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Growth of Bamboo Lobster (*Panulirus versicolor*; Latreille, 1804) Fed with Feed Made from Sosodek Fish Meal (*Atherinomorus lacunosus*)

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Abstract: Bamboo lobster (*Panulirus versicolor*) is a marine commodity with promising prospects for aquaculture development. Feed is a critical issue in the growth of *P. versicolor*, necessitating an effective, affordable solution that promotes optimal growth. This study aimed to examine the use of sosodek fish meal (*A. lacunasus*) as a nutrient source to enhance the growth of *P. versicolor*. Specimens of *P. versicolor* (weighing 79.97±38 g) were obtained from local fishermen in Togean District, Tojo Una-Una Regency, Central Sulawesi. The experiment tested the use of sosodek fish meal as a feed ingredient at different percentages: 0% (control), 10% (A), 20% (B), and 30% (C). The lobsters were kept in containers with 25 liters of seawater, with one lobster per container, and each treatment was replicated three times. Feed was given at 5% of body weight, three times daily. Body weight was measured every two weeks. Water quality was maintained within a range suitable for *P. versicolor*. The results indicated that weight gain and daily growth rates, from highest to lowest, were observed in treatment C (11.84 g and 0.49%/day), B (7.4 g and 0.21%/day), A (2.82 g and 0.09%/day), and control (2.38 g and 0.08%/day). Feed conversion ratios, from lowest to highest, were recorded as C (13.1), B (25.1), A (71.9), and control (64.0). Feed utilization efficiency, from highest to lowest, was seen in treatment C (10.28%), B (4.32%), A (1.85%), and control (1.72%). Survival rates for all treatments were 100%. The analysis showed that individual weight gain, daily growth rates, and feed utilization efficiency were significantly higher, and feed conversion ratios were lower in treatment C (30% sosodek fish meal) compared to other treatments ($P<0.05$). Utilizing 30% sosodek fish meal as feed ingredient significantly enhances the growth of *P. versicolor*.

Keywords: *A. lacunasus*, feed, feed efficiency, growth, *Panulirus versicolor*, survival rate.

Introduction

Bamboo lobster (*Panulirus versicolor*) is one of the species from the genus Panulirus that is widely favored by the public (Iqbal *et al*., 2024; Lastria *et al*., 2023; Matakupan *et al*., 2021; Yusuf *et al*., 2018). The demand for lobster, including *P. versicolor*, is increasing with prices that are quite high depending on the size and market (Ongkers *et al*., 2014; Vijayakumaran *et al*., 2019). The larger the lobster, the higher the selling price, and vice versa. However, currently, lobsters with a size >250 grams per individual are increasingly

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difficult to find in the waters and are generally only ≤250 grams per individual (Lastria *et al*., 2023). This condition directly affects the income of fishermen. Therefore, the practice of growing lobsters to market size is one effort that can be undertaken to increase fishermen's income. However, the suitability of the feed provided is still a problem in lobster farming (Apriliani *et al*., 2021; Hai & Speelman 2020; Jones, 2018; Nankervis & Jones, 2022).

In general, lobster farming still relies on fresh natural feed such as trash fish (Doddy *et al*., 2019), squid, clam meat, and marine worms (Pane *et al*., 2021; Wijaya *et al*., 2018). The use of fresh feed in lobster farming generally has several drawbacks, including relatively high cost, unreliable continuity, and a tendency to degrade water quality quickly (Makasangkil *et al*., 2017). One solution to these problems is to use artificial feed made from non-economical raw materials that still meet the nutritional needs of lobsters.

Sosodek fish (*Atherinomorus lacunosus*) is one of the non-economical fish (Rp. 2,000 - 3,000/kg), and it is generally only used by the community as fishing bait (Asrial *et al*., 2016, 2017). However, based on the results of a proximate analysis from preliminary research, sosodek fish meal contains high nutrients: protein (55.67%), carbohydrates (13.59%), fat (4.89%), and ash (12.43%), with a moisture content of 11.75%. The high nutrient content of sosodek fish meal has the potential to replace the commonly used economical fish meal in bamboo lobster (*P. versicolor*) feed. Additionally, the high ash content of sosodek fish meal is suspected to be a potential source of minerals to support lobster growth. Lobsters require minerals for the maintenance of colloid systems, acid-base balance, and the formation of their shells. This is evident from the hard shell of lobsters, which is composed of minerals. Moreover, the body of lobsters has been detected to contain a significant amount of minerals (Kommuri *et al*., 2021). Therefore, this study aims to assess the utilization of sosodek fish meal as a nutrient source to enhance the growth of bamboo lobster (*P. versicolor*).

