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Effects of Feed Type and Culture System on Growth and Survival of *Panulirus homarus* Puerulus in Situbondo, East Java

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ABSTRACT

Lobster (Panulirus homarus) aquaculture in Indonesia remains limited due to suboptimal feed management and culture systems, resulting in low growth and survival rates. This study aimed to evaluate the effects of different feed types and culture systems on growth performance, survival rate, feed efficiency, amino acid content, and carbonic anhydrase enzyme activity in lobster puerulus. The study was conducted using a factorial randomized block design with two factors: culture media (bottom cage, floating cage, and fiber tank) and feed types (kijing clams, trash fish, and shrimp head waste). Each treatment was replicated three times at a stocking density of 30 individuals per square meter. The results showed that the highest survival rate (90%) and best feed conversion ratio (6.6) were obtained in fiber tanks with kijing clam feed. The highest growth performance (5.11 g) and enzyme activity were recorded in fiber tanks with shrimp head waste feed. Amino acid content, particularly leucine, was also highest under the same treatment. Statistical analysis indicated that both feed type and culture system significantly influenced lobster performance, with strong relationships observed between feed composition and physiological responses. The conclusion is that the combination of appropriate feed and a controlled culture system is essential for improving lobster aquaculture performance. Fiber-based systems with high-quality feed provide optimal conditions for growth, survival, and metabolic activity, supporting more efficient and sustainable lobster farming.

INTRODUCTION

Lobster (*Panulirus homarus*) is one of Indonesia's high-value fishery commodities with strong export potential. However, its production still relies heavily on wild capture, which has declined significantly due to overfishing and environmental degradation. Coral reef damage and habitat loss have reduced natural lobster populations, leading to decreased productivity (Browne, 1997).

In addition to ecological pressures, socioeconomic factors also contribute to the decline of lobster resources. The decreasing availability of adult lobsters has driven fishers to harvest lobster seeds (puerulus) for illegal export, which threatens long-term sustainability (Pramesti et al., 2021). Despite this, lobster aquaculture has not yet been optimally developed in Indonesia, as current practices remain traditional, resulting in slow growth and low survival rates.

One of the major limitations in lobster aquaculture is the lack of optimized feed types and culture systems, particularly during the puerulus stage. Feed quality directly affects growth, molting, and survival, while culture media influences environmental stability and stress levels. Previous studies have shown that different feed types provide varying amino acid profiles that can affect physiological responses in crustaceans (Pramana et al., 2022). However, studies integrating feed type and culture system simultaneously are still limited.

Carbonic anhydrase (CA) is a key enzyme involved in respiration, acid-base balance, and exoskeleton formation during molting. Its activity is closely related to environmental conditions and nutritional status, making it a potential indicator of physiological performance in lobster culture (Warrillow, 2009).

Therefore, this study aims to evaluate the effects of different feed types and culture systems on growth, survival rate, amino acid content, and carbonic anhydrase activity of *Panulirus homarus* puerulus. This research is expected to provide a scientific basis for developing efficient and sustainable lobster aquaculture systems in Indonesia.

METHOD

This research was conducted at the Laboratory of Brawijaya University and at the lobster farming site in Kampung Kerapu, Klatakan Village, Situbondo Regency, from August to September 2024 (Figure 1). The tools and materials used in this study included a camera, smartphone, questionnaire, stationery, and measuring instruments. The research method applied was a quantitative approach supported by documentation techniques, following Yulianda (2007). The data collected focused on lobster culture activities, including growth performance, survival rate, feed utilization, and environmental parameters within the culture systems.

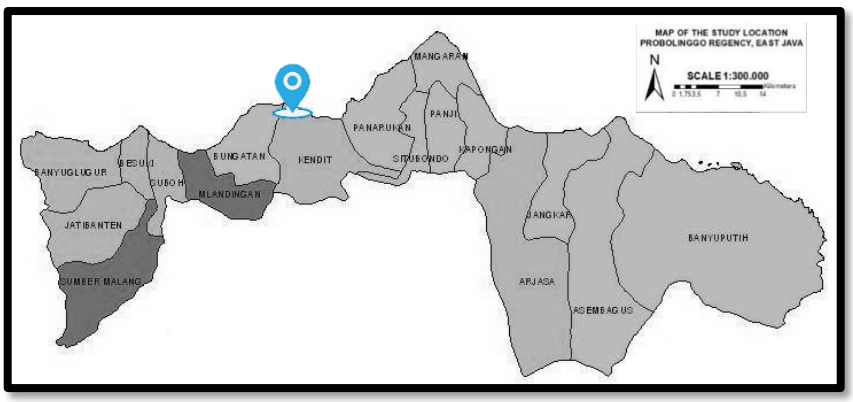

Figure 1. Research Location Maps

Research Design

This study utilizes a Factorial Randomized Block Design (RCBD Factorial). The RCBD is chosen due to the need for grouping experimental units (blocks) to minimize experimental error and ensure homogeneity within groups, while the factorial approach is used to simultaneously test two factors and examine their individual and interaction effects.

