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Study of the Bioconversion Process of Black Soldier Fly (*Hermetia illucens*) Larvae in Decomposition of Various Variations of Organic Waste

Wildan Muhlison[1*)], Listya Purnamasari[2], Irwanto Sucipto[3], Tri Wahyu Saputra[4], Nanda Khoirun Nisa Ahmad[5]

[1] *Agroteknologi Study Program, Agriculture Faculty, Jember University, Indonesia, wildan.muhlison@unej.ac.id*
[2] *Animal Husbandry Study Program, Agriculture Faculty, Jember University, Indonesia, listyap.faperta@unej.ac.id*
[3] *Agroteknologi Study Program, Agriculture Faculty, Jember University, Indonesia, irwanto.sucipto@unej.ac.id*
[4] *Agroteknologi Study Program, Agriculture Faculty, Jember University, Indonesia, tw.saputra@unej.ac.id*
[5] *Agroteknologi Study Program, Agriculture Faculty, Jember University, Indonesia, nandamagda@gmail.com*

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ABSTRACT

Poor waste management will affect various aspects such as environmental pollution due to piles of garbage that disturb the community. It needs a waste treatment process and one of them is the bioconversion process. This process uses the biological agent Black Soldier Fly (Hermetia illucens). This research was conducted with three organic matter variations, namely tofu pulp, eggplant pulp, and pumpkin pulp as bioconversion media. The ability of BSF larvae in bioconversion organic waste can be seen from several parameters, namely temperature, media pH, larvae weight growth, WRI (Waste Reduction Index), survival rate, consumption substrate and feed residue. The results were analyzed by one-way ANOVA test then the Least Significant Difference (LSD) test with a significance level of 95%. The research results with different bioconversion media are significantly different results on the ability of BSF larvae in the decomposition process. Tofu pulp media show the best results compared to other media with suitable conditions for the decomposition process with a final temperature of 28.8 oC, pH 7, weight growth 28.35%, WRI 5.38%, and 80.71% substrate consumption.

Keywords: bioconversion, BSF, waste, residue

ABSTRAK

Pengelolaan limbah yang tidak baik akan memberikan pengaruh dari berbagai aspek seperti adanya pencemaran lingkungan akibat tumpukan sampah yang mengganggu masyarakat. Perlu adanya proses pengolahan limbah dan salah satunya dengan proses biokonversi. Proses ini menggunakan agen biologi Black Soldier Fly (Hermetia illucens). Penelitian ini dilakukan dengan tiga variasi bahan organik yaitu ampas tahu, daging buah terong, dan daging buah labu sebagai media biokonversi. Kemampuan larva BSF dalam melakukan proses biokonversi limbah organik dapat dilihat dari beberapa parameter yaitu suhu, pH media, pertumbuhan berat larva, WRI (Waste Reduction Index), survival rate, substrat consumption, biomassa larva, residu pakan, dan analisis nutrisi residu. Hasil penelitian dianalisis dengan uji ANOVA satu arah dan dilanjutkan dengan Uji Beda Nyata Terkecil dengan taraf signifikansi 95%. Hasil penelitian dengan berbagai media biokonversi yang berbeda memberikan hasil yang berbeda nyata terhadap kemampuan larva BSF dalam proses dekomposisi. Media ampas tahu memberikan hasil terbaik dibandingkan media lain dengan kondisi yang sesuai untuk proses dekomposisi dengan suhu akhir 28,8 oC, pH 7, pertumbuhan berat 28,35%, WRI 5,38%, dan substrate consumption 80,71%.

Kata kunci: biokenversi, BSF, limbah, residu

INTRODUCTION

The Method of organic waste processing that has been carried out is not following the organic waste management techniques that are environmentally friendly, causing negative impacts on public health and the environment (Rahayu & Sukmono, 2013). A polluted place will cause various types of diseases and disturb the beauty of existing environmental management. There is a need for technology in the management process, one of which is composting (Ariany, 2019).

The process of waste degradation with the addition of activators or composting takes quite a long time, namely six weeks to decompose 90% of the total waste (Nurjazuli et al., 2016). Decomposing microorganisms also require appropriate environmental conditions and materials to survive, do not move or stay dormant to produce optimal compost (Ali et al., 2018). The process of decomposition of organic matter by microbes and earthworms requires energy for their metabolic processes. The decomposition process carried out by earthworms requires more macro nutrients and almost all micro elements for their metabolic needs (Anwar, 2009). Another alternative technology that can be used with the Black Soldier Fly as a bioconversion agent (Paz et al., 2015).

