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The Potency of Black Soldier Larvae (*Hermetia illucens* L.) as a Source of Protein for Livestock Feed

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Abstract

Black Soldier fly larvae is an insect capable to convert organic waste into body biomass. The purpose of this research was to determine the productivity, mass balance of the consumption process, and content of protein and fat of prepupa which has a potency as a livestock feed. This research used 6-day-old larvae, they were fed with cassava skin that has been smoothed with a variety of feeding doses: 12.5; 25; 50; 100; and 200 (mg / larvae / day) with ratio of feed and water 2: 1. The results showed that the feeding of 200 mg / larva / day produced the best larval growth with biomass productivity of 1.54 mg / day, residue yielded of 67.1 mg / day. The organic waste was convertion into larvae biomass. In this study, approximately consumption process scale is feed successfully converted to biomass 2.77%, metabolism 6.98%, and 90.24% residue. Protein content is 25.7%. It can be concluded that the larvae are able to convert organic waste into high protein biomass and potentially being used as a livestock feed. This research acts a model to predict mass balance of substrates for feed. The benefit of this research is the science approach used in this study that can be used as a reference by researchers and the community to determine the biomass production of an organism.

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INTRODUCTION

Black Soldier fly (BSF) is an insect that spreads in tropical and warm areas, which is around 45⁰ NL to 40⁰ SL (Diener *et al.* 2011). Black soldier fly are commonly found in warm areas (about 20 - 30) that is protected from sunlight, for example on the periphery house or under shady trees. The life cycle of black soldier fly consists of eggs, larvae, prepupa, pupa, and adult (Diener *et al.,* 2011). Black soldier fly larva (BSFL) is a polyphagus (can consume all types of food) and able to consume large amounts of food quickly and efficiently than other types of flies (St-Hilaire *et al.* 2007). Black soldier fly larvae are classified as detritivor organisms because they consume organic materials derived from living things such as fruits, leaves, carcasses, and human waste (Kim *et al.,* 2011). To grow optimally, black soldier fly larvae need a dark spot at a temperature of about 10 - 20 and a relative humidity of 60-75% with adequate food supply (Diener *et al.* 2009; Zheng *et al.*, 2012; Li *et al.*, 2011a.b).

Black soldier fly larvae will grow well in organic waste such as agricultural waste with optimal media conditions (Manurung *et al.* 2016; Supriyatna *et al.,* 2016a). The ability of Black soldier fly larvae to consuming organic waste because of cellulotic bacteria in their intestine that produce cellulase enzyme (Supriyatna *et al.,* 2016b). Organic waste contains lignocelluloses and nutrients that can be converted into valuable products for composting or livestock feed (Supriyatna and Putra, 2017). BSFL are able to convert organic waste into proteins and fats in their body biomass (Oliver, 2004; Newton *et al.* 2005; Li *et al.* 2011; Zheng *et al.*, 2011).

Black soldier fly larvae has high fecundity and tolerance in medium of life that make them suitable for cultivation activities (Newton *et al.,* 2005). High fecundity is very important for the cultivation of larvae. The high fecundity will make the larvae cultivation becomes more profitable. The biochemical composition of Black soldier fly larvae are 56% water and 44% dry weight, with protein details of 18.5%, animal fats of 15.5%, ash 7%, and other compounds (Newton *et al.*, 2005). With high amounts of protein and animal fats, Black soldier fly larvae are very potential as livestock feed ingredients and aquaculture (Diener *et al.,* 2009). In addition, dirt from Black soldier fly larvae is very potential to be used as high quality compost. The novelty of this research was the study of the development of Black soldier fly larvae for agricultural waste management. Especially larval biomass productivity, larval development time, and the potential of BSF larvae as high protein livestock feed. Furthermore, this research as a model to predict substrates mass balance of feed. The benefit of this research is the science approach used in this research that can be used as a reference by researchers and the community to determine the biomass production of an organism.

METHODS

The study was conducted for six weeks at the Departement Biology, Faculty of Science and Technology, UIN Sunan Gunung Djati Bandung, while Pre pupae protein analysis was conducted in laboratory of the Faculty of Animal Husbandry, Padjadjaran University (UNPAD).

Cassava skin were mashed with mesh size of 20, then the water was added with ratio feed: water (2: 1). Water works as a solvent to keep the medium from being dry. The medium was stirred evenly and loosely, then it was poured into the container (Sillmina, et al 2012).

Research procedure

This research was divided into several stages. The first stage was the preparation stage of media and container. The second stage was the determination of the location of the study. The third stage was the cultivation stage, and the last stage was harvesting the Black soldier fly larvae or the maggot.

Preparing the containers

5L plastic container was covered with perforated black plastic, with 2cm holes diameter, the distances between holes were 5 cm. The container was used for hatching the eggs of Black soldier fly larvae . 12 cm high plastic containers was covered with plastic with ± 1mm diameter, this container was used for treatment medium during the study.

