Effect of fish meal replacement with earthworm and maggot meals on feed utilization and growth of banana shrimp (*Penaeus merguiensis*)

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Abstract. This study aimed to investigate the effect of replacement of fish meal by earthworm meal and maggot meal at different ratios in artificial diet on protein digestibility, efficiency of feed utilization, and growth of banana shrimp (*Penaeus merguiensis*). The experimental fish used were banana shrimps with an average weight of 1.07±0.04 g. This study used experimental method with a Completely Randomized Design (CRD), 5 treatments, and 3 replicates. The treatment applied was replacement of fish meal with earthworm meal and maggot meal at different ratios in feed, namely treatment A (fish meal), treatment B (ratio of earthworm:maggot = 2:2), treatment C (ratio of earthworm:maggot = 2:4), treatment D (ratio of earthworm:maggot = 2:6), and treatment E (ratio of earthworm:maggot = 2:8). The data observed in this study included relative growth rate (RGR), efficiency of feed utilization (EFU), protein efficiency ratio (PER), feed conversion ratio (FCR), protein digestibility or apparent digestibility coefficient for protein (ADCp), and survival rate (SR). The results of this study showed that fish meal replacement by earthworm meal and maggot meal as animal protein sources successfully increased RGR, EFU, PER, FCR, ADCp, and SR of banana shrimp. In fact, replacement of fish meal by earthworm meal and maggot meal at 2:2 ratio resulted in the highest RGR (5.06% day^{-1}), EFU (78.79%), PER (2.87), FCR (1.60), ADCp (79.17%), and SR (89.28%) of banana shrimp, hence considered as the best ratio. It was also concluded that water quality of shrimp culture media (temperature, dissolved oxygen (DO), salinity, ammonia) was still within the suitable range for banana shrimp culture.
Key Words: alternative fish meal, banana shrimp, digestibility, growth, maggot, earthworm.

Introduction. Banana shrimp (*Penaeus merguiensis*) is an endogenous shrimp species native to Indonesia. This commodity technically has a profitable economic potential besides other favorable characteristics such as being more efficient in production (lower production cost) and more resistant to disease (Nur et al 2018). Kusrini (2011) reported that banana shrimp is one of penaeid species with high economic value in Indonesia. Banana shrimp is widely distributed throughout Indonesian waters which serve as its natural habitat. This species is benthic animal that lives on the surface of ocean floor. Banana shrimp excellently adapts to various types of ocean substrates, but prefer loamy, muddy, and sandy waters. In term of life cycle, this shrimp species live in marine and brackish waters (Tirtadanu & Ernawati 2016).

The success of banana shrimp culture is highly determined by the availability of high-quality feed. Feeds play an important role for successful fish culture activity. Production cost in fish culture business is mainly dominated by feed cost which accounts for 60-70% of the total production cost. One of the problems typically found in feed production is the high price of fish meal as the source of animal protein, which increases feed cost (Olmos et al 2011). According to NRC (2011), fish meal is an animal protein source majorly used in fish feed production that determines the quality of artificial feed. Therefore, alternative ingredients to replace fish meal with unconventional animal protein sources are required to reduce production costs. Unconventional animal protein sources are feed ingredients potentially used as livestock feed due to their large availability in many locals in Indonesia, contain nutrients required by livestock, and barely compete with human needs. Tadpoles, snails, maggots, termites, and earthworms are unconventional sources of animal protein possibly used to replace fish meal as animal protein sources in fish diets (Kader et al 2010; Monebi et al 2013; Djissou et al 2016a, b).

Earthworm meal has a considerably high nutrient content, is easily digested, and contains high protein that is relatively similar to that in fish meal. According to Parolini et al (2020) earthworm meal (*Lumbricus rubellus*) contained 63.0% crude protein, 5.9% crude lipid, 8.9% ash, 0.43% Na, 0.53% Ca, 0.62% K, 0.94%, and 1476 kJ/100 g energy for metabolism. In term of the composition of essential amino acids, earthworm meal contained arginine of 2.83 g kg^{-1}, histidine of 1.47 g kg^{-1}, isoleucine of 2.04 g kg^{-1}, leucine of 4.11 g kg^{-1}, lysine of 6.35 g kg^{-1}, phenylalanine of 6.26 g kg^{-1}, tryptophan of 4.43 g kg^{-1}, and valine of 4.43 g kg^{-1}.