BSF larvae can reduce organic waste piles. In addition, the results of BSF larvae decomposition produce better compost than animal and plant manure (Yuwono & Mentari, 2018). BSF larvae can convert various kinds of organic materials, have high nutritional content and are not disease vectors (Hakim et al., 2017). Bioconversion using the insect larvae of *Hermetia illucens* can be carried out within its life span of 4 weeks. In addition, BSF larvae can consume and degrade many organic materials contained in an organic waste of 55.1% and a biomass conversion rate of up to 11.8% (Lalander et al., 2015).

Utilization of organic waste as a decomposition medium can use tofu dregs with 26.6% protein, 42% carbohydrates and 55 mg minerals in 100 g of tofu dregs. Another potential and much organic waste is fruit waste. with a crude protein nutrient content of 1-15% and 5-38% crude fiber (Jalaluddin et al., 2017). This study aims to determine the ability of BSF larvae as decomposers.

METHODOLOGY

The experimental design used in this study was a completely randomized design with 3 and 7 replications on different media types. The treatment given was waste treatment, namely P1 = tofu waste; P2 = Waste flask; and P3 = eggplant waste. The waste used is waste from the nursery which does not use meat as a harvest but instead seeds. The waste treatment of eggplant, tofu pulp, and pumpkin will be calculated according to the moisture content to meet the needs of larvae in each container. The waste used is chopped to reduce the size of the organic waste using a chopping machine so that BSF larvae digest more easily (Nurjazuli et al., 2016). The media is subjected to a dewatering process or a drying process by filtering organic waste from high moisture content. The reduction in water content is carried out up to 70-75%. Media as a place to decompose by larvae is given once during the maintenance phase. The need for feed is obtained by calculating the increasing moisture content and age of the larvae. Each container was given as many as 200 heads. The number of larvae is equalized in the age phase at the age of 6 days of larvae.

The waste sample requirement for 15 days of maintenance is based on the larval feed ratio: 40 mg/larvae/day (dry weight), = 168 grams /day. Following the optimum average requirement of larvae based on dry weight, namely 40 mg /larvae/day (Diener et al., 2011). The results of the calculation of the total wet weight requirement of waste per day above are used as the total

wet weight of BSF larvae food in 1 (one) container. Feeding the larvae or the media given is adjusted to the age of the larvae and routine control is carried out, including measuring the temperature and humidity of the air every day (Popa & Green, 2012). Observations on the larvae of the container were carried out every 3 days. Larvae were counted and weighed by separating larvae from organic waste. The variables observed were sample temperature and pH, WRI (Waste Reduction Index), Survival rate, Substrate Consumption, and Feed Residue. The data obtained from the calculation results will be analyzed using ANOVA, and followed by the Least Significant Difference test with a confidence level of 5%.

RESULTS AND DISCUSSION

Experiment General Conditions

The bioconversion media for pumpkin and eggplant were obtained from the land of PT. EASWEST. The chemical properties analyzed at the Soil Chemistry Laboratory of the University of Jember give the results in Table 1 and the temperature and pH of the bioconversion media in Table 2.

Table 1. Composition of bioconversion media nutrients

No	Sample	Water Content %	pH	Corganic %	Ntotal	C/N
1.	Tofu dregs	87,6	6	66,8	1,8	37,11
2.	Eggplant pulp	92,3	5,5	80,6	2,0	40,30
3.	Pumpkin flesh	92,0	6,5	82,6	2,2	37,55

Table 2. Results of temperature and pH measurements on bioconversion media

No.	Sample	Early		Final	
		Tempt (^oC)	pH	Tempt (^oC)	pH
1.	Tofu dregs	29	5	28	7,1
2.	Eggplant pulp	30	5,5	29	7,1
3.	Pumpkin flesh	32	6	29	7

Based on the research results in Table 2, temperature and pH significantly affect the larval process of decomposing the media. The experimental results at the beginning of the process with the highest temperature of 32 oC were caused by the activity of the larvae in decomposing the given media. The optimal temperature for larval growth is between 24 - 33^{o}C. During the decomposition process, an increase in temperature occurs. This is due to larval activity during the metabolic process due to complex compounds broken down into simpler compounds. The metabolic activity gives rise to temperature so that temperature increases. BSF larvae seek a shady environment and stay away from sunlight. When the media is exposed to much sunlight, the larvae will enter deeper into the media layer to not overheat and avoid light (Kastolani, 2019). Temperature and pH affect the results of decomposition of different organic wastes, this is due to the mass feeding system. Feeding in bulk or quantities according to maintenance needs until the end so that the amount of waste is more significant. Large amounts of feed will produce lower oxygen and higher heat, increasing temperature in the container.

