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OPTIMIZATION OF FISH MEAL SUBSTITUTION WITH MAGGOT MEAL (*HERMETIA ILLUCENS*) FOR GROWTH AND FEED UTILIZATION EFFICIENCY OF JUVENILE *LITOPENAEUS VANNAMEI*

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***Key words**: Pacific white shrimp, Maggot, Growth, Feed efficiency.*

Abstract – Maggot (*Hermetia illucens*) has good nutritional value, high protein content and its inclusion in fish maintenance can avoid the competition of protein sources with humans. The purpose of this study was to know the effect of fish meal substitution with maggot meal to growth, feed utilization efficiency, and protein efficiency ratio of Pacific white shrimp (*Litopenaeus vannamei*) and to know the best composition of fish meal substitution with maggot meal for growth, feed utilization efficiency and protein efficiency ratio of Pacific white shrimp. The test fish used in this study were Pacific white shrimp with an average initial weight of 2.62 ± 0.12 g of 320 shrimp (20 shrimp on each test) from BBPBAP Jepara. This study used complete randomized design with 4 treatments, 3 replications. The treatments to be tested are as follows: A (substitution of fish meal with 0% of maggot meal), B (substitution of fish meal with 8% of maggot meal), C (substitution of fish meal with 16% of maggot meal), D (substitution of fish meal with 24% of maggot meal). The measured variables include: relative growth rate, total feed consumption, feed utilization efficiency, protein efficiency ratio, survival rate and water quality. The results showed that substitution of fish meal with maggot meal had significant effect (Sig <0.05) to relative growth rate, total feed consumption, feed utilization efficiency, feed conversion ratio, and protein efficiency ratio but had no significant effect (Sig> 0.05) to survival rate of Pacific white shrimp. The best composition of fish meal substitution with maggot meal was C treatment (substitution of fish meal with 16% of maggot meal) which able to produce relative growth rate of 7.51 ± 0.07%/day, feed utilization efficiency of 53.97 ± 0.82%, feed convertion ratio of 1.85±0.03 and protein efficiency ratio of 1.52 ± 0.02%.

INTRODUCTION

Pacific white shrimp *(Litopenaeus vannamei)* is one of the fishery products that have high economic value. Pacific white shrimphas advantages for ponds shrimp farming, those are: responsive to feed, more resistant to disease and poor environmental quality, faster growth, has high survival rate, high stocking density, and its maintenance time is relatively short that is around 90-100 days per cycle (Purnamasari *et al.*, 2017). Shrimp growth is highly dependent on nutrients contained in the feed. Fish meal is one of the ingredient sources for animal protein and contains minerals that are needed infeed composition. This high nutritional value in fish meal is what makes fish meal has a quite expensive price (Idowu and Afolayan, 2013). Therefore, it is necessary to find an alternative source of local ingredient that can be used as a source of animal protein feed to reduce the dependence on fish meal. One of the local ingredients that can be used as a substitution for fish meal is maggot.

Maggot is a larvae of a black soldier fly (*Hermetia illucens*) which grows widely in animal wastes such as cow manure, goat manure, poultry manure, and organic waste under good conditions. According to

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Cummins Jr *et al.*, (2017) maggot meal can substitute fish meal because it has almost the same nutritional content as fish meal. Maggot has quite high protein content, they are: 44.88% of protein, 14.65% of fat, and 9.90% of Nitrogen-free Extract (NFE). Besides that, maggot meal also contains complete essential and non-essential amino acids, they are : 6.06% of arginine, 3.01% of histidine, 3.05% of isoleucine, 6.35% of leucine, 4.23% of lysine, 1.82% of methionine, 3.53% of phenylalanine, 2.09% of threonine, 3.17% of tryptophan, 1.91% of valine, 3.84% of alanine, 4.31% ofaspartate acid, 1.2% of cysteine, 3.87% of glutamic acid, 2.76% of glycine, 1.58% of proline, 3.14% of serine, and 2.47% of tyrosine. Maggot at the pre-pupa phase has high potential, it can be used as a good source of nutrition for fish because at this phase maggot has fasting so it does not contain harmful substances. The inclusion of pre-pupa maggot in fish rearing can avoid competing of protein sources with humans. The use of alternative ingredients as a substitution for fish meal is one of the strategies in saving expenses. In addition to its abundant availability, maggot is also very easy to cultivate using simple technology (Idowu and Afolayan, 2013).

Study on the substitution of fish meal with maggot meal on Pacific white shrimp itself has been carried out by Cummins Jr *et al.*, (2017). The best composition in Cummins study for specific growth of Pacific white shrimp is 20% of fish meal protein substituted with maggot meal. Based on Cummins study, it is necessary to do further study on the substitution of fish meal with maggot meal to determine the best composition and its effect on growth and feed utilization efficiency of Pacific white shrimp.

The purpose of this study was to determine the effect of fish meal substitution with maggot meal on the growth and feed utilization efficiency, and determine the best composition of fish meal substitution with maggot meal for growth and feed utilization efficiency of Pacific white shrimp.

MATERIALS AND METHODS

The tested shrimp used in this study was Pacific white shrimp with an average initial weight of 2.62±0.12 g/shrimpa with the total of 320 shrimp (20 shrimp in each replication) originating from BBPBAP Jepara. The srimp are 23 days old when taken from the pond. Tested fish were selected based on weight, completeness of body organs and not potentially attacked by a disease. The tested ingredient used was maggot from maggot farms in Kandangan sub-district, Temanggung Regency, Central Java. Maggots that have become pre-pupa are then dried and crushed in order to be flour. Test feed that will be used in this study is artificial feed in the form of pellets with a diameter of 0.5 – 1.0 mm. Test feed was given 4 times a day at 08:00, 12:00, 16:00, and 20:00 (Western Indonesian Time) by fix feeding method. The container used in this study were 12 pieces of conical tank with a capacity of 1 ton. The tub is filled with 800L of water from the total volume of the tub and then was aerated.

