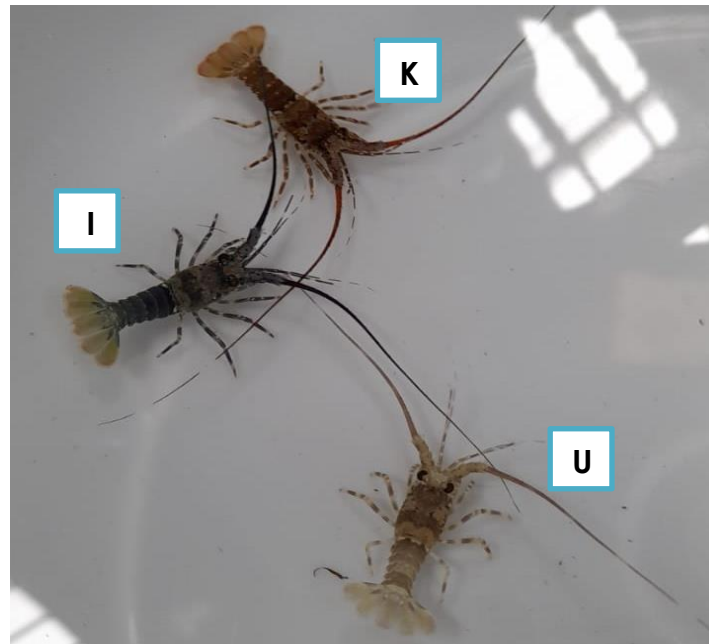


Figure 2. Juvenile spiny lobsters produced during the experiment

Table 3. Impairment reflex score juvenile spiny lobster *Panulirus homarus*

Vitality	Reflex impairment score		
	Treatment		
	K	I	U
2	0	0	30
3	11	0	14
4	25	5	5
5	5	60	0
Total Harvest	41	65	49

day after dusk can be recommended, although feeding four times daily can reduce feed completion and *agonistic behavior* of lobsters in captivity. Syafrizal *et al.* (2018) reported the results of their research on maintaining juvenile *P. versicolor* for 30 days, with feeding several times per day could have a beneficial effect, namely, there is a trend of increasing survival and other growth variables, but further studies are needed to confirm this.

Physiological response indices

Physiological response parameters or stress parameters are factors that influence the health of lobsters. The stress response is a normal physiological reaction to changes in environmental conditions (Evans, 2003). According to Celi *et al.* (2015), Total Hemocyte Count (THC) is one of the parameters that can indicate stress in crustaceans. The stress response is a physiological parameter that can be observed quantitatively to determine the effect of using different feeds. THC examination results can be seen in Figure 3.

The measurement of physiological response parameters used in this study were total hemocyte count (THC) and hemolymph glucose levels. According to Verghese *et al.* (2007), the stress response is a physiological variable affecting growth, feed efficiency, and lobsters survival.

The parameter that can indicate stress in crustaceans is the total hemocyte count (THC). The stress response can also be related to the water quality conditions in the rearing medium. Changes in environmental conditions can cause stress on the spiny lobster, affecting the immune response by marked changes in the total concentration of THC (Djai *et al.*, 2017).

When viewed the total amount of hemocytes obtained in each treatment, namely K; $119.15 \pm 15.95 \times 10^4$, the treatment I; $207.7 \pm 31.25 \times 10^4$, U treatment; $248.33 \pm 12.82 \times 10^4$, and the control treatment was $91.29 \pm 10.17 \times 10^4$. The results obtained, the K treatment had better results or stress levels and was not significantly different from the control treatment. The THC concentration in treatment K is lower than in treatments I and U. The low THC value indicates that the lobsters have a lower stress level. Adiyana *et al.* (2014) reported that the THC concentration of lobster seeds in their research was 81.50 ± 16.26 to $914.87 \pm 68.76 \times 10^4$ cells/ml in their research of different shelter technology applications. Meanwhile, according to Verghese *et al.* 2007, the normal THC range for lobsters ranges from 2.3 to 6.5×10^6 .