Method

Test Organism Preparation

The bamboo lobster seeds (*P. versicolor*) used in this study had an average weight of 79.97±38 g. These seeds were sourced from local fishermen in Togean District, Tojo Una-Una Regency, Central Sulawesi. The test organisms were transported to the Mini Nutrition Laboratory, Aquaculture Study Program, Tadulako University, by speedboat for 12 hours and by car for 13 hours. A total of 30 lobsters were transported in plastic containers measuring 100 cm x 50 cm x 50 cm, each containing 100 liters of water. The containers were equipped with an aeration system and shelters made from 2-inch PVC pipes, corresponding to the number of lobsters. Water changes of 50% were performed every six hours during transportation. Upon arrival at the laboratory, the lobsters were transferred to recovery containers with a volume of 250 liters, filled with 150 liters of water. The water quality, shelters, and oxygen supply were designed to match the conditions during transport. The lobsters were kept in these containers for seven days. During the recovery period, they were fed fresh trash fish.

Formulation and Manufacturing of Test Feed

Table 1. Formulation and nutrient composition of test feed

Feed Ingredients	Sosodek Fish Meal Treatment (g/100)			
	Control (0%)	A (10%)	B (20%)	C (30%)
Fish Meal	40.00	30.00	20.00	10.00
Sosodek Fish Meal	0.00	10.00	20.00	30.00
Soybean Meal	33.00	30.00	27.00	23.00
Rice Bran	6.00	8.00	10.00	11.00
Corn Meal	5.50	6.50	7.50	10.50
Vegetable Oil	2.50	2.50	2.50	2.50
Fish Oil	2.50	2.50	2.50	2.50
Tapioca Flour	8.00	8.00	8.00	8.00
Vitamin & Mineral Mix	2.50	2.50	2.50	2.50
Total	100.00	100.00	100.00	100.00
Target GE (kcal/kg)	4336.02	4331.55	4327.08	4326.07
C/P	11.40	11.37	11.34	11.37
Nutrient content of test feed (%)				
Protein	39.01	38.73	38.61	38.55
Fat	19.32	17.73	19.32	10.72
NFE (Nitrogen-Free Extract)	4.75	3.30	4.32	2.48
Ash	10.38	15.21	20.14	25.40
Crude Fiber	9.44	7.62	7.18	7.40
Moisture	17.15	17.41	17.41	15.45

The feed was formulated from several raw materials, including commonly used commercial fish meal (Table 1). The use of commercial fish meal decreased with the increasing dosage of sosodek fish meal as an animal protein source in the feed. The tested dosages of sosodek fish meal were 0% (control), 10% (A), 20% (B), and 30% (C) per kilogram of feed. The target protein content was 38%, with an energy content of approximately 4300 kcal. Feed preparation began with weighing each raw material according to the formulated recipe (Ma *et al*., 2021; White *et al*., 2018). The weighed ingredients were then mixed together until homogeneous (Safir, 2018). After thorough mixing, the mixture was steamed at 60 °C for 15

minutes. The steamed mixture was then formed into pellets and dried in an oven at 80 °C until the moisture content was around 16-17%. Once dried, the feed was subjected to proximate analysis to confirm the nutrient content of the treated feed.

Container preparation and fish maintenance

The study was designed using a closed recirculation system. Each container (with a volume of 45 L) was equipped with one shelter made of 2-inch PVC pipe measuring 30 cm in length, serving as a hiding place for the test organisms. Subsequently, each container was filled with seawater with a salinity of 30 ppt, totaling 25 L, and labeled according to the treatment. Bamboo lobsters (*P. versicolor*) as the test organisms were then introduced, with one specimen per container, to acclimatize to both the holding containers and the treatment feed for a period of 3 days. After the acclimation period, the test organisms were weighed, and their weights were recorded from each container.

Bamboo lobsters (*P. versicolor*) were maintained for six weeks. Treatment feed was provided at a rate of 5% per day, administered three times daily until the end of the maintenance period (Syafrizal *et al*., 2018). Monitoring of body weight gain was conducted every two weeks. Water quality was maintained within suitable ranges for the maintenance of bamboo lobsters (*P. versicolor*) by periodic control measures, including siphoning off excess feed and water exchange both before and after feeding. Water quality during maintenance included temperature (27-29°C), pH (6.9-8.1), salinity (30-33 ppt), dissolved oxygen (3.9-7.5 ppm), and ammonia (0.05-0.2 ppm).

Observation Variables and Data Analysis

The observed variables from the feeding of sosodek fish meal-based diets, including the control, on bamboo lobsters (*P. versicolor*) include individual weight gain, specific growth rate, feed conversion ratio, feed efficiency, and survival rate, calculated using equations referenced by Rathinam *et al*., 2014; Ilyas *et al*., (2018); Syafrizal *et al*., 2018; Safir *et al.,* 2022). All obtained data were analyzed using ANOVA at a confidence level of 95%. The influence of treatments on the test organisms was further tested using the Duncan test.

