The nutrient content of Nile tilapia fed with black soldier fly (BSF) larvae

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Abstract. The use of fresh black soldier fly (BSF) larvae or maggot directly as an alternative live food for Nile tilapia is rarely discussed. This study was conducted to compare the nutrient content of Nile tilapia (*Oreochromis niloticus*) fed with a commercial feed and fresh maggot (alternative feed). Six hundred Nile tilapia with an initial body weight of 173±8 g were distributed into six units of hapa (net cages) at a density of one hundred fish. The fish were fed to satiation with two dietary treatments, maggot (A) and a commercial fish feed (B). This research was carried out for 40 days. The results of the present study demonstrated that the fish growth was not significantly different between the treatments. The feed conversion ratios were 2.1 and 1.9 for maggot and commercial feed treatments, respectively. Nile tilapia fed with maggot demonstrated a higher fillet proportion (34%) than those fed with a commercial feed (30%), but no significant differences in the proximate composition. Leucine, lysine, and glutamic acid were higher in the fish fed with maggot. Palmitic acid was found to dominate the saturated fatty acid content in tilapia, while unsaturated fatty acids were found mainly in the form of linoleic and linolenic acids. Tilapia fed with maggot demonstrated higher cholesterol levels (78.35±19.86 mg 100 g^{-1}) than those fed with the commercial feed (54.16±3.89). Furthermore, tilapia fed with maggot also showed higher taurine levels. at about 6.56±0.23 mg 100 g^{-1}. It is concluded that the growth and quality of nutrients in fish are just as good between the two treatments, indicating that the administration of fresh maggot can replace commercial feed for tilapia.

Key Words: maggot, tilapia, black soldier fly, organic waste.

Introduction. Aquaculture contributes in providing animal protein for humans, thus achieving food security, particularly in developing countries (Beveridge et al 2013). The Indonesian government has selected tilapia as one of the commodities in the national aquaculture development programs. From 2015 to 2018, tilapia production in Indonesia has been steadily increasing at a level of 12.85%, reaching up to 1.546.675 tons in 2018 (DJPB-KKP 2018). The increase in aquaculture production directly impacts the demand for fish feed. Approximately 60% of the production cost in fish farming is accounted for feed cost, hence the fish feed industry dynamics, for example the scarcity of fishmeal, will directly affect the development of aquaculture business (Devic et al 2017). Fishmeal is an important source of protein in fish diet formulation, yet its availability has been stagnant since the 1990s, due to a continuously increasing demand and to the over exploitation (FAO 2015).

BSF larva has a complete nutrient profile, thus, it has the potential to be used as an alternative feed for fish. Maggot contains 10-13% ash, 38-42% protein, 28-35% fat, fatty acids and amino acids (Caruso et al 2014; Henry et al 2015). Besides its role as an alternative source of protein, BSF larva also plays a role as bioconversion agent used in the processing of the organic waste. BSF larva has the potential to be developed as the solution for fish feed, especially for small-scale fish farmers who experience some difficulties to access the commercial feed (Devic et al 2017). However, many studies related to the use of maggot in tilapia farming were more focused on using maggot as an alternative protein source, by adding maggot meal in the formulation of fish diet (Devic et al 2017), which can be technically difficult to be applied by small-scale fish farmers.

The use of maggot directly as an alternative fish diet is supported by the results of several previous studies, which demonstrated the benefit of using BSF larva: the maggot does not contain pathogenic bacteria, which can be harmful both for fish and human (Bosch et al 2019), the BSF larva can be easily produced by using available natural resource (Rana et al 2015) and the direct feeding with maggot as supplement could enhance the fish growth and improve the fish health status. In this context, this study was carried out to compare the nutrient content of tilapia fed with commercial feed and maggot meal.