Maggot in this study was the black soldier fly (*Hermetia illucens*) larva from Order Diptera known as decomposer. Maggots use fruits and vegetables as feed source and habitat; therefore, maggots of *H. illucens* contain a fairly high protein amount and amino acids similar to those in fish meal. According to Park (2016), maggot (*H. illucens*) contains a high protein amount of 42.1%, lipid of 24.8%, ash of 10.3%, moisture of 7.9%, crude fiber of 7%, calcium of 5%, phosphorus of 1.5%, and NFE of 1.4%. Djissou et al (2015) investigated that amino acids in maggot were quite similar to those in fish meal, included arginine of 2.29%, histidine of 1.50%, isoleucine of 1.87%, lysine of 2.71%, methionine of 0.66%, phenylalanine of 1.63%, threonine of 1.70%, tryptophan of 0.555, valine of 2.56%, and leucine of 3.23%. Furthermore, earthworm meal and maggot meal are easy to obtain since they are available in sufficient quantity in nature and relatively cheap, thus potentially used as fish meal replacement in artificial diets.

The unconventional protein sources that can replace fish meal in feed should at least contain ten essential amino acids (EAA) required by fish (Médale et al 2013). Several studies were conducted on replacing fish meal by other animal protein sources, such as earthworm for common carp, *Cyprinus carpio* (Pucher et al 2014), for red tilapia, *Oreochromis* sp. juvenile (Jabir et al 2012), and for *Macrobrachioum rosenbergii* (Habashy 2012); maggot for *Oreochromis niloticus* (Ezewudo et al 2015) and for *Clarias gariepinus* (Aniebo et al 2009); also earthworm and maggot for *C. gariepinus* (Djissou et al 2016a). The results of those studies generally showed that fish meal replacement led to decreased feed intake while increasing feed efficiency and growth performance (Imorou Toko et al 2008). This study aimed to investigate the effect of fish meal replacement by earthworm meal and maggot meal at different ratios in artificial diet on protein digestibility, efficiency of feed utilization, and growth of banana shrimp (*P. merguiensis*).

Material and Method

Experimental animal. Experimental animals used in this study were banana shrimps with an average weight of 1.07±0.04 g $shrimp^{-1}$. Banana shrimps used were obtained from the hatchery of Center for Brackish Water Aquaculture Development (BBPBAP), Jepara Regency, Central Java, Indonesia. A total of 300 shrimps were maintained in 15 containers at density of 20 shrimp $container^{-1}$. Prior to observation, experimental animals were selected based on size and weight, completeness of the body organs, and physical health. Later, adaptation was carried out for 7 days (Rachmawati et al 2017). Observation of shrimp growth in weight was done once a week for 42 days of culture period from July to August 2021.

Experimental diets. Experimental diets used were commercial feeds in the form of 1 mm pellets containing at least 40% protein. The composition of feed ingredients included fish meal, earthworm meal, maggot meal, soybean meal, corn meal, wheat flour, fish oil, palm oil, vit-min mix, and carboxymethyl cellulose (CMC). Replacement of fish meal by combination of earthworm meal and maggot meal at different ratio in this study consisted of 5 treatments, namely treatment A (fish meal), treatment B (ratio of earthworm:maggot = 2:2), treatment C (ratio of earthworm:maggot = 2:4), treatment D (ratio of earthworm:maggot = 2:6), and treatment E (ratio of earthworm:maggot = 2:8).

The feed ingredients were previously analyzed for their proximate composition before being used as experimental diet. Results of proximate analysis of experimental feed ingredients and formulation are presented in Table 1 and 2. Shrimps were fed at a fixed feeding rate of 5% biomass^{-1} day^{-1} in a frequency of 5 times a day, namely at 06.00, 10.00, 14.00, 18.00, and 21.00 Western Indonesian Time (WIB).

Table 1

Proximate composition of banana shrimp (*P. merguiensis*) feed ingredients required in the study (dry matter basis %)

Ingredients	*Component (%)*					*Total (%)*
	*Protein**	*NFE**	*Lipid**	*CF**	*Ash**	
Fish meal	61.17	2.15	11.15	1.71	23.82	100
Maggot meal	58.09	17.95	12.45	0.00	11.41	100
Earthworm meal	45.86	2.95	16.45	24.03	10.64	100
Soybean meal	50.73	35.05	3.28	3.47	7.47	100
Rice bran	15.07	0.94	15.80	66.93	1.24	100
Wheat flour	9.12	90.12	0.00	0.00	0.76	100

Note: * analysis result obtained at the Laboratory of Animal Nutrition, Faculty of Animal Sciences and Agriculture, University of Diponegoro (2021); CF = crude fiber; NFE = nitrogen-free extract.