Preparing the medium

Each container contains different treatment doses, which were 12.5, 25, 50, 100, and 200 (mg / larva / day) (wet weight) The research design used was a completely randomized design (RAL) with 4 replications. Cassava skin media were obtained from cassava processing factory. The larvae used in each unit was 6 days old larvae, with totaling 200 larvae.

Harvesting Prepupa

The existing Black soldier fly larvae in the medium were harvested after reaching the prepupa stage. Prepupa was marked with the color of larvae skin turned into brown color, the way of harvesting was by using a sieve. Prepupa larvae were separated from the media, then weighed. The remaining media (residue) were weighed to determine the percentage of larval consumption.

Observation

Observation parameters were productivity of larval biomass, mass scale and protein content of prepupa. The productivity of larvae was known by calculating the final biomass of the larvae produced during the treatment period. The mass scale was determined by calculating the amount of feed used to produce the biomass, the metabolism, and the amount of residue produced. While the protein content was analyzed by using Kjeldahl method, prepupa sample was analyzed by the determining the amount of nitrogen content then multiplied by 6.25 as a conversion factor so that the final result was known as the amount of protein.

RESULTS AND DISCUSSION

The productivity of larval biomass fed with cassava skin was different in each feeding treatment (Figure 1)

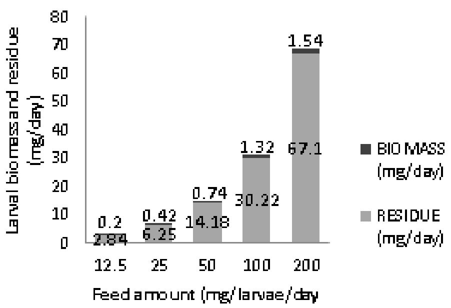

Figure 1. The productivity of larval biomass and residue (per day)

Figure 1 shows that the process of cassava skin waste reduction by black soldier fly larvae produces two products i.e.larval biomass and residue undigested feed mixed with potent pelletized (poting) larvae as quality fertilizer. The feeding of 200 mg / larva / day resulted in the highest larval biomass of 1.54 mg/ day (dry weight) and residue formation of 52.88 mg/day (dry weight). Cassava leaf contains 16.42% cellulose and 31% hemicellulose (Ruqayyah, *et al.* 2011). High cellulose and hemicellulose contents facilitate larvae in digestion and then converted into biomass body.

Other growth parameters observed were treatment duration and growth time. The growth time is the summary of the treatment duration with hatching time. The hatching time used in this study was 6 days. Treatment duration, growth time, along with the final weight of the larvae at each treatment is shown in Table 1.

Table 1. Final Weight, treatment duration, and growing time of black soldier fly larvae based on feed amount.

Parameters	Feed amount (mg/larvae/day)				
	12.5	25	50	100	200
Final weight (mg/ larvae)	10.77	17.35	21.73	26.37	30.8
Treatment duration (day)	47.7	35.66	23.33	14	14
Growth time (day)	53.7	41.66	29.33	20	20

Table 1. Shows that the time of growth is accelerated with the increase in the number of feed amount. In accordance with Diener at.al (2009), that feeding less can slower the growth time of the larvae. In this study, the treatment of 200 mg / larva / day feed resulted in the highest biomass and fastest growing time.

Black soldier fly larvae that fed by cassava skin substrate can live by converting the substrate. The converting ability is depending on the amount of substrate treatment. In the substrate ranged from 12.5 - 200 mg / larva / day, the higher substrate resulted in the higher larval biomass. In this study, the amount of substrate of 200 mg / larva / day produced the highest larvae biomass.

The calculation of mass consumption process scale was conducted to determine the amount of feed used in the process of consuming. In the treatment with 12.5 mg / larva / day (wet weight) feeding, 186.34 mg (dry weight) cassava skin was fed to Black soldier fly larvae. The feeding process for 53.7 days resulted in an increase of 10.77 mg (dry weight) or 5.78% of the mass of the initial cassava skin and left as much as 118.37 mg or 63.5% of the initial mass in casting. During the feeding process, the larvae converted 57.2 mg or 30.7% of the initial mass to the metabolic process.

