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The use of fish silage to increase feed efficiency and growth of grouper (*Epinephelus coioides*) in floating net cages

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ABSTRACT

This study aimed to investigate the efficiency of fish silage mixed in compounded diets on growth and survival rate of grouper (*Epinephelus coioides*). Grouper (2,34±0,24 cm, and 4,17±1,82 g) were divided into four groups and cultivated in 1x1x1,5 m floating net cages. Each group fed with compounded diets containing 0, 1, 3 and 5 g/kg fish silage diet twice daily. Fish were sampled for growth performances and feed efficiency at 14 days interval for 10 weeks. Results indicated that compounded diets at 1 and 3 g/kg silage affected the growth rate. Total length, specific growth rate and weight gain significantly increased in fish received 1 and 3 g/kg silage diets. The feed intake seen to be highest in groups administered 3 g/kg silage, whereas the best feed conversion ratio was found in fish fed 1 g/kg silage. Thus, this study indicated that using fish silage in compounded diets may affect feed efficiency and growth performances of grouper juveniles.

Introduction

Currently, the fisheries sector is developing in several countries including Indonesia, which is targeting the value of fishery exports to reach USD 6 billion by 2021. To achieve this target, the government increase production from aquaculture, which is one of the food providers in the world, specifically grouper, shrimp, and seaweed (KKP, 2021). Some countries such as Taiwan, China, Thailand, and Indonesia had succeeded in producing fish intensively (Samad *et al.,* 2014a; Liao *et al*., 2001; Rimmer *et al*., 2004). Several species such as grouper, snapper, shrimp, and sea bream (Sadovy, 2000; Liao *et al*., 2001; Sogeloos *et al*., 1995) have been cultivated intensively to obtain good quality seeds to increase their productivity.

Grouper (*Epinephelus coioides*) is one of the Indonesian marine fishery commodities with high economic value (Suko *et al*., 2014). However, in its cultivation, aquaculturists still depend on the availability of live feed (Samad *et al*., 2014a; Samad *et al*., 2014b, Shahaama and Adam, 2005), fishermen's catch, and it is considered less economical because of the relatively high price of live feed (Eusebio *et al*., 2004). Meanwhile, low feed efficiency causes a high feed conversion ratio (Rimmer *et al*., 2004), which can lead to water pollution when it is not consumed (Phillips, 1998). Therefore, the use of artificial feed with the addition of silage is being considered to increase the efficiency of grouper feed and prevent damage to aquaculture water.

Among the advantages of grouper cultivation is fast growth and massive production through intensive cultivation technology. Furthermore, it has soft meat, easily processed as seafood, and some sectors of the grouper fillet industry are currently being used for export needs (Burhan, 2016; Purwandi, 2020). Grouper cultivation also shows very good prospects for continuous development because of the protein content, provision of

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employment, and increasing the income of aquaculturists. Therefore, a strategy for managing feed and water quality is needed to support its production (Prayogo and Isfanji, 2014).

One of the methods applied in improving the quality and feed efficiency of grouper (*E. coioides*) is to mix mixing fish silage in the compounded diets. Silage is a fermentation process that hydrolyses proteins and other components of feed ingredients in an acidic environment to prevent spoilage bacteria, maintain feed ingredients for a long time and improve nutritional value (Dwi, 2007; Jatmiko, 2002; Mukodiningsih *et al.*, 2003). Furthermore, it is a liquid product made from fish which are liquefied by enzymes in the fish (Abun, 2004; Nunung, 2012). The purpose of making fish silage is to prevent spoilage bacteria that can damage the quality and nutritional content of the fish and control the growth of microorganisms during the fermentation process (Adawyah, 2008; Sulistyoningsih, 2015; Lisnawaty *et al.*, 2019). Several studies on silage have been conducted in livestock, however, none of the studies discussed its use on groupers. Therefore, this study aims to examine the effect of using fish silage in compounded diets for improving feed efficiency to increase the growth and survival rate of grouper (*E. coioides*).

Materials and Methods

Location and time of research

This study was carried out in Kuala Langsa, Aceh, using the floating net cages with a mesh size of 5 mm, which were specifically designed for this experiment (1 x 1 x 1.5 m). The water quality parameters were checked regularly every 5 days in the morning before feeding time and recorded in situ using a multi-parameter analyzer (MPG-6099 analyzer).