Table 2

Formulation of experimental diets used in the study

Ingredients	*Feed composition (%/100 g feed)*				
	A	*B*	*C*	*D*	*E*
Fish meal	40.00	0.00	0.00	0.00	0.00
Maggot meal	0.00	20.00	26.70	30.00	32.00
Earthworm meal	0.00	20.00	13.30	10.00	8.00
Soybean meal	32.00	36.30	34.30	33.10	32.70
Corn meal	5.00	6.00	6.70	7.70	7.00
Wheat flour	9.70	5.20	6.50	6.70	7.80
Fish oil	2.80	2.00	2.00	2.00	2.00
Palm oil	2.00	2.00	2.00	2.00	2.00
Vitamin-mineral mix	6.00	6.00	6.00	6.00	6.00
CMC	2.00	2.00	2.00	2.00	2.00
Cr_2O_3	0.5	0.5	0.5	0.5	0.5
Total (%)	100	100	100	100	100
Proximate analysis					
Protein (%)	40.81	40.84	40.87	40.83	40.87
NFE (%)	19.33	21.82	23.30	23.57	24.71
Fat (%)	11.74	11.94	11.71	11.70	11.50
Energy (kcal)	328.29	334.16	330.16	332.58	332.92
E/P ratio (kcal)	8.04	8.18	8.07	8.15	8.15

Note: A = experimental diet with animal protein source of earthworm meal:maggot meal - 0:0; B = experimental diet with animal protein source of earthworm meal:maggot meal - 2:2; C = experimental diet with animal protein source of earthworm meal:maggot meal - 2:4; D = experimental diet with animal protein source of earthworm meal:maggot meal - 2:6; E = experimental diet with animal protein source of earthworm meal:maggot meal - 2:8.

Experimental container. The containers used in this study were plastic tanks with dimensions of 60 x 40 x 25 cm^3. Containers were cleaned before use with water and dried to minimized plastic smell, filled with water at salinity of 25 ppt to a height of 20 cm, and aerated to maintain dissolved oxygen (DO) in the water. Shrimp culture media was treated beforehand with calcium hypochlorite ($CaClO_2$) at a concentration of 30 ppm, aerated for 24 hours to kill any pathogens, and further treated with sodium thiosulfate ($Na_2S_2O_3$) at a concentration of 15 ppm. Monitoring of water quality parameter was conducted daily. Each culture tank was aerated to maintain optimal level of DO. Culture media was siphoned every 2 days in the morning with a 20% water change.

Experimental materials. Earthworm meal used in this study was commercial earthworm meal from Villa Cacing Arjasari Farm, Bandung, Indonesia with protein content of 45.86%. Moreover, maggot meal used was commercial maggot meal produced by PT. Magalarva Sayana Indonesia, Bogor with protein content of 56.08 %.

Research methods. Research methods in this study applied experimental method with Completely Randomized Design (CRD) of 5 treatments. Data analysis was done using ANOVA. Significant ($p < 0.05$) or greatly significant ($p < 0.01$) results of ANOVA were followed by the multiple range test (DUNCAN) to determine the difference of means among treatments using Microsoft Excel 2016, while analysis of water quality was done descriptively.

Research variables. Research variables observed in this study included relative growth rate (RGR), efficiency of feed utilization (EFU), protein efficiency ratio (PER), feed conversion ratio (FCR) referred to Tacon (1987), protein digestibility (ADCp) referred to Fennuci (1981), and survival rate (SR) referred to NRC (2011). The equations used in this study are written as follows:

$$RGR\ (\%) = 100 \times (\text{final weight - initial weight})/(\text{experimental periods in days x initial weight})$$

$$EFU\ (\%) = \text{final weight – initial weight/weight of feed consumed x 100}$$

$$PER = \frac{\text{Wet weight gain (g)}}{\text{Protein intake (g)}} \times 100$$

$$FCR = \frac{\text{Dry feed intake (g)}}{\text{Weight gane (g)}} \times 100$$

$$ADC_P = 100 \times [(\%Cr_2O_3 \text{ in feed x \%protein in feces})/(\%Cr_2O_3 \text{ in feces x \%protein in feed})]$$

$$SR\ (\%) = \frac{\text{Final number of fish}}{\text{Initial number of fish}} \times 100$$