The test feed preparation conducted in this study to prepare in advance the feed ingredients to be used in the study. The ingredients used to make the feed are fish meal as a source of animal protein, Maggot meal as a source of animal protein and as an ingredient that substitute fish meal, soy meal as a source of plant protein, corn meal, rice bran meal and wheat meal as a source of carbohydrates, fish oil and palm oil as a source of fat, minerals and vitamin mix as a source of vitamins and minerals, and CMC as a binder or adhesive.

The next preparation is to do a proximate analysis of feed ingredients, formulate a feed in accordance with requirements of tested shrimp and create test feed based on formulations that have been made. Proximate analysis of feed ingredients is done to determine the nutrient content in raw materials which will be used to make test feed formulations. The results of the proximate analysis of the constituent ingredients in the test feed can be seen in Table 1.

Based on the results of the proximate analysis in Table 1 it can be seen the nutritional content of each ingredient to calculate the feed formulation. The formulation and results of the proximate analysis of the test feed used in the study are presented in Table 2.

The results of the analysis of essential amino acid content of each feed used in the study are presented in Table 3.

The treatments were a modification of the study conducted by Cummins Jr *et al.* (2017). The best composition in the study was substitution of 20% protein of fish meal with maggot meal which able to produce 4.07% of specific growth with 2.01 of Feed Conversion Ratio (FCR). In the study it was also suggested that substitution of fish meal with maggot mealfor shrimp should be <25%.

The data observed in this study were absolute

Table 1. Proximate analysis of ingredients for preparing feed used in the study (in% dry weight)

Ingredients	Water	Ash	Fat	CF	Protein	NFE	Total
Fish meal (**)	0	33.17	5.53	0.00	58.01	3.29	100.00
Maggot meal (*)	0	20.75	14.65	9.82	44.88	9.90	100.00
Soybean meal (**)	0	7.64	0.94	3.72	50.35	37.36	100.00
Corn meal(*)	0	1.56	0.34	3.94	9.53	83.21	100.00
Wheat meal(*)	0	0.72	1.06	1.20	10.57	86.45	100.00
Rice bran meal (*)	0	10.24	8.03	21.08	11.29	49.36	100.00

Description: Nitrogen-free extract (NFE) and Crude Fiber (CF)
Source: *Laboratory of Animal Feed Sciences, Faculty of Animal Husbandry and Agriculture, Diponegoro University (2018)
**Jepara BBPAP Test Laboratory (2017)

Table 2. Test feed formulation and proximate analysis results of test feed used in study

Types of Feed Ingredients	Composition			
	A (0%)	B(8%)	C(16%)	D(24%)
Fish meal	32.00	29.44	26.88	24.32
Maggot meal	0.00	3.31	6.62	9.90
Soybean meal	26.00	26.00	26.00	26.00
Corn meal	6.00	6.00	6.00	5.00
Rice bran meal	11.00	10.05	10.00	10.00
Wheat meal	17.50	18.00	17.50	18.15
Fish oil	2.75	2.50	2.50	2.30
Palm oil	2.75	2.70	2.50	2.30
Vitamins-minerals mix	1.00	1.00	1.00	1.00
Carboxymethylcellulose (CMC)	1.00	1.00	1.00	1.00
Total	100.00	100.00	100.00	100.00
Protein (%)*	36.03	35.61	35.48	36.37
Fat (%)*	10.16	10.56	10.70	10.19
NFE (%)*	30.54	30.93	29.55	31.84
DE (kcal)[a]	284.75	287.47	284.69	289.43
E/P[b]Ratio	8.00	8.07	8.02	8.00

Description:
a. Calculated based on Digestible Energy according to Wilson (1982) for 1 g of protein is 3.5 kcal/g, 1 g of fat is 8.1 kcal/g, and 1 g of carbohydrate is 2.5 kcal/g.
b. According to De Silva (1987), E / P values for optimal growth of fish range from 8-12 kcal/g.
c. *Laboratory of Animal Food Sciences, Faculty of Animal Husbandry and Agriculture, Diponegoro University (2018)

growth rate (FWG), relative growth rate (RGR), total feed consumption (TFC), feed utilization efficiency (FUE), protein efficiency ratio (PER), survival rate (SR) and water quality parameters.

Absolute growth rate (FWG)

The absolute growth rate in this study was calculated using the formula by Goddard (1996) as follows:

$$FWG=\frac{W_t-W_0}{t}$$

Description:
FWG = Absolute growth rate (g)
W_0 = Biomass weight of tested shrimp at the beginning of the experiment(g)
W_t = Biomass weight oftested shrimp at the end of the experiment(g)
t = Length of experiment(day)

Relative growth rate (RGR)

Relative growth rate in this study was calculated using the formula by Steffens (1989) as follows:

$$RGR=\frac{W_t-W_0}{W_0\times t}\times 100\%$$

Description:
RGR = Relative growth rate (%/day)
W_0 = Biomass weight of tested shrimp at the beginning of the experiment(g)

W_t = Biomass weight of tested shrimp at the end of the experiment(g)
t = Length of experiment(day)

Total feed consumption (TFC)

Total feed consumption in this study was calculated using the formula by Okumus and Mazlum (2002) as follows:

FC = FG - FU

Description:
FC = Feed consumption (g)
FG = The amount of feed given (g)
FU = The amount of leftover feed (g)

Feed utilization efficiency (FUE)

Feed Utilization Efficiency can be determined using the formula by Tacon (1987), as follows:

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

Description:
FUE = Feed Utilization Efficiency(%)
W_0 = Biomass weight of tested shrimp at the beginning of the experiment(g)
W_t = Biomass weight of tested shrimp at the end of the experiment(g)
F = The amount of test shrimp feed consumed during the experiment(g)

Feed conversion ratio (FCR)

