



Research Article

Bamboo Lobster (*Panulirus versicolor*) Hemocyte Count Differentiation Given a Combination of Three Mollusca Meat Meals

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Abstract | The research aims to determine the total and differentiation of hemocyte count of bamboo lobsters given a combination of three mollusca meat flours, which was carried out in August-December 2023, at the Fisheries Cultivation, Hatchery and Production Laboratory, Faculty of Fisheries and Marine Sciences, Halu Oleo University. The method used was a Randomized Block Design (RBD) with four treatments and three groups. Four types of feed are made based on a combination of three mollusca flours, namely mangrove snail flour (MSF), kepah clam flour (KCF), and golden snail flour (GSF). Treatment A (20% tembang fish meal (TFM)+20% flying fish meal (FFM), Treatment B (10%MSF+15%KCF+15%GSF), Treatment C (15%MSF+15%KCF+10%GSF), and Treatment D (15%MSF+10%KCF+15%GSF). The findings showed that the Total Hemocyte Count (THC) of bamboo lobsters (*Panulirus versicolor*) was highest in treatment A (1.19×10^6 cells/ml), while the lowest was in treatment B (1.09×10^6 cells/ml). The highest Differential Hemocyte Count (DHC) of hyaline cells was in treatment C (49.5%), while the lowest was in treatment D (44.9%), was obtained in treatment A (17.7%), while the lowest was in treatment B (16.8%). The highest number of granular cells were in treatment D (34.7%), while the lowest was in treatment C (33%). Feeding with treatment B provided the best total and differentiation of coun hemocytes in bamboo lobsters reared in controlled containers.

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Keywords | Bamboo lobster, Growth, Kepah clam flour, Mangrove snail flour, Mas snail flour, Differential hemocyte count (DHC), Total hemocyte count (THC)



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Introduction

Sea lobster is an organism with high economic value, both internationally and locally. This lobster has

relatively high monetary value; besides its delicious taste, it is also rich in health benefits. One example of the benefits of eating lobster is maintaining brain health (Addison and Bannister, 1994). According to

data from the Ministry of Maritime Affairs, the export volume of Indonesian sea lobsters in 2020 was 2.022 tons or 4.21 percent of the world export market. The bamboo lobster (*Panulirus versicolor*) is a sea lobster that lives in coral reef areas and prefers coral reefs in relatively shallow areas. Bamboo lobsters generally live in water depths of 1-8 m. Bamboo lobsters are usually called ornate spiny (spiny lobsters) and have green bodies with yellow stripes (Booth and Tarring, 1986).

The status of the sea lobster business in Indonesia, including in Southeast Sulawesi, is still limited to natural exploitation, so the technology developed is only limited to techniques for exploiting and storing caught lobsters. Efforts to temporarily shelter bamboo lobsters in Southeast Sulawesi have been carried out for a long time in several coastal villages in Indonesia. The mastery of handling technology during temporary storage whether in containers at sea or storage tanks on land is crucial, as it directly influences the quality and quantity of live shrimp destined for the market. Fishermen typically gather and store their daily catch until they accumulate sufficient quantities for sale. Proper handling and storage practices ensure the shrimp remain healthy and maintain their value, ultimately supporting both the productivity and profitability of the fishermen's efforts. Entrepreneurs who buy from fishermen will also collect lobsters in holding tanks until the quantity is suitable and profitable for sale or export.

One factor that must be considered is feed management (Phillips and Booth, 1994). The nutrient composition, ratio and frequency of feeding during the temporary shelter period differ from that in cultivation conditions where the main objective is growth (Aiken and Waddy, 1995). Food for lobsters is intended not only as a source of energy for limited movement but also to maintain weight and survival (Lipcius *et al.*, 1997). Excessive feed can have undesirable impacts, such as rapidly decreasing water quality, shrimp experiencing cannibalism and lowering prices (Kittaka and Booth, 2000), and operational costs increasing sharply (Naylor *et al.*, 2000).

Feed plays a vital role in the cultivation of aquatic organisms, including lobsters. In lobster-producing regions of Indonesia, local farmers commonly utilize natural and readily available feed sources such as papaya leaves, coconut meat, and trash fish.

