

Analysis of the use of media resulting from bioconversion of organic waste in the production of maggots BSF (black soldier fly)

Analisis penggunaan media hasil biokonversi sampah organik pada produksi maggots BSF (black soldier fly)

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ABSTRACT

Maggots is an organism derived from the eggs of the black fly, *Hermentia illucens* (black soldier fly, BSF), which undergoes metamorphosis in the second phase after the egg phase and before the pupa phase which then turns into an adult fly. The purpose of this study was to analyze the utilization of organic waste substrate on the production of BSF maggots cultivation. This research was conducted outdoor at the Freshwater Aquaculture Fisheries Center (BPBAT) Sungai Gelam Jambi with a completely randomized design (CRD) with 4 treatments and 3 replications; Treatment A: PKM (palm kernel meal) 100%, B (PKM 50% + cabbage vegetable waste 50%), C (PKM 50% + coconut pulp 50%) and D (PKM 50% + coconut pulp 25% + vegetable waste cabbage 25%). The average yield parameter of high maggots biomass in treatment A was 673.67 g/4 kg substrate and the lowest biomass in treatment D was 239.67 g/4 kg substrate. For the average weight and length of the best maggots in treatment A (0.20 g/individual) and (1.83 cm), the lowest was in B (0.12 g/Ind. and 1.58 cm). The highest was in treatment B (5,182.31 individual/4 kg substrate) and the lowest was in D (1,479.44 ind./4 kg substrate). The highest bioconversion value of maggots to organic matter OSE (organic substrate efficiency) was highest in treatment A (16, 84%) and the lowest was in D (5.99%). Technically, treatment A was slightly better than B, while economically the best organic substrate medium for maggots cultivation was in treatment B with a production cost of Rp. 7.257 and the ECR (economic conversion ratio) value of 5.81 was lower than the other 3 treatments.

Keywords: Maggots, black soldier fly, *Hermentia illucens*, organic waste.

ABSTRAK

Maggots merupakan organisme yang berasal dari telur serangga lalat hitam, *Hermentia illucens* (*black soldier fly*, BSF). Tujuan penelitian ini yaitu menganalisis pemanfaatan substrat limbah organik terhadap produksi budidaya maggots BSF. Penelitian ini dilaksanakan di Balai Perikanan Budidaya Air Tawar (BPBAT) Sungai Gelam, Jambi dengan rancangan acak lengkap (RAL) 4 perlakuan 3 ulangan yaitu perlakuan A : PKM (palm kernel meal) 100%, B (PKM 50% + limbah sayur kol 50%), C (PKM 50% + ampas kelapa 50%), dan D (PKM 50% + ampas kelapa 25%+ limbah sayur kol 25%). Rata-rata biomassa tertinggi didapatkan pada perlakuan A (673,67g/4 kg substrat) dan biomassa terendah dihasilkan pada perlakuan D (239,67g/4 kg substrat). Untuk bobot rata-rata dan panjang maggots terbaik dihasilkan pada perlakuan A (0,20 g/individu dan 1,83 cm/individu), terendah pada B (0,12 g/individu dan 1,58 cm). Jumlah populasi maggots yang terbanyak dihasilkan pada perlakuan B (5.182,31 ind/4 kg substrat) dan terendah pada D (1.479,44 individu/4 kg substrat). Nilai biokonversi maggots terhadap bahan organik OSE terbaik (organic substrate efficiency) tertinggi pada perlakuan A (16,84%) dan terendah pada D (5,99%). Secara teknis perlakuan A sedikit lebih baik dari B sedangkan secara ekonomi media substrat organik terbaik untuk budidaya maggots terdapat pada perlakuan B dengan biaya produksi sebesar Rp. 7.257 dan nilai ECR (*economic conversion ratio*) sebesar 5.81 lebih rendah dari ke 3 perlakuan lainnya.

Kata kunci: Maggots, *black soldier fly*, *Hermentia illucens*, limbah organik.