Material and Method

Culture of experimental fish. The experimental fish used in this study was a tilapia strain of genetically improved farmed tilapia (GIFT) with an initial average body weight of 173±8 g. A total of 600 experimental fish were cultured in two round tanks built of concrete, with a diameter of 3 m and a height 0.8 m. Each tank was divided into three compartments, using hapa nets, and each compartment was assigned to a replication of each treatment. Each compartment contained 100 fish specimens. The water quality in each tank was maintained by a recirculation system. The study was conducted by comparing two treatments, in triplicates: fish fed with maggot (M) and fish fed with commercial feed (P). Maggot were self-produced using food waste collected from restaurants and hotels as the culture media. The maggot culture was performed for 14 days. The commercial diet used in the present study consisted of floating pellets, with a protein content of 32% (dry weight). The study was conducted for 40 days. The feeding frequency was twice a day (morning at 08.00 and afternoon at 16.00), at satiation.

Sampling of experimental fish. Prior to the treatment, the experimental fish was fasted for two days. On the third day of fasting, fish samples were collected and denoted as day 0 sample (control). Next sampling was performed on day 20 and day 40 after feeding treatment. About 30 fish specimens were randomly collected for length, height and body weight measurements, and approximately 10 fish specimens were collected for fish quality analyses, including fillet yield and proximate content measurements: amino acids, taurine, fatty acids and cholesterols analyses. The measurement of body weight (g) and yield (g) was done using a digital scale; the body length (cm) and height (cm) measurement was conducted using a ruler, while the chemical analysis was performed following the (AOAC 2005).

Proximate, amino acid, and fatty acid analyses. The proximate analysis included: moisture, ash, protein, fat and carbohydrate content of maggot, commercial feed and experimental fish. Amino acid composition was determined using High-performance liquid chromatography (HPLC), which consisted of four stages, namely: production of protein hydrolysate, drying, derivatization, injection and amino acid analysis.

The fatty acid measurement was done by extracting fat from the sample. Approximately 20 mg of sample was put into test tube with a teflon cap, added with 1 mL of NaOH 0,5 N in methanol and heated in water bath for 20 minutes. About 2 mL of BF3 20% solution and 5 mg mL^{-1} of internal standard was added into the mixture. Further, the mixture was heated for 20 minutes, cooled and added with 2 mL of saturated NaCl and 1 mL of isooctane. Later, the isooctane layer formed was transferred using a Pasteur pipette to a tube containing 0.1 g of Na_2SO_4 anhydrate and left for 15 minutes. The liquid formed was separated, while 1 μL of oil produced was injected into the chromatograph, following the injection of 1 μL of FAME standard mixture (Supelco 37 component fatty acid methyl ester mix). Identification of fatty acid was performed by injecting methyl ester into the gas chromatograph. The retention time and the peak of each fatty acid were measured and compared with the retention time of the standard to determine the type and concentration of fatty acid in the sample.

The cholesterol analysis was performed following the method of Liebermann-Burchard colour reaction (1974). A sample of 0.1 g was put into a centrifuge tube, added with 8 mL of ethanol and petroleum benzene solution at a ratio of 3:1, and stirred until homogenous. The stirrer was then rinsed with 2 mL of ethanol and petroleum benzene solution (3:1) and centrifuged for 10 minutes (3,000 rpm). The supernatant was poured into 100 mL beaker glass and evaporated in a water bath. The residual was gradually evaporated using chloroform while being poured into a scaled tube (to reach 5 mL volume). The residual was added with 2 mL of acetic anhydride and 0.2 mL of H_2SO_4. Later, the sample was homogenized and incubated for 15 minutes. The absorbance was determined using a spectrophotometer at a wave length (λ) of 420 nm.

The taurine analysis of content was performed using HPLC, according to the AOAC method (2005). About 5 g of sample was weighed, added with 80 mL of distilled water and 1 mL of carrez reagent (potassium hexacyanoferrate), and stirred until homogenous. The product was diluted, added with 1 mL of carrez reagent 2 (zinc acetate dihydrate), stirred until homogenous and further diluted. The filtrate was collected in an Erlenmeyer flask and kept in the dark. Later, derivatization stage was performed by putting 1 mL of sample extract into a flask of 10 mL volumetric capacity and added with 1 mL of sodium carbonate (buffer) and 1 mL of dansyl chloride solution. Furthermore, the sample was left for 2 hours, stirred and added with 0.5 mL of methylamine hydrochloride solution to be further stirred until homogenous. About 40 μL of derivatization product was separated and injected into the chromatograph, in order to determine the taurine content of the sample. Taurine content in the material is calculated using the following formula (AOAC 2005):

$$\%\, taurine = \frac{sample\ area}{standard\ area} \times C \times \frac{dilution\ factor}{weight\ of\ sample\ (g)}$$

Where:
C - the standard concentration of taurine.