Factors and Treatments

The study investigates two factors, resulting in a total of 9 treatment combinations, each replicated 3 times at the designated stocking density.

Factor 1: Culture Media (3 levels)

1. KJD (Kerangkeng Jaring Dasar / Bottom Cage)
2. KJA (Keramba Jaring Apung / Floating Net Cage)
3. Fiber (Fiber Tank)

Factor 2: Feed Type (3 levels)

1. Kijing Clams
2. Trash Fish
3. Shrimp Head Waste

Treatment Combinations (Total 9): All treatments use a stocking density of 30 ind/m^2.

KJD A 1 : KJD + Kijing Clams
KJD A 2 : KJD + Trash Fish
KJD A 3 : KJD + Shrimp Head Waste
KJA B 1 : KJA + Kijing Clams
KJA B 2 : KJA + Trash Fish
KJA B 3 : KJA + Shrimp Head Waste
Fiber C 1 : Fiber + Kijing Clams
Fiber C 2 : Fiber + Trash Fish
Fiber C 3 : Fiber + Shrimp Head Waste

Research Procedures

- Test Animals: Post-larvae Lobster (Benih Bening Lobster/BBL) sourced from Pacitan, East Java, weighing approximately 1 gram/ind.
- Stocking: BBL are stocked at a density of 30 ind/media and conducted in the morning (07.00 - 08.00 AM WIB). 10 samples are placed in each culture unit.
- Maintenance:
  - Feeding frequency is twice daily (08.00-09.00 AM and 03.00-04.00 PM WITA).
  - Feed is administered at 5% of the total lobster biomass per unit, adjusted every 7 days based on weekly biomass measurements.

Research Parameters

The observed parameters include:

1. Absolute Weight Growth (W): W = Wt – Wo
2. Absolute Length Growth (Pm): Pm = Lt – Lo
3. Survival Rate (SR): SR = (Nt/No) x100%
4. Water Quality: Temperature, pH, and Dissolved Oxygen (DO).
5. Biochemical Parameters: Carbonate Anhydrase and Amino Acid levels.

Analysis

Data were analyzed using two-way ANOVA to determine the effect of feed type, culture media, and their interaction. If significant differences were found ($p < 0.05$), further analysis was conducted using Duncan Multiple Range Test (DMRT). Normality was tested using the Kolmogorov–Smirnov test.

RESULT AND DISCUSSION

Survival Rate (SR) of Lobster

The culture of lobster (Panulirus spp.) in Indonesia faces challenges in improving the survival rate (SR) and growth of the lobster. One crucial factor affecting the SR is the type of feed provided (Pramana et al., 2022). This study aims to evaluate the effect of feeding with Kijing clams, trash fish (lemuru fish), and shrimp head waste on the lobster's SR across three different culture media: floating net cages (KJA), bottom net cages (KJD), and on-land fiber tanks (KD).

The SR data from this study is presented in Table 1:

Table 1. Lobster Survival Rate

No	Media Type	SR (%)
1	KJD1	66%
2	KJD1	68%
3	KJD1	78%
4	KJD2	70%
5	KJD2	56%
6	KJD2	58%
7	KJD3	78%

No	Media Type	SR (%)
8	KJD3	74%
9	KJD3	80%
10	KJA1	78%
11	KJA1	76%
12	KJA1	72%
13	KJA2	78%
14	KJA2	80%
15	KJA2	86%
16	KJA3	72%
17	KJA3	66%
18	KJA3	78%
19	KD1	84%
20	KD1	80%
21	KD1	78%
22	KD2	80%
23	KD2	90%
24	KD2	86%
25	KD3	84%
26	KD3	86%
27	KD3	76%

Key: KJD: Bottom Net Cage; KJA: Floating Net Cage; KD: Land-based Pond/Fiber Tank

Research results indicate that the highest SR was obtained in fiber tanks fed with Kijing clams (90%). Conversely, the lowest SR was found in the KJD fed with Kijing clams (56%).