Chemical analysis. Proximate analysis of feed used the method of AOAC (2005). The moisture content was measured using gravimeter in the hot air oven at 100ºC for 24 hours. The ash content was calculated from the samples that were put in the oven at 500ºC for 10 hours. The raw protein content was measured with the micro-Kjeldahl method. Moreover, the raw lipid content was determined using the Soxhlet extraction method. The EAA composition of experimental diets and banana shrimp were analyzed using Amino Acid Analyzer. A total of ±1 mg of the sample was weighed, put in a closed tube and hydrolyzed with 6N HCl for 22 h at 110ºC. After being filtered through 0.2 mm, the sample was ready to be injected into a High-Speed Amino Acid Analyzer with an ion exchange resin column measuring 4.6 x 150 mm, temperature 53^{o}C. The separation of amino acids was done using a gradient system with sodium citrate buffer solution pH 3.3; pH 4.3; and pH 4.9 with a flow rate of 0.225 mL min^{-1}. Reagent post column with a solution of ninhydrin at the speed of 0.3 mL min^{-1} was used to identify each acidic amino in length wave 570 nm and 440 nm (Ju et al 2008).

Water quality parameters. Parameters of water quality measured in this study included salinity using Refractometer, temperature (^{o}C), power of hydrogen (pH), and dissolved oxygen (DO) using Water Quality Checker (Lutron DO-5512SD) twice a day at 08.00 and 16.00 WIB, and ammonia (NH_3) with acidimetric titration in the beginning, middle, and end of study.

Results. Means of RGR, EFU, PER, FCR, ADCp, and SR of banana shrimp during the study are presented in Table 3.

Table 3 shows that banana shrimp fed diets containing combination of earthworm and maggot as animal protein sources obtained a significantly higher growth compared with those fed fish meal as animal protein source. The highest RGR, EFU, PER, ADCp, FCR, and SR values of 5.06% day^{-1}, 78.79%, 2.87, 79.19%, 1.60 and 89.28%, respectively were obtained by banana shrimp fed the diet B.

Table 3

Means of relative growth rate (RGR), efficiency of feed utilization (EFU), protein efficiency ratio (PER), feed conversion ratio (FCR), protein digestibility (ADCp), and survival rate (SR) of banana shrimp during research

Parameters	*Experimental diets*				
	A	*B*	*C*	*D*	*E*
RGR(% day^{-1})	2.13 ± 0.15^{e}	5.06 ± 0.15^{a}	3.72 ± 0.37^{b}	3.17 ± 0.08^{c}	2.67 ± 0.12^{d}
EFU (%)	51.55 ± 1.37^{e}	78.79 ± 0.81^{a}	68.78 ± 0.91^{b}	60.21 ± 0.67^{c}	58.96 ± 0.32^{d}
FCR	1.94 ± 0.05^{e}	1.60 ± 0.02^{a}	1.73 ± 0.04^{b}	1.82 ± 0.03^{c}	1.89 ± 0.01^{d}
PER	1.29 ± 0.03^{e}	2.87 ± 0.02^{a}	2.13 ± 0.0^{b}	1.98 ± 0.02^{c}	1.66 ± 0.01^{d}
ADCp (%)	57.34 ± 0.32^{e}	79.17 ± 0.56^{a}	70.64 ± 0.38^{b}	64.24 ± 0.57^{c}	60.39 ± 0.82^{d}
SR (%)	83.23 ± 6.21^{a}	89.28 ± 3.15^{a}	85.25 ± 2.25^{a}	85.19 ± 4.32^{a}	85.16 ± 3.10^{a}

Note: Means±SD in the same row with the same superscript indicated a not significant difference ($p > 0.05$).

EAA content of experimental diets and essential amino acid requirement of banana shrimp are presented in Table 4.