Statistical analysis. Calculation results of weight, height and total length of fish body were analyzed using ANOVA. Moreover, the proximate analysis and the fatty acid, amino acid, taurine and cholesterol composition of fresh tilapia for each treatment were determined on day 0, day 20, and day 40. The data were analysed by calculating the mean value and standard deviation. Later, a T-test was applied to compare the results of the two treatments. The analysis of variance (ANOVA) and t-test were done using Microsoft Excel 2010.

Results. The environmental condition of the fish culture in this study was within the tolerance limit for tilapia growth (El-Sayed 2013), with a temperature range of 28.5-31^{o}C and a dissolved oxygen range of 6.9-8.2 g L^{-1}.

Proximate composition of maggot and the commercial feed. The nutrient composition of the maggot and of the commercial feed used in the current study is presented in Table 1.

Table 1

Nutrient content of maggot and commercial feed used as fish diet in this study

Proximate (%)	*Maggot*	*Commercial feed*	*Maggot**
Moisture content	71.18	11	
Fat	9.91	3.37	2.86*
Protein	9.6	33.71	2.77*
Ash	1.88	10	0.54*
Crude Fiber	1.47	5.62	0.42*

* based on dry matter (%).

The determination of the chemical composition of magot and commercial feed was carried out according to its delivery condition: maggot was wet and commercial feed was dry. The result of the proximate analysis showed that crude fat was similar to the commercial pellet. However, the crude protein, ash and crude fibre contained in the commercial feed were 10.8, 16.5 and 11.9 times higher than those of maggot (based on dry matter).

Growth of tilapia GIFT. Fish average body weight growth was not significantly different between the treatments (P>0.05). The fish body weight gain throughout the experimental period is presented in Figure 1. The results of the study indicated that both maggot and commercial feed provided excellent responses of Nile tilapia. This indicate that both feeds were consumed and utilized by the fish for metabolism and growth. The length and height of fish were also not significantly different between the diet treatments (P>0.05) (Table 2). On average, the morphometric results showed that the fish given the commercial feed had better response compared to the fish fed with maggot, but the difference was not significant.