Effect of Feed Type on SR

The provision of Kijing clams showed the highest SR across all media compared to trash fish and shrimp head waste. This is consistent with research showing that natural feed like clams can enhance lobster survival (Rostika et al. 2024).

Effect of Culture Media on SR

The fiber tank offers better environmental control, reducing stress on the lobster and increasing the SR. Conversely, the KJD, located at the bottom of the water, is susceptible to the accumulation of residual feed and feces, which can degrade water quality and lower the lobster's SR.

Lobster Culture Feed Conversion Ratio (FCR)

One important parameter in assessing feed efficiency is the Feed Conversion Ratio (FCR), which describes the amount of feed required to produce one unit of lobster body weight (Ulkhaq, M. F, 2021). This study aims to evaluate the effect of feeding with Kijing clams, trash fish, and shrimp head waste on the lobster's FCR across three different culture media: floating net cages (KJA), bottom net cages (KJD), and on-land fiber tanks (KD). The FCR data from this study is presented in Table 2.

Table 2. Feed Conversion Ratio (FCR)

No	Media Type	FCR
1	KJD1	9.00
2	KJD1	8.74
3	KJD1	7.62
4	KJD2	8.49
5	KJD2	10.61
6	KJD2	10.24
7	KJD3	7.62
8	KJD3	8.03

No	Media Type	FCR
9	KJD3	7.43
10	KJA1	7.47
11	KJA1	7.66
12	KJA1	8.09
13	KJA2	7.47
14	KJA2	7.28
15	KJA2	6.77
16	KJA3	8.09
17	KJA3	8.82
18	KJA3	7.47
19	KD1	6.67
20	KD1	7.43
21	KD1	7.62
22	KD2	7.43
23	KD2	6.60
24	KD2	6.91
25	KD3	7.07
26	KD3	6.91
27	KD3	7.82

Key: KJD: Bottom Net Cage; KJA: Floating Net Cage; KD: Land-based Pond/Fiber Tank

Research results show that feeding Kijing clams in the fiber tank yielded the best FCR of 6.6. Conversely, feeding Kijing clams in the KJD resulted in the highest FCR of 10.6. This indicates that the fiber tank culture medium is more efficient in converting feed into lobster growth compared to the KJD.

Effect of Feed Type on FCR

The provision of Kijing clams showed the lowest FCRacross all media compared to trash fish and shrimp head waste. This is consistent with research indicating that natural feed like clams can enhance feed conversion efficiency in lobster (Rostika et al. 2024).

Effect of Culture Media on FCR

The fiber tank provides better environmental control, reduces stress on the lobster, and enhances feed utilization efficiency. Conversely, the KJD, located at the bottom of the water, is susceptible to the accumulation of residual feed and feces, which can degrade water quality and lower feed utilization efficiency (Pramana et al. 2022).

Lobster Growth

This study aims to evaluate the effect of feeding with shrimp head waste, trash fish, and Kijing clams on lobster growth across three different culture media: floating net cages (KJA), bottom net cages (KJD), and on-land fiber tanks (KD). The results show that feeding shrimp head waste in the fiber tank resulted in the highest lobster weight gain of 5.11 grams, while feeding shrimp head waste in the KJD resulted in the lowest weight gain of 4.76 grams.

This aligns with previous research indicating that natural feed like shrimp head waste can enhance lobster growth (Pramana et al., 2022). The effectiveness of the feed is also influenced by the culture media's environmental conditions, such as water quality and stocking density, which can affect nutrient absorption and lobster metabolism. Selecting the appropriate culture medium and providing the right feed are essential for achieving optimal lobster growth (Ulkhaq, M. F, 2021). Lobster growth data is presented in Table 3.