INTRODUCTION

Feed is one of the most important in aquaculture. The availability of feed will affect the growth and survival of fish which can increase fish production. The price of commercial feed increases gradually due to the raw materials supply. Feed is the main component in aquaculture activities because it plays a major role in the cost aspect, approximately 50–75% of total production costs are generated from feed utilization so that the efficiency of using small amounts of a feed helps to reduce production costs and increase payback period (Adéyèmi *et al.*, 2020). A payback period indicates a certain period to recover an investment cost (Fika *et al.*, 2016; Izmaniar *et al.*, 2018). The type of commercial feed is the main factor in the high cost of aquaculture production. The increasing price of a commercial decreases the income of farmers (Baki & Yücel, 2017; Azhari *et al.*, 2020). The use of local raw materials in the formulation of artificial feed can reduce feed costs. The utilization of organic waste as raw material for artificial feed can be applied to aquaculture, yet the composition of the organic content will reduce protein content in feed (Tugiyono *et al.*, 2020; Cahya *et al.*, 2021).

In addition to artificial feed formulations, organic waste was also used for the production of maggots as a natural feed for fish farming. Maggots production using organic waste could be done by composting or maggots bioconversion techniques (BSF). A 2-week maggots are ready to be used as feed (Mokolensang *et al.*, 2018). Cicilia and Susila (2021) explained that the maggots given to cultured fish can be in the form of fresh maggots, crushed maggots, and it can also be used as raw material for making fish feed instead of fish meal. The bioconversion process aims to change the form of organic waste by insect larvae and convert it into biomass (Leong *et al.*, 2016). The conversion of organic waste produces simpler forms through a biotransformation process with nutritional content consisting of polypeptides containing proteins, lipids, peptides, amino acids, chitin, and vitamins (Liu *et al.*, 2019). Therefore, BSF maggots are potential non-pest insects as an important protein source for the 21st century (Rui *et al.*, 2017).

Maggots derived the pre-pupa stage has a high protein content (Herawati *et al.*, 2020). Maggots in the form of flour has advantages compared to other artificial feed raw materials because it is rich in protein nutrients and amino

acids, 40–50% of protein, and 30% of fat. The amino acid content consists of cysteine, histidine, tryptophan, and tyrosine (Cummins *et al.*, 2017; Herawati *et al.*, 2020). According to Fauzi and Sari (2018), maggots are a type of natural feed that has high protein containing 41–42% crude protein, 31–35% ether extract, 14–15% ash, 4.8–5.1% calcium, and 0.6–0.63% phosphorus in dry form. Arifin *et al.* (2020) explained that the use of maggots flour as a protein source in the formulation of tilapia feed can be substituted for 75% of fish meal. The body composition of BSF maggots larvae is highly dependent on the quality and quantity of food ingested (Nguyen *et al.*, 2015).

In technical cultivation, BSF maggots need a substrate to live that serves as a food source for BSF maggots. To produce better maggots at a low cost, it can be done by engineering the type of organic medium substrate or improving the environment of the maggots medium itself. Several types of substrates have been used for the cultivation of BSF maggots, including coffee grounds (Lardé, 1990), manure (Newton *et al.*, 2005), beet pulp, grains (Tschirner & Simon, 2015), tofu pulp, bran, coconut pulp, oil palm meal, various fermented ingredients (Lestari *et al.*, 2020), and its combination (Rizki *et al.*, 2017). Fahmi *et al.* (2009) reported that BSF (black soldier fly) maggots larvae living in oil palm dregs were able to reduce organic waste by up to 56%. In addition, Syahrizal *et al.* (2014) also reported that there was a difference in the production of maggots *Hermetia illucens* in the use of 100% palm kernel meal (PKM) (4 kg) with a combination of 1 kg PKM (25%) and 3 kg of tofu dregs where 100% of PKM produced the highest maggots production of 1.66 ± 0.13 kg (41.5%) while the combination of 1 kg of PKM (25%) and 3 kg of tofu dregs produced the lowest maggots production of 0.57 ± 0.13 kg (14.25%).

