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Effect of Feeding Commercial Diet and Its Combination with Fish Meal and Shrimp Head Meal on Growth of Eel (*Anguilla* sp.)

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ABSTRACT

The eel (*Anguilla* sp.) is one of the species that is highly marketable in the international market. Intensive aquaculture practices are essential. The aims of this study are to find out the effect of dieting comercial diet, and its combination with fish meal, shrimp head meals on growth, survival rate and feed convertion ratio (FCR) of eel (*Anguilla* sp.). This research was conducted for 60 days from March to May 2024. This study used completely randomized design (CRD). Diet tested were commercial diet, and its combination for each: treatment A (100% commercial diet), B (50% commercial diet + 50% fish meal), C (50% commercial diet + 50% shrimp waste). Variabel observed were absolute growth, specific growth rate, survival rate and feed conversion ratio. The results showed that the highest absolute growth was found in treatment B (373.33 ± 21.73 g), followed A (304.33 ± 56.76 g), and the lowest in C (256.33 ± 66.03 g). The highest specific growth rate was recorded in treatment B (0.82 ± 0.3%), followed by treatment of A (0.66 ± 0.06%) and the lowest in C (0.57 ± 0.12%). The lowest for feed conversion rasio was found on treatment B (2.67±0.93), followed by treatment of A (3.23±0.52), and the highest in C (3.77±0.52). Results of analysis of variance showed that all the treatments gave significantly difference on absolute growth, specific growth rate and feed conversion ratio (P< 0.5), and not significantly difference on survival rate (P> 0.5).

INTRODUCTION

The eel (*Anguilla* sp.) is a fish species of high economic value and an important export commodity in the fisheries sector (Budiatma, 2020). The eel (*Anguilla* sp) is one of the species that is highly marketable in the international market, particularly in Japan and South Korea. Japan is the world's largest consumer of eel, with an annual consumption of approximately 100,000 tonnes, followed by China, South Korea, the United States, and several European countries (Syahril *et al.,* 2016; Shahkar *et al.,* 2016). To meet the demand for eel exports, efforts are needed to ensure a sustainable and continuous supply through controlled aquaculture.

Aquaculture can provide a sustainable supply of fish in terms of both quality and continuity. To prevent shortages resulting from continuous fishing activities, which may disrupt the balance of wild fish populations, aquaculture development is necessary. In addition, one of the key factors contributing to the success of aquaculture is the availability of high-quality seed, while the diet provided must adequately meet the nutritional requirements of the cultured fish. The nutritional requirements of eels are highly dependent on diet availability. However, eel diet is currently imported at relatively high prices, resulting in increased production costs. The high cost of diet is one of the major economic constraints faced by eel farmers (Cholifah *et al.,* 2012). To address this issue, eel farmers often use commercial diets formulated for shrimp or eels. Another approach is to utilise waste generated by the fisheries processing industry as an alternative protein source, which is available in relatively large quantities in Kendari.

Trash fish represent an alternative raw material for diet formulation, as they are available in considerable quantities (Syamdidi *et al.,* 2016). Their utilisation is expected to provide a low-cost alternative diet ingredient for eel aquaculture. Similarly, shrimp head waste can be used as an alternative raw material for diet production. This is based on the fact that shrimp constitutes a major component of the natural diet of eels (Bouchereau *et al*., 2012; Engman *et al*., 2017). Based on the foregoing, research is needed to investigate the provision of commercial diet and its combination with fish meal and shrimp head meal, as well as their effects on the growth of eels (*Anguilla* sp.).

One potential approach is the utilisation of fisheries processing waste, particularly trash fish and shrimp head waste, as alternative feed ingredients. Trash fish can serve as an alternative protein source due to its relatively abundant availability, while shrimp head meal has considerable potential as a feed ingredient because shrimp is one of the natural dietary components of eels. The utilisation of these materials is expected to reduce dependence on commercial diets and minimise feed production costs in eel aquaculture.

Based on these considerations, this study aimed to evaluate the effects of commercial diets and their combinations with trash fish meal and shrimp head meal on the growth performance of eels (*Anguilla* sp.). The findings are expected to provide scientific information on the potential use of alternative feed ingredients as an effective and economical feeding strategy to improve eel growth performance and support the sustainability of eel aquaculture.

METHODS

Research Location and Period

This study was conducted from March to April 2024 at the Fish Hatchery Technology Laboratory, Bombana Polytechnic. Proximate analysis was carried out at the Laboratory of the Faculty of Fisheries, Halu Oleo University.

