Striped snakehead fish (Channa striata) feed utilizing maggot meal substitution for fish meal : nutrient content, effects on growth, and feed utilization efficiency

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Original Article

Striped snakehead fish (*Channa striata*) feed utilizing maggot meal substitution for fish meal: Nutrient content, effects on growth, and feed utilization efficiency ♣

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Abstract

Maggot is a feed ingredient with a high nutrient content, 44.89% crude protein, 14.67% of crude fat, 9.82% of crude fiber, 20.75% of ash, and 9.87% of nitrogen-free extract. The objective of this study was to determine the effects of maggot meal use as fish meal substitute to improve the efficiency of feed utilization and growth of striped snakehead fish (*Channa striata*). Fish samples used were striped snakehead fish with an average individual weight of 0.87 ± 0.01 gram/fish. Feeding the fish was daily at 08:00, 12:00, and 16:00 in West Indonesia Time at a fixed feed rate. Fish were reared for 60 days with a stocking density of 1 head/L. This experimental study was conducted following a completely randomized design with four treatments and three replications. Treatment A was without maggot meal substitution, B was with 10% maggot meal substitution, C was with 20% maggot meal substitution, and D was with 30% maggot meal substitution. Data were collected for feed utilization efficiency, protein efficiency ratio (PER), relative growth rate (RGR), survival rate (SR), and water quality. The best choice of fish meal substitution degree with maggot meal was the treatment C with 20% maggot meal to fish meal composition, which resulted in 14.12 ± 0.76% RGR, 71.57 ± 2.82% feed utilization efficiency, and 2.01 ± 0.08% PER. In conclusion, test feed with a 20% -25% substitution by maggot meal of fish meal was the best alternative for striped snakehead fish growth.

Keywords: maggot, fish meal, feed utilization, growth, survival rate

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1. Introduction

Striped snakehead fish (*Channa striata*) is one of the local commodities with high economic value. The sales of striped snakehead fish (*C. striata*) on the market are still profitable, with a price range of Rp 40,000-60,000 per kg in Indonesia. Striped snakehead fish contains 60% albumin compounds in 100 g of meat, which is higher than for other types of fish (Permadi *et al*., 2017). The high price of fish is caused by the high usage of good quality fish meal as feed, which is still expensive as a processed feed ingredient. Indonesia imports 70,000 tons of fish meal valued at Rp 1.17 trillion, equivalent to Rp 17,000 / kg, while the use of local fish meal is only 30,000 tons per year, so the price of fish meal remains high (Muliantara, 2012).

Feed is the most important factor influencing growth and the feed utilization in striped snakehead fish (*C. striata*) is desired to be more efficient. Maggot meal is an alternative feed ingredient that has high nutritional value profile almost similar to fish meal, but its price is lower than fish meal. The addition of maggot meal in artificial feed can increase the growth of striped snakehead fish (*C. striata*) because maggot meal has a high protein content. Maggots have the same protein content as fish meal, about 40-50% (Kardana *et al*., 2012). The use of maggots as feed ingredient has many advantages including reducing organic waste, not carrying or becoming an agent of disease, it makes the striped snakehead fish (*C. striata*) live with a wide pH tolerance and have a long life (± 4 weeks), and does not require high technology to procure. Maggots with the highest protein content are in their pre-pupa phase, and in that phase the maggot larvae have not eaten and are ready to become cocooned (Fahmi *et al*., 2008).

Study on the substitution of maggot meal for fish meal as alternative feed ingredient for pomfret fish (*Colossoma macropomum*) showed as the best choice a 20% substitution of maggot meal in place of fish meal, according to Kardana *et al*., (2012). Based on this study, the substitution of maggot meal for fish meal in prepared feed has been demonstrated to improve feed utilization efficiency and fish growth. However, no prior study on the utilization of maggot meal as fish meal substitute for striped snakehead fish (*C. striata*) has been done. So, a study on the utilization of maggot meal as fish meal substitute to improve growth and feed utilization efficiency in striped snakehead fish (*C. striata*) fingerlings was conducted.

The purpose of this study was to determine and analyze appropriate maggot meal substitution level for fish meal to improve growth and feed utilization efficiency in striped snakehead fish (*C. striata*) fingerlings. The results of this study are expected to provide information to farmers in choosing the usage of feed alternatives that can meet the nutritional needs of striped snakehead fish (*C. striata*) and improve its growth and feed utilization efficiency. This research was carried out from December 2017 to April 2018 at the Mijen Fish Seed Center and the Aquaculture Laboratory at Diponegoro University Semarang.