Table 3. Lobster Growth

No	Media Type	Weight Gain (grams)	Length Gain (cm)
1	KJD1	4.76	1

No	Media Type	Weight Gain (grams)	Length Gain (cm)
2	KJD1	4.76	1
3	KJD1	4.79	1
4	KJD2	4.77	1
5	KJD2	4.71	1
6	KJD2	4.72	1
7	KJD3	4.79	1
8	KJD3	4.78	1
9	KJD3	4.80	1
10	KJA1	4.89	1.3
11	KJA1	4.89	1.3
12	KJA1	4.88	1.3
13	KJA2	4.89	1.3
14	KJA2	4.90	1.3
15	KJA2	4.91	1.3
16	KJA3	4.88	1.3
17	KJA3	4.86	1.3
18	KJA3	4.89	1.3
19	KD1	5.11	1.4
20	KD1	4.80	1.4
21	KD1	4.79	1.4
22	KD2	4.80	1.4
23	KD2	4.82	1.4
24	KD2	4.81	1.4
25	KD3	4.81	1.4
26	KD3	4.81	1.4
27	KD3	4.79	1.4

Key: KJD: Bottom Net Cage; KJA: Floating Net Cage; KD: Land-based Pond/Fiber Tank

Carbonic Anhydrase Enzyme Test

The results show that feeding shrimp head waste in the fiber tank yielded the highest carbonic anhydrase (CA) enzyme level of 375.9 µg/mL. Conversely, feeding shrimp head waste in the KJD resulted in the lowest enzyme level of 110.1 µg/mL. Enzyme levels in the KJA and fiber tank media with trash fish and Kijing clams fell between these two extremes. Generally, the highest CA enzyme level was found in the combination of shrimp head waste feed and fiber tank medium, while the lowest was found in the combination of shrimp head waste feed and KJD medium.

The CAenzyme plays a crucial role in respiration and carapace formation in lobsters. Its activity can be influenced by the type of feed and the environmental conditions of the culture medium. Providing shrimp head waste feed, which is rich in protein and essential amino acids, can increase the synthesis of the CA enzyme, especially in media that support optimal growth like the fiber tank. Conversely, environmental conditions in the KJD, such as water quality and stocking density, can affect enzyme activity and lobster metabolism (Henry et al, 2024).

Previous research by Henry et al (2024) indicated that laserpuncture induction can increase the CA enzyme level in female sand lobster (*Panulirus homarus*). This suggests that external factors, in addition to feed type and culture media, can also influence enzyme activity in lobsters. However, further research is needed to understand the interaction between these factors in influencing lobster metabolism. The CA enzyme level results are presented in Table 4.

Table 4. Carbonic Anhydrase Enzyme Data

No	Media Type	Carbonic Anhydrase Data (µg/mL)
1	KJD1	110.388

No	Media Type	Carbonic Anhydrase Data (µg/mL)
2	KJD1	136.762
3	KJD1	147.526
4	KJD2	180.897
5	KJD2	163.211
6	KJD2	196.821
7	KJD3	247.876
8	KJD3	217.243
9	KJD3	231.020
10	KJA1	128.235
11	KJA1	144.549
12	KJA1	168.882
13	KJA2	308.981
14	KJA2	297.015
15	KJA2	327.124
16	KJA3	209.136
17	KJA3	191.460
18	KJA3	227.850
19	KD1	275.920
20	KD1	300.103
21	KD1	267.465
22	KD2	326.154
23	KD2	352.183
24	KD2	320.962
25	KD3	375.968
26	KD3	339.596
27	KD3	359.728

Key: KJD: Bottom Net Cage; KJA: Floating Net Cage; KD: Land-based Pond/Fiber Tank

Amino Acid Test

Based on the laboratory test results at the Faculty of Fisheries Cultivation, Muhammadiyah Malang University, feeding shrimp head waste in the fiber tank yielded the highest Leucine amino acid level of 6.84%. Conversely, feeding shrimp head waste in the KJD resulted in the lowest Leucine level of 6.71%. Leucine levels in the KJA and fiber tank media with trash fish and Kijing clams fell between these two values. Generally, the highest Leucine amino acid level was found in the combination of shrimp head waste feed and fiber tank medium, while the lowest was found in the combination of shrimp head waste feed and KJD medium.

Leucine is an essential amino acid important for protein synthesis and tissue formation in lobsters. CA enzyme activity also plays a role in amino acid metabolism, including Leucine. Providing shrimp head waste feed, which is rich in protein and essential amino acids, can increase Leucine levels in the lobster's body, especially in media that support optimal growth like the fiber tank. Conversely, environmental conditions in the KJD, such as water quality and stocking density, can affect nutrient absorption and amino acid metabolism in lobsters (Jones, D. A., & Simons, J. 1996).

According to Mustika et al. (2024), feeding a mixture of clam flour can increase amino acid levels in lobsters. This indicates that the type of feed influences the amino acid profile in lobsters. However, feed effectiveness is also influenced by the culture media's environmental conditions, such as water quality and stocking density, which can affect nutrient absorption and amino acid metabolism in lobsters.