The use of PKM as the main live medium has been proven to have resulted in high maggots production. However, this research still needs to be continued to increase the production of maggots with different combination materials and the use of PKM is not a monopoly or high dependence on this material. Therefore, the results of the research by Syahrizal *et al.* (2014) become the basis for the implementation of this research. In addition to the combination of PKM with other ingredients, information that is important to find is the amount or ratio of the use of PKM with the combined ingredients. This study aims to analyze the PKM

organic waste medium and its combination of product performance and economic analysis.

MATERIALS AND METHODS

Experimental design

This research was conducted in May 2020 for 30 days at the Sungai Gelam, Jambi Freshwater Aquaculture Center. This study used a completely randomized design (CRD) with 4 treatments and 3 replications, i.e. treatment A : PKM 100%, treatment B: 50% PKM + 50% cabbage vegetable waste (CVW), treatment C: 50% PKM + 50% coconut meal (CM), and treatment D: 50% PKM + 25% coconut meal (CM) + 25% cabbage vegetable waste (CVW).

Equipment and materials

The used containers were 12 round plastic buckets with a diameter of 50 cm and all of them were covered with corrugated tin roofs. Then put the dried banana leaves on the substrates (as a medium for *H. illucens* flies to lay their eggs) as much as 3 pieces. The container was placed randomly at a predetermined location and the container was 20 cm high. The research site was fenced using a 1-meter high net.

Research procedure

The implementation of the maggots cultivation research experiment was carried out by placing the waste media material into a plastic bucket for each treatment. Then, 4 L of freshwater was added to the container as a solvent and stirred evenly. The top of each medium was covered with dry banana leaves. After that, each bucket is covered with corrugated plastic zinc so that flies can still enter the experimental bucket.

The live medium substrates maggots *Hermetia illucens* from black soldier fly (BSF) used as a treatment in the form of palm kernel meal,

coconut waste, and proximate cabbage vegetable waste the results can be seen in Table 1. Substrate composition is the result of the initial analysis of the proximate profile of the media content that will be used in this study. The filter media materials in the treatment included oil palm waste, coconut waste, and cabbage vegetable waste. The composition of the proximate value of maggots growing media is also presented in Table 1.

Data collection

Data production of maggots was observed by measuring the weight of the maggots produced in the media in each treatment and 10 gs of maggots samples were taken to count the number of individuals. Maggots length was measured using a ruler at the end of the study by taking 10 samples from each treatment randomly. The conversion value and medium efficiency (bioconversion) were by comparing the amount of maggots produced with the number of substrates used. Observation of nutrient content in maggots by conducting proximate analysis includes water content, ash content, fat content, protein content, and carbohydrates contained in maggots. The bioconversion of organic substrate medium is calculated by the ratio of substrate medium to maggots production, namely substrate absorption efficiency (ASE) and bioconversion ratio rate (BcRR). Proximate analysis was carried out at Jambi University's Animal Husbandry Laboratory. To see the efficiency of the organic waste used, it was calculated using the economic conversion ratio (ECR), which was a comparison of the costs incurred to produce maggots with production results.

Data analysis

The data obtained were tabulated with Microsoft Office Excel 2013 and analyzed for variance using the SPSS 22. This analysis was

Table 1. Composition of the proximate value of maggots substrates *Hermetia illucens* in palm kernel meal, coconut meal, and cabbage vegetable waste.

Treatment	Medium material (%)			Proximate (%)			
	PKM	CM	CVW	P	C	F	A
A	100	0	0	15.98	30.76	10.35	3.69
B	50	50	0	14.88	24.21	7.66	3.25
C	50	0	50	8.54	24.04	17.09	2.75
D	50	25	25	9.90	23.63	14.86	3.10

PKM = palm kernel meal, CW = coconut waste, CVW = cabbage vegetable waste, P = protein, C=carbohydrate, F = fat, and A = ash

applied to determine the effect of treatment on each parameter tested at a 95% confidence level. If there was a significant difference, then it would be continued with the LSD test to see the difference between treatments. Other data to support the research would be analyzed descriptively.