Another factor that affects the temperature in the container is the environment every day. pH can affect the availability of nutrients for BSF larvae in the decomposition process. The enzymes in the larvae's body are the enzymes in the saliva and intestines of BSF larvae, which play a role in digesting rotting waste. The main enzymes found in the digestive tract are amylase, lipase and protease. Protease activity is specifically related to pH, and activity increases at pH 7. BSF

larvae can change the conditions on the media to a neutral pH value during the decomposition period (Meneguz et al., 2018). Based on the research results in Table 2, the pH of tofu pulp media 5 becomes 7.1. The pH of the eggplant medium is 5.5 to 7.1. Then the pH of the pumpkin medium 6 becomes 7. The pH change during composting of organic waste was shown during the initial and final pH. The volatilization of ammonia causes the mechanism of changing pH during composting. The process of volatilization of ammonia from (NH3) then H is released from microbial nitrification during decomposition and the production of organic, inorganic acids, as well as the release of carbon dioxide during composting so that it affects a pH that is close to neutral (Ritika & Rajendra, 2015).

In addition to temperature and pH which influence the decomposition process, the type of feed media also affects the weight of larvae in the growth process. This is due to the different nutritional content in the media. As well as the ability of larvae to break down or degrade organic waste. The primary nutrients that can support the needs of BSF larvae are protein, carbohydrates and fat. Lipids are needed for development and food storage (Permana & Putra, 2018). The best use of feed as a medium for decomposition is tofu dregs. This is because the tofu dregs medium has the most significant fat content of 7.78% compared to pumpkin and eggplant media (Prayitno et al., 2019).

Larva Weight Growth Variable

In the 5% LSD test results, the effect of giving bioconversion media on P1 and P2 treatments was significantly different. Meanwhile, in P3, the difference is not significant. The heaviest larval weight at the P1 treatment value was 28.35 grams. The lowest larval weight was found in P2 treatment, namely 22.19 grams. So that the provision of different types of media can provide recommendations to get the highest substrate consumption weight, namely at P1. The 5% LSD test results on the observed variable weight growth of larvae are presented in Figure 1.

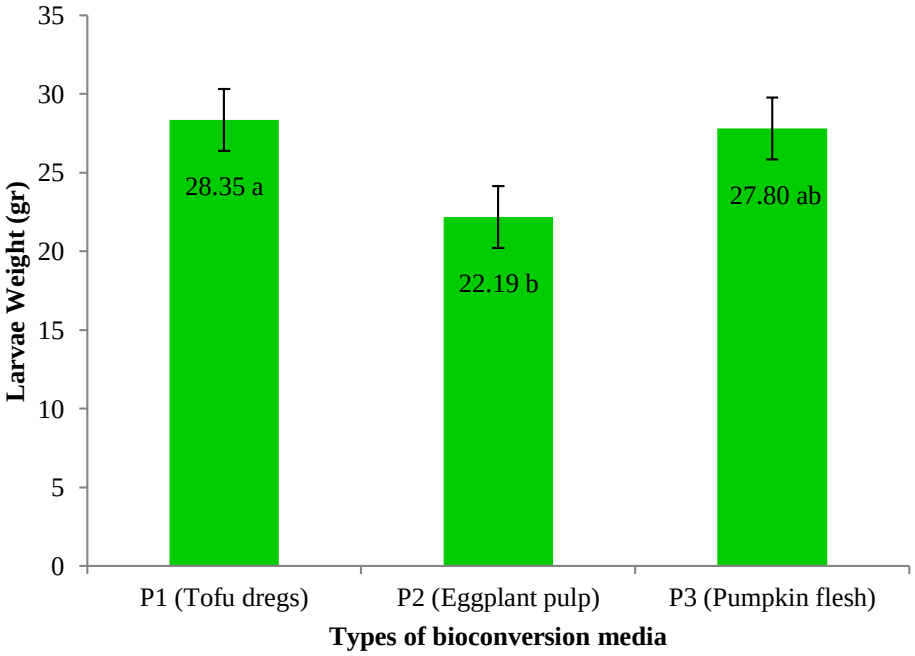

Figure 1 Test results on variable weight growth observation of larvae

The decomposition process in the media is also influenced by the ability of the larvae to break down. Figure 1 shows the ability of larvae to degrade organic waste such as tofu pulp which