Result and Discussion

The growth of bamboo lobsters (*P. versicolor*), including individual weight gain and daily growth rate, varied among treatments, including the control, when fed with sosodek fish meal-based diets (Table 2). Individual weight gain in bamboo lobsters increased with the increasing use of sosodek fish meal as a substitution for sardine fish meal in the feed. Bamboo lobsters exhibited the highest individual weight gain and daily growth rate in treatment C (30% sosodek fish meal and 10% sardine fish meal), at 11.84 g and 0.49% per day, respectively. The number of molting lobsters was observed in treatments using 20% (3 individuals) and 30% (5 individuals) sosodek fish meal.

The feed conversion ratio in lobsters fed with treatment diets, including the control, ranged from low to high, as indicated in treatment C (30% sosodek fish meal; 10% sardine fish meal), B (20% sosodek fish meal; 20% sardine fish meal), A (10% sosodek fish meal; 20% sardine fish meal), and the control (40% sardine fish meal) (Table 2). Statistically, the feed conversion ratio in treatment C (30% sosodek fish meal; 10% sardine fish meal) was lower compared to other treatments ($P<0.05$), except for treatment B (20% sosodek fish meal; 20% sardine fish meal) ($P>0.05$). The feed utilization efficiency in bamboo lobsters fed with sosodek fish meal supplementation and the control ranged from 1.72% to 10.28%. The analysis results indicated that the highest feed utilization efficiency ($P<0.05$) was obtained in treatment C (30% sosodek fish meal; 10% sardine fish meal) compared to other treatments, including the control.

Table 2. Individual weight gain, daily growth rate, feed conversion ratio, feed efficiency, and survival rate of bamboo lobsters *Panulirus versicolor* fed with different doses of sosodek fish meal

Observation Variable	Feed Treatment			
	Control (0%)	A (10%)	B (20%)	C (30%)
Individual Weight Gain (g)	2.38±0.67[a]	2.82±0.89[a]	7.4±3.81[b]	11.84±3.92[b]
Speific growth rate (%/day)	0.08±0.03[a]	0.09±0.05[a]	0.21±0.08[a]	0.49±0.30[b]
Feeding Conversion Ratio	64.0±28.26[b]	71.9±46.06[b]	25.1±10.07[ab]	13.1±8.73[a]
Feed Efficiency (%)	1.72±0.60[a]	1.85±1.01[a]	4.32±1.60[a]	10.28±6.21[b]
Survival rate (%)	100±0.0[a]	100±0.0[a]	100±0.0[a]	100±0.0[a]
Number of Molting Lobsters (tail)	0	0	3	5

The results showed that individual weight gain and daily growth rate of bamboo lobsters were influenced by the level of sosodek fish meal in the diet, with higher levels resulting in greater growth. Feed conversion ratio and feed efficiency were also affected, with lower values observed in treatments with higher sosodek fish meal content. However, survival rates remained consistently high across all treatments.

The effects of different doses of sosodek fish meal on the growth performance of bamboo lobsters (P. versicolor) were investigated in the study. It was found that the growth parameters, including individual weight gain and daily growth rate, were significantly influenced by the dietary treatments.

Enhanced growth performance in bamboo lobsters was observed with the increasing percentage of sosodek fish meal in the diet. Specifically, the highest individual weight gain and daily growth rate among all treatments were resulted from treatment C, which consisted of 30% sosodek fish meal and 10% sardine fish meal. It was suggested by the study that sosodek fish meal can be a valuable dietary component for promoting the growth of bamboo lobsters.

Furthermore, other performance indicators such as feed conversion ratio and feed efficiency were evaluated in the study. It was noted that as the proportion of sosodek fish meal increased in the diet, there was a notable improvement in feed conversion ratio and feed efficiency. This indicates that better utilization of feed resources by bamboo lobsters can result from the inclusion of sosodek fish meal in the diet, leading to more efficient growth.

Additionally, the survival rate of bamboo lobsters remained consistently high across all dietary treatments, indicating that the overall health and survival of the organisms were not negatively impacted by the inclusion of sosodek fish meal.

Overall, it was suggested by the findings that sosodek fish meal can be a promising alternative ingredient in the diet of bamboo lobsters, offering benefits in terms of growth performance and feed utilization efficiency. Further research could focus on optimizing the inclusion levels of sosodek fish meal to maximize its benefits while ensuring the overall nutritional balance of the diet for bamboo lobsters.