RESULTS AND DISCUSSION

Result

Maggots biomass

Maggots biomass was represented by two parameters, namely the average biomass of maggots per 4 kg of media and the average weight of maggots in g per individual. Based on the results of statistical tests, there were differences in the average biomass between treatments, the highest maggots biomass was in treatment A (100% oil palm waste) of 673.67 g/4 kg of media, this result was as good as treatments B and C. While the lowest maggots biomass was found in treatment D (50% oil palm waste + 25% coconut waste + 25% cabbage waste) was 239.67 g/4 kg of media. The results are presented in Table 2 as follows.

Average length

The average maggots length measured during the study was presented in Table 3 below. The results showed that there was no difference ($P > 0.05$) between treatments on the average length of the maggots. The average maggots length for each treatment was A (1.83 cm), B (1.58 cm), C (1.67 cm), and D (1.70 cm).

Amount of maggots

In addition to measuring the biomass, average weight, and length of maggots, measurements were also made of the number of individual maggots during the study. The results of the study are presented in Table 4 as follows. Based on the results of statistical tests showed that there was a difference ($P < 0.05$) between treatments. The highest amount of maggots was found in treatment B (50% PKM + 50% cabbage waste), the lowest amount of maggots was found in D treatment (50% PKM + 25% coconut waste + 25% cabbage vegetable waste).

Maggots bioconversion

This bioconversion is a form of changing organic elements from waste (substrate)

Table 2. Average biomass and weight of maggots, *Hermetia illucens* on palm kernel meal, coconut waste, and cabbage vegetable waste.

Treatment	Medium materials (%)			Average maggots biomass (g/4 kg substrates)	Average maggots weight (g/individual)
	PKM	CC	CVW		
A	100	0	0	673.67 ^a	0.20
B	50	50	0	606.33 ^a	0.12
C	50	0	50	513.00 ^a	0.16
D	50	25	25	239.67 ^b	0.16
Total average				508.17	0.161

PKM = Palm kernel meal, CW=coconut waste, CVW = cabbage vegetable waste. Different letters in different columns showed significant different ($P < 0.05$)

Table 3. The average length of maggots, *Hermetia illucens* on palm kernel meal, coconut waste, and cabbage vegetable waste.

Treatment	Medium materials(%)			Length average maggots (cm/individual)
	PKM	CC	CVW	
A	100	0	0	1.83 ^a
B	50	50	0	1.58 ^a
C	50	0	50	1.67 ^a
D	50	25	25	1.71 ^a
Total average				1.70

PKM = Palm kernel meal, CW= coconut waste, CVW = cabbage vegetable waste. Different letters in different columns showed significant different ($P < 0.05$)

to maggots which is measured using the parameters of substrate absorption efficiency and the bioconversion ratio rate from the use of substrate from palm kernel waste, cabbage waste, and coconut waste combined as much as 4 kg. Substrate absorption efficiency (SAE) and Bioconversion ratio (BRR) in the utilization of organic substrates by maggots are presented in Figure 1 below.

Based on the picture above, it can be seen that the best SAE was found in treatment A (16.83%) followed by treatment B (16.82%), treatment C (11.41%). The lowest SAE was found in treatment D which was equal to (5.99%). The results of this study showed that PKM combined with other materials showed a decrease in substrate absorption efficiency. This result is inversely related to the BRR. The best level of BRR was

found in treatment D (16.74%) followed by treatment C (7.80%), treatment D (6.60%). The lowest level of BRR is found in treatment A, which is equal to (5.94 %). There is an increase in the rate of bioconversion ratio when PKM is combined with other materials.

Profil of proximate maggots

The cultured BSF maggots at the end of the study was analyzed for its proximate profile to see the nutritional content of the BSF maggots. The results of the proximate profile analysis are presented in Table 5 below. The results of the analysis showed that there were differences in the results of the nutritional content of each treatment. The difference is in the protein content. The highest protein content was found in treatment A at 46.50%, followed by treatment C 38.10%,

Table 4. The average amount of maggots, *Hermetia illucens* on palm kernel meal, coconut waste, and cabbage vegetable waste.