2. Materials and Methods

The tested fish used in this study were striped snakehead fish (*C. striata*) with an average weight of 0.87 ± 0.01 g / fish. Stocking density of striped snakehead fish for each container was 1 fish / L. The 180 striped snakehead fish were obtained from Budi Fish Farm Sleman, Yogyakarta. Feed was given 3 times daily at 08:00, 12:00 and 16:00 in West Indonesia Time, with a fixed feeding rate. The containers used in this study were 12 plastic buckets with a water volume of 15 L as treatment units, and each bucket had an aerator installed. The experimental design was a completely randomized design (CRD) with 4 treatments and 3 replications. The treatments were as follows:

1. Treatment A: test feed with a 0% substitution of maggot meal for fish meal
2. Treatment B: test feed with a 10% substitution of maggot meal for fish meal
3. Treatment C: test feed with a 20% substitution of maggot meal for fish meal
4. Treatment D: test feed with a 30% substitution of maggot meal for fish meal

The study design refers to a previous study conducted by Kardana *et al*. (2012) which stated that the best maggot meal dose was 20% substitution, which produced 2.027% Specific Growth Rate (SGR) and 56.80% Feed Utilization Efficiency (FUE). The stages before making the test feed were to prepare all the ingredients, furthermore, proximate analysis of the ingredients was done for calculating the feed formulation to be used. After knowing the proximate analysis results of each ingredient, the feed formulation was decided. Proximate analysis and composition of feed ingredients are presented in Table 1. The feed used in this study had a protein content of 35%. Nutritional content from proximate results was used to calculate feed formulations. The composition of the feed used in the study is presented in Table 2. The observations in this study were for assessing specific growth rate (SGR), feed utilization efficiency (FUE), protein efficiency ratio (PER), survival rate (SR), and water quality parameters.

Table 1. Proximate analysis of feed ingredients (in % of dry weight)

Ingredient	Water	Protein	Nitrogen-free extract	Fat	Crude fiber	Ash	Total (%)
Fish Meal	0	48.01	13.29	5.53	0.00	33.17	100
Maggot Meal	0	44.89	9.87	14.67	9.82	20.75	100
Soybean Meal	0	50.53	37.36	0.94	3.72	5.28	100
Corn Gluten Meal	0	9.67	84.41	0.34	3.99	1.59	100
Bran Meal	0	11.29	49.36	8.03	21.08	10.24	100
Wheat Flour	0	10.57	86.45	1.06	1.20	0.72	100

Table 2. Composition and proximate analysis of feeds used during experiment

Ingredient	Tested feed (g/100 g of Feed)			
	A (0%)	B (10%)	C (20%)	D (30%)
Fish Meal	31.00	27.90	24.80	21.70
Maggot Meal	0.00	4.01	8.01	12.02
Soybean Meal	28.00	28.00	29.00	29.00
Corn Gluten Meal	5.00	5.00	5.00	5.00
Bran Meal	14.00	14.00	13.00	13.00
Wheat Flour	13.00	12.09	11.19	10.28
Fish Oil	3.00	3.00	3.00	3.00
Corn Oil	2.00	2.00	2.00	2.00
Vitamins-minerals mix	3.00	3.00	3.00	3.00
Carboxymethylcellulose (CMC)	1.00	1.00	1.00	1.00
TOTAL (%)	100.00	100.00	100.00	100.00
Proximate Analysis Results				
Protein (%)	35.58	35.71	35.61	35.58
Nitrogen-free extract (%)	34.51	34.02	33.44	32.95
Fat (%)	8.25	8.66	9.00	9.40
Energy (kcal)*	277.45	279.18	281.46	283.19
E/P Ratio**	8.81	8.88	8.88	8.95

Description: *Nutrition and Feed Laboratory, Department of Animal Husbandry, Faculty of Animal Husbandry and Agriculture, Diponegoro University, 2018.
**E/P value for optimal fish growth ranged between 8-9 kcal/g (De Silva, 1987).

2.1 Specific growth rate (SGR)

Specific growth rate in this study was calculated using the formula by Wirabakti (2006) as follows:

$$SGR = \frac{\ln W_t - \ln W_0}{T} \times 100\%$$

where SGR = Specific growth rate (%/day)
W_t = Total weight of fish at the end of maintenance (g)
W_o = Total weight of fish at the beginning of maintenance (g)
t = Length of maintenance (day)

2.2 Feed utilization efficiency (FUE)

Feed utilization efficiency can be determined using the formula by Watanabe (1988), as follows:

$$FUE = \frac{W_t - W_0}{F} \times 100\%$$

where FUE = Feed Utilization Efficiency (%)
W_t = Biomass weight of tested fish at the end of the experiment (g)
W_0 = Biomass weight of tested fish at the beginning of the experiment (g)
F = The amount of feed given to fish during the experiment (g)