The bamboo lobsters (*P. versicolor*) raised for six weeks showed an increase in weight gain with increasing doses of sosodek fish meal in the feed. It was depicted by the study that sosodek fish meal could substitute nutrients from *Sardinella* sp. fish meal, as the usage of the latter decreased. The relatively similar nutrient composition, especially protein content, of both animal feed ingredients was suspected. Based on the preliminary research analysis where sosodek fish meal contained 56.77% protein and *Sardinella* sp. fish meal contained 50.39% protein, both with a moisture content of 10%. Furthermore, the treatment with higher growth was shown at the dosage of 30% sosodek fish meal in the feed (11.84 g). The higher growth of this treatment was supported by the higher growth rate produced compared to dosages of 20%, 10%, and 0% sosodek fish meal (control), which were 233.3%, 544.4%, and 612.5%, respectively. The significant growth difference was suspected due to the amino acid profile in the feed originating from sosodek fish meal, which could alter the amino acid composition to be more balanced. A balanced amino acid profile would optimize amino acid absorption into the body (Aragão *et al*., 2004). Additionally, the higher growth in the 30% sosodek fish meal treatment was suspected to be related to the relatively high mineral content in the feed. This was reinforced by the increasing ash content in the feed with the increasing use of sosodek fish meal. The presence of high ash content indicates the presence of mineral content in the feed.

Lobsters are crustaceans that require mineral intake for maintaining colloid system and acid-base balance in the body, as well as for forming new shells during the molting process (Kommuri *et al*., 2021). When nutrients, including the required minerals, are sufficient, the molting interval of crustaceans, including lobsters, tends to be higher, and the molting process will proceed normally (Greenavvay, 1985; Lemos & Weissman, 2021). This was suspected to be applicable vice versa. This study also showed that the higher ash content in the feed with higher sosodek fish meal content indicated a higher number of molting lobsters (5 individuals). The molting of lobsters directly increases their body weight. The increased body weight with the same percentage of feed directly correlates with the resulting FCR value. The FCR in this study was relatively higher compared to that reported by some researchers such as Jayakumar *et al.* (2011), who tested several types of fresh natural feeds on *P. homarus* lobsters and obtained FCR values ranging from 8.64 to 13.88, Glencross *et al.* (2001), who tested feeds with 6% and 10% fat content with protein contents of 30%, 35%, 40%, 45%, 50%, and 55% in *P. cygnus* lobsters, resulting in FCR ranging from 2.5 to 7.6. The high FCR, especially in the 10% and control treatments, was caused by the absence of molting in the lobsters during maintenance with these treatments. This was different from the 20% and 30% sosodek fish meal addition treatments, which showed molting in the test lobsters. The obtained FCR in this study (with 30% and 20% sosodek fish meal usage) was lower (table 2) than the research results reported by Cox and Davis (2009) using dry feeds, which was 36.1. This can also be seen from

the relatively high feed efficiency compared to other treatments, including the control (table 2). The low FCR values in both treatments indicate that the absorbed protein in the feed is more used for growth than as an energy source.

The use of sosodek fish meal as a raw material for animal protein feed, including control feed, did not have a direct or indirect effect on bamboo lobsters (P. versicolor) as test organisms. The direct effect is the occurrence of death directly in lobsters, while the indirect effect is the decrease in water quality in the maintenance media. Water quality during maintenance is still within the appropriate range for the maintenance of bamboo lobsters (*P. versicolor*) (Junaidi *et al*., 2019; Slamet *et al.,* 2020, 2021; Stegeman *et al*., 2020)

Conclusion

The utilization of sosodek fish meal as a feed ingredient has an impact on the daily growth rate, individual weight gain, feed conversion ratio, feed efficiency, and survival rate in bamboo lobsters (*P. versicolor*). The highest daily growth rate, individual weight gain, feed conversion ratio, feed efficiency, and survival rate were obtained in the treatment utilizing 30% sosodek fish meal per kg of feed raw material. Recommendation: Based on these findings, it is recommended to consider incorporating sosodek fish meal at a level of 30% per kg of feed raw material to optimize the growth performance, feed utilization efficiency, and survival of bamboo lobsters. Further research could explore different inclusion levels to fine-tune the formulation and maximize the benefits while ensuring nutritional balance in the diet. Additionally, investigating the long-term effects of sosodek fish meal inclusion on the health and performance of bamboo lobsters would provide valuable insights for sustainable aquaculture practices.

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Author Contributions
M.S. led the conceptualization and methodology development. I.S.M. was responsible for data curation and formal analysis. N.S. handled the investigation and validation processes. R.A.I. worked on resources and writing – review & editing.

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Conflicts of Interest
The authors declare no conflict of interest.

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