Treatment	Medium materials (%)			Amount maggots average (individual)
	PKM	CC	CVW	
A	100	0	0	3.437,09 ^a
B	50	50	0	5.182,31 ^b
C	50	0	50	3.309,68 ^a
D	50	25	25	1.479,44 ^c
Total average				13.308,52

PKM = palm kernel meal, CC= coconut waste, CSW = cabbage vegetable waste. Different letters in different columns showed significant different ($P < 0.05$)

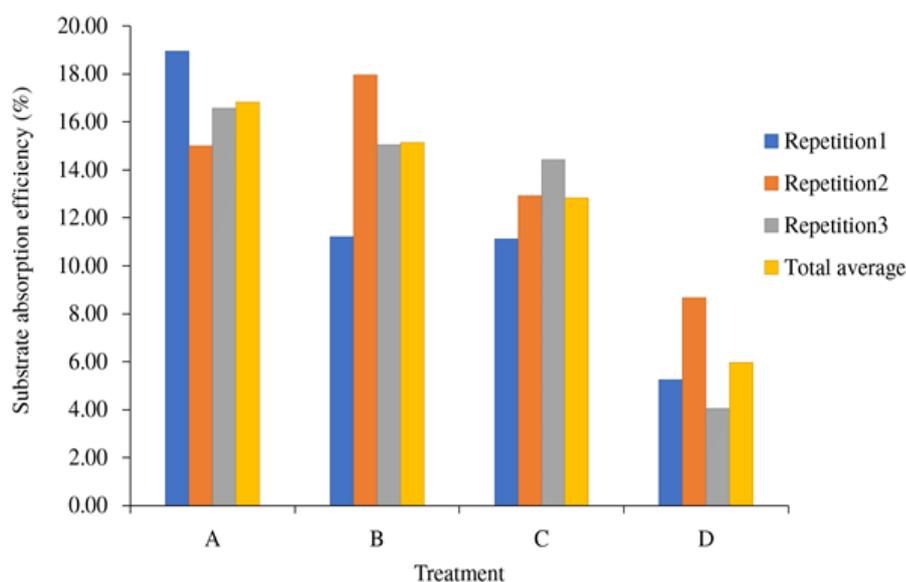


Figure 1. The average percentage SAE and BRR from bioconversion in organic substrates by maggots produced on each treatment for 21 days of the experiment. A: 100% PKM, B: 50% PKM + 50% CW, C: 50% PKM + CSW, and D: P 50% PKM + 25% CC + 25% CSW. PKM = palm kernel meal, CW= coconut waste, CVW = cabbage vegetable waste.

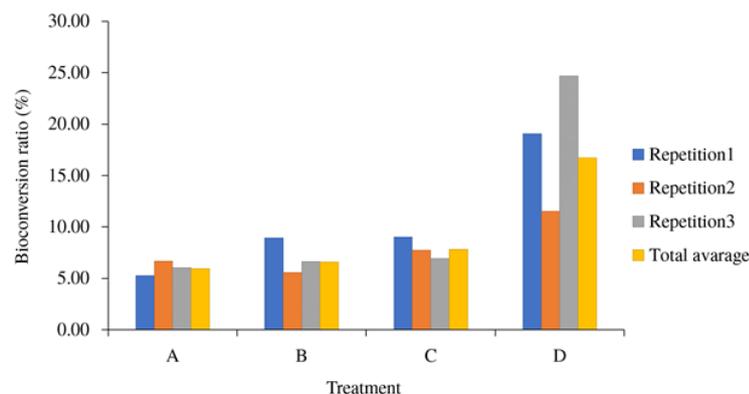
treatment B 35.90%. The lowest protein content was found in treatment D, which was 22.30%. Carbohydrate, fat, and ash content in this study ranged from 5.80–22.40%, 36.90–46.60%, and 8.10–9.30%, respectively.