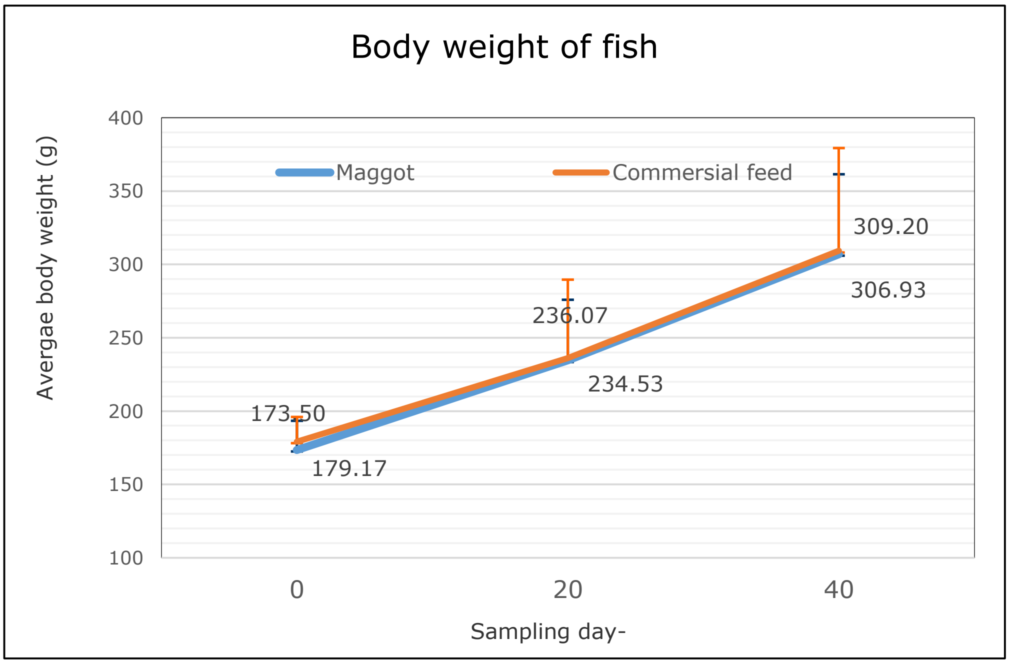

Figure 1. The average body weight of Nile tilapia fed with fresh maggot and commercial feed for 40 days of culture.

Table 2

Average body weight, height, total length and growth of Nile tilapia fed with maggot and commercial feed

Parameter	*Treatment*	
	Commercial feed (P)	*Maggot (M)*
Average final body weight (g)	306.9±5.68^a	309.2±6.77^a
Average final body height (cm)	8.4±0.48^a	8.1±0.19^a
Average final total length (cm)	26.1±0.74^a	25.9±0.2^a
Absolute growth in weight (g)	133	130
Specific growth rate in weight (% day^{-1})	1.43	1.36
Specific growth rate in length (% day^{-1})	0.43	0.32
Feed conversion ratio (FCR)	1.96	2.2

The proportion of meat, viscera, and skin of the fish fed with maggot were higher compared to the fish fed with commercial feed (Figure 2). Moreover, the proportions of the bone and head of fish fed with the commercial feed were higher than those of fish fed with maggot.

Table 3 provides the proximate composition of experimental fish collected from all treatments on each sampling time (day 0, day 20 and day 40). At the end of study, the moisture, ash, fat and crude fiber contents of the fish fed with maggot and commercial feed were not significantly different. However, fish specimens' carbohydrate content for each treatment showed significant differences at the end of the study (the 3rd sampling): the fat and carbohydrate contents of the fish fed with maggot were higher than those fed with commercial feed (Table 3). Although, the nutrient composition of fat and carbohydrate produced in the fish's body is different, both are not different on growth. This suggests that the weight growth is not related to the quality or composition of nutrients in the body of the fish.

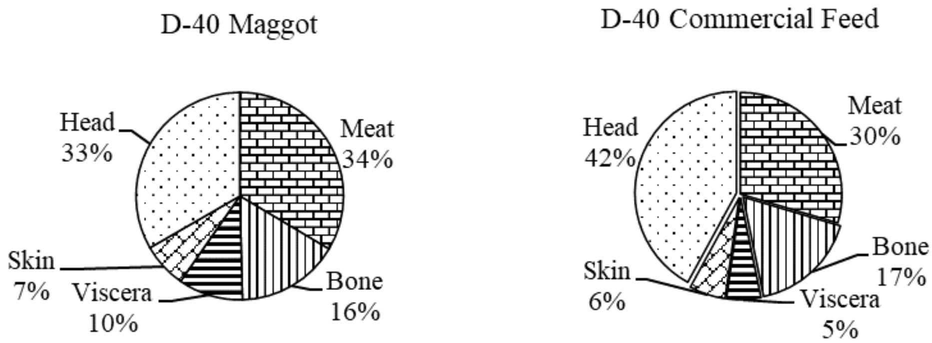

Figure 2. The proportion of meat, viscera, skin, head and bone of tilapia fed with maggot and commercial feed.