Feed conversion ratioin this study was calculated using the formula from Zonneveld *et al.* (1991) as follows:

$$FCR=\frac{F}{W_t - W_0}$$

Description:
FCR = Feed conversion ratio
W_0 = Biomass weight of tested shrimp at the beginning of the experiment(g)
Wt = Biomass weight of tested shrimp at the end of the experiment (g)
F = The amount of test shrimp feed consumed during the experiment(g)

Protein efficiency ratio (PER)

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

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

Description:
PER = Protein efficiency ratio(%)
W_0 = Biomass weight of tested shrimp at the beginning of the experiment(g)
Wt = Biomass weight of tested shrimp at the end of the experiment(g)
Pi = The amount of test feed consumed is multiplied by the protein content of the test feed

Survival rate (SR)

Survival Rate (SR) calculated to determine the survival rate of test animals during experiment,

Table 3. Analysis of the essential amino acid content in the test feed used in the study

Essential Amino Acids	A (0%)	B (8%)	C (16%)	D (24%)	Reference*
Arginine	2.03	2.02	2.01	2.00	1.9
Histidine	0.75	0.77	0.79	0.81	0.7
Isoleucine	1.29	1.29	1.29	1.29	1.08
Leucine	1.87	1.91	1.95	1.99	1.6
Lysine	2.17	2.14	2.12	2.10	1.6
Methionine	0.69	0.67	0.65	0.63	0.6
Phenylalanine	1.42	1.41	1.40	1.39	1.2
Threonine	1.37	1.36	1.35	1.33	1.1
Valine	1.26	1.24	1.23	1.21	1.2

Description:
*Soares *et al.* (2015)

This study used a Completely Randomized Design (CRD)with 4 treatments and 3 replications. The treatments in this study were fish meal substitution with maggot meal in artificial feed with different compositions. The treatments that will be tested are as follows:
A: Artificial feed by substituting 0% fish meal with maggot meal.
B: Artificial feed by substituting 8% fish meal with maggot meal.
C: Artificial feed by substituting 16% fish meal with maggot meal.
D: Artificial feed by substituting 24% fish meal with maggot meal.

Survival Rate can be determined using the formula by Goddard (1996):

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

Description:

SR = Survival Rate (%)

N_0 = Number of test shrimp at the beginning of the experiment(shrimp)

Nt = Number of test shrimp at the end of the experiment(shrimp)

Water quality

Observation of water quality parameterswere includes temperature, dissolved oxygen (DO), salinity of ammonia content (NH_3) and acidity level (pH). Water quality observation of amonia content (NH_3) conducted in the middle and the end of experiment. Observation of temperature and salinity was carried out every day in the morning and afternoon, while DO and pH observations were carried out every five times a week on Monday – Friday, in the morning and evening. Measurement of ammonia content was analyzed using a spectrophotometer, while pH measurements were carried out using a pH meter, by dipping the pH meter in the maintenance container and seeing the results. Dissolved oxygen (DO) measurements used DO meters by dipping the probe into the water then wait until it is constant and record the value.

Proximate analysis

Proximate analysis of the chemical content of the ingredients and test feed was carried out using the method from AOAC (2005) and Herawati *et al.* (2018). The crude protein content is calculated by multiplying the total nitrogen factor. Nitrogen-free extract (NFE) was calculated using arithmetic method. According to Anand *et al.* (2014) NFE level content can be calculated using the following equation:

NFE = 100 – (CP + EE + CF + ash + water)

Description:

NFE = Nitrogen-free extract (%)

CP = crude protein (%)

EE = crude fat (%)

CF = crude fiber (%)

Data analysis which carried out were 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, then they were analyzed using analysis of variance (ANOVA) with confidence intervals of 95% to see the effect of the treatments. Before analyzing the variance, the normality test, homogeneity test, and additivity test were first carried out. Normality test, homogeneity test, and additivity test were carried out to ensure the data is spread normally, homogeneous, and additive. Data is analyzed (F test) with confidence intervals of 95%. If there are significant differences ($P<0.05$) in the analysis of variance, then Duncan's multiple range test will be conducted to find out the 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.

RESULTS

To determine the uniformity of shrimp weight used in the experiment, shrimp weighing was done to determine the initial weight. The initial Weights (W_0) results are made into histogram which is presented in Figure 1 as follows.

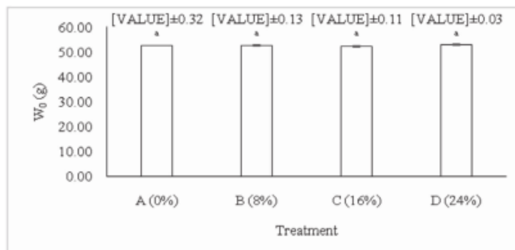

Fig. 1. Initial weight histogram (W_0) (g) of Pacific white shrimp during experiment

Based on the histogram above, the initial weight of shrimp used in the study has a uniform size with the average biomass weight of shrimp that is 52.50 g.The Final Weights(Wt) histogram during the experiment is presented in Figure 2 as follows.

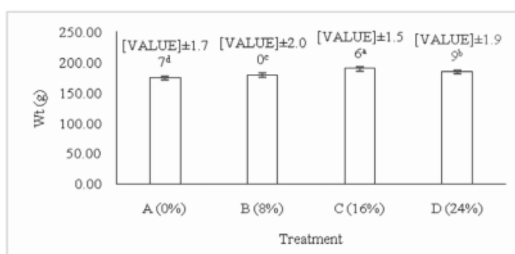

Fig. 2. Histogram of final weight (Wt) (g) of Pacific white shrimp during experiment

Based on the histogram above, the highest average final weight value is treatment C (fish meal substitution with 16% of maggot meal) with a value of 189.30 ± 1.56[a] and the lowest is treatment A (fish meal substitution with 0% of maggot meal) with a value of 174.16±1.77[d]. The difference between treatment C and treatment A is 15.14 g.