These feed options not only support the growth and development of lobsters but also help minimize production costs, making them a sustainable and economical choice for cultivation (Makasangkil *et al.*, 2017). The reasons given by lobster farmers are that it has become a habit, is cheap, easy to obtain, and is liked by the lobsters themselves. However, these feeds will not always be available, and their nutritional content cannot be adjusted to suit the lobster's needs (Jones, 2009). Because of this, artificial feed is made to replace fresh feed. Artificial feed is made from a mixture of various kinds of feed raw materials, both vegetable and animal (Vijayakumaran *et al.*, 2009). Protein is an essential nutrient in feed (Jones, 2010). This is due to many things, including protein having the most significant percentage of feed ingredients, around 20-60% (Devani and Basriati, 2015).

The primary source of protein in artificial feed is fish meal. However, obtaining a good quality and cheap fish meal is increasingly challenging. So, other raw animal materials are needed to replace the presence of fish meal in feed ingredients. Several local ingredients can be used as alternative raw materials as a substitute for fish meal, one of which is mollusca flour, such as mangrove snails, kepah clams and golden snails. The mangrove snail (*Telescopium telescopium*) is easy to find. The price of this snail on the market ranges from Rp20.000-Rp 30.000/Litre. This mangrove snail contains 12.60% more protein than free-range chicken eggs, which contain only 10.8% protein. The fat content of this snail is 0.27%, and carbohydrates are 13.45% (Sihite *et al.*, 2020).

The kepah clam (*Polymesoda erosa*) is a type of bivalve mollusca that can accumulate heavy metals in water. This shellfish lives in coastal areas, and it is a benthic organism. Kepah clams have high nutrition. Protein reaches 7.06-16.87%, fat reaches 0.40-2.47%, and carbohydrates 2.36-4.95% (Safitri *et al.*, 2023). Golden snails (*Pomacea canaliculata*) are a type of Mollusca pest for farmers because they damage rice. Golden snails are often used as an alternative to fish meal in making feed because they are pests, abundant in number, and easy to find in swamps and ponds. Golden snail protein content reaches 11.16%, fat 0.54%, and 2% carbohydrates (Saputra *et al.*, 2018).

The nutritional content of the feed that will be given to lobsters greatly influences their hemolymph (Dunham, 2012; Southgate, 2012). Fibre is one of the

feed ingredients that has a significant role in forming lobster hemolymph (Silva *et al.*, 2012). High fibre in feed will increase the mobilization of hemocytes in the lobster's body to increase immunity and recognize foreign objects or pathogens that enter the lobster's body. So, it is essential to research to determine the effect of feed with a combination of three mollusca flours on Total Hemocyte Count (THC) and Differential Hemocyte Count (DHC) in bamboo lobsters.

Materials and Methods

This research was carried out for six months, from August to December 2023. Lobster rearing occurs at the Fisheries Cultivation, Hatchery and Production Laboratory, Faculty of Fisheries and Marine Sciences, Halu Oleo University, Kendari. Feed proximate content analysis was carried out at PT. Saraswanti Indo Genetech (PT. SIG), Bogor and water quality analysis were conducted at the Aquatic Productivity and Environment Laboratory, Faculty of Fisheries and Marine Sciences, Halu Oleo University, Kendari.

Container preparation

The maintenance container is an aquarium measuring 60 x 50 x 40 cm³. There were 12 aquariums used, each aquarium containing three lobsters with four treatments and three groups. The aquarium is cleaned first to avoid contamination by microorganisms, pathogens and dangerous chemicals that could affect the research. The aquarium is then filled with 40 cm of seawater and left for 24 hours with circulation and aeration for acclimatization.

Test feed

The percentage of raw feed materials used in this research has been regulated in composition, is given in Table 1.

Preparation of test animals

The test animals used were male and female bamboo lobsters weighing 140-230 g. The test animals came from Tapulaga Village, Soropia District, Konawe Regency, Southeast Sulawesi Province. Test animals have different sizes. The test animals were weighed one by one and grouped into three groups based on their weight, and two animals were added to each aquarium, group 1 ranging between 140-170 g; group 2 ranged from 171-200 g; and group 3 ranged from 201-230 g.

Table 1: Feed formulation.