Table 3

The proximate composition of tilapia fed with maggot and with commercial feed on the initial, day 20 and day 40 of the experimental period

Parameter	*D0*	*D-20*		*D-40*	
		Commercial feed (P)	*Maggot (M)*	*Commercial feed (P)*	*Maggot (M)*
Moisture	$78.1±0.23^a$	$78.5±0.32^a$	$79.7±0.18^a$	$79.2±0.01^a$	$79.4±0.29^a$
Ash	$1.3±0.04^a$	$1.8±0.01^a$	$1.2±0.07^b$	$1.2±0.02^a$	$1.2±0.01^a$
Protein	$18.2±0.25^a$	$17.3±0.59^a$	$17.8±0.12^a$	$16.5±0.38^a$	$17.5±0.13^a$
Fat	$1.6±0.08^a$	$1.0±0.01^b$	$0.5±0.01^b$	$1.8±0.03^a$	$1.4±0.05^c$
Carbohydrate	$0.9±0.02^a$	$1.38±0.41^b$	$1.1±0.24^b$	$0.54±0.06^a$	$1.2±0.03^b$

Referring to the sampling time, there was a decline in the protein content of the fish fed with maggot and with commercial feed, on both the day 20 and the day 40. However, this protein content decrease was not significant, while the fat content significantly increased from day 20 to day 40 in both the applied feed treatments. In terms of carbohydrate percentage on day 0, day 20, and day 40, maggot fed fish demonstrated a significant increase, while the fish fed with commercial feed demonstrated an increase from day 0 to day 20, but subsequently decreased on day 40 ($P<0.05$).

***Amino acid, fatty acid and cholesterol**.* Essential and non essential amino acids content of the experimental fish is presented in Figure 3. The levels of most amino acids in the fish fed with the commercial feed was generally higher than in those fed with maggot. Leucine and lysine reached the highest levels of essential amino acids found in the fish fed with both the maggot and the commercial feed. Moreover, in terms of non-essential amino acids, the concentrations of glutamic acid and proline were found to be the highest.

On day 20 and day 40, the leucine content in tilapia fed with maggot was 4.66% and 5.50%, respectively, lower than in the fish fed with commercial feed. On day 20 and day 40 the levels of glutamic acid in the fish fed with maggot were 10.94 and 11.99%, respectively, lower than in the fish fed with commercial feed (15.43 and 12.01%, respectively). The measurement of taurine content in the experimental fish was done only at the end of study. The result showed that the fish fed with maggot contained higher taurine, at a level of 6.56±0.23 mg 100 g^{-1}, compared to the fish fed with commercial feed (5.65±0.02 mg 100 g^{-1}).