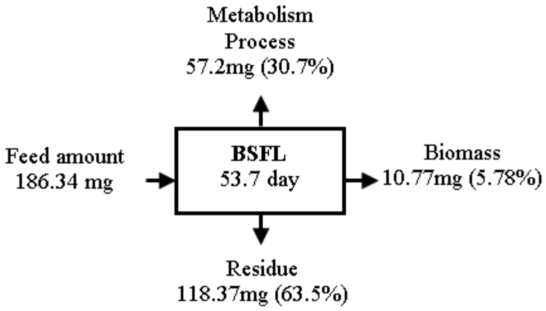

Figure 2. The mass balance of the substrate consumption process is 12.5 mg / larvae / day

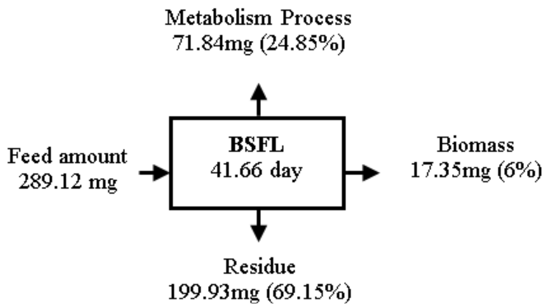

Figure 3. The mass balance of the substrate consumption process is 25 mg / larvae / day

In the feed treatment of 25mg / larva / day (wet weight), 289.12 mg (dry weight) cassava skin was fed to Black soldier fly larvae. The feeding process for 41.66 days resulted in a 17.35 mg (dry weight) larval biomass increase or 6% of initial cassava skin mass and leaving 199.93 mg or 69.15% of initial mass in casting. During the feeding process, the larvae convert was 71.84 mg or 24.85% of the initial mass to the metabolic process.

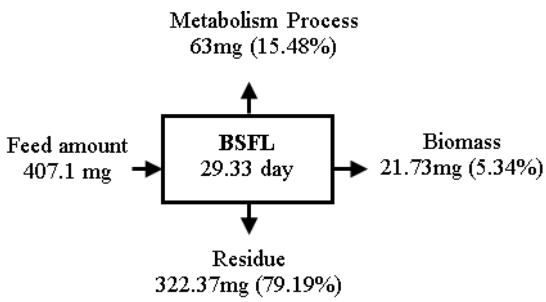

Figure 4. The mass balance of the substrate consumption process is 50 mg / larvae / day

At the treatment of 50 mg / larva / day (wet weight), 407.1 mg (dry weight) cassava skin was fed to Black soldier fly larvae. The feeding process for 29.33 days resulted in a 21.73 mg increase in larval biomass (dry weight) or 5.34% of the initial cassava skin mass and left 322.37 mg or 79.19% initial mass in casting. During the feeding process, the larvae convert 63mg or 15.48% of the initial mass to the metabolic process.

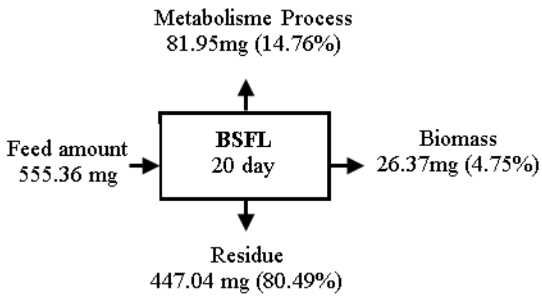

Figure 5. The mass balance of the substrate consumption process is 100 mg /larvae /day

At the treatment of 100 mg / larva / day (wet weight), 555.36 mg (dry weight) cassava skin was fed to Black soldier fly larvae. The feeding process for 20 days resulted in 26.37 mg (dry weight) larval biomass increase or 4.75% from the initial cassava skin mass and leaving as much as 447.04 mg or 80.49% initial mass in casting. During the feeding process, the larvae convert 81.95mg or 14.76% of the initial mass to the metabolic process.

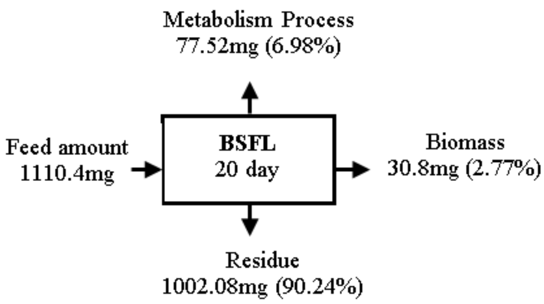

Figure 6. The mass balance of the substrate consumption process is 200 mg /larvae/ day

In the feeding treatment of 200 mg / larva / day (wet weight), as much as 1110.4 mg (dry weight) cassava skin was fed to Black soldier fly larvae. The feeding process for 20 days resulted in a 30.8mg increase in larval biomass (dry weight) or 2.7% of the initial cassava skin mass and left as much as 1002.08mg or 90.24% of the initial mass in casting. During the feeding process, larvae convert 77.52mg or 6.98% of the initial mass to metabolic processes.

The data in Fig. 2-6 shows that the process of consumption of cassava peel substrate by Black soldier fly larvae yields the product of larval biomass and substrate residue. The treatment of 200 mg / larva / day feed resulted in the highest larvae biomass and faster digestion process. This result shows that the more substrate will accelerate the process of prepupa formation, besides substrate thickness effect on larvae feeding activity.