2.3 Protein efficiency ratio (PER)

Protein efficiency ratio can be determined using the formula by Tacon (1987), as follows:

$$PER = \frac{W_t - W_0}{Pi} \times 100\%$$

where PER = Protein efficiency ratio (%)
W_t = Total weight of fish at the end of experiment (g)
W_0 = Total weight of fish at the beginning of experiment (g)
Pi = The amount of test feed consumed is multiplied by the protein content (%) of the test feed

2.4 Survival rate (SR)

Survival rate (SR) was calculated to determine the mortality rate of tested fish during experiment, Survival Rate can be determined using the formula by Wirabakti (2006), as follows:

$$SR = \frac{N_t}{N_0} \times 100\%$$

where SR = Survival Rate (%)
Nt = The total amount of fish that survive at the end of the observation (fish)
N_0 = The total amount of fish at the beginning of the observation (fish)

Data analysis were carried out for the relative growth rate (RGR), total feed consumption (TFC), feed utilization efficiency (FUE), protein efficiency ratio (PER), and survival rate (SR). After the data were obtained, they were subjected to analysis of variance (ANOVA) with 95% confidence threshold to distinguish the effects of the treatments. Before analyzing the variance, normality test, homogeneity test, and additivity test were first carried out to ensure the data are spread normally, homogeneous, and additive. Data were analyzed (F test) for 95% confidence intervals. If there were significant differences ($P < 0.05$) from the analysis of variance, then Duncan's multiple range test was conducted *post hoc* to assess significance of the median value differences between treatments. Normality, Homogeneity, Duncan and Descriptive Tests were carried out using SPSS version 23 software. Additivity test was done using Microsoft Excel 2016, and water quality analysis was carried out descriptively to verify feasibility to support growth.

2.5 Proximate analysis

The proximate chemical composition of the samples was determined using a standard procedure (AOAC 2005; Herawati *et al*., 2018). The crude protein content was calculated by multiplying the total nitrogen with a correction factor. The carbohydrate content was estimated as a difference.

2.6 Essential amino acid profile

The amino acid composition of the sample was determined using HPLC (Shimadzu LC-6A) (AOAC 2005; Herawati *et al*, 2018).

2.7 Fatty acid profile

The fatty acid composition of the sample was determined using a gas chromatograph (Shimadzu) (AOAC 2005; Herawati *et al*, 2018).

3. Results

Based on the results of the study, the effects of maggot meal substitution for fish meal in a prepared feed towards specific growth rate, efficiency of feed utilization, protein efficiency ratio, survival rate, and biomass weight are presented in Table 3.

The specific growth rate (SGR), feed utilization efficiency (FUE), protein efficiency ratio (PER) and survival rate (SR) of striped snakehead fish (*C. striata*) for 45 days of observation during alternative dietary treatments were obtained. The highest average specific growth rate (SGR) was found for treatment C (20% maggot meal substitution) namely 4.61 ± 0.011%, while the lowest result was for treatment A (without maggot meal substitution) at 3.02 ± 0.20 %. The highest average feed utilization efficiency (FUE) was also for treatment C (20% maggot meal substitution) at 71.57 ± 2.82%, while the lowest was for treatment A (without maggot meal substitution) at 42.94 ± 3.58%. The highest protein efficiency ratio (PER) was for treatment C (20% of maggot meal substitution) at 2.01 ± 0.08%, and the lowest for treatment A (without maggot meal substitution) at 1.21 ± 0.10%. The highest survival rate (SR) was for treatment C (20% of maggot meal substitution) at 84.44 ± 3.85%, while the lowest was for treatment A (without maggot meal substitution) at 80.00 ± 6.67%.

Analysis of variance on specific growth rates (SGR), efficiency of feed utilization (FUE), protein efficiency ratio (PER) and biomass weight in striped snakehead fish (*C. striata*) showed that maggot meal substitution level of fish meal had a significant effect ($P < 0.05$), while an analysis of variance result of survival rate (SR) in striped snakehead fish (*C. striata*) did not show a significant effect ($P > 0.05$) from the alternative dietary treatments.

The results of orthogonal polynomial test and curve analysis of specific growth rate (SGR) of striped snakehead fish (*C. striata*) for 45 days of observation are presented in Figure 1. A quadratic relationship ($y = -0.0031x^2 + 0.1357x + 2.9689$) and $R^2 = 0.9276$ were obtained from Orthogonal Polynomial test of the Specific Growth Rate (SGR). Based on the curve analysis results, the optimum dose is 21.9%. R^2 for the model fit was 92.76%.