Experimental design

This study used a completely randomized design with four treatment groups and three replication in each group. Every floating net cage consisted of 30 juveniles weighing 4.17 ± 1.82 g and cultured for 10 weeks. The treatments were as follows:

SF_0 = Artificial diet (control)
SF_1 = Artificial diet + 1% fish silage
SF_3 = Artificial diet + 3% fish silage
SF_5 = Artificial diet + 5% fish silage

Feed ingredients as shown in Table 1.

Data collection

Observations were made daily during experimental periods to determine the survival rate of the grouper, while for growth performances, weight and length were measured once in two weeks. A total of 50% of the samples were taken randomly in each sampling time and the fish were caught using soft nets to avoid stress or damage. Subsequently, the weight and length data were taken immediately and the samples were measured using digital balance, while for length increment, a digital caliper was used. All grouper juveniles were returned to their respective floating cages after sampling. The water quality was also observed daily by measuring the dissolved oxygen (DO), pH, and temperature in the media.

For growth responses, parameters such as: weight gain = [(final weight (g) – initial weight (g)]/initial weight (g) x 100 and specific growth rate = [(lnWt – lnWo)/ T] x 100, where, Wt: final weight, Wo: initial weight and T: days, were measured (Zhao *et al*, 2012). Moreover, condition factor was measured using formula K= [(10^5 x fish weight (g)) / (fish length)^3 (cm)] (Samad *et al.*, 2014a) and the survival rate was recorded using formula: SR = (final no. of fish/ initial no. of fish) x 100 (Khan *et al*, 1994).

Silage preparation

The process of making silage was carried out by preparing fish meat (*Euthynnus affinis*), soybeans, and molasses in a ratio of 1:1:1, and preparing 2 L of lactic acid bacteria (Dwi, 2007). The soybeans were soaked for 24 hours at the temperature of 45°C, steamed for 1 hour until they become soft, and were blended. The fish meat that has been separated from the bone was also blended using 1 L of bacteria. Furthermore, all the ingredients were mixed and 1 L of bacteria was added and stirred until mixed completely. The mixed ingredients were then stored at room temperature for 1 month to achieve the required feed.

Table 1. Percentage of ingredients in different treatments

Ingredients (%)	Treatments			
	SF_0	**SF_1**	**SF_3**	**SF_5**
Fish meal	65.0	65.0	65.0	65.0
Fish oil	10.0	10.0	10.0	10.0
Corn meal	8.00	8.00	8.00	8.00
Vitamin mix	2.00	2.00	2.00	2.00
Mineral mix	3.00	3.00	3.00	3.00
Fish silage	0.00	1.00	3.00	5.00
Cellulose	12.0	11.0	9.00	7.00
Crude protein	45.03	45.35	45,81	45,87
Crude lipid	14.05	13.78	14.02	14.04
Crude fiber	3.29	2.67	2.52	2.35
Ash	14.27	14.50	14.29	14.86
Moisture	8.83	7.81	7.88	8.38

Feed utilization measurements

All treated fish were fed with 3% of the biomass in each cage twice a day at 08:00 and 17:00. The unconsumed feed was collected 10 minutes after feeding time and dried before measurement. In this study, feed intake was calculated using the formula: FI (g) = [dry diet given – dry diet remained]/no. of fish, while the feed conversion ratio (FCR) was measured using: FCR= feed intake/[final body weight – initial body weight] (Stickney, 2005).

Data Analysis

All data were examined using a one-way analysis of variance with fish silage dose as a factor. Tukey's test was used to compare the means between treatments when the differences were significant at the $P < 0.05$ level. Meanwhile, statistical analysis was performed using SAS.

Results

Fish growth was significantly affected by silage mixed in compounded diets. Meanwhile, a summary of growth responses, weight gain, specific growth rate, and condition factors in each group is shown in Table 1.

Table 1 showed that the highest growth performances were observed in the group fed with fish silage 1 g/kg diets. It showed a significant difference in the weight (g), length (cm), and weight gain (%) with 82.52 ± 6.49 g, 10.45 ± 0.89 cm, and 18.80 ± 1.55 %, respectively, compared to other treatments. However, there was no significant difference between SF1 and SF3, while the data analyzed also showed that the lowest growth response occurred at SF_0 (control).