has a significant effect on larval weight gain. Giving media to larvae will affect the quality and quantity of larvae and the resulting residue (Tomberlin et al., 2002). The type of media on research shows that tofu pulp media is the most recommended medium than fruits and vegetables. When the substrate is high in protein, the development of the larvae will be faster. Meanwhile, based on the research, larvae with vegetable and fruit waste gave unfavorable results. Larvae with fruit and vegetable substrate resulted in 40% lower larval biomass/weight value. The weight of larvae produced by the vegetable and fruit media substrate was 40% lower than other media. (Spranghers et al., 2017).

Waste Reduction Index

In the 5% LSD test results, the effect of bioconversion media on P1 treatment was significantly different from P2 and P3. The highest treatment was WRI in the P1 treatment of tofu waste as much as 5.38%. Meanwhile, the lowest treatment in P2 treatment was eggplant waste with a WRI value of 4.35%. So that the provision of different types of media can provide recommendations to get the highest WRI, namely at P1. The results of the 5% LSD test on the WRI observation variable are presented in Figure 2.

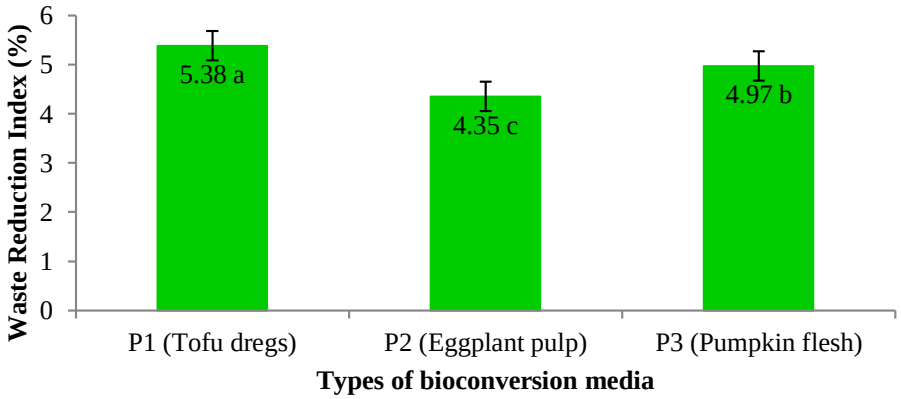

Figure 2. test results on WRI variables

Based on the research results in Figure 2, the level of decomposition of organic waste degraded by BSF larvae through the resulting WRI value was 5.38% tofu pulp media as the recommended medium. A high WRI value indicates the ability of larvae to reduce high organic waste. The WRI value will also be directly proportional to the value of larvae consumption of the organic waste provided. If the consumption value is high, the WRI value is also high. With the WRI calculation, it can be seen that the efficiency of larvae in reducing the given waste and the length of time needed to reduce waste (Supriyatna & Putra, 2017). Apart from the amount of feed, WRI is inversely related to the final residual value. This is because the highest WRI value will give the result at the lowest final residual level. The highest WRI was tofu pulp, then the lowest residue was tofu pulp. WRI with the highest score of 5.38% with the lowest residue level of 19, 29%. Meanwhile, the highest residue media was eggplant 34, 73%. The greater the WRI, the better the resulting substrate reduction efficiency (Diener et al., 2009).

Substrate Consumption

The results of the 5% BNT test, the effect of giving bioconversion media on the level of media consumption in P1 treatment was significantly different from P2 and P3. The highest percentage value of substrate consumption was in the P1 treatment of tofu dregs waste of 80.71%. While the lowest percentage value is in the P2 treatment of eggplant pulp waste with a value of 65.27%.

So that the provision of different media types is able to provide recommendations to get the highest WRI, namely P1. The results of the 5% BNT test on the WRI observation variable are presented in Figure 3.

The ability of larvae to degrade organic waste is also influenced by the amount of substrate that can be consumed. Based on the results of the study in Figure 3, media with different substrates showed significant differences in tofu dregs media which were significantly different from vegetable and fruit media. The ability of larvae to decompose vegetable and fruit waste shows low yields, because most of the food is converted into biomass (Kinasih et al., 2018). This is related to the moisture and water content of vegetables and fruit which allows the larvae to use less energy for metabolism and concentrate on the formation of biomass. At high consumption levels, undigested vegetables and fruit will go through the evaporation process due to the liquid waste that is released. On medium tofu dregs give the best results because the water content is not much and appropriate.