Research Materials and Equipment

Experimental Units

The experimental units used in this study were tanks measuring 1 × 1 m^2. Before use, each tank was cleaned with lime to eliminate potential sources of disease. The water was obtained from a borehole and was stored in a holding tank before being supplied to the tanks. A total of nine tanks were used in this study, operating under a recirculating aquaculture system (RAS). A pump with a capacity of 1,500 L h^{-1} was used for water recirculation. In addition, each tank was equipped with an aeration system.

Diet Preparation

The raw materials used for the experimental diets consisted of three treatments: Treatment A (100% commercial diet), Treatment B (50% commercial diet + 50% trash fish meal), and Treatment C (50% commercial diet + 50% shrimp head meal) (Saleh, 2014).

Before being processed into meal, the trash fish and shrimp heads, obtained from PT Sultra Tuna, Kendari, were steamed and drained, then sun-dried until completely dry. Once dried, the materials were ground into a fine powder. The diet ingredients corresponding to each treatment were thoroughly mixed, and warm water was added to ensure that all ingredients were evenly incorporated, forming a paste-like mixture.

Eel Acclimatisation

The eels used in this study were obtained from fishermen who caught them in the Nanga-Nanga River, Kendari, Southeast Sulawesi, Indonesia. The eels, with an average biomass of 500 g, were stocked in tanks equipped with aeration systems and acclimatised to commercial diet, trash fish meal, and shrimp head meal for two weeks. Following the acclimatisation period, the eels were weighed to determine their initial biomass at the beginning of the observation period.

Feed Method

Diet was provided directly to the eels twice daily, at 08:00 and 16:00 Central Indonesia Time (WITA), on an ad libitum basis. Uneaten diet was collected once the eels no longer responded to the diet offered. The remaining diet was then dried and weighed to calculate the diet conversion ratio (FCR).

Experimental Design

The experimental design used in this study was a completely randomised design (CRD) consisting of three treatments, each with three replicates (Saleh, 2014), as follows:

Treatment A : 100% commercial diet
Treatment B : 50% commercial diet + 50% trash fish meal
Treatment C : 50% commercial diet + 50% shrimp head meal.

Observed Parameter

Growth performance, survival, and diet utilization were evaluated using weight gain (WG), specific growth rate (SGR), diet conversion ratio (FCR), and survival rate (SR) was determined according to Kurnia *et al*., (2025); Zheng *et al.,* (2019); De Silva & Anderson (1995):

- Weight gain (WG) was calculated as the difference between the mean final and initial body weights:

$$WG = W_t - W_0$$

- Specific growth rate (SGR) was calculated using the following equation:

$$SGR = [\ln(W_t) - \ln(W_0)]/t \times 100\%$$

- Feed conversion ratio (FCR) was calculated as the ratio of diet intake to the increase in fish biomass:

$$FCR = F/(W_t - W_0)$$

- Survival rate (SR) was calculated using the following equation:

$$SR = N_t/N_0 \times 100\%$$

Data Analysis

Data on weight gain, specific growth rate, FCR, diet efficiency, survival rate, and protein retention. Statistical analysis was performed using one-way analysis of variance (ANOVA) at a 5% significance level. When the ANOVA results indicated a significant effect, further analysis was conducted using Duncan's Multiple Range Test (DMRT) to determine differences among treatment means. Statistical analyses were performed using SPSS software.

RESULTS

Results

The results of the observations recorded throughout the study are presented in Table 1**:**

Table 1. Results of Observations for Each Parameter Across Treatments

Parameter	Treatments		
	A	B	C
Weight gain (g)	304.73±56.7[ab]	373.22±21,73[a]	256.54±66.03[b]
Specific growth rate (%/day)	0.66±0.06%[ab]	0.82±0.03%[a]	0.57±0.12%[b]
Feed conversion ratio	3.23 ± 0.36[a]	2.67±0.21[a]	3.77± 0.51[b]
Survival rate (%)	80±2.31[a]	80±4.6[a]	80±2.31[a]

Note: The same superscript letters indicate no statistically significant difference, whereas different superscript letters indicate a statistically significant difference among treatments at the 95% confidence level (P < 0.05)

Weight Gain

The mean absolute growth of eels after 60 days of rearing is presented in Figure 1.