During data collection, all treated groups showed an increase in weight and length regularly every two weeks. The grouper juveniles showed the weight escalation, while groups that received fish silage had a better quality in growth responses compared to the control (Figures 1 and 2).

The best weight gain, 18.80 ± 1.55% and specific growth rate 4.26 ± 0.05%, were viewed in SF_1, maintained significantly higher than other groups and decreased steadily to 3.87%/day, which ranged from 3.61% to 4.26% after 10 weeks.

Feeding performances

This study indicated that feed intake and conversion ratio were significantly affected by fish silage mixed diets. The highest FI was discovered in SF_3 (artificial diets + 3 % silage) with 59.37 ± 3.92 g/fish, while the lowest was in the control (40.52 ± 4.19 g/fish). However, the best FCR was discovered in SF1 with 1.57 ± 0.08 (Table 2).

The results also showed that the juveniles fed with fish silage mixed diets consume more feed compared to the SF_0 (control). However, there are no statistical differences in the survival rate among all treatments.

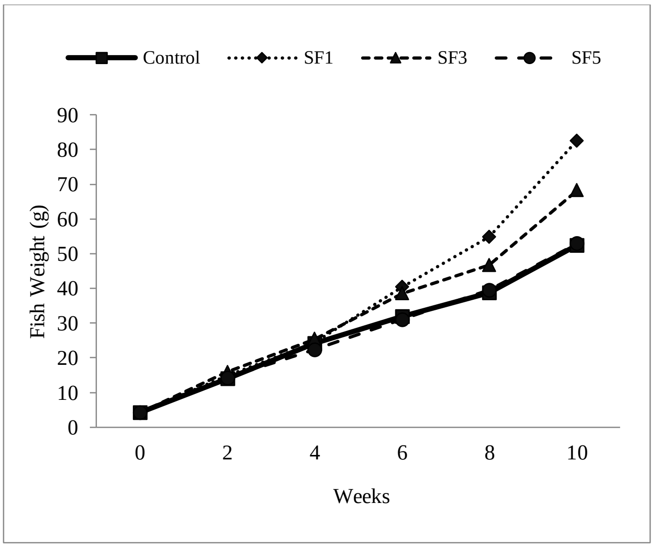

Figure 1. Final weight of grouper treated with experimental diets.

Water quality parameters

The mean of water quality is provided in Table 3, while some parameters such as temperature, salinity, pH, and dissolved oxygen were inspected every 5 days. During the trial, the temperature ranged 29.42 – 29.46 °C, while salinity ranged from 27.5 to 27.50 ppt. Data showed that during the experiment, water quality seemed to be stable and the result indicated that the used diets did not affect pH and dissolved oxygen.

Table 1. Growth responses of grouper fed different compounded diets.

Treatments	Length (cm)		Weight (g)		WG (%)	SGR (%)	K (g/cm)
	Initial	Final	Initial	Final			
Control	2.34±0.24[a]	8.31±0.36[c]	4.17±1.82[a]	53.37±4.51[b]	11.56±1.08[c]	3.61 ± 0.12[b]	9.14±0.88[b]
SF1	2.34±0.24[a]	10.45±0.89[a]	4.17±1.82[a]	82.52±6.49[a]	18.80±1.55[a]	4.26 ± 0.11[a]	7.36±1.38[a]
SF3	2.34±0.24[a]	9,26±0.72[ab]	4.17±1.82[a]	68.24±5.63[ab]	15.37±1.35[b]	3.99 ± 0.11[a]	8.78±2.04[b]
SF5	2.34±0.24[a]	8,54±0.56[bc]	4.17±1.82[a]	52.89±5.31[b]	11.69±1.27[c]	3.62 ± 0.13[b]	8.54±0.82[b]

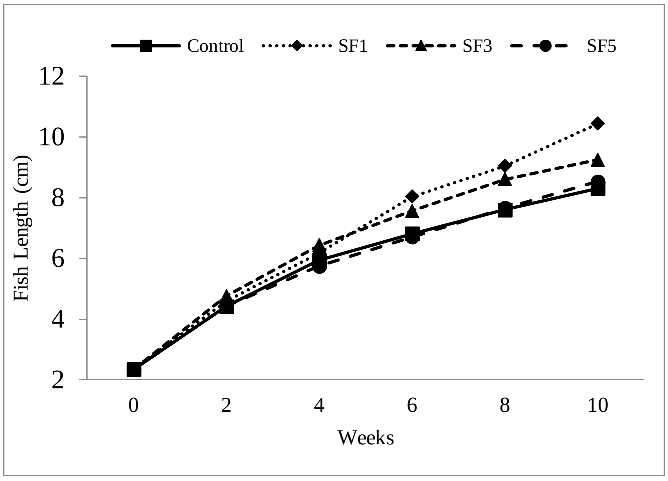

Figure 2. Final length of grouper treated with experimental diets.