Histogram of absolute growth rate (FWG) during the study is presented in Figure 3 as follows.

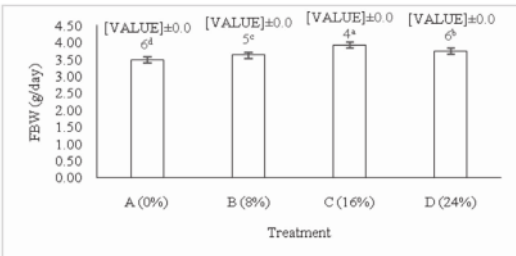

Fig. 3. Histogram ofabsolute growth rate (FWG) (g/day) during experiment

Based on the histogram above, the highest absolute growth rate of Pacific white shrimp during the study was treatment C (fish meal substitution with 16% of maggot meal) with a value of 3.92±0.04 g/day, and the lowest was treatment A (fish meal substitution with 0% of maggot meal) with a value of 3.48±0.06[d]. The difference between treatment C and treatment A is 0.44 g/day.

The test results of Orthogonal Polynomial absolute growth rate are presented in Figure 4 as follows.

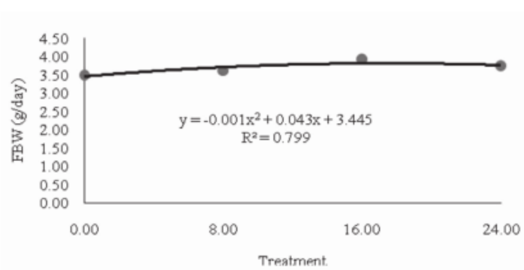

Fig. 4. Test results of orthogonal polynomial absolute growth rate (g/day) of Pacific white shrimp duringthe experiment

Based on the Orthogonal Polynomial test, a quadratic pattern relationship was obtained ($y = -0.0012x^2 + 0.0433x + 3.4459$ and $R^2 = 0.7993$). From this equation, an optimal composition of fish meal substitution with maggot meal is obtained at 18%, which able to produce a maximum absolute growth rate of 3.84g / day. The R^2 value indicates that 80% of the absolute growth rate is influenced by the substitution of fish meal with maggot meal, while 20% of absolute growth rate is influenced by environmental factors.

Histogram of relative growth rate (RGR) during the experimentis presented in Figure 5 as follows.

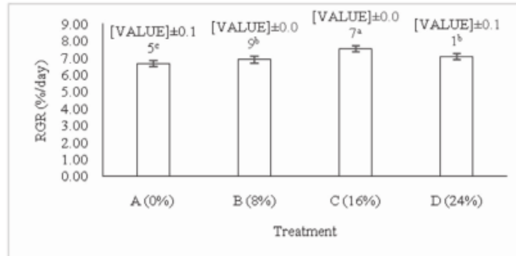

Fig. 5. Histogram of relative growth rate (RGR) (%/day) of Pacific white shrimp during the experiment

Based on the histogram above, the highest average relative growth rate is treatment C (fish meal substitution with 16% of maggot meal) with a value of 7.51±0.07[a] %/day and the lowest is treatment A (fish meal substitution with 0% of maggot meal) with a value of 6.64±0.15[c] %/day. The difference between treatment C and treatment A is 0.87%.

Orthogonal Polynomial test results of the relative growth rate are presented in Figure 6 as follows.

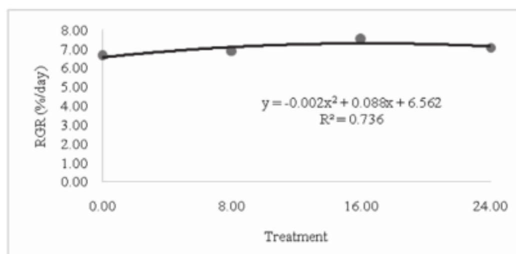

Fig. 6. Orthogonal Polynomial test results of the relative growth rate (%/hari) of Pacific white shrimp during the experiment

Based on the Orthogonal Polynomial test, a quadratic pattern relationship was obtained ($y = -0.0027x^2 + 0.0883x + 6.5627$ and $R^2 = 0.7365$). From this equation, an optimal composition of fish meal substitution with maggot meal is obtained at 16.4%, which able to produce a maximum relative growth rate of 7.28%/day. The R^2 value indicates that 74% of the relative growth rate is influenced by the substitution of fish meal with maggot meal, while

26% of relative growth rate is influenced by environmental factors.

Histogram total feed consumption (TFC) during the experimentis presented in Figure 7 as follows.

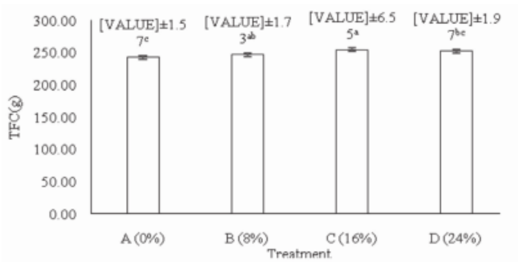

Fig. 7. Histogram of total feed consumption (TFC) of Pacific white shrimp during the experiment

Based on the histogram above, the highest average total feed consumption is treatment C (fish meal substitution with 16% of maggot meal) with a value of 254.10±6.55[a] g and the lowest is treatment A (fish meal substitution with 0% of maggot meal) with a value of 242.22±157[c] g. The difference of total feed consumption between treatment C and treatment A is 9.89 g.

Orthogonal Polynomial test results of total feed consumption of Pacific white shrimp during the experiment are presented in Figure 8 as follows.