Orthogonal polynomial test results and curve analysis of Feed Utilization Efficiency (FUE) of striped snakehead fish seeds (*C. striata*) for 45 days of observation are presented in Figure 2. A quadratic relationship ($y = -0.0486x^2 + 2.2846x + 41.767$) and $R^2 = 0.9093$ were obtained from Orthogonal Polynomial test of Feed Utilization (FUE). Based on the curve analysis results, the optimum dose was estimated as 23.5%. R^2 of the model fit was 90.93%.

Orthogonal polynomial test results and curve analysis of Protein Efficiency Ratio (PER) of striped snakehead fish (*C. striata*) fingerlings for 45 days of observation are presented in Figure 3. A quadratic relationship ($y = -0.0013x^2 + 0.0637x + 1.1733$) and $R^2 = 0.9071$ were obtained from Orthogonal Polynomial test for Protein Efficiency Ratio (PER). Based on the curve analysis, the optimum dose was estimated as 24.5%. R^2 for the model fit was 90.71%.

Table 3. The averages of specific growth rate, efficiency of feed utilization, protein efficiency ratio, survival rate, and biomass weight by the alternative 45-day dietary treatments

Parameter	Treatment			
	A	B	C	D
SGR (%)	3.02 ± 0.20^{d}	3.87 ± 0.15^{a}	4.61 ± 0.011^{a}	4.23 ± 0.08^{a}
FUE (%)	42.94 ± 3.58^{d}	56.23 ± 1.57^{bc}	71.57 ± 2.82^{ab}	65.43 ± 0.76^{bc}
PER (%)	1.21 ± 0.10^{d}	1.57 ± 0.04^{cb}	2.01 ± 0.08^{ab}	1.84 ± 0.02^{bc}
SR (%)	80.00 ± 6.67^{a}	84.44 ± 3.85^{a}	84.44 ± 3.85^{a}	82.22 ± 3.85^{a}
W_0 (g)	0.88 ± 0.01^{a}	0.87 ± 0.01^{a}	0.88 ± 0.01^{a}	0.87 ± 0.01^{a}
W_t (g)	3.90 ± 0.06^{d}	5.25 ± 0.07^{bc}	7.20 ± 0.09^{a}	4.56 ± 0.09^{cb}
FBW (g)	3.023 ± 0.063^{d}	4.38 ± 0.08^{cb}	6.32 ± 0.09^{a}	5.39 ± 0.08^{bc}

Description: The means with the same superscript are statistically similar ($P > 0.05$), while different superscripts indicate significant differences ($P < 0.05$) between the treatments.

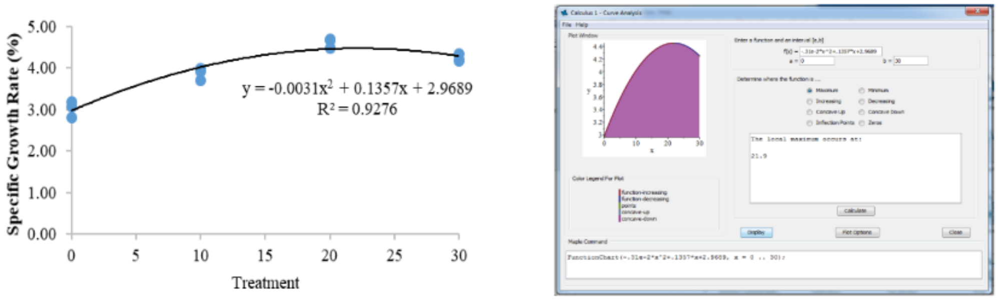

Figure 1. Polynomial Orthogonal Graph and Curve Analysis Result for Specific Growth Rate (SGR)

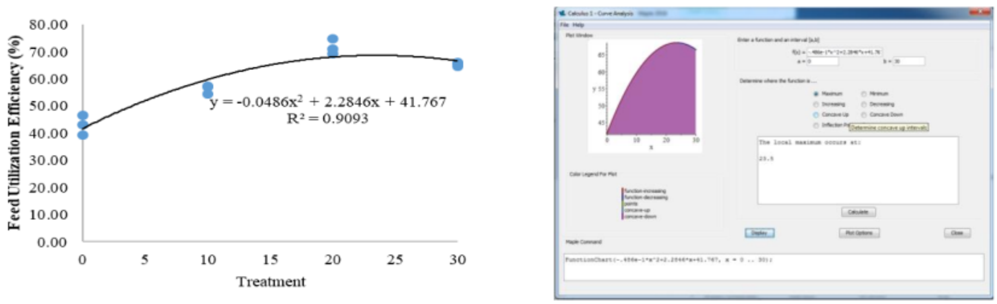

Figure 2. Polynomial Orthogonal Graph and Curve Analysis Result for Feed Utilization Efficiency (FUE)