Raw material	Treatment			
	A	B	C	D
Tembang fish meal	20	0	0	0
Flying fish meal	20	0	0	0
Mangrove snail flour	0	10	15	15
Kepah scallop flour	0	15	10	15
Mas snail flour	0	15	15	10
Shrimp head flour	15	15	15	15
Soybean flour	25	25	25	25
Cornstarch	9	9	9	9
Dedek flour	5	5	5	5
Sago flour	4	4	4	4
Corn oil	0,5	0,5	0,5	0,5
Fish oil	0,5	0,5	0,5	0,5
Squid oil	0,5	0,5	0,5	0,5
Top mix	0,5	0,5	0,5	0,5
Total	100	100	100	100

Maintenance stage

Bamboo lobster rearing was carried out for 50 days in 12 aquariums, and each aquarium contained two lobsters to avoid overcrowding. During maintenance, siphoning is carried out in the morning to clean faeces and food residue, which disrupts water quality during the maintenance period. Feed is given at 2% of body weight, done twice daily, namely at 09.00 WITA and 14.00 WITA, with a presentation of 1% per hour each. The feed given is commercial in the form of a combination of 3 types of mollusca flour. Water changes in the aquarium occur once every five days during maintenance, which is carried out by reducing the water in the aquarium by 30%.

Hemolymph retrieval

Before taking the hemolymph, the weight of the lobster from which the hemolymph will be taken is first weighed. Hemolymph was collected from the fifth leg of the lobster with a 1 ml syringe. The hemolymph of 2 lobster tails was taken for each group as a sample of 0.1 ml of hemolymph was taken from each lobster sample and mixed with 0.1 ml of anticoagulant (Abdi *et al.*, 2022). Hemolymph collection was carried out three times, namely on days 0.25 and day 50.

Total hemocyte count observation

THC was observed by dripping the hemolymph taken into the hemocytometer and counting the number of cells in the hemocytometer sections A, B, C, and D under a microscope with 100 times magnification.

Differential hemocyte count observation

Differential hemocyte count observations were carried out by dripping the hemolymph onto a glass slide, making a scratch, drying it in air, and then fixing the Preparation using methanol for 15 minutes. After fixation using methanol, the Preparation was soaked in gym solution for 10 minutes, washed with fresh water, left to dry, and observed using a microscope with a magnification of 4×0.10 (Abdi *et al.*, 2022).

Research design

The design of this research was a Randomized Block Design (RDB) with four treatments and three groups. Grouping is done based on the body weight of each lobster. The treatment is as follows:

- Treatment A: 20%TFM+20%FFM
- Treatment B: 10%MSF+15%KCF+15%GSF
- Treatment C: 15% MSF+15%KCF+10%GSF
- Treatment D: 15% MSF+10%KCF+15%GSF

The layout used in the research can be seen in Figure 1.

A1	C1	D1	B1
C2	B2	A2	D2
D3	A3	B3	C3

Figure 1: Research lay out plan.

Research variable

Total Hemocyte Count (THC) was observed three times (Jussila *et al.*, 1997), calculated using the formula as follows:

$$THC = \sum \text{blood cells} \frac{1}{\text{Box Volume}} \times \text{Dilution Factor}$$

Differential Hemocyte Count (DHC) was observed three times during the study (Martin and Graves, 1985), using the formula as follows:

$$DHC = \frac{\text{Hemocyte Cell Count}}{\text{Total Hemocytes}} \times 100\%$$

Absolute growth is the difference between the organism's body weight at the end of the study and

the body weight at the beginning. Absolute growth can be calculated using a formula:

$$Wm = Wt - Wo$$

Wm= Absolute growth (g); Wt= body weight at the End of the study (g); Wo= initial body weight of research (g).

During water quality maintenance, temperature was observed every day, pH was at the beginning, middle, and end of the study, and DO was observed at the beginning and end of the study.

Data analysis

Data on Total Hemocyte Count (THC), Differential Hemocyte Count (DHC), and Absolute Growth (PM) will be analyzed using analysis of variance with the help of the SPSS version 22 program. Water quality data will be analyzed descriptively.