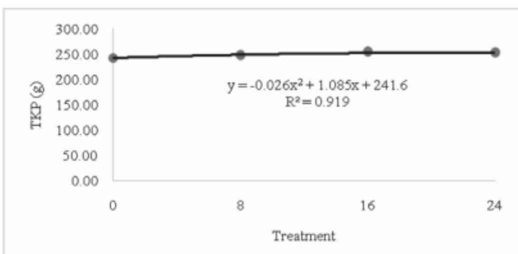

Fig. 8. Orthogonal Polynomial test results of total feed consumption (g) of Pacific white shrimp during the experiment

Based on the Orthogonal Polynomial test, a quadratic pattern relationship was obtained ($y = -0.026x^2 + 1.0852x + 241.63$ and $R^2 = 0.9195$). From this equation, an optimal composition of fish meal substitution with maggot meal is obtained at 20.9%, which able to produce a maximum total feed consumption of 252.95g. The R^2 value indicates that 92% of the total feed consumption is influenced by the substitution of fish meal with maggot meal, while 8% of total feed consumption is influenced by environmental factors.

Histogram feed utilization efficiency (FUE) of Pacific white shrimp during the experiment is presented in Figure 9 as follows

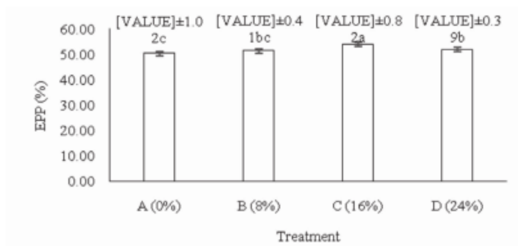

Fig. 9. Histogram of feed utilization efficiency (FUE) (%) of Pacific white shrimp during the experiment

Based on the histogram above, the highest average of feed utilization efficiency is treatment C (fish meal substitution with 16% of maggot meal) with a value of 53.97±0.82[a]% and the lowest is treatment A (fish meal substitution with 0% of maggot meal) with a value of 50.26±1.02[c] %. The difference of total feed consumption between treatment C and treatment A is 3.71%.

Orthogonal Polynomial test results of feed utilization efficiency of Pacific white shrimp during the experiment are presented in Figure 10 as follows.

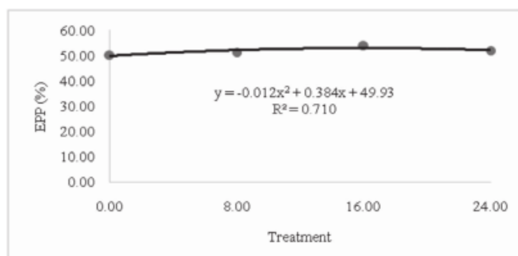

Fig. 10. Orthogonal Polynomial test results offeed utilization efficiency (%) of Pacific white shrimp during the experiment

Based on the Orthogonal Polynomial test, a quadratic pattern relationship was obtained ($y = -0.0121x^2 + 0.3848x + 49.934$ and $R^2 = 0.7107$). From this equation, an optimal composition of fish meal substitution with maggot meal is obtained at 15.9%, which able to produce a maximum feed utilization efficiency of 52.99%. The R^2 value indicates that 71% of feed utilization efficiency is influenced by the substitution of fish meal with maggot meal, while

29% of feed utilization efficiency is influenced by environmental factors.

Histogram feed conversion ratio (FCR) of Pacific white shrimp during the experiment presented in Figure 11 as follows.

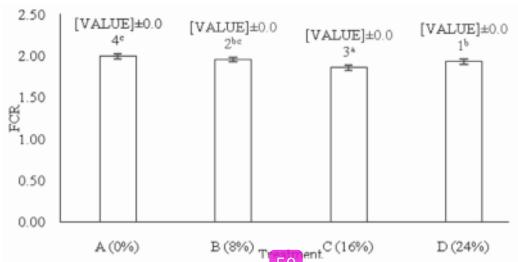

Fig. 11. Histogram of food conversion ratio (FCR) of Pacific white shrimp during the experiment

Based on the histogram above, the highest average of FCR is treatment A (fish meal substitution with 0% of maggot meal) with a value of 1.99± $0.04^{c}$and the lowest is treatment C (fish meal substitution with 16% of maggot meal) with a value of 1.85 ± 0.03^{a}. The difference of total feed consumption between treatment A and treatment C is 0.14.

Orthogonal Polynomial test results of food conversion ratio of Pacific white shrimp during the experiment are presented in Figure 12 as follows.

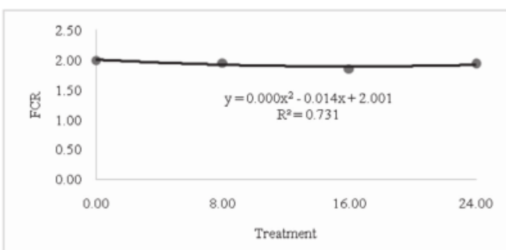

Fig.12. Orthogonal Polynomial test results of food conversion ratio of Pacific white shrimp during the experiment

Based on the Orthogonal Polynomial test, a quadratic pattern relationship was obtained ($y = 0.0004x^2 - 0.0142x + 2.0017$ and $R^2 = 0.7314$). From this equation, an optimal composition of fish meal substitution with maggot meal is obtained at 17.8%, which able to produce a minimumfeed conversion ratio of 1.88. The R^2 value indicates that 73% of food conversion ratio is influenced by the substitution of fish meal with maggot meal, while 29% of food conversion ratio is influenced by environmental factors.

Histogram food conversion ratio of Pacific white shrimp during the experiment presented in Figure 13 as follows.

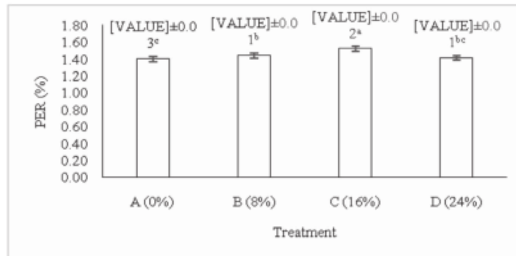

Fig. 13. Histogram of protein efficiency ratio (PER) (%) of Pacific white shrimp during experiment

Based on the histogram above, the highest average of protein efficiency ratio is treatment C (fish meal substitution with 16% of maggot meal) with a value of 1.52 ± 0.02^{a} % and the lowest is treatment A (fish meal substitution with 0% of maggot meal) with a value of 1.40± 0.03^{c} %. The difference of total feed consumption between treatment A and treatment C is 0.12 %.