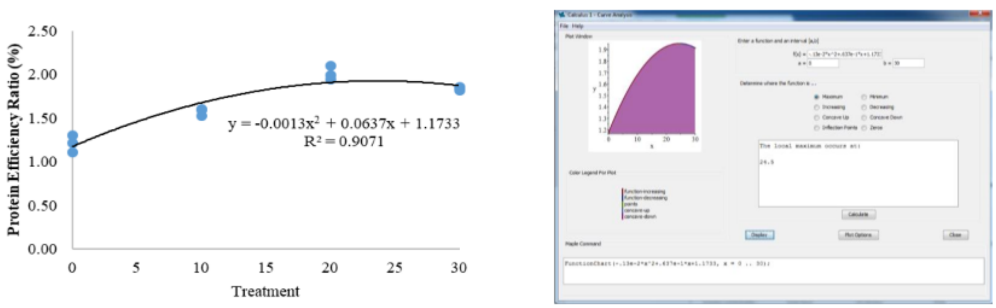

Figure 3. Polynomial Orthogonal Graph and Curve Analysis Result for Protein Efficiency Ratio (PER)

Amino acid content of each treatment and amino acid requirements of striped snakehead fish through manual calculation are presented in Table 4. The highest amino acid in the profile was leucine at 3.38%. The fatty acid content of each treatment and the fatty acid requirements of striped snakehead fish (*C. striata*) are presented in Table 5. The highest essential fatty acid found was linolenic fatty acids at 5.76%.

3.1 Water quality parameters

The various measured water quality parameters during striped snakehead fish (*C. striata*) maintenance in this study are summarized in Table 6.

4. Discussion

The growth of striped snakehead fish (*C. striata*) was assessed from specific growth rates calculated based on the final weight after 45 days of dietary treatment. The results show that the highest specific growth rate (SGR) was with 20% substitution of maggot meal (C) giving 4.61%, and the lowest was without any substitution of maggot meal (treatment A) giving 3.02%. The specific growth rate (SGR) is directly proportional to the feed utilization efficiency, so that a high feed utilization efficiency is paired by a high growth rate. The study found that substitution of maggot meal for fish meal prepared feed for snakehead fish (*C. striata*) gave a significant effect ($P < 0.05$) on the growth of snakehead fish. The results of the study were strengthened using Duncan's

Table 4. Amino acid contents in each feed, and amino acid requirements of the striped snakehead fish (*C. striata*)

Amino acid	Requirement*	A (0%)	B (10%)	C (20%)	D (30%)
Arginine	1.74	2.70	2.96	3.49	3.36
Histidine	0.78	0.88	1.04	1.36	1.28
Isoleucine	0.99	1.61	1.75	2.01	1.98
Leucine	2.01	2.51	2.81	3.41	3.38
Lysine	1.16	1.97	2.14	2.50	2.46
Methionine	1.07	1.23	1.69	2.41	2.34
Phenylalanine	1.64	1.89	2.04	2.34	2.19
Threonine	0.90	1.49	1.55	1.66	1.60
Tryptophan	1.91	0.84	1.02	1.39	1.36
Valine	0.96	1.97	2.00	2.07	2.04

Description: * Rahayu *et al*. (2016)

Table 5. The fatty acid contents in each feed and the fatty acid requirements of striped snakehead fish (*C. striata*)

Saturated fatty acid	Sample				
	Requirement*	A (0%)	B (10%)	C (20%)	D (30%)
Methyl Butyrate	< 0.1	0.88 ± 0.09	0.33 ± 0.06	2.66 ± 0.02	0.88 ± 0.09
Methyl Hexanoate	< 0.1	1.89 ± 0.03	1.63 ± 0.02	3.52 ± 0.07	1.89 ± 0.03
Methyl Undecanoate	< 0.1	1.09 ± 0.02	2.25 ± 0.09	3.47 ± 0.03	3.09 ± 0.02
Methyl Laurate	0.23	1.83 ± 0.02	1.90 ± 0.08	2.82 ± 0.04	1.83 ± 0.02
Methyl Tridecanoate	0.89	3.82 ± 0.06	2.65 ± 0.08	4.78 ± 0.03	3.82 ± 0.06
Methyl Pentadecanoate	2.27	3.46 ± 0.08	3.75 ± 0.09	4.99 ± 0.01	3.86 ± 0.08
Methyl Palmitate	0.73	7.85 ± 0.02	5.93 ± 0.06	7.09 ± 0.03	7.85 ± 0.02
Methyl Heptadecanoate	0.97	1.28 ± 0.07	1.80 ± 0.09	2.15 ± 0.05	1.28 ± 0.07
Methyl Arachidate	4.75	4.73 ± 0.07	5.45 ± 0.03	6.65 ± 0.02	5.37 ± 0.07
Methyl Tricosanoate	1.26	1.35 ± 0.02	1.93 ± 0.06	2.09 ± 0.03	1.85 ± 0.02
Unsaturated Fatty Acid					
Linoleic	< 0.1	2.06±0.02	2.97±0.06	4.81±0.04	4.06±0.02
Linolenic	< 0.1	2.74±0.05	3.08±0.09	5.76±0.06	3.74±0.05
Erucate	2.93	1.63±0.02	2.62±0.05	3.05±0.01	2.83±0.02
Eicosapentaenoic	0.93	1.08±0.04	2.07±0.03	2.67±0.01	1.98±0.04
Docosahexaenoic	< 0.1	0.72±0.02	1.15±0.06	1.59±0.07	1.22±0.02