Results and Discussion

Total hemocyte count (THC)

The results of the THC for bamboo lobsters during the study can be seen in Figure 2. In Figure 2, it can be seen that the bamboo lobster THC was highest in the first acclimatized lobster, namely 1.31×10^6 cells/ml, followed by treatment C on days 25 and 50, namely 1×10^6 cells/ml, and finally treatment B on day 25, namely 0.99×10^6 cells/ml. Analysis of variance showed that giving different feeds had no significantly different effect on the THC of bamboo lobsters (Sig= 0.775). Total Hemocyte Count (THC) is one parameter used to measure crustaceans' stress levels. This THC is influenced by gender, moulting, reproductive status, nutrition, size, sex, and body weight (Sari *et al.*, 2012). The results of the 50-day study showed that on day 0, the total lobster hemocytes were the highest compared to other days, namely 1.31×10^6 cells/ml. This was thought to be due to the transfer of lobsters from nature to smaller containers so that the lobsters were still stressed.

The increase in THC at the start of the study was a response to environmental changes (Leland *et al.*, 2013). On the 25th day, the lobster's THC began to decrease. This condition shows that the kept lobsters can adapt to their new environment. This aligns with previous research that lobsters will adjust to the new environment on the 14th day after being moved to

the new environment (Aprilia *et al.*, 2023). On the 50th day, the lobster's THC increased again, but the increase in THC on the 50th day did not exceed the THC obtained on day 0. This is in line with research conducted by (Putri *et al.*, 2013), which states that the increase in the number of hemocytes is an immune response in the lobster's body. The THC of lobsters from day 0 to day 50 is still far from the normal range, namely around $8.4\text{--}32.36 \times 10^6$ cells/ml. This is thought to be because lobsters experience stress due to being kept in limited spaces and large rearing containers. It is too transparent, so feed consumption decreases, and as a result, the lobster uses up the energy reserves in its body. This aligns with previous research, namely, even a decrease in the number of homocytes (Verghese *et al.*, 2007). Previous research stated that lobsters kept in transparent containers are more stressed than those kept in coloured containers (Lesmana and Mumpuni, 2021).

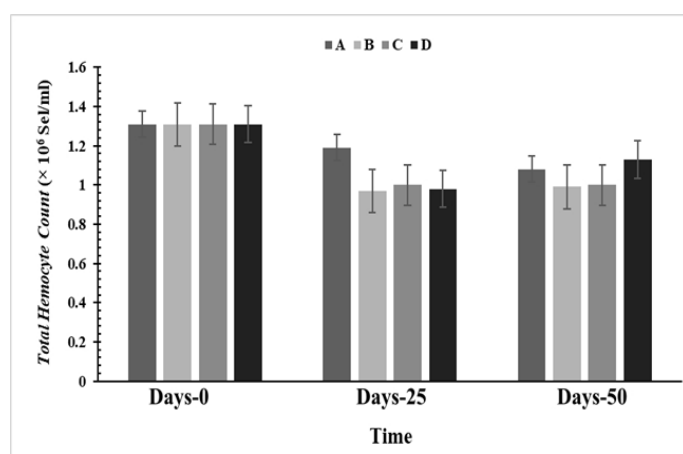


Figure 2: Bamboo lobster THC, Treatment A (20%TFM + 20%FFM), Treatment B(10%MSF + 15%KCF + 15%GSF), Treatment C(15% MSF + 15%KCF + 10%GSF), Treatment D(15% MSF + 10%KCF + 15%GSF).

The THC obtained in treatment A was 1.31×10^6 cells/ml, treatment B was 0.99×10^6 cells/ml, treatment C was 1×10^6 cells/ml, and treatment D was 1.13×10^6 cells/ml. The highest THC was obtained in treatment A, and the lowest THC was obtained in treatment B, allegedly because the protein content in feed A contained the highest protein, namely 38.52%, while in treatment B, it was only 33.76%. Feed with the highest protein produces the highest total hemocytes, while feed with low protein produces the lowest total hemocytes. However, a high number of hemocytes does not guarantee the health of the lobster (Haryanti *et al.*, 2017). The THC value obtained is not within the normal range. This indicates that the organism's condition is deteriorating (Jussila *et al.*, 1997). This

low hemocyte is thought to be because the lobster cannot adapt to the new environment.

Differential hemocyte count (DHC)

The results of the DHC for bamboo lobster research can be seen in Figure 3. Figure 3 shows that the highest number of hyaline cells were found in treatment C on day 25, 52.3%, followed by all treatments on day 0, 49.9%, and finally, treatment D on day 50, 37.7%. Analysis of variance showed that giving different feeds had no significant effect on hyaline cells (Sig=0,169>0,05).