Economic analysis

Economic analysis of maggots cultivation production using an organic waste substrate with PKM medium combined with coconut waste and treated cabbage vegetable waste can be seen in Table 6 below. The results of the economic analysis showed that the production cost of maggots using the PKM+Cabbage vegetable waste medium (Rp.7.257) was lower than the other mediums in treatment A, C, and D, each of which was Rp. 11,875, Rp. 8,577 and Rp. 18.359 per kg, as well as the ECR (economic conversion ratio) value in treatment B (PKM + vegetable cabbage waste), resulted in an ECR value of 5.805; lower than the other treatments, namely PKM+coconut waste+cabbage vegetable waste (D) of 14.687, PKM+coconut meal (C) of 6.862 and PKM (D) of 9.

Discussion

Maggots production is strongly influenced by the substrate or growing media (Odjo *et al.*, 2018). In a long period, many research results have reported the efficiency level of several types of substrates in maggots production (Odjo *et al.*, 2018). The productivity of the utilization of these substrates varies greatly depending on their function and nature (Djissou *et al.*, 2015). The results of maggots production showed that the best maggots biomass was in treatment A of 673.67 (0.20) g, followed by treatment B of 606.33 (0.12) g, treatment C of 513.00 (0.16) g, and the lowest was in treatment D of 239.69 (0.16) g (Table 2). Based on analysis of variance, treatments A, B, and C were relatively great and significantly different from treatment D. This was because the composition of the media in treatments A, B, and C were able to meet the nutritional needs for the growth of BSF larvae. In media A, B, and C, it was estimated that the nutritional content was relatively sufficient and balanced to stimulate the growth of the maggots. Good organic matter for maggots growth is a material that must contain



[Continue] Figure 1. The average percentage SAE and BRR from bioconversion in organic substrates by maggots produced on each treatment for 21 days of the experiment. A: 100% PKM, B: 50% PKM + 50% CW, C: 50% PKM + CSW, and D: P 50% PKM + 25% CC + 25% CSW. PKM = palm kernel meal, CW= coconut waste, CVW = cabbage vegetable waste.

Table 5. The average value of the composition of the proximate maggots *Hermetia illucens* in the medium of palm kernel meal, coconut waste, and cabbage vegetable waste

Treatments	Medium materials (%)			Maggots proximate (%)			
	PKM	CM	CVW	P	C	F	A
A	100	0	0	46.50	7.30	36.90	9.30
B	50	50	0	35.90	13.40	41.90	8.80
C	50	0	50	38.10	5.80	47.90	8.10
D	50	25	25	22.30	22.40	46.60	8.7

PKM = palm kernel meal, CM= coconut meal, CVW = cabbage vegetable waste, P = protein, C=carbohydrate, F = fat, A = ash

a lot of nutritional elements, especially organic matter. This product was in line with the results of research by Syahrizal *et al.* (2014) that PKM used as media for maggots maintenance resulted in higher maggots production (0.18 ± 0.68 g/individual) than the combination of PKM with tofu waste (0.17 ± 0.68 and 0.16 ± 0.68 g/individual). Monita *et al.* (2017) explained that BSF larvae have body weights ranging from 0.09–0.11 mg. According to Cicilia and Susila (2021), the average weight of maggots produced by this media composition was 0.30 g/head. This relationship also appeared to be linear with a high proximate value of protein medium which is directly proportional to maggots production in PKM medium. Whereas, the results of proximate protein in PKM (15.98%) and followed by coconut waste (14.88%), cabbage waste (8.54%), and a combination of 9.90% are presented in Table 5.

The results of the measurement of the average length of the maggots in each treatment obtained results for treatment A of 1.83 cm, treatment B of 1.58 cm, treatment C of 1.67 cm, and treatment D of 1.70 cm (Table 3). This was not significantly different between treatments ($P > 0.05$). Maggots production appears linear with bioconversion of nutrient material obtained from the treatment medium in the form of proximate Table 1 such as protein, carbohydrates, fat, and ash media, respectively oil palm waste (15.98%, 30.76%, 10.35%, and 3.369%), followed by coconut waste (14.88%, 24.21%, 7.66%, and 3.25%), cabbage waste (8.54%, 24.04%, 17.09 and 2.75%) and combinations (9.90%, 23.63%, 14.86%, and 3.10%). According to Syahrizal *et al.* (2014)

that maggots aged 3–4 weeks reared using PKM media have a length ranging from 1.8 to 2.30 cm. Monita *et al.* (2017) said that BSF larvae ranged in length from 15.85–16.44 mm.