Orthogonal Polynomial test results of protein efficiency ratio of Pacific white shrimp during the experiment are presented in Figure 14 as follows.

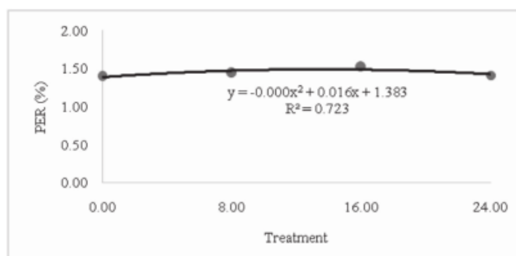

Fig. 14. Orthogonal Polynomial test results of protein efficiency ratio (%) of Pacific white shrimp during the experiment

Based on the Orthogonal Polynomial test, a quadratic pattern relationship was obtained ($y = -0.0006x^2 + 0.016x + 1.3837$ and $R^2 = 0.7235$). From this equation, an optimal composition of fish meal substitution with maggot meal is obtained at 13.3%, which able to produce a maximum protein efficiency ratio of 1.49%. The R^2 value indicates that 72% of protein efficiency ratio is influenced by the substitution of fish meal with maggot meal, while 28% of protein efficiency ratio is influenced by environmental factors.

Histogram of survival rate (SR) Pacific white shrimp during experiment presented in Figure 15 as follows.

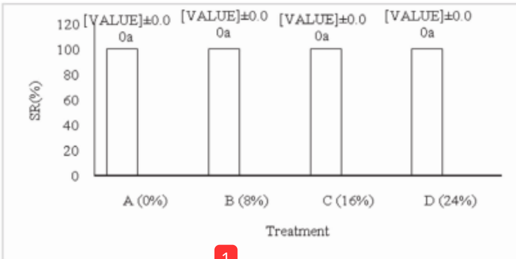

Fig. 15. Histogram of survival rate (SR) (%) of Pacific white shrimp during experiment

Based on the histogram above, the average value of the survival rate of Pacific white shrimp in each treatment during the study was 100.00±0.00 %.

Water quality parameters measured in this study includes temperature, pH, DO, salinity and ammonia. The results of measurements of water quality during the study are presented in Table 4 as follows.

The results of measurements of water quality indicate that the value of water quality during the study is still in the range that is suitable to be used as Pacific white shrimp culture media, this is based on the reference on optimum water quality conditions for Pacific white shrimp.

DISCUSSION

Growth and feed utilization

Pacific white shrimp growth can be known through the calculation of the absolute growth rate and the relative growth rate of shrimp observed for 35 days. Based on the experiment that has been done, the highest absolute growth rate of pacific white shrimp is treatment C (fish meal substitution with 16% of maggot meal) with value of 3.92±0.04 g/day and the lowest is treatment A (fish meal substitution with 0% of maggot meal)with value of3.48±0.06[d] g/day. The difference between treatment C with treatment A is 0.44 g/day. The absolute growth rate value is in line with the relative growth rate (RGR) of Pacific white shrimp. Based on the experiment that has been done, the highest relative growth rate of pacific white shrimp is treatment C (fish meal substitution with 16% of maggot meal) with value of 7.51±0.07[a] %/day and the lowest is treatment A (fish meal substitution with 0% of maggot meal) with value of 6.64±0.15[c] %/day. The difference between treatment C with treatment A is 0.87%. Growth in Pacific white shrimp occurs because of the energy input from feed so that it can be used by the body for metabolic and growth processes. The feed used in the study has nutritional content that matches the nutritional needs of Pacific white shrimp. According to Moreno-Arias *et al.* (2017), Pacific white shrimp requires feed with 35% protein, 7-8% fat, 4-5% crude fiber and 17 kJ/g energy. Riani *et al.* (2012) also states that growth is an increase in size, length or weight at a time. Growth occurs because of the increase in tissue from mitosis cell division which occurs due to excess energy input and protein derived from feed. Excess energy input is used by the body for metabolism, motion, reproduction and replacing damaged cells. Duncan's multiple range test results of RGR values indicate that treatment C (fish meal substitution with 16% of maggot meal) was significantly different from other treatments. It is suspected that the amount of feed given can also affect the growth rate of Pacific white shrimp. The amount of feed given in treatment C (fish meal substitution with 16% of maggot meal) more than other treatments. According to Sahrijanna and Sahabuddin (2014), Shrimp growth rate is strongly influenced by water quality, quantity of feed given and environmental conditions. If the environmental

Table 4. Results of water quality measurement during study

Water Quality Value Range	Treatments				Reference Value Range
	A	B	C	D	
Temperature (°C)	28.1– 30.2	28.1–30.2	28.1–30.2	28.1–30.2	15 – 33[c]
pH	8.00 – 8.09	8.00 – 8.09	8.00 – 8.09	8.00 – 8.09	7.4–8.9[c]
Salinity (ppt)	29 – 32	29 – 32	29 – 32	29 – 32	25– 35[a]
DO (mg/L)	4.12– 4.93	4.14–4.77	4.45–4.82	4.40–4.77	>3[c]
NH_3 (mg/L)	0.00 – 0.00	0.00 – 0.01	0.00 – 0.02	0.00 – 0.02	<0.10[b]

Description: a: Maica *et al*., (2014), b : Perez *et al*., (2013), c: Briggs (2004) conditions are good and the feed quality is of good, the growth rate of shrimp will be faster.