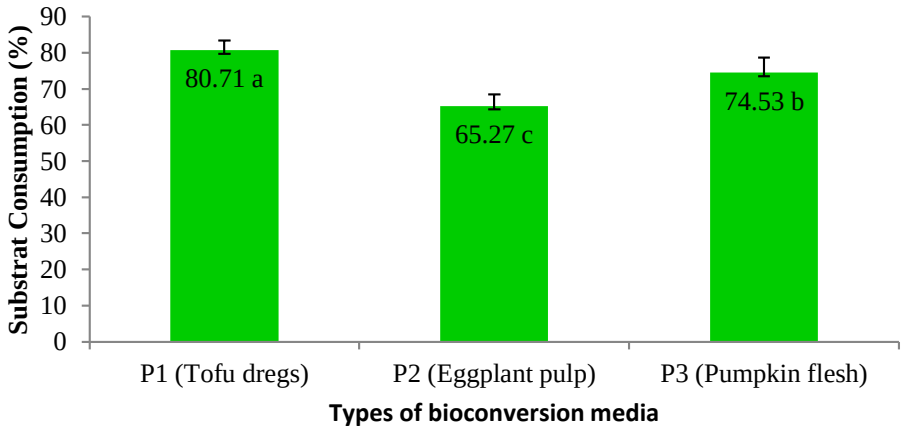

Figure 3. Test results on substrate consumption variable

Larval development will be related to the quality of food, especially the balance in nutritional content. Imbalance of nutrition in the media can lead to an increase in the length of time for larval consumption to replace nutritional deficiencies, especially protein and carbohydrates. Lack of certain nutrients affects the time when the larvae reach a critical stage of development (Kinasih et al., 2018). Tofu dregs contain 23.62% protein which causes larvae to be able to consume more tofu dregs media than fruit and vegetable media. Biowaste treatment with black soldier fly larvae improves performance through protein and carbohydrate-based biowaste formulations (Gold et al., 2020). In addition, a factor that affects the ability of larvae to consume media is particle size (Cheng et al., 2017). Raw materials with particle sizes smaller than 1 to 2 cm in diameter allow larvae, chewing at the mouth to be easier to digest (Dortmans et al., 2017). This is because the substrate will be easily absorbed if it is small so it is easy to digest (Kastolani, 2019). The higher the substrate consumption value, the larvae are able to consume more of the given substrate, so the higher the substrate value that can be consumed, the greater the potential for larvae to decompose waste (Hakim et al., 2017).

Survival Rate

The results of the LSD 5% P1 test were significantly different from P2 and P3. The highest survival rate value at P1 tofu dregs waste is 86.57%%. In comparison, the lowest value on P3 pumpkins flesh waste was 58.7%. So that the provision of different types of media can provide

recommendations to get the highest level of ability of live larvae, namely at P1. The 5% LSD test results on the survival rate observation variable are presented in Figure 4.

Based on the study results in Figure 4., the survival rate of larvae on tofu dregs 86 medium was 57%, significantly different from the two other media. The ability of the larvae to survive in various types of media can be seen through the feeding system (Meneguz et al., 2018). Feeding the larvae with an extensive quantity system at the same time will produce liquid waste, which causes the larvae to be flooded by water. The stagnant condition of the container or bioreactor causes anaerobes. Then it causes the death of the larvae (Yuwono & Mentari, 2018).