The seed lobster hemolymph glucose level test was conducted at the Pramitra Biolab Indonesia Clinical Laboratory in Bandar Lampung (Figure 4). using the GOD-PAP (Glucose Oxidase – Aminoantypyrin Peroxidase) method. The GOD-PAP method of blood glucose examination is mainly carried out in the laboratory because it is considered to have higher accuracy so that more accurate results are obtained. The tool used to check blood glucose in this method is a spectrophotometer. The principle of examination using the GOD-PAP method is that glucose in the sample is oxidized to form gluconic acid and hydrogen peroxide (Subiyono *et al.*, 2016).

From the results of the response data on the value of lobster hemolymph glucose during the study, information was obtained that the control treatment (Comparison) had the lowest value compared to the three treatments. However, when viewed from the three treatments, the hemolymph glucose response produced in the K treatment was lower/better. Statistical tests showed that the hemolymph glucose levels of lobsters during rearing were significantly different in all treatments ($P < 0.05$).

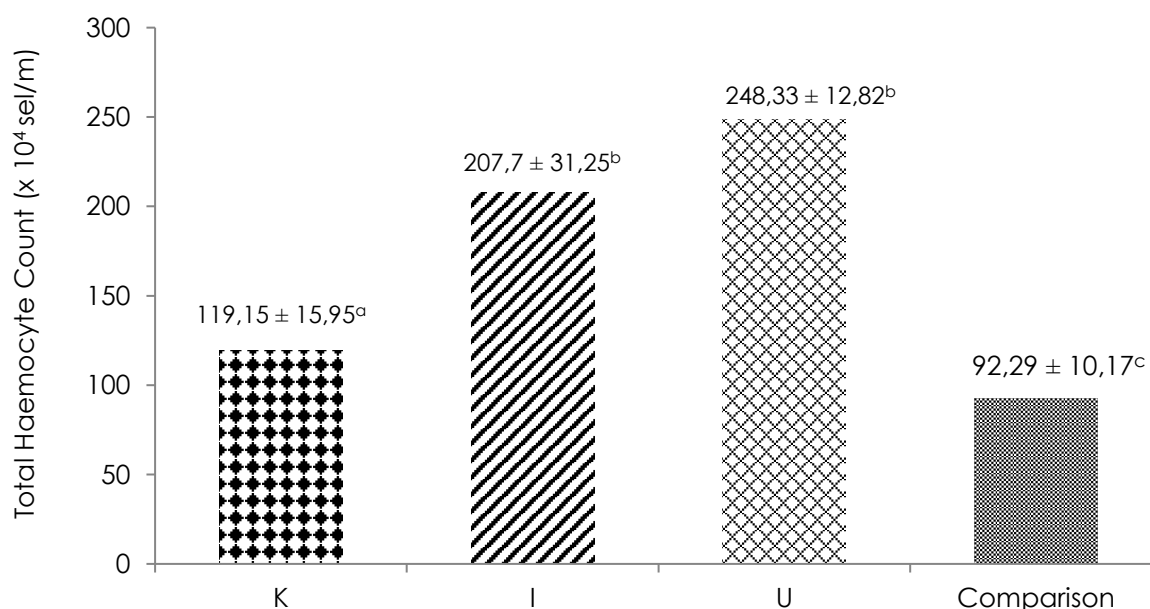


Figure 3. Total Haemocyte Count (*P. homarus*)

Note : K= Shellfish (*P. viridis*), I= Commercial pellet for fish, and U= Commercial pellet for shrimp, comparison: lobsters reared freely with various feed combinations. Using Duncan's advanced test, different superscript letters in the figure indicate a significantly different treatment effect ($P < 0.05$). The value shown is the result of the mean \pm standard deviation.