Effect of Clam Feed Amino Acids on Lobster Amino Acids

The Kolmogorov-Smirnov test yielded a significance value of $p > 0.05$. Thus, the null hypothesis (H0) is accepted, meaning the regression model residuals are normally distributed.

This fulfills the regression assumption, and the model results can be used for valid inference. The ANOVA test on clam amino acid data and amino acid data in lobsters fed clams yielded an F value of 409.562 with a significance of $p < 0.001$, indicating that the overall regression model is significant. This means the clam feed variable has a real effect on lobster growth.

The value of R = 0.994 shows a very strong relationship between the clam feed variable and lobster growth. $R^2 = 0.988$ means 98.8% of the variation in lobster growth can be explained by the clam feed variable, and only 1.2% is influenced by other factors.

Effect of Trash Fish Amino Acids on Lobster Amino Acids

The Kolmogorov–Smirnov test yielded a significance value of $p > 0.05$, indicating that the residuals of the regression model are normally distributed. Therefore, the assumption of normality is satisfied, and the regression model is appropriate for further analysis and inference. The ANOVA results showed an F value of 3175.656 with a significance level of $p < 0.001$, indicating that the regression model is statistically significant. This means that the amino acid content of the feed has a significant effect on the amino acid content observed in lobster.

The correlation coefficient (R) of 0.997 indicates a very strong relationship between feed amino acid composition and lobster amino acid content. The coefficient of determination (R^2) of 0.994 implies that 99.4% of the variation in lobster amino acid content can be explained by the feed composition, while the remaining 0.6% is influenced by other factors not included in the model.

Effect of Shrimp Head Waste Amino Acids on Lobster Amino Acids

The Kolmogorov-Smirnov test yielded a significance value of $p > 0.05$. Thus, the null hypothesis (H0) is accepted, meaning the regression model residuals are normally distributed, and the results can be used for inference. The ANOVA test on trash fish amino acid data and amino acid data in lobsters fed clams yielded an F value of 2824.766 with a significance of $p < 0.001$, indicating that the overall regression model is significant. This means the shrimp head waste feed variable has a real effect on lobster growth. The value of R = 0.997 shows a very strong relationship between the clam feed variable and lobster growth. $R^2 = 0.994$ means 99.4% of the variation in lobster growth can be explained by the clam feed variable, and only 1.6% is influenced by other factors.

Effect of Carbonic Anhydrase Enzyme on Lobster Length and Weight

- CA → Length: The Kolmogorov-Smirnov test yielded $p > 0.05$ (Normality assumed). The ANOVA test yielded F = 19.281 with $p < 0.001$ (Significant). R= 0.660 R^2= 0.435, meaning 43.5%of the variation in lobster growth can be explained by CA.
- CA → Weight: The Kolmogorov-Smirnov test yielded $p < 0.05$ (Normality rejected). The ANOVA test yielded F= 0.648 with $p > 0.001$ (Not Significant). R= 0.159, R^2 = 0.025, meaning only 2.5% of the variation in lobster weight can be explained by CA.

Effect of Carbonic Anhydrase Enzyme on Lobster SR and FCR

Both CA to SR and CA to FCR passed the Kolmogorov-Smirnov test ($p > 0.05$), meaning the residuals are normally distributed.

- CA → SR: F= 22.522 with $p < 0.001$ (Significant). R = 0.688, $R^2 = 0.474$), meaning 47.4% of SRvariation is explained by CA.
- CA → FCR: F= 15.294 with $p < 0.001$ (Significant). R= 0.616, $R^2 = 0.380$, meaning 38% of FCR variation is explained by CA.

The interpretation is that the CA enzyme has a positive and significant influence on the lobster survival rate (SR); every increase in CA is followed by an increase in SR.

Table 5. Interpretation of CA on Lobster SR and FCR

Relationship	Direction	Significant?	Strength (R)	Interpretation
CA→ FCR	Negative	Yes ($p < 0.001$)	Moderate (0.616)	Higher CAleads to lower FCR (more efficient)

Relationship	Direction	Significant?	Strength (R)	Interpretation
CA→ SR	Positive	Yes ($p < 0.001$)	Quite Strong (0.688)	Higher CA leads to increased survival rate

Both relationships show that the CA enzyme plays an important role in feed efficiency and lobster survival. Both regression models are feasible and significant.