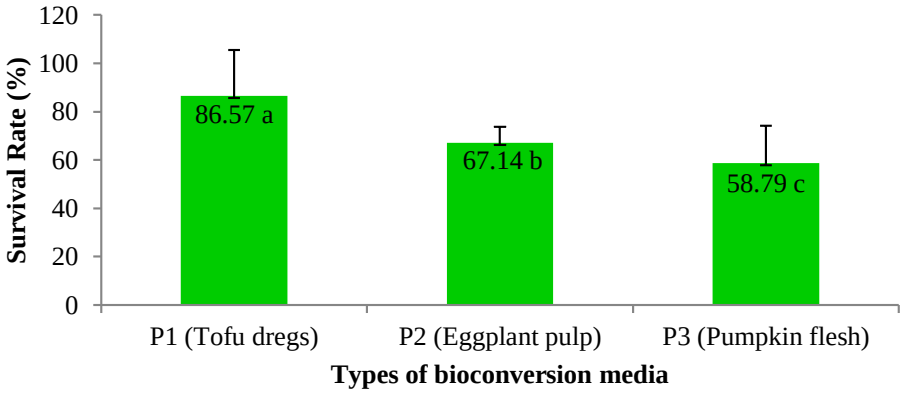

Figure 4. Test results on survival rate variable

Feed Residue

LSD test results 5% effect of giving bioconversion media to the residual level of P2 of eggplant pulp waste was significantly different to P3 and P1. The highest feed residue value was in P2 eggplant pulp waste 34.73%, while the lowest feed residue value was in the P1 treatment of tofu waste dregs 19, 29%. So that the provision of different types of media can provide recommendations to get the lowest residue level, namely at P1. The 5% LSD test results on the feed residue observation variables are presented in Figure 5.

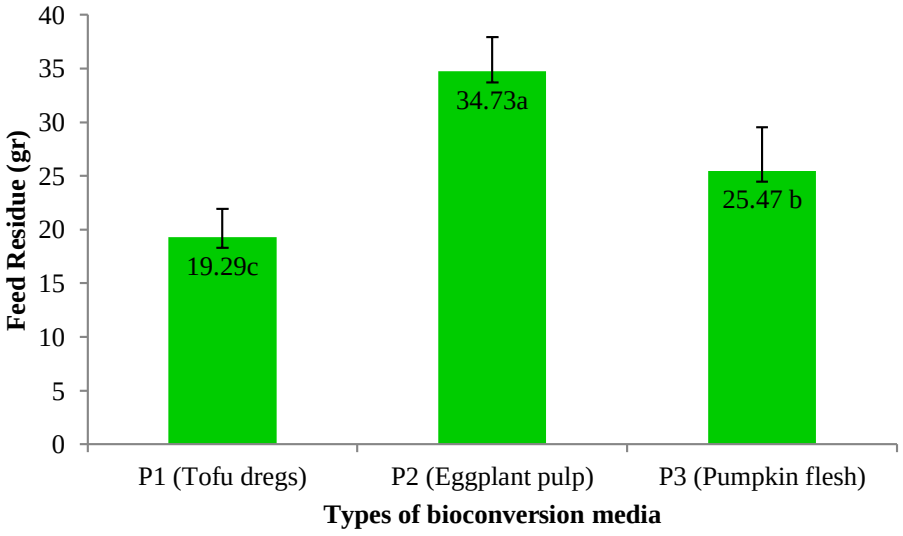

Figure 5. Test results on feed residue variable

Based on the use of different types of organic waste, which is used as a medium for decomposition, the larvae have bacteria with a high number of bacteria and microbial diversity. Microbes in organic waste and intestinal larvae have several essential functions for larval performance. Microbes play a role in the hydrolysis of waste macronutrients, especially in waste with non-biodegradable fiber. The process of the larvae in decomposing waste, namely the absorption of the media through feeding activities, then the larvae secrete enzymes such as amylase or maltase from the salivary glands by mouth (Terra & Ferreira, 1988). After absorption, food enters the endoperitropic space, where blood has contact with enzymes to catalyze the initial decomposition of maltase (carbohydrates), pepsin, and trypsin (protein), lipases, phospholipases (lipids). The enzymes then return to find a new substrate to hydrolyze. Microbial inactivation by larvae. When exceeding a specific size and density due to larval inactivation mechanisms, the larvae can control the fungi in the diet. They compete with nutrients and some of the fungi that survive inside the intestines. Microbes that survive in the stomach are candidate microbes that contribute to the developing larvae. The bacteria in the larvae have enzymes that can absorb hydraulics starch, cellulose, protein, and lipids, thus contributing to the decomposition of organic waste (Gold et al., 2018).

CONCLUSION

Based on the research that has been done, the type of bioconversion media has a significant effect on the results of decomposition with an increase in larval weight gain, larvae ability to survive, larval preference level, and reduction rate of each waste within 15 days of decomposition. Based on the research that has been done, the type of bioconversion media on the residual nutrient content has a significant effect on the residues produced by the bioconversion media types that are significantly different from the ability of the best larvae in the decomposition process, namely tofu dregs. Tofu dregs media with suitable conditions for larvae to decompose with a final temperature of 28.8 oC and pH 7. The value of weight growth was 28.35%, WRI 5.38%, and substrate consumption 80.71%.

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