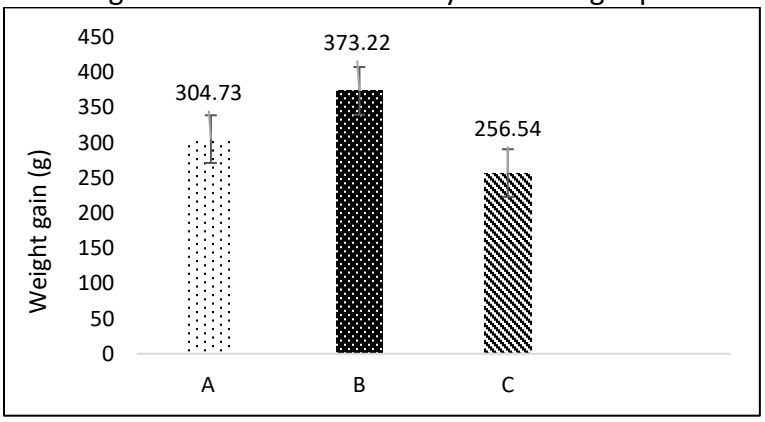


Figure 1. Mean Absolute Growth of Eels Diet A (100% Commercial Diet), Diet B (50% Commercial Diet + 50% Trash Fish Meal), and Diet C (50% Commercial Diet + 50% Shrimp Head Meal)

Specific Growth Rate

Figure 2 illustrates the mean specific growth rate (SGR) of eels observed over a 60-day rearing period.

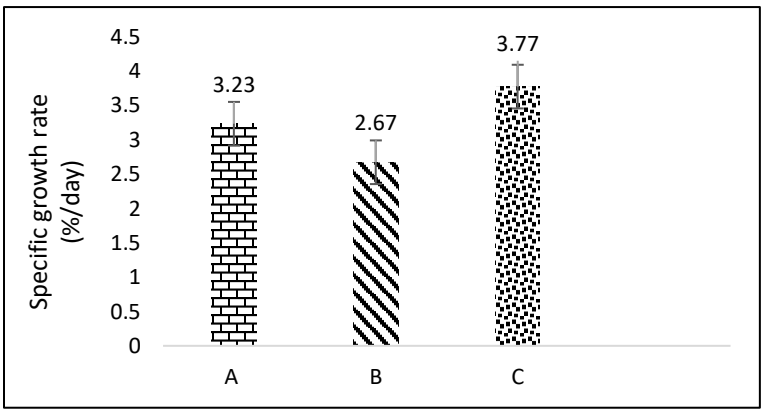


Figure 2. Mean Specific Growth Rate of Eels Diet A (100% Commercial Diet), Diet B (50% Commercial Diet + 50% Trash Fish Meal), and Diet C (50% Commercial Diet + 50% Shrimp Head Meal)

Feed Conversion Ratio

The mean feed conversion ratio of eels after 60 days of rearing is presented in Figure 3.

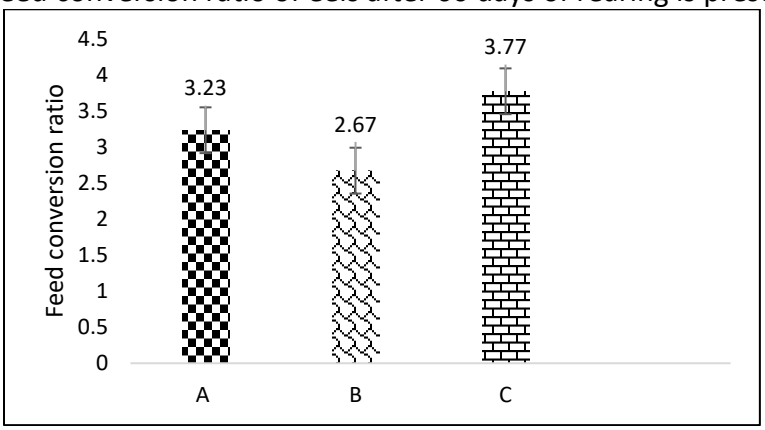


Figure 3. Mean Feed Conversion Ratio of Eels Diet A (100% Commercial Diet), Diet B (50% Commercial Diet + 50% Trash Fish Meal), and Diet C (50% Commercial Diet + 50% Shrimp Head Meal)

Survival Rate

The survival rate of eels after 60 days of rearing is presented in Figure 4.