Results Analysis

Lobster Survival Rate (SR)

SR is a primary indicator of successful culture. The highest SR (90%) was achieved in the fiber tank with Kijing clam feed. The lowest SR (56%) was found in the KJD with the same feed. This suggests that while feed type is important, the culture media environment has a significant impact on survival. Kijing clams proved superior to trash fish and shrimp head waste in increasing SR, supported by Rostika (2024) who suggested natural feeds like clams enhance immunity. The fiber tank provides a more stable and controlled environment than KJD or KJA, reducing stress and limiting the accumulation of waste and uneaten feed (Ulkhaq, 2021).

Feed Conversion Ratio (FCR)

The best FCR (lowest) of 6.6 was obtained in the fiber tank with Kijing clam feed. The worst FCR (highest) of 10.6 was in the KJD with the same feed. This implies that although Kijing clams are biologically efficient, the culture media significantly affects their effectiveness. The fiber tank allows for optimal environmental management, while the KJD is prone to waste sedimentation, which compromises water quality and feed metabolism (Parama *et al*, 2022).

Lobster Growth (Length and Weight)

The highest weight gain (5.11 grams) was achieved with shrimp head waste feed in the fiber tank, while the lowest (4.76 grams) was in the KJD with the same feed. The best length gain (1.4cm) was consistently observed in the fiber tank media. This indicates that shrimp head waste, rich in protein and essential amino acids, supports high growth (Pramana et al., 2022), but the KD media is the critical factor determining whether the feed's nutritional potential is optimally absorbed.

Carbonic Anhydrase Enzyme (CA) Activity

The highest CAlevel 375.9 µg/mL) was found in lobster cultured in the fiber tank with shrimp head waste feed. The lowest (110.1 µg/mL) was in the KJD with the same feed. This elevation indicates that high-quality feed and environmental stability stimulate the synthesis of the CA enzyme, which is vital for respiration and carapace growth (Henry et al, 2024).

Leucine Amino Acid Content

The highest Leucine content (6.84%) was found in lobster fed shrimp head waste in the fiber tank, consistent with the trend that optimal media enhances the absorption and metabolism of essential amino acids provided by the protein-rich feed.

Statistical Analysis Interpretation

The statistical analysis confirmed the following:

- Feed Quality: All feed types showed a highly significant and very strong relationship ($R > 0.99$) with lobster growth, underscoring the importance of nutritional profile.
- CA Enzyme: CA proved to be a reliable predictor:
  - It has a positive and significant effect on SR (47.4% of variation explained).
  - It has a negative and significant effect on FCR (38% of variation explained), meaning higher CA results in better efficiency.
  - It has a significant effect on length growth, but no significant effect on weight gain (F is low, $p > 0.05$). This suggests that CA is strongly linked to molting (length), but weight gain is influenced more directly by other external factors besides the enzyme's activity.

CONCLUSION

This study demonstrates that both feed type and culture system play a significant and interdependent role in determining the biological and physiological performance of *Panulirus homarus* puerulus. The findings confirm that controlled culture environments, particularly fiber tanks, consistently provide more favorable conditions for lobster survival, growth, and metabolic efficiency compared to open systems such as KJA and KJD. While feed type contributes to performance, its effectiveness is strongly influenced by the culture environment. Shrimp head waste, as a high-protein feed source, was found to enhance growth performance, amino acid content (leucine), and carbonic anhydrase (CA) enzyme activity, indicating improved metabolic and physiological processes. In contrast, kijing clam feed showed superior performance in terms of survival rate and feed efficiency, suggesting that different feed types contribute differently to lobster performance depending on the parameter observed. The study also reveals that carbonic anhydrase (CA) enzyme activity serves as an important physiological indicator, significantly influencing survival rate, feed efficiency, and length growth, but not weight gain. This indicates that CA is more closely associated with molting and structural growth rather than biomass accumulation.

Overall, this research highlights that successful lobster aquaculture requires an integrated approach that combines nutritionally appropriate feed with a stable and controlled culture system. These findings contribute to the development of more efficient and sustainable lobster farming strategies in Indonesia, particularly for the puerulus stage.

However, this study is limited by the relatively short culture period and the restricted range of environmental parameters observed. Future research should explore longer cultivation periods, include more detailed water quality variables (such as ammonia, alkalinity, and organic matter), and investigate additional physiological indicators to better understand lobster metabolism and optimize culture systems.

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