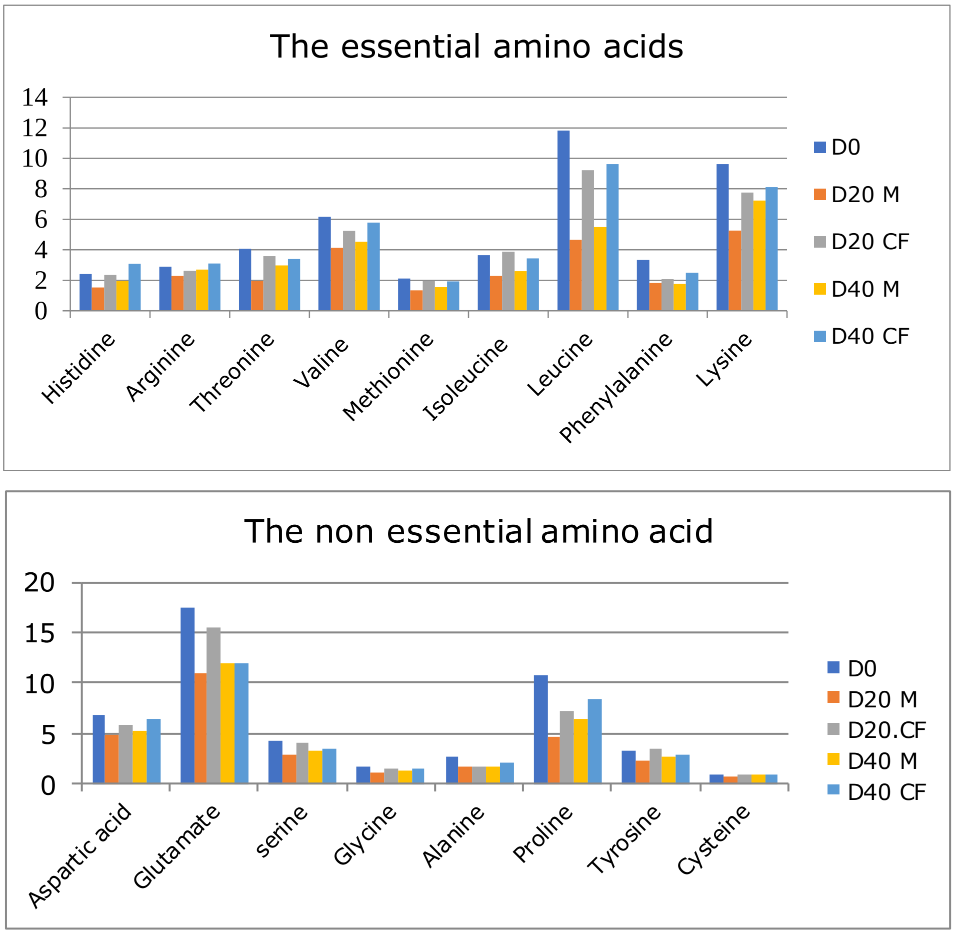

Figure 3. Essential and non-essential amino acids content of tilapia fed with maggot and commercial feed.

The fatty acid profile of the experimental fish in this study is presented in Table 4. A total of 10 fatty acids were included in the analysis, consisting of four saturated fatty acids (lauric, myristic, palmitic and stearic acids), one monounsaturated fatty acid (oleic) and five polyunsaturated fatty acids, namely linoleic, linolenic, arachidonic, eicosapentaenoic (EPA) and docosahexaenoic (DHA) acids.

The highest concentration of saturated fatty acids observed in the fish was due to the palmitic acid, while the highest concentration of unsaturated fatty acids was due to the linoleic acid and linolenic acid. The results of the present study showed that the fatty acid components of experimental fish fed with maggot were generally higher compared to the fish fed with commercial feed, except for stearic, linolenic and linolenic acids. The palmitic acid content in the fish fed with commercial feed and with maggot, at the end of study, was 27.18±0.84 and 28.50±0.47, respectively.

The highest content of fish specimens' polyunsaturated fatty acid in the present study was due to the linoleic acid. Tilapia fed with maggot contained 13.28±1.78% of linolenic acid (day 20) and 11.71±0.63% (day 40), respectively. This value was lower than in the fish fed with commercial feed, which was of 31.90±1.15 (day 20) and 20.38±0.72 (day 40). The only monounsaturated fatty acid observed in this study was the oleic acid. It was observed that tilapia given maggot contained a higher level of oleic acid (38.58±1.02%) than the fish fed with commercial feed (35.92±0.39%).