Table 2. Feeding parameters and survival rate of juveniles during the experiment.

Treatments	FI (g)	FCR	SR (%)
Control	40.52 ± 4.19^{b}	1.85 ± 0.07^{ab}	100
SF1	54.32 ± 4.64^{ab}	1.56 ± 0.08^{b}	100
SF3	59.37 ± 3.92^{a}	2.04 ± 0.24^{ab}	100
SF5	46.20 ± 3.77^{b}	2.20 ± 0.31^{a}	100

Note: Data in the same column with a different letter are significantly different (p<0.05) among treatments. Values are means of triplicate groups' ± S.D.

Table 3. Mean salinity, dissolved oxygen, pH and temperature of grouper

Treatments	Salinity (ppt)	Dissolved oxygen (ppm)	pH	Temperature (°C)
Control	27.50±0.52	5.82±0.29	7.40±0.34	9.43±0.71
SF1	27.50±0.52	5.87±0.37	7.26±0.19	9.42±0.63
SF2	27.46±0.51	5.71±0.37	7.17±0.08	9.46±0.74
SF3	27.48±0.52	5.80±0.46	7.18±0.11	9.42±0.56

Discussion

This study showed that fish silage mixed diets had greater effects on fish growth responses and conversion, but had no impact on water quality. Growth rate and feed conversion were higher in groups that received silage mixed diets due to the ability of silage to hydrolyze protein content and improve the nutritional value of the feeds. According to Jatmiko (2002), silage powder increases the efficiency of artificial feed. Mukodiningsih *et al.* (2003) also stated that it increases protein, fat, and crude fiber in animal flesh. This showed that silage is a preservation method that lowers the pH of the material to inhibit the growth of spoilage bacterial, which affect nutrient absorption in fish.

Furthermore, it was discovered that fish silage mixed diets affect the growth of grouper juveniles as shown by the data of fish that received the mixed diets.

However, the feed conversion ratio seemed to be better in control (SF0) and SF1 compare to SF3 and SF5. This is because the fish silage mixed diets can meet the nutritional need and appetites of cultivated fish. Although the highest FCR was in SF5, it was still significant in aquaculture, specifically in grouper aquaculture. Stable water quality also plays a significant role in affecting feed intake. Several studies have been described on the efficiency of water quality in increasing feed intake and fish appetite (Taylor *et al.*, 2006), feed intake (Imsland *et al.*, 1995, Samad *et al*, 2014b), feeding ratio (Agus *et al*, 2013 and Nordgarden *et al.*, 2003), and feed efficiency in aquaculture (Trippel and Neil, 2003). Based on observations, the schooling behavior of groupers affects the fish appetence, hence, feed intake can be accelerated in SF1 and SF3. This is in line with Webster *et al.* (2001) which proposed that higher feed consumption maintains the growth increment and energy demand.

Studies on fish silage involve correlation with other parameters such as water quality (Hastein *et al.*, 2005). The results showed that water quality values were not significantly different in each group. This occurred because the experimental site and the floating net cages were close to each other and the water was stable during the experiment.

In this study, the juveniles were reared in high stocking density (30 fish/cages) which caused a decrease in swimming due to limited space. This condition is attributed to less energy expenditure, hence, the consumed feed can be used for growth optimization. This result was similar to previous studies conducted by Samad *et al* (2014a) on *Epinephelus coioides*, North *et al.* (2006) on *Oncorhynchus mykiss,* and Papoutsoglou *et al.* (1998) on *Dicentrarchus labrax*, which described an increase in growth in high stocking density.

Conclusion

The results showed that growth performances and feed conversion were affected by fish silage mixed diets. Therefore, the use of fish silage in compounded diets to attain a maximum growth of grouper juveniles is recommended. However, providing enough food and maintaining acceptable water quality are required to sustain growth and fish health.

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