Description: * Rahayu *et al*. (2016)

Table 6. Measured ranges of the various water quality parameters during the maintenance of striped snakehead fish (*C. striata*) in the dietary 45-day experiment

Water quality parameter	Range of values	Reference range
Temperature (℃)	24 – 30	26 – 32*
pH	6.7 - 7.4	5.2 – 7.8*
DO (mg/L)	2.96 - 3.06	> 3.00**
NH_3 (mg/L)	0.022 – 0.288	0.54 – 1.57***

Citation for source of reference range: * : Hidayatullah *et al*. (2015), ** : Fariedah and Widodo (2016), *** : Extrada *et al*. (2013)

multiple range test, which shows that the specific growth rates for 10% maggot meal substitution treatment (B); for 20% substitution (C), and for 30% substitution (D) significantly differ ($P<0.05$) from treatment without maggot meal (A). However, there was no significantly difference ($P>0.05$) between the actual treatments including maggot meal. The optimum level of maggot meal substitution for fish meal based on the growth of snakehead fish fingerlings was determined by Orthogonal Polynomials test. A quadratic relationship ($y = -0.0031x^2 + 0.157x + 2.9689$) with $R^2 = 0.9276$ was obtained from the Orthogonal polynomial test of SGR. Based on the polynomial test with curve analysis, the optimum dose was estimated as 21.9%. This proves that the growth of snakehead fish (*C. striata*) grows relatively faster on substituting maggot meal for fish meal in the feed. This relatively faster growth is due to the higher protein content in maggot meal compared to fish meal, and the amino acid profile in the feed can meet the requirements of snakehead fish. The results of this study are consistent with the statements by Fariedah and Widodo (2016) in their study, which explained that protein is one of the very important nutrients needed in the growth of snakehead fish, with 35-60% to be converted from feed into body tissue.

The use of maggot meal in this study greatly affected the suitability of the feed given to snakehead fish (*C. striata*) as proven by higher growth than without added maggot meal. That statement is in line with the results of Spikadhara *et al*. (2012) who found that the suitability of the type of feed greatly affects an organism for its growth and breeding. Snakehead fish (*C. striata*) are carnivorous fish that use protein more than other feed components as a support for growth and as energy source.

Specific growth rates obtained during the study were higher than in a previous study conducted by Kardana *et al*. (2012) who found the highest growth rate of 3.027% with 20% substitution of maggot meal in pomfret fish weighing 2.5 g; and Priyadi *et al*. (2009) with specific growth rate 3.69% observed with 20% substitution of maggot meal in balashark fish weighing 1.28 g. The difference in growth between feed containing maggot meal and feed without maggot meal was statistically significant, and the feed efficiency also affects the response of fish to feeding. The higher the feed efficiency, the better is the response to the feed, as indicated by the rapid growth of fish (Arief *et al*., 2014).

The utilization of maggot meal (10%, 20% and 30%) as a substitute for fish meal gave statistically significant differences ($P < 0.05$) in feed utilization efficiency (FUE) of snakehead fish (*C. striata*). The highest feed utilization efficiency (FUE) from substitution of fish meal with maggot meal was with 20% substitution (C) at 71.57 ± 2.82%, and the lowest was without maggot meal (A) at 42.94 ± 3.58%. The feed utilization efficiency indicates that maggot meal substitution was suitable for fish, because it meets the requirement of good FUE exceeding 50%. The results of this study were strengthened by Duncan's statistical test which showed that the efficiency of feed utilization in treatments using 10% (B), 20% (C) and 30% (D) maggot meal substitution significantly differed ($P < 0.05$) from not using maggot meal substitution (A). The optimum content of maggot meal substitute for fish meal based on the growth of snakehead fish (*C. striata*) was determined by Orthogonal Polynomials test. A quadratic relationship ($y = -0.0486x^2 + 2.2846x + 41.767$) and $R^2 = 0.99093$ was obtained by Orthogonal Polynomial test on FUE. Based on the polynomial fit, the optimum dose is estimated as 23.5%. The response of fish to feed that uses maggot meal in feed is faster than to feed without maggot meal (treatment A). This statement is in line with Arief *et al*. (2014) who stated that the higher the feed efficiency, the better is response of the fish to feed, which is indicated by the rapid growth of fish. Kardana *et al*. (2012) stated that maggot meal added in prepared feed provides stimulation to the feeding fish, so that the maggot meal with a higher protein content results in rapid growth. The use of maggot meal as a substitute for fish meal has a significant effect on fish growth and efficiency of feed utilization. This is proven by the results of this study that show 30% substitution of maggot meal providing feed utilization efficiency that is directly proportional to its growth. The results of this study are in accordance with Kardana *et al*. (2012) stating that feed efficiency is a comparison between body weight produced to the amount of feed given during cultivation, and the greater the feed efficiency, the better the fish utilizes the food consumed, so that the weight of meat produced by fish is increased directly proportionally to body weight.