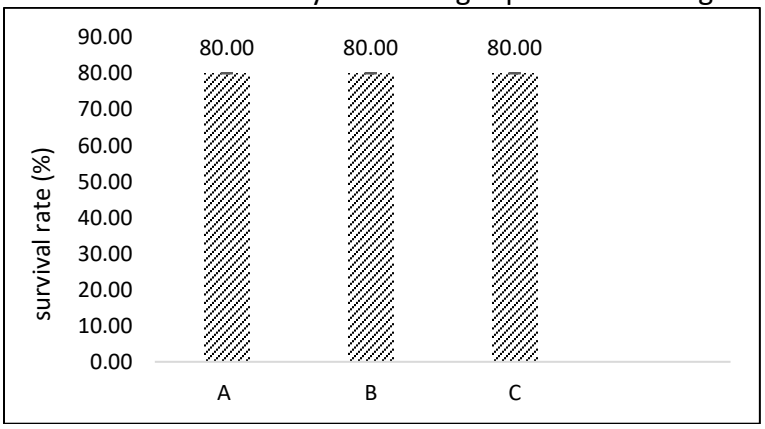


Figure 4. Mean Survival Rate of Eels Diet A (100% Commercial Diet), Diet B (50% Commercial Diet + 50% Trash Fish Meal), and Diet C (50% Commercial Diet + 50% Shrimp Head Meal)

Water Quality Parameters

The water quality parameters measured during the eel-rearing period ranged from 25–27°C for temperature, 5–7 for pH, and 7–7.4 ppm for dissolved oxygen. The results of the water quality observations are presented in Table 2.

Table 2. Results of Water Quality Parameters

Parameter	Unit	Range	Reference
Temperature	^{0}C	25-27	23-30 (Yudiarto *et al*., 2012; Subekti *et al*., 2011; Mulis, 2015)
pH	-	6-7	7-8 (Sarwono, 2008)
Dissolved oxygen	ppm	7.4	5-7 (Hanif, 2013)
Ammonia	ppm	0.0194	<0.02 (Hanif, 2013)

DISCUSSION

The mean absolute growth ranged from 256.33 ± 66.03 g to 373.33 ± 21.73 g. The results showed that eels fed Treatment B (50% commercial diet + 50% fish meal) and reared for 60 days exhibited the highest absolute growth (373.33 ± 21.73 g) The results indicated that this treatment produced higher values than the other dietary treatments, with statistically significant differences observed among treatments ($P < 0.05$). This value was higher than that reported by Saleh (2014), who found that eels reared for 60 days and fed a diet consisting of 100% shrimp achieved a growth value of 86.33 ± 11.93 g (432.4453% lower).

The highest mean absolute growth in Treatment B (50% commercial diet + 50% fish meal) may have been due to the combination of commercial diet and fish meal producing a distinctive aroma similar to that of specialised artificial eel diet from Japan, thereby increasing diet consumption. Sholeh (2004); Bounchereau *et al.* (2012); Rahayu *et al*. (2014), stated that eels in the wild can detect the presence of food using their olfactory organs, even while remaining hidden. Eels rely primarily on their sense of smell to detect food. Consequently, increased diet consumption may lead to a higher growth rate. In addition, the commercial diet contained 37% protein, while the fish meal contained 35.7128% protein, resulting in an average protein content of 36.3564%, which was higher than that of the other treatments. According to Aljabbar (2005), an adequate supply of nutrients in diet not only provides energy for fish metabolism but also meets the nutritional requirements for growth. Fish growth occurs when the amount of nutrients digested and absorbed exceeds the amount required for body maintenance.

The lowest mean absolute growth was observed in eels fed Treatment C (50% commercial diet + 50% shrimp head meal), with an absolute growth value of 256.33 ± 66.03 g. This result may have been due to lower diet consumption and the average nutrient content of the commercial diet and shrimp head meal, which was 35.18%. The lower nutrient content may have contributed to the lower absolute growth of the eels.

The specific growth rate (SGR) is used to calculate the percentage increase in fish body weight per day (Agustono *et al*., 2009). The mean specific growth rate in this study ranged from 0.57 ± 0.12%/day to 0.82 ± 0.03%/day. Eels fed Treatment B (50% commercial diet + 50% fish meal) exhibited the highest specific growth rate (0.82 ± 0.03%), which differed significantly from those receiving the other dietary treatments ($P < 0.05$).

The higher mean specific growth rate observed in this treatment may have been attributable to the aroma of the diet, which made it more attractive to the eels and allowed the diet to be utilised more efficiently for growth. This finding is consistent with Mulyana (2004), who stated that when diet consumption exceeds the amount required for body maintenance, a greater increase in body weight can occur. Furthermore, Bakeer (2006) reported that the growth of the eel (*Anguilla anguilla*) increased with increasing diet consumption.

The nutritional composition of the diet also determines eel growth. The commercial diet used in Treatment B 37% protein, while the fish meal 35.7128% protein. The combination of 50% commercial diet and 50% fish meal may have complemented the nutritional composition of the diet, thereby resulting in a higher specific growth rate in eels.