Table 4

Fatty acid profile of tilapia fed with maggot and with commercial feed

Fatty acid	*D0*	*D-20*		*D-40*	
		Commercial feed (P)	*Maggot (M)*	*Commercial feed (P)*	*Maggot (M)*
Saturated fatty acid					
Lauric (C12:0)	1.86±0.05	1.10±0.06	2.27±0.51	1.03±0.06	9.04±0.12
Myristic (C14:0)	3.04±0.22	2.39±0.47	2.74±0.39	3.31±0.10	9.85±0.13
Palmitic (C16:0)	16.48±2.63	17.65±1.50	27.98±0.61	27.18±0.84	28.50±0.47
Stearic (C18:0)	1.08±0.30	0.65±0.10	0.81±0.11	2.01±0.01	0.78±0.08
Total SAFA	22.46±1.22	21.78±0.53	33.79±0.41	33.53±0.25	39.14±0.20
Polyunsaturated fatty acid					
Linoleic (C18:2n6c)	14.20±0.86	31.90±1.15	13.28±1.78	20.38±0.72	11.71±0.63
Linolenic (C18:3n6)	2.16±0.84	12.09±1.58	0.62±0.31	8.74±0.02	0.64±0.20
Arachidonic (C20:5n3)	0.91±0.05	0.51±0.11	2.95±0.16	0.89±0.11	0.26±0.11
EPA (C20:5n3)	0.02±0.00	0.02±0.00	0.02±0.00	0.02±0.00	0.02±0.00
DHA (C22:6n3)	0.05±0.01	0.03±0.00	0.03±0.00	0.03±0.00	0.03±0.00
Total PUFA	17.34±0.45	44.55±0.74	16.9±0.75	30.06±0.31	12.66±0.26
Monounsaturated fatty acid					
Oleic (C18 : 1n9c)	47.59±2.36	31.08±2.11	38.17±3.30	35.92±0.39	38.58±1.02
Total MUFA	47.59±2.36	31.08±2.11	38.17±3.30	35.92±0.39	38.58±1.02
Total fatty acid	87.39±0.96	97.41±0.85	88.86±1.58	99.51±0.07	90.39±0.46
Total unidentified	12.61±0.96	2.59±0.85	11.14±1.58	0.49±0.07	9.61±0.46

The cholesterol content of the experimental fish is presented in Table 5. It was found that cholesterol content of the fish fed with maggot (78.35±19.86%) was higher than in the fish fed with the commercial feed (54.16±3.89 %).

Table 5

Cholesterol content of tilapia fed with maggot and commercial feed

Sample	*Cholesterol content (mg 100 g^{-1})*
Tilapia D-0	74.88±13.53
Tilapia D-20 Maggot	122.93±6.59
Tilapia D-20 Commercial feed	83.92±21.48
Tilapia D-40 Maggot	78.35±19.86
Tilapia D-40 Commercial feed	54.16±3.89

Discussion. The existence of magot as an alternative diet has been a great hope to redevelop aquaculture sector, particularly in the areas which are difficult to be reached by commercial feed distributors. The ease of maggot production process and the abundant availability of food waste is the major factor that motivates fish farmers to use it. Barroso et al (2014) and Henry et al (2015) reported that the nutrient content and composition of diptera larvae could naturally replace the use of fishmeal. Yet, the main obstacle faced by the fish farmers in using maggot is its high-fat content, particularly in the larvae older than 20 days, and its variability in protein content, which strongly depends on the culture media (NCR 2011; Aniebo & Owen 2010; van Huis et al 2013).

Previous studies demonstrated that maggot was mainly applied in meal, in order to substitute fishmeal in the feed formulation (Devic et al 2017; Barroso et al 2014; Henry et al 2015). However, fish farmers technically used fresh or live maggot directly as an alternative diet for fish. The present study evaluated the effect of a direct use of the maggot as a substitute for the tilapia commercial feed on the growth response, carcass yield and nutrient content of tilapia.

The growth of the fish fed with maggot and with commercial feed in this study was not significantly different, indicating that the maggot could replace the commercial feed, normally used by tilapia farmers. Similar result was also shown by previous studies regarding the substitution of fishmeal with maggot meal (Devic et al 2017; El-Siyed 2013), which demonstrated insignificant differences in the growth response between treatments. This shows that the fish fed with maggot were able to quickly adapt to the diet given, without experiencing stress (which could have negative impact on the fish growth). Tilapia easily adapts to maggot, since it is a natural feed for both freshwater and saltwater fish (Howe et al 2014; Henry et al 2015), with aquite similar amino acid, fatty acid, mineral and vitamin content as the fishmeal.

Fish proximate composition. The condition of the feed directly given to the fish was found to affect the amount of nutrients intake. Fresh maggot had a moisture and a protein content of 71 and 9.6%, respectively. In contrast, the moisture and protein content of commercial feed were 11 and 33.3%, respectively. Based on the FCR value, it can be calculated that protein intake between the fish fed with maggot and commercial feed was 1:3. This study provided the first scientific evidence on the comparison between the direct use of maggot and of commercial feed in tilapia culture. Low protein and carbohydrate intake observed in the fish fed with maggot did not correlate with the fish growth and nutrient content. Bonelli et al (2020) reported that maggot can also adapt to various types of organic matters besides having the micronutrient potential to be used as a feed ingredient. A recent study on micronutrients showed that maggot contain bioactive compounds with high biotechnology and medical potential, such as chitin and antimicrobial peptides (Bonelli et al 2020; Lugo et al 2003).