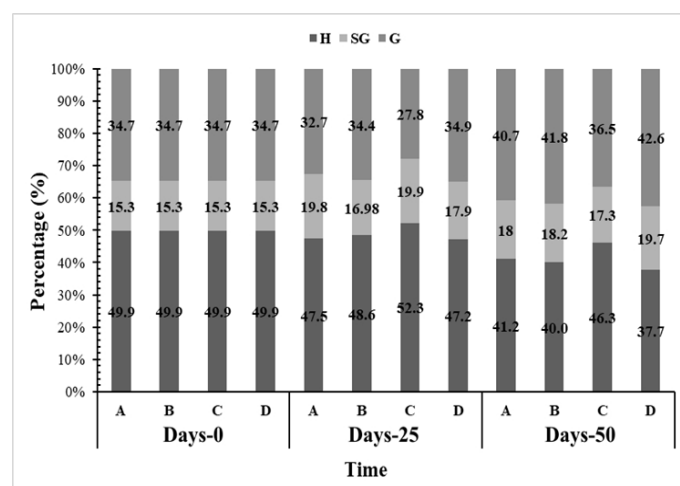


Figure 3: DHC bamboo lobster, Treatment A (20%TFM + 20%FFM), Treatment B(10%MSF + 15%KCF + 15%GSF), Treatment C(15% MSF + 15%KCF + 10%GSF), Treatment D(15% MSF + 10%KCF + 15%GSF).

The highest semi-granular cells were obtained in treatment C day 25, 19.9%, treatment A day 25, 19.8%, and finally, treatment D day 50, 15.9%. Analysis of variance showed that providing different feeds had no significant effect on hyaline cells (Sig=0,927>0,05). The highest granular cells were found in treatment D day 50, namely 47.3%, followed by treatment A day 50, 40.9%, and finally treatment C day 25, 24.2%. Analysis of variance showed that giving different feeds had no significant effect on hyaline cells (Sig=0,305>0,05).

Differential Hemocyte Count (DHC) is a presentation of hemocyte cell types. Hemocyte cells consist of three kinds, namely hyaline cells, semi-granular cells, and granular cells. Each type of hemocyte cell has a different role in the crustacean body's defence system. Hyaline and granular cells play an essential role in the phagocytosis process. While semi-granular cells play a less familiar role in the phagocytosis process, these cells play a more critical role in the encapsulation process,

indicating the combination of several hemocyte cells to block foreign particles in blood circulation (Ardiansyah *et al.*, 2023). Apart from having different functions, the three hemocyte cells above also have other shapes. Hyaline cells have an irregular shape and have a large nucleus surrounded by a thin layer of cytoplasm. The granules in hyaline cells are relatively few, so they are small when viewed with a microscope. Semi-granular cells also have an irregular shape. They typically display many dense electron granules. Lastly are granular cells, which are round or oval in shape and are characterized by dense granules, large, lacking structure, and covered by an electron membrane. These granules are more prominent than hyaline and semi-granular cells, occupying more than 50% of the cytoplasmic space.

Based on observations made for 50 days. The highest DHC was hyaline cells, 52.3%; granular cells, 42.6%; and semi-granular cells, 19.9%. An increased percentage of certain types of hemocytes is due to induced cellular proliferation, recruitment of cells from non-circulating hemolymph compartments, and rapid cellular differentiation in response to antigenic challenges (Aladaileh *et al.*, 2007). From Figure 3, it can be seen that the percentage of hyaline cells from day 0 to day 50 fluctuates. The percentage of hyaline cells ranges from $40.0 \pm 52.3\%$. This percentage is still below the normal range. The rate of normal hyaline cells ranges between 50-93% (Darwanti and Sidik, 2016). The high level of hyaline cells compared to other cells is thought to be because the lobster is experiencing stress, so the cells that play a role in the phagocytosis process are high. The high percentage of hyaline cells is caused by phagocytosis in the crustacean body to ward off pathogens.