Cassava skin has a high cellulose content that can be digested by Black soldier fly larvae . The process of consuming organic waste may occur because of the presence of enzymes in the salivary and intestinal tracts, namely leucine arylamidase, α-galactosidase, β-galactosidase, α-mannosidase, and α-fucosidase (Kim *et al.,* 2011). α-galactosidase is an enzyme that can hydrolyze complex sugars (oligosaccharides) (Liu *et al.,* 2015), β-galactosidase hydrolyze lactose to galactose and glucose (Hronska *et al.,* 2009). According to Supriyatna (2016) and Kim *et al.* (2012), in the gut larvae there are cellulotic bacteria that produce cellulase enzymes that play a role in degrading cellulose.

During development toward the larvae BSF has different live rates based on the treatment of feed amounts (Figure 7).

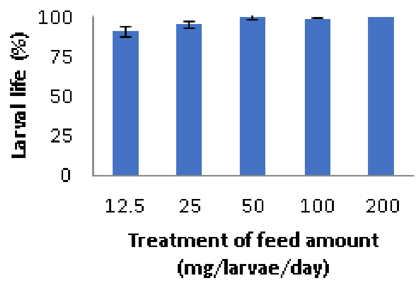

Figure 7. Larval life rate of black soldier larvae in each feed amount treatment

Figure 7 shows the difference in larval life rate during the development ofprepupa. The feed treatment of 200 mg / larva / day has a 100% pass rate, 50 and 100 treatments (mg / larva / day) approaching 100%. This shows that the higher the amount of feed given the higher the level of larval life. Diener et al (2009) stated that the development of larvae depends on the quality and amount of substrate provided.

The larval biomass obtained acts as animal feed because it has protein content. The results of the protein content of the prepupa analysis are presented in Table 2.

Table 2 shows that the protein and fat content of the preparations varies with each treatment of the amount of feed. Prepupa of BSF contains protein and fat, because larvae are able to convert organic waste in large quantities (Sheppard *et al.,* 2002).

Table 2. Protein content of BSF prepupa treated with cassava leaf feed

Composition	Treatment of Feed Amount (mg/ larvae/day)				
	12.5	25	50	100	200
Protein (%)	33.2 ±0.6	32.6 ±0.5	31.6 ±0.3	28.5 ±1.6	25.7 ±0.5
Fat (%)	9.23 ±0	11.9 ±0.2	11.5 ±0.1	9 ±0.2	8.3 ±0

Substrate protein content has an effect on larval growth and development rate, protein content in cassava skin is 8.2% (Oboh, G. 2006). The ability of the larval digestive system is due to the protein content in the substrate that are required by the microbes in the gastrointestinal tract. In the gastrointestinal tract, proteins will be hydrolyzed into oligopeptides by proteolotic enzymes that are produced by microbes, and these oligopeptides are hydrolyzed into amino acids (Koddang *et al.* 2008).

Larvae contain proteins and lipids, because they can convert large quantities of organic waste (Sheppard *et al.*, 2002). The ability of Black soldier fly larvae in consuming organic waste is relatively high, because it has a variety of digestive enzymes in its digestive tract (Tomber et al 2002). Black soldier fly larvae also have cellulase enzymes as digestive enzymes in their saliva and gut which are higher than those of house fly larvae (Kim *et al.*, 2011).

The concentration of lipid in prepupa in this study was lower than the lipid content of prepupa which was given livestock manure substrate, that is equal to 34.18% (Newton *et al.* 2005). This low lipid concentration is caused by the low fat content on cassava skin that is equal to 3.1% (Oboh, G. 2006).

Based on SNI standard, the minimum protein content standard for chicken feed is 13.5%, while the standard fat content in chicken feed is 3.5% (SNI 01-3929-2006 and SNI 01-3909-2006). Standard for protein content in fish feed is 25-35% and fat 5% (SNI 01-4266-2006). Based on the SNI standard, the content of protein and fat of BSF prepupa in all treatments of the amount of substrat in this study has met the standardof SNI. The benefit of this research is the science approach used in this study that can be used as a reference by researchers and the community to determine the biomass production of an organism.

CONCLUSIONS

Cassava skin feed to black soldier fly larvae in the amount of 200 mg / larva / day is the optimal treatment. Parameter value in the form of larvae dry weight of 30.8 mg, duration of treatment 14 days, and growth time value for 20 days. 200 mg / larva / day treatment yielded larval biomass productivity of 1.54 mg / day and residue of 67.1 mg / day. Life survival rate of larvae reaches 100%. Protein content of prepupae reaches 25.7% - 33.2% and fat content of prepupae reaches 8,3-11,9%. The content of proteins and fats has reached the SNI standard, so the prepupae has the potential to be used as animal feed.

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