The feed utilization efficiency found in this study is higher than in previous study on maggot meal substitution by Kardana *et al*. (2012), where the highest feed utilization efficiency was 56.80% with 20% maggot meal substitution in pomfret weighing 2.5 g. The content of protein in feed greatly affects the feed utilization efficiency. Protein is one of the most important nutrients needed for growth of fish, at least of striped snakehead fish that requires 35-60% protein in its feed to be converted from feed to body tissue (Fariedah & Widodo, 2016).

The results show that the use of maggot meal (10%, 20% or 30%) as a substitute for fish meal significantly differed ($P < 0.05$) in protein efficiency ratio (PER) of snakehead fish (*C. striata*). The highest PER was for 20% maggot meal substitution (C) at 2.01 ± 0.08% and the lowest was without maggot meal (A) at 1.21 ± 0.10%. The PER is related to the utilization of protein in feed. The high PER for the 20% treatment (C) suggests that the increased protein and energy content in the feed could meet the minimum protein requirements by snakehead fish for growth. Yulisman *et al*. (2012) corroborate the results of this study, as a protein content of 35% in the feed met the minimum requirements for snakehead fish.

The higher the PER, the higher the specific growth rate (SGR), because protein can break down into amino acids so that it is easily absorbed and utilized by the body. This is reinforced by Craig and Helfrich (2017) showing that high protein efficiency ratio is caused by protein being broken down into amino acids and their constituents, so that the absorption of protein by the fish will be easier. Good protein absorption has a positive impact on biomass growth. This is reinforced by Li *et al*. (2012) according to whom the higher the protein conversion value of a feed indicates that the feed is more efficient, because the existing protein can be used optimally.

The high PER and SGR are thought to be due to the amino acid content and fatty acids in feed that meet the needs of striped snakehead fish. This is reinforced by Bicudo and Cyrino (2014) stating that feed in fish farming must be complete and balanced, providing essential amino acids and adequate fatty acids for optimal growth and health. According to Craig and Helfrich (2017), essential amino acids and fatty acids are the key molecules for building proteins, and furthermore fatty acids are also key molecules to regulate metabolic pathways including cell signaling, appetite stimulation, growth and development, energy utilization, immunity, osmoregulation, ammonia detoxification, anti-oxidative defense, metamorphosis, pigmentation, intestinal and neural development, stress response, reproduction, and emphasis in aggressive behavior of aquatic animals.

Arginine is an essential amino acid that is useful in increasing the body's resistance or in production of lymphocytes, increasing the release of growth hormone or human growth hormone (HGH), and increasing male fish's fertility (Linder, 1992). Glutamic acid is a non-essential amino acid that plays a role in supporting brain function, facilitating learning, and strengthening memory. Besides, glutamic acid is also useful to increasing muscle mass (enlarging muscles) (Winarno, 2008). Tryptophan (Trp) is an EAA precursor of serotonin that contributes in protein synthesis and growth performance, influences behavior and food intake, and acts as a metabolic precursor of the vitamin niacin (Ahmed, 2010). When associated with niacin, Trp interferes with the metabolism of proteins and lipids. In addition to these functions, Trp is an amino acid that stimulates the growth hormone and the secretion of insulin (Rossi & Tirapegui, 2004; Dyer *et al*., 2004). Leucine is the most effective amino acid that has an effect on protein synthesis and degradation in mammals and plays an important role in body adipose deposition. Leucine has been proven to be an EAA for fish, and a deficiency or an excess of dietary leucine level causes reduced growth performance and feed utilization in several fish species (Mingchun *et al*., 2015).