The percentage of granular cells obtained exceeds normal limits. The percentage of normal granular cells in crustaceans ranges between 17-40% (Darwanti and Sidik, 2016). The high rate of granular cells compared to semi-granular cells is thought to be due to the formation of a new exoskeleton so that the phenoloxidase process occurs as a defence activity. The high level of granular cells indicating a high immune response correlates with higher phenoloxidase activity, causing a respiratory explosion 24-48 hours after moulting (Liu *et al.*, 2004). Furthermore, from Figure 3, it can be seen that the granular cells obtained are still within the normal range. The percentage of normal semi-granular cells is 13-49% (Johansson *et*

al., 2000). This type of cell is the type of cell with the lowest percentage obtained. This is thought to be because when lobsters experience stress, hyaline cells play the most role. Hyaline cells are the type of cells that play the most role when a pathogen attacks them, which prevents these cells from developing into semi-granular cells.

Absolute growth

The results of the average absolute growth of bamboo lobsters during the study can be seen in Figure 4. In Figure 4, it can be seen that the highest absolute growth was obtained in treatment C, namely 5.67 ± 14.86 g, followed by treatment B at 9.21 ± 13.67 g, then treatment D was 3.73 ± 10.22 g, finally, treatment A was 1.74 ± 1.62 g. Analysis of variance showed that giving different feeds did not significantly differ in the absolute growth of bamboo lobsters (Sig. = 0,149 > 0,05). Absolute growth is the increase in body weight and length of an organism. Every organism will continue to grow throughout its life. Growth can be supported by several factors, one of which is feed. Providing food with sufficient nutrition will accelerate the growth rate of an organism (Ririhena and Palinussa, 2021).

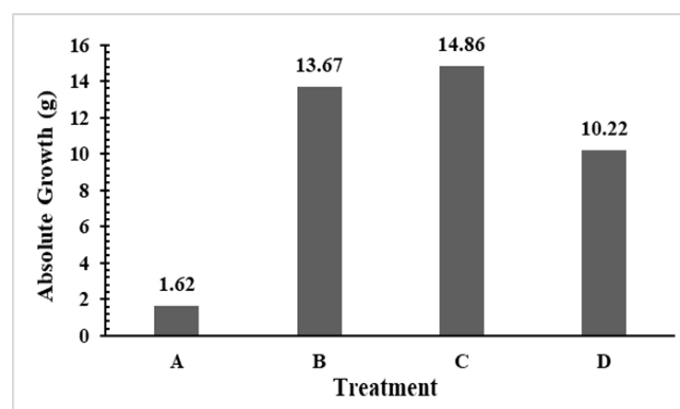


Figure 4: Absolute growth of bamboo lobster, treatment A (20%TFM + 20%FFM), treatment B(10%MSF + 15%KCF + 15%GSF), treatment C(15% MSF + 15%KCF + 10%GSF), treatment D(15% MSF + 10%KCF + 15%GSF).

The absolute growth of treatment A was 1.74 ± 1.62 g, treatment B was 9.21 ± 13.67 g, treatment C was 5.67 ± 14.86 g, and treatment D was 3.73 ± 10.22 g. Statistical analysis showed that the absolute growth of the four treatments showed no significantly different effects. This was thought to be because the protein from the four feeds provided was by the lobster's needs. This statement is strengthened (Ikhsan *et al.*, 2019) by stating that lobster protein requirements range from 23-57%. The height and low growth experienced by

freshwater lobsters are influenced by the absorption of energy from feed, so metabolic processes in the body take place quickly, allowing the number of cells and body tissues to increase (Faiz *et al.*, 2021).

The highest growth was obtained on feed made from shellfish. This is thought to be because lobsters can make maximum use of the protein in feed made from shellfish. Using shellfish as feed ingredients can meet the nutritional needs of lobsters and produce high growth (Makasangkil *et al.*, 2017). Meanwhile, previous research found that the best lobster growth was made by feed with a mixture of 20% mangrove snail flour +2% traditional coconut oil +2 % fish oil +20% fish meal 4.34 g (Haikal *et al.*, 2017).

Water quality

Several water quality parameters are measured during maintenance, as shown in Table 2. Water quality is a significant factor in supporting the life of lobsters during the rearing period. Water quality is one of the parameters that can help the life of kept lobsters. Based on Table 2, it can be seen that the results of water quality measurements consisting of temperature (°C), salinity (ppt), pH value, and DO (mg/L) are still in the optimal range for lobster rearing. Water quality is essential in lobster cultivation because the conditions of the rearing media will significantly affect the organisms that will be reared (Lesmana and Mumpuni, 2021).

Table 2: Water quality parameter measurement.