The total feed consumption shows how much feed the Pacific white shrimp consumed during the study. Based on observations made, the highest average value of total feed consumption is treatment C (fish meal substitution with 16% of maggot meal) with value of 254.10±6.55[a] g, and the lowest is treatment A (fish meal substitution with 0% of maggot meal) with value of 242.22±1.57[c] g. The difference between treatment C with treatment A is 9.89 g. Treatment C has a higher total feed consumption value than other treatments because feed C has a better physical form and color than other feeds so that it can affect Pacific white shrimp feed consumption. According to Abidin *et al.* (2015), total feed consumption in fish is influenced by several factors, one of them is the physical properties of feed such as smell, taste, size, and color. Duncan's multiple range test results of TFC shows that treatment C significantly different from other treatments. The total feed consumption besides being influenced by feed quality is also suspected due to optimum and stable environmental conditions and in accordance with the needs of shrimp. WWF (2014) stated that appetite depends on environmental conditions and the rate of feed consumption will increase in optimum environmental conditions. In addition, the growth of pacific white shrimp is also strongly influenced by the ability of shrimp to digest or utilize the feed given.

The feed utilization efficiency shows how much feed can be utilized by shrimp for growth. The results showed that the highest average value of feed utilization efficiency was treatment C (fish meal substitution with 16% of maggot meal) 53.97±0.82[a]% and the lowest was treatment A (fish meal substitution with 0% of maggot meal) for 50.26±1.02[c]%. The difference in the value of the efficiency of feed utilization between treatment C (fish meal substitution with 16% of maggot meal) with treatment A (fish meal substitution with 0% of maggot meal) was 3.71%. The value of feed utilization efficiency is inversely proportional to the value of feed conversion ratio. The highest average FCR value was treatment A (fish meal substitution with 0% of maggot meal) of 1.99 ± 0.04c and the lowest was treatment C (fish meal substitution with 16% of maggot meal) of 1.85±0.03[a]. The difference between treatment A (fish meal substitution with 0% of maggot meal) with treatment C (fish meal substitution with 16% of maggot meal) is 0.14. Treatment C (fish meal substitution with 16% of maggot meal) has the highest feed efficiency value and the lowest FCR value is suspected because feed of treatment C (fish meal substitution with 16% of maggot meal) has a lower carbohydrate content than other treatments so that it allowed shrimp to digest feed well and efficiently. This was also reinforced by Pinandoyo *et al.* (2014) that high levels of carbohydrates in feed can reduce shrimp digestibility, so that feed cannot be utilized optimally and growth will be inhibited. Duncan multiple range test resultan of FUE and FCR values showed that treatment C (fish meal substitution with 16% of maggot meal) is different from other treatments. The high efficiency of feed has a meaning that the feed that enters the body of the fish is utilized properly in the body and vice versa if the value of feed efficiency is low. The value of the efficiency of the utilization of feed is in line with the value of growth rate of shrimp. The higher the value of feed utilization efficiency, the higher the shrimp growth rate and vice versa. According to Amin *et al.* (2011), the more feed consumed and efficient use of feed will increase the retention or storage of protein in the body, so that the shrimp growth will increase. Shrimp growth is also strongly influenced by the ability of shrimp to digest or utilize protein consumed for metabolic processes and growth.

Protein efficiency ratio shows how much the ability of protein feed can be utilized for the growth of Pacific white shrimp. Based on the observations made, the average value of the highest protein efficiency ratio was treatment C (fish meal substitution with 16% of maggot meal)of 1.52±0.02[a] % and the lowest treatment A (fish meal substitution with 0% of maggot meal) that is 1.40± 0.03[c] %. The difference between treatment C (fish meal substitution with 16% of maggot meal) with treatment A (fish meal substitution with 0% of maggot meal) was 0.12%. The treatment C (fish meal substitution with 16% of maggot meal) has the highest PER value compared to other treatments even though feed energy of treatment C (284.69 kcal) is lower than treatment A (284.75 kcal), B (287.47 kcal) and D (289.43 kcal). These results indicate that feed of treatment C (fish meal substitution with 16% of maggot meal) can be used well for growth despite having the lowest energy. Yolanda *et al.* (2013) also suggested that protein efficiency was significantly influenced by energy levels in feed. High feed energy content causes protein utilization to be less efficient, because too much energy can cause a reduction in feed intake and also reduce nutrient intake. Furthermore, excess of feed energy can cause an increase in body fat, if the energy level of the feed is too low, the protein will be used for energy instead of tissue synthesis. The Duncan multiple range test results showed that the treatment C (fish meal substitution with 16% of maggot meal) was significantly different from other treatments. The protein efficiency value is in line with the relative growth rate of shrimp. Treatment A (fish meal substitution with 0% of maggot meal) has the lowest PER value presumably because feed protein of treatment A (fish meal substitution with 0% of maggot meal) is not able to be utilized maximally by shrimp, so the growth rate of shrimp in treatment A (fish meal substitution with 0% of maggot meal) is also lower than the other treatments. According to Yustianti *et al.* (2013), high feed protein does not always produce better growth, depending on the feed ingredients which is used and the balance of the composition of feed ingredients. Ridwan and Idris (2014) also stated that protein is an essential nutrient that is major for sustaining life and spurring growth. Protein is an expensive component in feed, therefore, it must be pursued so that at its minimum concentrations can still guarantee maximum growth.