The lowest mean specific growth rate was observed in Treatment C (50% commercial diet + 50% shrimp head meal), at 0.57 ± 0.12%/day. The low specific growth rate may have been due to reduced diet consumption, resulting in an insufficient supply of nutrients to meet the nutritional requirements for growth. According to Ansori (2007), growth rate depends on

water quality and other factors, including genetics, diet intake, age, resistance, and the fish's ability to utilise diet. Ansori (2007) further stated that diet intake must exceed the amount required for body maintenance and activity for fish to sustain growth.

Survival rate refers to the proportion of individuals that remain alive from the beginning to the end of the study. The results showed that all treatments achieved a survival rate of 80%. This was attributed to fungal infections that caused some eels to die during the rearing period. In addition, the paste-form diet rapidly affected water quality, despite the addition of a binding agent (binder). Similar findings were reported by Djajasewaka (2003), who found that eels reared for 82 days and fed artificial diets in pellet, paste, or combined forms exhibited survival rates below 50%. Arief *et al*. (2011) also stated that fish survival is influenced by good aquaculture management, including stocking density, diet quality, water quality, and the presence of parasites or diseases.

The feed conversion ratio (FCR) is the ratio of the amount of diet consumed to the resulting increase in body weight (Ekawati *et al.,* 2019). Nopriyadi (2008) stated that a lower FCR indicates better diet quality because less diet is required to produce a given increase in body weight.

The mean FCR values recorded in this study were 2.67 ± 0.93 for Treatment A, 3.23 ± 0.52 for Treatment B, and 3.77 ± 0.52 for Treatment C. Eels fed Treatment C (50% commercial diet + 50% shrimp head meal) exhibited a higher mean FCR than those receiving the other dietary treatments. Analysis of variance indicated a significant effect on FCR ($P > 0.05$).

The lowest mean FCR was reported for Treatment B (2.67 ± 0.93). The diet consisting of 50% commercial diet and 50% fish meal was considered the best treatment for eels because it produced the lowest FCR. This finding were consistent with Arsyadan *et al.* (2017) and Parker (2011), who stated that a lower FCR indicates better diet efficiency because less diet is required to produce a given increase in body weight.

Water quality is also an important factor supporting the survival and growth of eels. Good water quality in the rearing environment is essential for eel growth (Yudiarto *et al*., 2012). Temperature is one of the water quality parameters that affects fish appetite and growth. The water temperature measured during the study ranged from 24 to 27 °C. This temperature range is within the tolerance limits of eels and is considered optimal for their growth. This finding is consistent with Yudiarto *et al.* (2012), who reported that the suitable temperature range for eel growth is 23–30°C.

The water pH measured during the study ranged from 5.6 to 7. These pH values were considered less than optimal for eel growth, as the recommended pH range for eel aquaculture is 6–9. Furthermore, Sarwono (2008) stated that the optimal pH for eel growth is 7–8, whereas Hanif (2013) reported that the optimal pH range for eel farming is 6.5–7. The low pH may have been caused by the paste-form feed, which had a high-water content and poor stability in water, allowing it to deteriorate rapidly and affect water quality. This were consistent with Djajasewaka (2003) and Affandi *et al.* (2013), who explained that paste-form feed can cause water pollution because, in addition to its relatively high-water content, its texture is not cohesive, even when a binding agent (binder) is added. Such pollution can adversely affect important environmental parameters influencing eel growth, including ammonia concentration, temperature, and pH.

The dissolved oxygen concentration measured during the study ranged from 7 to 7.4 ppm. This concentration was considered optimal for eel rearing. According to Hanif (2013), the optimal dissolved oxygen concentration for eel aquaculture is 5–7 ppm.

The ammonia concentration measured during the study was 0.0269 ppm. This concentration was considered tolerable and not harmful to eel survival. However, Degani *et al*. (1985), as cited by Hanif (2013), reported that the ammonia concentration for eel rearing should be below 0.02 mg/L.

CONCLUSION

Based on the results and discussion, the provision of a diet consisting of 50% commercial feed and 50% fish meal (Treatment B) resulted in the highest growth performance compared with 100% commercial feed (Treatment A) and a combination of 50% commercial feed and 50% shrimp head meal (Treatment C). The different dietary treatments did not significantly affect the survival rate but significantly influenced absolute growth, specific growth rate, and feed conversion ratio (FCR).

ACKNOWLEDGEMENT

The combination of commercial feed with shrimp head meal or fish meal can be used as an alternative feed in aquaculture to improve eel growth and reduce feed costs. However, further studies are needed to identify a suitable binding agent to ensure that the feed, when provided in powder form, does not adversely affect water quality.

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