Table 4

EAA content of experimental diets and EAA requirement of banana shrimp in g/100 g crude protein

Types of amino acids	*Experimental diets*					*Banana shrimp*
	A	*B*	*C*	*D*	*E*	
Arginine	6.75	7.67	7.12	7.25	7.16	7.54
Histidine	0.15	0.93	0.52	0.48	0.13	0.86
Isoleucine	3.83	2.65	1.98	1.57	1.04	2.46
Leucine	4.13	4.97	4.36	4.02	3.83	5.27
Lysine	6.82	6.36	6.07	6.48	6.21	6.32
Methionine	0.86	1.38	0.98	0.74	0.49	1.43
Phenylalanine	2.84	2.32	1.96	1.78	1.23	2.29
Threonine	1.85	1.98	1.39	1.02	0.56	2.15
Valine	2.08	2.98	2.23	2.19	1.76	2.86
Tryptophan	2.35	1.26	0.98	0.49	0.25	1.13

* EAA requirements of banana shrimp according to NRC (2011).

In Table 4, the profile of EAA content of experimental diet B was quite similar to that of banana shrimp.

Nutrient content of banana shrimp in the beginning and the end of study is seen in Table 5. Nutrient content of banana shrimp listed in Table 5 indicated a significant increase of protein in the body of banana shrimp fed experimental diets A, B, C, D, and E compared with the initial nutrient content of banana shrimp body. The highest protein content was found in banana shrimp fed experimental diet B.

Observation of water quality during study is provided in Table 6.

Table 5

Nutrient content of banana shrimp in the beginning and the end of study (dry matter basis %)

Parameters	*IV*	*Experimental diets*				
		A	*B*	*C*	*D*	*E*
Protein	60.81	63.15±0.64[a]	68.89±0.32[b]	68.49±0.47[b]	68.54±0.29[b]	68.50±0.25[b]
Lipid	2.99	3.86±0.37[a]	3.68±0.42[a]	3.57±0.53[a]	3.62±0.60[a]	3.77±0.56[a]
Carbohydrate	22.29	24.21±0.22[a]	24.51±0.36[a]	24.38±0.23[a]	24.40±0.19[a]	24.43±0.20[a]
Ash	3.90	4.27±1.36[a]	4.39±0.98[a]	4.20±1.21[a]	4.39±0.76[a]	4.28±1.12[a]
Crude fiber	2.85	3.28±0.98[a]	3.36±0.75[a]	3.32±0.79[a]	3.29±0.84[a]	3.30±0.76[a]

Note: IV = initial value; means±SD in the same row with the same superscript indicated a not significant difference ($p > 0.05$).

Table 6

Value of water quality parameters in banana shrimp culture

Water quality parameters	*Treatments*					*Reference range*
	A	*B*	*C*	*D*	*E*	
Temperature (^oC)	27-35	27-35	27-35	27-35	26-34	28.5-30.55*
DO (mg L^{-1})	4.6-5.8	4.7-5.9	5-5.8	5-5.7	4.6-5.5	> 3*
pH	7.0-8.0	7.0-8.0	7.0-8.0	7.0-8.0	7.0-8.0	7-8.5*
Salinity (ppt)	25	25	25	25	25	25-35*
Ammonia (mg L^{-1})	0.004-0.051	0.004-0.048	0.004-0.068	0.004-0.043	0.004-0.040	< 0.1*

Note: *Boyd (1992).

Values of water quality parameters in banana shrimp culture media during study were still within the reference range, thus ensuring the growth of banana shrimp.

Discussion. Banana shrimp fed experimental diets B, C, D, and E obtained higher RGR, EPP, PER, ADCp, FCR, and SR compared with those given experimental diet A. It is expected that animal protein source used in experimental diets B, C, D, and E which consisted of the combination of earthworm and maggot are rich in EAA required by banana shrimp. In this regards, Parolini et al (2020) and Olaniyi & Salau (2013) mentioned that earthworm and maggot are rich in EAA, thus they are good sources of dietary animal protein. Feeds suitable for shrimps are those with EAA profile similar to EAA profile of shrimp (Akiyama et al 1992; Adesina 2012). Both earthworm and maggot culture have a short production cycle, making them good unconventional protein sources to replace fish meal as animal protein source in fish diets (Djissou et al 2016a, b).

According to Jabir et al (2012), PER and FCR are highly determined by ADCp. Furthermore, Jabir et al (2012) said there is linear relationship between ADCp and PER and FCR. Therefore, higher ADCp will lead to higher PER and the lowest FCR. Result of this study showed that banana shrimp given feed B obtained the highest ADCp, followed by the highest PER and the lowest FCR compared with other treatments.