The results showed that substitution of fish meal with 16% of maggot meal (treatment C) gave the highest relative growth rate (RGR) of 7.78 ± 0.07%/day and a specific growth rate of 3.82%/day, feed efficiency value (FUE) of 53.97 ± 0.82%, feed conversion ratio (FCR) of 1.85 ± 0.03 and the mean value of PER of this study was 1.52 ± 0.02%. These results are slightly smaller than those of Cummins Jr *et al.* (2017) which produced a specific growth of 4.07%/day with a composition of fish meal protein substitution with maggot meal as much as 20%. FUE and FCR values in this study are better than the previous study results conducted by Cummins Jr *et al.* (2017) with an average FUE value of 32.10% and FCR of 2.01. While the PER value in this study is better than the study results conducted by Olaniyi and Salau (2013) in catfish with PER value of 0.6%, but lower than the study results conducted by Stamer *et al.* (2014) on rainbow trout with PER of 1.57%. The PER value of each cultivan is certainly different at the level of absorption of nutrients from cultivan and the quality of each test feed. According to Yolanda *et al.* (2013), protein efficiency values influenced by several factors, they are: size of fish, physiological function of fish, feed quality, and feeding rate. Helper (1988) also stated that the PER value is also influenced by the ability of fish to digest feed. This ability is influenced by several factors, one of them is the composition of feed, where the higher the protein utilized by the body so that the protein used is more efficient.

Survival rate (SR)

Survival rate is a comparison between live fish at the beginning of the experiment with fish that are still alive at the end of the experiment. This comparison aims to find out how much percentage of fish can still survive at the end of the experiment after treatment according to the method (Henditama *et al.*, 2015). The average value of survival rate of Pacific white shrimp in each treatment during the experiment was 100.00 ± 0.00%. This value shows that the substitution of fish meal with maggot meal in feed does not affect the survial rate (SR) of Pacific white shrimp. Death in Pacific white shrimp in the experiment is usually due to cannibalism of the tested shrimp. During the experiment, the test shrimp did not experience death, it was suspected that the feed which is given to shrimp was sufficient. Feed is given four times a day according to body weight which is thought to affect the survival rate value of shrimp. Zainuddin *et al.* (2014) stated that feeding four times a day allows Pacific white shrimp to not compete in foraging so that it does not cause cannibalism which can reduce the value of survival. The average value of survival rate in this study is much better than the Cummins Jr *et al.* (2017) study, with a value of 91.11% and Sookying *et al.* (2011) with a value of 96.10%. This is because the stocking density of shrimp is different, the higher the stocking density will also affect water quality, feed competition and place competition. According to Henditama *et al.* (2015), survival rates are strongly influenced by environmental factors such as oxygen content, temperature, pH, disease factors, genetic factors and stocking density.

Water quality

Based on the results of water quality measurements have been conducted, the average value of DO and temperature in this study is quite high and stable, that is 4.56 mg/L and 29.21 ºC. The high DO value is due to the diffusion of oxygen through a powerful blower so that the oxygen which dissolved in the water is also very high. According to Sahrijanna and Sahabuddin (2014), oxygen is a water quality parameter that plays a direct role in the metabolic process of water biota, especially shrimp. The availability of dissolved oxygen in water is a factor in supporting growth, development and life of shrimp. The temperature range in this study is very stable in the range of 29-30 °C. The stable temperature is due to sufficient water depth so that the water is able to maintain temperature and containers that are covered with nets so that sunlight is not directly related to the waters. According to Briggs *et al.* (2004) and Hutabarat (1999), Pacific white shrimp can grow optimally in the oxygen range from 4.8 to 8.9 mg/L, temperature of 23-30 °C but can tolerate low temperatures up to 15 °C and high temperatures up to 33 °C, and pH range from 7.4 to 8.9.

Salinity is one of the environmental parameters that affect biological processes and will directly affect the lives of organisms, including influencing growth rates, the amount of food consumed, the value of food conversion, and survival rate. Salinity in this study was maintained in the range of 30 ppt. According to Ye *et al.* (2009), Salinity is one of the most important abiotic factors in aquaculture. While some species of crustaceans show a level of euryhalinity, where the optimal level of salinity for growth, survival and production efficiency is often different for each species. In general, changes in the conditions from normal salinity media (30 ppt) to low salinity mediain the early stages of shrimp cultivation will cause the shrimp to be easily stressed and also weak. The decrease in salinity causes an increase in the rate of metabolism and osmoregulation processes which are directly correlated with the decline in survival and growth of shrimp. According to Kaligis (2015) and Lara *et al.* (2013), Pacific white shrimp can tolerate a salinity range of 0.5-40 ppt and grow optimally in salinity 15-30‰. Pacific white shrimp can survive in conditions of high salinity susceptibility of 0.5 to 40 ‰, but this shrimp will grow normally in the range of salinity 5 to 35‰.

Ammonia is measured on days 14 and 35 of culture. Ammonia value during this study can still be tolerated by shrimp. This is because the pond is cleaned and water is replaced every dayso that there is no left over food and feces that can increase the ammonia. According to Hossain *et al.* (2013), ammonia is the most important inorganic-N which must be known in the aquatic environment or pond. Ammonia levels in shrimp ponds must be less than 1 ppm. Perez *et al.* (2013) also stated that the total ammonia that can be tolerated by Pacific white shrimp is 0-1.0 mg/L.

CONCLUSION

The conclusion that can be drawn from the results of this study is that the substitution of fish meal with maggot meal had a significant effect (Sig <0.05) on the relative growth rate, total feed consumption, feed utilization efficiency, feed conversion ratio, and protein efficiency ratio but had no significant effect (Sig> 0.05) for the survival rate of Pacific white shrimp.The best composition of fish mealprotein substitution with maggot meal protein is treatment C (substitution of fish meal with16% of maggot meal) which is able to produce a relative growth rate (RGR) of 7.51 ± 0.07%/day, feed utilization efficiency (FUE) with the value of 53.97 ± 0.82%, feed conversion ratio (FCR) with the value of 1.85 ± 0.03 and protein efficiency ratio (PER) with the value of 1.52 ± 0.02%. The optimum composition of fish meal substitution with maggot meal for Pacific white shrimp is 17.05%.

The suggestion that can be given from the results of this study is that fish meal substitution with 17.05% of maggot meal can be used in Pacific white shrimp cultivation to increase its RGR, FUE, PER and reduce FCR so that it can reduce the production costs. It is recommended to do further study on fish meal protein substitution with maggot meal protein using different compositions to Pacific white shrimp with different stages, and also to other species.

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