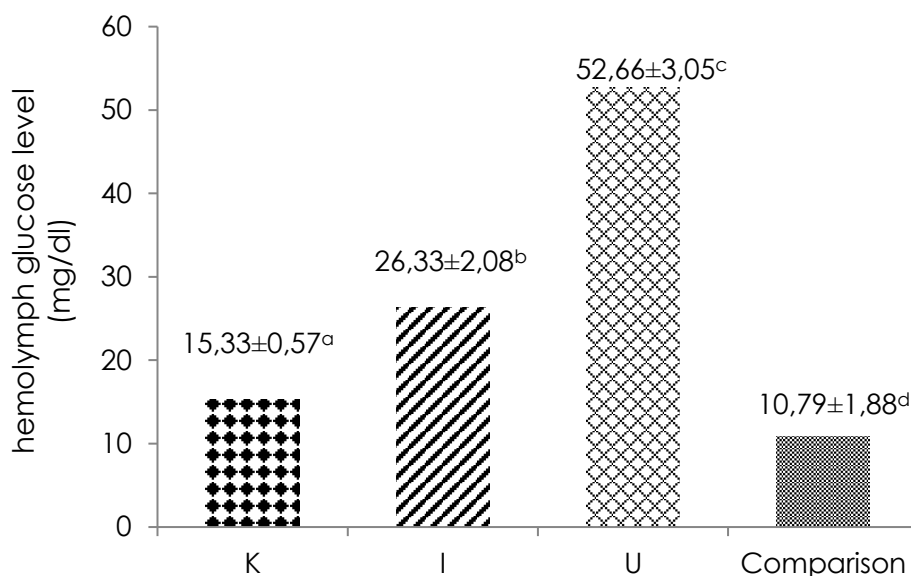


Figure 4. Hemolymph glucose level (*P. homarus*)

Note: K= Flesh mussel (*P. viridis*), I= Commercial pellet for fish, and U= Commercial pellet for shrimp. Comparison: lobsters reared freely with various feed combinations. Using Duncan's advanced test, different superscript letters in the figure indicate a significantly different treatment effect ($P<0.05$). The value shown is the result of the mean \pm standard deviation.

Blood glucose is the primary source of energy supply and an essential substrate for cell metabolism, especially brain cells. The brain will function when the energy source that comes from glucose is continuously available. Physiologically, lobsters can normally live at glucose levels ranging from 11.64-15.05 mg/dL (Pratiwi *et al.*, 2016). Adiyana *et al.* (2014) 8.29±2.85 to 12.10±3.17 mg/dL, and according to Lorenzon *et al.* (2007), the gap value indicates stress on crustaceans when blood glucose levels >15 mg/dL. From the description above, it can be interpreted that the U treatment, which had the highest glucose level when compared to the two treatments, was because the feed used was not suitable, causing an increase in hemolymph blood sugar levels and, as a result, the resulting growth was less than optimal. This is the opinion of Fotedar *et al.* (2006), who state that stress can cause a decrease in the immune system or immunity to disease, poor growth, poor reproductive performance, and low life recovery.

Water quality is a crucial factor affecting spiny lobster juveniles' survival and growth rate in controlled nurseries. Measurement of water quality in this study was measured three times a week. Water quality parameters observed in this study were temperature 28.9-29.5°C, pH 8.3-8.65, salinity 31-32 ppt, dissolved oxygen (DO) 4.5-6.1 mg.L⁻¹, nitrite (NO₂) 0.069-0.091 mg.L⁻¹, and ammonia (NH₃) 0.083-0.30 mg.L⁻¹. Mai and Tran (2022) reported the results of their research that the recommended water quality for spiny lobsters is a temperature ranging from 25-30°C, dissolved oxygen (DO) 2.7-5.4 mg.L⁻¹, and NH₃ <0.1 mg.L⁻¹. Ningtias *et al.* (2019) added that the optimal temperature when rearing spiny lobster juveniles ranges from 28-29 °C, salinity 32-33 ppt, dissolved oxygen (DO) 5-6 mg.L⁻¹ and pH 8-8.06. According to Supriyono *et al.* (2017), a relatively stable and optimal pH ranges from 6.86-8.15. Adiyana *et al.* (2014) reported that pH values in the 7.07-7.86 still support the life of spiny lobster juveniles. Based on the water quality parameter measurement data results, the water quality during this study period was still at an average level and in an excellent range to support lobster life during the study.

CONCLUSION

The provision of different feeds in the nursery of juvenile spiny lobster in land-based nurseries affects the survival rate and the biomass produced. Feeding fish pellets (I) produced the best

productivity performance, namely survival (54.17±4.19%), biomass (141.7±0.29 g), and good vitality juveniles. The flesh mussel (K) feeding treatment showed better growth and stress response, but the K treatment had the lowest survival rate.

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