Parameters	Measurement	Optimum value results
Temperature (°C)	24-26	25-32 °C (Prana and Kurniaji, 2022)
Salinity (ppt)	36	32-36 ppt (Giri <i>et al.</i> , 2019)
pH value	7	7-8,5 (Kittaka and Booth, 2000)
DO (mg/L)	4.9-5.9	>3mg/L (Aiken and Waddy, 1995)

The temperature obtained during the research ranged from 24-26°C, still considered the optimal value for lobster cultivation. The optimum temperature for cultivating lobsters is 25-32°C (Prana and Kurniaji, 2022). Temperatures too high can increase stress and even death in fish (Simanjuntak and Pramana, 2013). Meanwhile, temperatures that are too low can affect the organism's ability to bind oxygen, thereby hampering its growth. The salinity obtained during rearing was 36 ppt, which is still within the optimal

salinity range for lobster cultivation. The optimal salinity for lobster cultivation ranges from 32-36 ppt (Giri *et al.*, 2019).

The pH value obtained during 50 days of rearing is 7, which is considered optimal for maintaining lobsters. The optimal pH value for lobster cultivation ranges from 7 to 8.5. The pH value of the water used for cultivation is significant because it will affect the dissolved oxygen content of the cultivation medium (Lestari and Dewantoro, 2018). Dissolved oxygen levels during the rearing period ranged from 4.9-5.9 mg/L. This value is still within the optimal value range for lobster cultivation. The optimal dissolved oxygen level for lobster cultivation is >3 mg/L (Amrillah *et al.*, 2022).

Conclusions and Recommendations

Based on the research results and discussion, it can be concluded that (1) the combination of three mollusc meat meals, namely mangrove snails, kepah clams, and golden snails in feed does not have a significantly different effect on THC, hyaline DHC, semi-granular DHC, granular DHC, and absolute growth of bamboo lobsters, (2) combination of 20 % flying fish meal + 20% tembang fish meal gave the highest total hemocytes in rearing bamboo lobsters, while the combination of 10% mangrove snail flour + 15% kepah mussel flour + 15% golden snail flour, gave the absolute best growth in rearing bamboo lobsters in a container controlled.

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Novelty Statement

This study provides novelty in understanding the cellular immune response of bamboo lobster (*Panulirus versicolor*) to various feeding treatments in a controlled culture system. The results showed that the highest THC was achieved in treatment A (1.19×10^6 cells/ml), while the lowest was in treatment B (1.09×10^6 cells/ml). In addition, the distribution of DHC revealed that the highest hyaline cells were found in treatment C (49.5%) and the lowest in

treatment D (44.9%). The highest semi-granular cells were found in treatment A (17.7%) and the weakest in treatment B (16.8%), while the highest granular cells were found in treatment D (34.7%) and the lowest in treatment C (33%). The main novelty of this study is the discovery that feeding in treatment B resulted in optimal total and differentiation of hemocytes, providing new insights into the immunomodulation approach through nutrition in bamboo lobster under controlled culture conditions. These findings can be the basis for developing feeding strategies to improve lobster health and endurance in aquaculture systems.

Author's Contribution

Wellem H. Muskita: Designing the research and methodology, Leading discussions and team meetings, Supervising the research process, and being Responsible for the Preparation and final editing of the article.

Agus Kurnia: Collecting bamboo lobster (*Panulirus versicolor*) specimens, determining the type of mollusca meat meals that will be used, and supervising the treatment of specimens during the research.

Muhaimin Hamzah: Perform hemocyte counts on lobsters, analyze data related to hemocyte count differentiation and interpret laboratory results.

Khairunnisa Khairunnisa: Analyzing the nutritional content of Mollusca meat meals, supervising the feeding process of specimens, and collecting data related to lobster growth and health.

La Ode Muh. Munadi: Designing statistical methods for data analysis, carrying out statistical analysis of the data collected, and compiling the results of the study in a form that is easy to understand.

Achmad Selamet Aku: Carrying out observations and recording data in the field, Collecting relevant environmental data (for example, temperature, water pH), and Compiling daily/weekly reports on research progress in the field.

La Ode Sahaba: Assisted in drafting articles, editing and editing writing to ensure clarity and consistency, and was responsible for references and citations in articles.

Conflict of interest

The authors have declared no conflict of interest.

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