Lipid composition and fatty acid composition in fish differ depending on various factors: their aquatic environment (marine water, freshwater, and cold or warm water) and the biological, physical, and chemical properties of that environment. Furthermore, seasonal changes, migration, sexual maturity and spawning period, species, feeding habits, and whether reared in aquaculture or grown in natural habitats affect the lipid/fatty acid composition (Aras *et al*., 2002). The linoleic refers to the substrate forming long chain of PUFA. The results of this research are strengthened by the statements of (Ouli 2012; Pratiwi *et al*., 2009) that the linoleic acts as the basic substrate of forming the long chained Omega 6 and Omega 3.

The palmitic content was found at the highest level in this research because of the function of energy storage both in phytoplankton and zooplankton. This matches the results of Lim *et al*. (2011), stating that palmitic serves as energy storage that later is used for the biosynthesis of SAFA.

The results were strengthened by Duncan's statistical test showing that protein efficiency ratio in treatments using 10% (B), 20% (C) and 30% (D) substitution of maggot meal was significantly different ($P < 0.05$) from that without maggot meal (A). The optimum substitution level of maggot meal in fish meal based on the growth of snakehead fish (*C. striata*) fingerlings was determined by Orthogonal Polynomials test. A quadratic relationship ($y = -0.0013x^2 + 0.0637x + 1.1733$) with $R^2 = 0.9071$ was obtained by Orthogonal Polynomial test on PER. Based on the polynomial, the optimum dose was estimated as 24.5%. This is because maggot meal can affect the protein utilization ratio. The energy obtained for growth comes from protein, and feed protein can be said to be good if it has a good digestibility level. Feed protein with good digestibility will be utilized by the body so that it can produce growth. Snakehead fish is a type of carnivorous fish that requires high protein for its growth. Fariedah and Widodo (2016) explained that protein is one of the nutrients that is very important for the growth of fish that requires 35-60% protein in its feed for conversion into body tissues, like most carnivorous fishes that experience optimum growth when the availability of protein is around 35-50% in the feed.

The protein efficiency was higher than in prior study of maggot meal substitution conducted by Priyadi *et al*. (2009), with the highest protein efficiency ratio of 0.83% for 10% maggot meal in balashark fish weighing ± 2.2 g. The difference in protein efficiency ratio is thought to be due to temperature differences that can significantly affect the appetite of snakehead fish. A significant decrease in temperature decrease snakehead fish's appetite, even though the striped snakehead fish can still survive (Fariedah & Widodo, 2016).

The results showed that the use of maggot meal as a substitute for fish meal in prepared feed had no significant effect ($P > 0.05$) on the survival rate of snakehead fish (*C. striata*). The highest average survival rate was for 20% substitution of maggot meal (C) and the lowest was without maggot meal (A) at 80.00 ± 6.67%. Survival rate did not much differ between the dietary treatments, showing that maggot meal substitution for fish meal did not directly affect the survival. Fish deaths were thought to be due to stress during the study. This was caused by the water quality, especially the fluctuating temperatures. Widayarti (2017) stated that the low survival rate is thought to be related to a decrease in the fish's resistance to stress. Low survival rate is not due to the treatment by commercial feed. Fish maintenance is supported by the presence of fecal filtration and routine filter cleaning that can support the life of snakehead fish. Based on the water quality parameters that have been observed during the maintenance of snakehead fish (*C. striata*) for 45 days, the fluctuating temperatures ranged within 24-30ºC but the range of temperatures was still tolerable. The observations in this study are in line with Hidayatullah *et al*. (2015) who stated that the temperature range that can be tolerated by snakehead fish is 27–32ºC. Furthermore, the pH was 6.7 – 7.4. According to Hidayatullah *et al*. (2015), pH of 5.2 – 7.8 is still considered tolerable by the snakehead fish. Sasanti and Yulisman (2012), stated that snakehead fish can still survive in acidic and alkaline water. Ammonia content during the study ranged from 0.022 to 0.288 mg/L. According to Extrada *et al*. (2013), ammonia content for snakehead fish fingerling cultivation of 0.54 – 1.57 mg/L can still be tolerated by the fish. The dissolved oxygen level in this study was 2.96 – 3.06 mg/L. Dissolved oxygen levels in this study are considered normal. Fariedah and Widodo, (2016) stated that dissolved oxygen needed by striped snakehead fish is more than 3 mg/L.

5. Conclusions

The best choice of tested feed have 20% substitution of maggot meal for fish meal, resulting in 4.61% SGR; FUE 71.57%; PER 01.01% and FBW 6.32 g. Based on orthogonal polynomial fits, the optimal dosing for SGR was estimated as 21.9%, for PER as 24.5%, and for FUE as 23.5%. Overall, feed with a 20%-25% substitution of maggot meal for fish meal is near optimal for the growth of striped snakehead fish.

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