Feeding on artificial diets contained earthworm and maggot at different ratios to replace fish meal as animal protein source did not significantly affect ($p > 0.05$) the SR of banana shrimp. It is expected that experimental diets containing the combination of earthworm and maggot at different ratios as animal protein source did not have negative impact on the health of banana shrimp during the study. Banana shrimp fed experimental diet B obtained the highest survival rate of 89.28% compared with experimental diets A (83.23%), C (85.25%), D (85.19%), and E (85.16%). Similar finding was reported by Djissou et al (2016a) that combination of fish meal and maggot as animal protein source in fish feed did not have significant effect on SR of *Oreochromis niloticus*.

Peres & Oliva-Teles (2009) confirmed that completeness of EAA profile and amount in feed that meet the needs of fish is the main requirement for fish growth. Collins et al (2013) reported that the mix of earthworm and maggot as animal protein source in feed could replace fish meal to enhance fish growth if the dietary EAA profiles fulfil the EAA requirement of fish. Based on the result of this study, the profile of EAA (arginine, histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, valine) in the feed B was quite similar to the EAA profile requirement of banana shrimp compared with the EAA profile in other experimental diets of A, C, D, and E, thus banana shrimp fed experimental diet B obtained higher protein digestibility, feed utilization, and growth compared with those given other treatments. In contrast, Table 4 displays a decrease in protein digestibility, feed utilization, and growth of banana shrimp fed experimental diets A, C, D, and E since these feeds did not have essential similar amino acid profile that is similar to the EAA requirement of banana shrimp. Djissou et al (2016a, b) revealed that feed containing EAA profile similar to that in fish will result in the best fish growth. Conversely, if the dietary EAA profile does not meet the EAA profile requirement of fish, nitrogen catabolism may occur, contributing to aquatic environment contamination and declining protein retention, thus causing slow fish growth (Médale & Kaushik 2009).

The value of protein digestibility, efficiency of feed utilization, and growth performance of banana shrimp fed experimental diets containing earthworm meal and maggot meal at different ratio (B, C, D, and E) to replace fish meal as animal protein source was observed higher than that given control feed (A) because the ratio between lysine and arginine in the experimental diets was below 1. The highest protein digestibility, efficiency of feed utilization, and growth performance was found in banana shrimp fed experimental diet B. It is expected that the ratio between lysine and arginine in feed B was the lowest (0.83) compared to the ratio in diets C, D, and E of respectively 0.85, 0.89, and 0.91. Furthermore, banana shrimp given fish meal based feed (A) obtained the lowest protein digestibility, efficiency of feed utilization, and growth expectedly due to the low quality of fish meal used, thus the ratio between lysine and arginine was above 1, namely 1.01. A slow fish growth might be caused by poor quality of fish meal used as protein source besides the high ratio between lysine and arginine in fish diet (Djissou et al 2016a). Mai et al (2006) mentioned that lysine in artificial feed is the limiting factor in fish diet. Moreover, Médale & Kaushik (2009) suggested that lysine becomes the limiting factor in fish diet since plant protein source is lack of lysine. Moreover, lysine is one of essential amino acids that plays role in fish growth process (Li et al 2009). However, antagonistic interaction between lysine and arginine may enhance arginase activity, causing increase in dietary arginine concentration (Kestemont 2007; Cabral et al 2013).

Observation result of the nutrient content of banana shrimp in Table 5 shows that protein content of banana shrimp significantly increased in shrimps given experimental diets A, B, C, D, and E compared with the initial protein content of banana shrimp. The highest protein content of 68.89% was found in banana shrimp fed experimental diet B compared with experimental feeds A (63.15%), C (68.49%), D (68.54%), and E (68.50%). Banana shrimp given experimental diet B obtained the highest PER of 2.87 compared with those fed diets A, C, D, and E of 1.29, 2.13, 1.98, and 1.66, respectively.

Conclusions. Based on this study, it is concluded that replacement of fish meal by earthworm meal and maggot meal as animal protein source successfully decreased FCR and increased RGR, EFU, PER, ADCp, and SR of banana shrimp. Replacement of fish meal by earthworm meal and maggot meal at ratio of 2:2 resulted in the highest RGR (5.06% day^{-1}), EFU (78.79%), PER (2.87), FCR (1.60), ADCp (79.17%), and SR (89.28%) of banana shrimp, hence considered as the best ratio. The replacing fish meal with earthworm meal and maggot meal as a source of animal protein feed was an effort to reduce dependence on fish meal as a source of animal protein for fish feed.

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Conflict of interest. The authors declare that there is no conflict of interest.

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