The result of the proximate analysis on the muscle of experimental fish showed that the nutrient content of fish treated with different feeds was quite similar: the protein and moisture content of both treatments was not significantly different, while fat, ash and carbohydrate differed significantly. The fish nutrient content in this study is relatively similar to the values reported in previous studies. Lugo et al (2003) for instance, reported tilapia compositions of moisture, ash, protein and carbohydrate of 79.1, 3.09, 81.00 (dry weight) and 5.62%, respectively. Another study by Chaijan (2011) showed that tilapia had a moisture level of 80.08%, an ash level of 3.26%, a protein content of 90.06% (dry weight) and a carbohydrate content of 5.22%. Santos et al (2012) reported that tilapia had a moisture and a protein content of tilapia of 72-80% and of 13-25% (wet weight), respectively.

Fish amino acid and fatty acid composition. The maggot has the ability to convert different types of organic waste into biomass with a high nutrient content, transforming the nutrients stored in the organic waste. Maggot has a quite high amount of protein content, thus it is widely used as protein source in fish and livestock diets or even as an alternative feed.

Tschirner & Simon (2015) reported that leucine and lysine were thedominant essential amino acids observed in maggot, while among the non-essential amino acids, the glutamic acid's concentration was the highest. This finding was confirmed by the results of the present study. High leucine and lysine contents in this study were also in line with the results of the study conducted by Tasbozan et al (2013), of 5.9 and 7.17% (dw), respectively. However, the level of glutamic acid in Tasbozan et al (2013) was lower than in the present study (7.04%).

Taurine is a non-essential amino acid which contains sulphur, but, due to the absence of a carboxyl group (-COOH) required to form peptide bond, it does not belong to the proteins group. It has a main function in maintaining the balance of cell membranes of the active tissues. The present study demonstrated that the experimental fish fed with maggot had a higher taurine level (6.56±0.23 mg 100 g^{-1}), compared to the fish fed with commercial feed (5.65±0.02 mg 100 g^{-1}). This value was higher than the taurine content of 1.15 mg 100 g^{-1} observed in nile tilapia and reported by (El-Sayed 2013). This demonstrates that the maggot has the ability to increase the taurine content in experimental fish.

The highest saturated fatty acid content was dominated by the palmitic acid which confirmed the result of previous studies (Devic et al 2017). The palmitic acid content recommended in food ranges from 15 to 50% of all fatty acids. In the body, palmitic acid functions as a source of calories with low oxidation rate. Furthermore, the lauric acid level in the fish fed with maggot was higher than than in fish fed with commercial feed. This result is possible since magot also contains high amount of lauric acid (Caruso et al 2014). Lauric acid is a unsaturated fatty acid which has the benefit to strengthen the immune system. The result of the present study showed that the cholesterol level of tilapia fed with maggot was higher than those fed with commercial feed, since magot contained a relatively high amount of fatty acids (Coruso et al 2014; Shumo et al 2019).

Conclusions. This study successfully assessed the response of nile tilapia when maggot is directly used as an alternative live food. Feed conversion ratios of 2.1 and 1.9 for maggot and commercial feed, respectively, showed that the fish growth and nutrient content of tilapia fed with fresh maggot were not significantly different from tilapia fed with commercial feed. The highest levels of essential amino acids observed in tilapia fed with maggot were measured for the leucine and lysine, while the highest non-essential amino acid concentration was recorded for the glutamic acid. Tilapia fed with fresh maggot was higher in taurine and cholesterol levels, compared to those fed with the commercial diet. These results suggest that fresh maggot might potentially replace the utilization of commercial feed as alternative fish feed.

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Conflict of interest. The authors declare no conflict of interest.

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