The highest number of maggots was found in treatment B and the lowest in treatment D. The high number of maggots in treatment B was thought to be caused by their relatively small size when compared to A, C, and D and the late arrival of BSF maggots to the organic medium. Treatment D, which had fewer than 1,479.44 tails, was caused by suboptimal nutritional elements and insufficient aroma that could bring BSF as an attractant for laying eggs. According to Gold *et al.* (2018) that for the performance process of organic waste heat is needed for inactivation and safety. In addition, oxygen and pH are needed in the intestinal environment because they affect food decomposition, enzyme activity and form the number and diversity of microbes. Tomberlin *et al.* (2009) explained that the black army fly *Hermetia illucens* was reared on a wheat diet at 27, 30, and 36°C. Survival of 4-to-6-day old larvae to adults averages 74–97% at 27 and 30°C but only 0.1% at 36°C. Flies require an average of 4 days (11%) longer to complete larval and pupal development at 27°C than at 30°C. At 27 and 30°C, females weigh on average 17–19% more than males but require an average of 0.6–0.8 days (3.0–4.3%) longer to complete larval development. Azir *et al.* (2017) explained that the high production of maggots from green flies *Chrysomya megacheala* for laying eggs because the organic medium provides a distinctive aroma and is easily decomposed by maggots.

Tabel 6. Economic analysis of BSF maggots with organic waste substrate media combined for one cycle of 21 days of the maintenance period.

Parameter	Treatment			
	A	B	C	D
Amount of medium (kg)	4.00	4.00	4.00	4.00
Amount of maggots produced (kg)	0.674	0.606	0.513	0.240
Media price (per kg)*	8.000	4.400	4.400	4.400
Maggots price (Rp/kg)	5.000	5.000	5.000	5.000
SAE (substrate absorption efficiency)%**	16.84	15.16	12.83	5.99
Production cost (Rp/kg maggots)***	11.875	7.257	8.577	18.359
Economic conversion ratio (ECR)****	9,500	5,805	6,862	14,687

* PKM price Rp 2,000/kg, Coconut dregs Rp 200/kg, cabbage vegetable waste Rp 200/kg

** Maggots conversion = number of maggots generated/number of media \times 100%

*** Maggots production cost = media price / amount of maggots produced

**** ECR = (Number of medium \times medium price) / (maggots production \times maggots selling price)

PKM= palm kernel meal, CC = coconut waste, CVW = cabbage vegetable waste

Overall, the experimental results of media bioconversion to maggots were relatively great. Azir *et al.* (2017) explained that the yield of fish waste was 8.2347% and the best material was the combination of 50% fish waste with 19.16% coconut pulp. According to Pathiassana *et al.* (2020), the average value of bioconversion (substrate consumption) of maggots in carrots and radishes were 48.42% boiled and 57.9% fermented. The best substrate bioconversion used by the development of maggots production occurred in treatments A (16.84%), and B (16.82%), while in treatments C (11.41%) and D (5.99%) were lower, this was related to the requirement and availability of protein for maggots as the main nutritional element. High and low bioconversion were consequences of retention of absorption of protein and other nutritional elements in the form of carbohydrates, fats, minerals, and environmental factors available in maggots living substrate medium. In addition to organic matter which is aromatic and easily decomposed, BSF may be attracted to the nutrients and water content of the substrate medium. Surendra *et al.* (2020) explained that in increasing the biomass of larvae or pupae, BSF utilized more mechanical and automatic system to produce bioactive compounds, such as antimicrobial peptides, medium-chain fatty acids, and chitin, as well as their derivatives. Indariyanti and Barades (2018) explained that maggots *Hermetia illucens* was an organism that consumes organic material which contained anti-microbial and anti-fungal properties so that it did not carry disease agents.

The composition of the BSF maggots proximate test results *Hermetia illucens* which was developed on a medium has given oil palm meal, coconut meal, and cabbage vegetable waste showed that there were differences in the results of the nutritional content of each treatment. On the contrary, the protein content between treatment A was 46.5%, treatment B was 35%, treatment C was 38%, and treatment D was 22% (Table 5). The carbohydrate content was different amongst A and B, C, and D. The fat content was also different in treatments A and B with C and D, while the mineral elements (ash) were relatively similar amongst treatments. The difference in the composition of the nutritional elements of maggots might be related to lifestyle and the composition of the elements of the maggots medium. Indariyanti and Barades (2018), stated that maggots biomass was 435.2, protein content was 44.58%, fat was 4.89%, crude fiber was 8.02%, linolenic acid was

1.98, and linoleic acid was 3.67. Fauzi and Sari (2018) explained that maggots is a type of natural feed that has high protein containing 41–42% crude protein, 31–35% ether extract, 14–15% ash, 4.8–5.1% calcium, and 0.6–0.63% phosphorus for dry weight. Fahmi *et al.* (2007) explained that maggots contains about 32.31–60.2% protein and quite high fat around 9.45–13.3% depending on the age and quality of the substrate. Monita *et al.* (2017) explained that BSF larvae had a protein content of 33.31–33.88% and a fat content of 30.07–34.39%. The high production and protein maggots in the PKM medium in this study was thought to be due to the aroma attractant factor and the adequacy of the nutritional and water elements needed for BSF life needs compared to other organic mediums. According to Rachmawati *et al.* (2010) that the level of maggots protein in PKM media aged 5 days was 61.42%. higher than day 20 (42.07%). Cicilia and Susila (2021) explained that fresh maggots protein was 9.11%; water 73.69% and in the form of flour 31.30%; 0.79% water, 17.11% fresh fat, and 34.36% flour. According to Gold *et al.* (2018) that larval BSF biomass contains 32–58% proteins and 15–39% lipids. The better the medium protein content and the faster the maggots was produced, the higher the maggots protein content will be (Suciati & Faruq, 2017).

The results of economic analysis of maggots cultivation production using an organic waste substrate with PKM medium combined with coconut waste and cabbage waste shows that the production cost of maggots using PKM medium + cabbage waste is Rp 7,257 lower than other mediums in treatments A, C, and D. Each of which is Rp 11,875, Rp 8,577 and Rp 18,359 per kg, as well as the ECR (economic conversion ratio) value in treatment B (PKM + vegetable cabbage waste), resulted in an ECR value of 5.805; lower than the other treatments, namely PKM +coconut waste+cabbage vegetable waste (D) of 14,687, PKM +coconut meal (C) of 6.862 and PKM (D) of 9,500. Rachmawati *et al.* (2010) explained the results of research conducted in the field, it is known that to obtain 1 kg of fresh *H. illucens* larvae take 3 kg of PKM. To obtain 1 kg of dry *H. illucens* larvae (raw feed material) required 3 kg of fresh *H. illucens* larvae (water content 63,72%). Production of *H. illucens* larvae in Sungai Gelam Jambi, it was known that the price of *H. illucens* larvae-based pellets produced is only Rp 3,500.00 per kilo (PKM price is Rp 200.00/kg), cheaper than the price of commercial pellets, which is Rp 7,000.00 per kilo.

CONCLUSION

The best maggots production was found in treatments A (100% PKM) with biomass of 673.67 g/4 kg medium, and 0.20 g/individual) and B (50% PKM + 50% CVW) with total maggots (5,182.31 in./4 kg medium). The best organic medium bioconversion in maggots production was found in treatments A (16.84%), and B (16.82%) with proximate proteins A (46.5%) and B (35%). The cost of producing maggots with PKM+CVW media (Rp 7,257) is relatively cheaper in succession than other media (A, C, and D), which is Rp 11,875, Rp. 8,577 and Rp 18,359 per kg, with the ECR value of PKM + CVW was 5.805.

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