

Influence of food variation on the growth of maggots

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Abstract

One solution currently being developed is the use of *Hermetia illucens* larvae as natural decomposers in organic waste treatment. This study aims to determine the effect of feed medium variation on the fresh weight and dry weight of larvae, as well as to evaluate the potential of larvae as agents for the bioconversion of organic waste. The method used was a Completely Randomized Design (CRD) with one factor, namely the type of feed substrate (tofu dregs, corn pulp, and vegetable waste). Each treatment was repeated 9 times, resulting in a total of 27 experimental units. The results showed that the type of feed medium had a significant effect on larval growth and productivity. Soybean curd residue (P3) produced the best growth due to its more balanced and easily digestible nutritional content. The results of the statistical method analysis (Anova) test showed a significance value of less than 0.05 ($p < 0.05$), indicating that there was a statistically significant difference between the treatment groups, which indicated that the type of feed medium given had a significant effect on the fresh weight and dry weight of the maggots. The highest substrate reduction efficiency (WRI) was found in media with low crude fiber content, while the lowest WRI occurred in corn bran, which contains lignocellulose that is difficult to degrade. The findings of this study indicate that *H. illucens* larvae have the potential to be developed as an efficient and environmentally friendly organic waste bioconversion technology, while also supporting sustainable waste management strategies.

Abstrak

Pengelolaan limbah organik menjadi tantangan utama seiring meningkatnya volume limbah rumah tangga dan industri makanan. Salah satu solusi yang berkembang, yaitu pemanfaatan larva *Hermetia illucens* sebagai pengurai alami dalam pengolahan limbah organik. Penelitian ini bertujuan untuk mengetahui pengaruh variasi media pakan terhadap berat segar dan berat kering larva, serta menilai potensi larva sebagai agen biokonversi limbah organik. Metode yang digunakan yaitu Rancangan Acak Lengkap (RAL) satu faktor, yaitu jenis substrat pakan (ampas tahu, ampas jagung, dan limbah sayuran). Setiap perlakuan diulang sebanyak 9 kali, sehingga menghasilkan total 27 satuan percobaan. Hasil penelitian menunjukkan bahwa jenis media pakan berpengaruh nyata terhadap pertumbuhan dan produktivitas larva. Media sisa tahu (P3) menghasilkan pertumbuhan terbaik karena kandungan nutrisinya lebih seimbang dan mudah dicerna. Hasil analisis metode statistik (Anova) menunjukkan nilai signifikansi kurang dari 0,05 ($p < 0,05$), yang menunjukkan adanya perbedaan yang signifikan secara statistik antara kelompok perlakuan, yang menunjukkan bahwa jenis media pakan yang diberikan memiliki pengaruh yang signifikan terhadap berat segar dan berat kering larva. Efisiensi pengurangan substrat (WRI) tertinggi

terdapat pada media dengan serat kasar rendah, sedangkan WRI terendah terjadi pada dedak jagung yang memiliki lignoselulosa sulit terurai. Temuan penelitian mengindikasikan bahwa larva *H. illucens* berpotensi dikembangkan sebagai teknologi biokonversi limbah organik yang efisien dan ramah lingkungan, sekaligus mendukung strategi pengelolaan limbah berkelanjutan.

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1. Introduction

Organic waste management is a major challenge in preserving the environment as the volume of household and food industry waste increases. Waste such as food waste, tofu dregs, corn pulp, and vegetable waste is often not utilized optimally, causing accumulation in landfills, producing odors, increasing greenhouse gas emissions, and triggering environmental pollution [1]. This situation requires innovative solutions that can reduce waste volume while providing added value. One rapidly developing approach is the use of *Hermetia illucens* larvae or maggots as natural decomposers. According to [2], maggots have the ability to decompose organic waste quickly, reducing waste volume by 50–70% in 10–14 days, and producing economically valuable biomass that can be used as alternative feed for fish and poultry.

Organic waste such as tofu dregs, corn pulp, and vegetable waste are abundant sources of organic waste but are often not utilized optimally. Tofu dregs is a solid waste rich in protein [3], corn pulp has a high carbohydrate and crude fiber content [4], while vegetable waste contains moisture as well as vitamins and minerals necessary for larval growth. The nutritional content of this waste makes it highly potential as a cheap and easily obtainable larval culture medium. The use of various types of organic waste as a larval medium not only helps reduce waste but also optimizes previously wasted resources [5]. Larval culture using organic waste-based media provides significant ecological benefits. A study by [6] found that tofu waste produced faster larval growth rates compared to high-fiber-based media. Although the use of this waste shows great potential, research on larval feed variations still has many limitations.

Most studies focus on only one type of medium, thus failing to provide a comprehensive picture of the impact of nutritional differences on larval growth, feed conversion efficiency, biomass quality, and bioconversion capacity. Research on media combinations, the impact of physical characteristics of feed such as moisture and texture, and their suitability for mass production is still very limited [7]. The lack of studies on larval performance on different feed variations indicates an important research gap that needs to be addressed. Given these conditions, this study aims to analyze the impact of three types of feed media, namely dregs pulp, corn pulp, and vegetable waste, on larval growth, waste bioconversion efficiency, and the quality of the biomass produced. The results of this study are expected to provide recommendations on the most optimal feed media for fly larvae cultivation while supporting efforts to manage organic waste sustainably.

2. Research Methods

This study is a quantitative experimental study that aims to examine the effect of feed substrate variation on the fresh weight and dry weight of *Hermetia illucens* larvae. The research design used is a completely randomized design (CRD) with one factor, namely the type of feed substrate (tofu dregs, corn pulp, and vegetable waste). Each treatment was repeated 9 times, resulting in a total of 27 experimental units, with 313 larvae per unit.

Maintenance was carried out for 14 days, starting from 6-day-old larvae with an initial weight of 1.13 grams, in controlled environmental conditions with a temperature of 24–30°C and humidity of 60–80%. The research variables consisted of independent and dependent variables. The independent variables in this study were the types of feed substrate, which included tofu dregs, vegetable pulp, and corn pulp. Meanwhile, the dependent variable was the dry weight of *Hermetia illucens* larvae measured after a certain rearing period.

Fresh weight and dry weight of larvae. Data were analyzed using descriptive and inferential statistics. Fresh weight and dry weight data of *Hermetia illucens* larvae will be analyzed to determine significant differences between groups fed with different media variations. One Way ANOVA was used to test the hypothesis and determine the effect of feed substrate variation on larval growth. The results of the analysis will be interpreted to provide relevant conclusions regarding the effect of feed substrate on fresh weight and dry weight of *Hermetia illucens* larvae. If significant differences are found, then post-hoc tests, such as Tukey or DMRT tests, can be conducted to determine which treatments are significantly different.

Measurement of remaining media. After harvesting the larvae on day 14, the next step was to measure the remaining residu substrate. This process begins by separating the remaining media from the larvae using a coarse sieve so that no larvae are carried away. The remaining media is weighed using a digital scale that has been pre-tested. Weighing was done by placing the media in a special calibrated container, to ensure that the data obtained truly represented the weight of the remaining feed. The weighing data was recorded carefully. Then the calculation of the remaining feed is done by calculating the feed reduction value using the formula proposed by Diener et al. (2009), namely:

$$WRI = \frac{D}{t} \times 100\%$$

$$D = \frac{W-R}{W}$$

Description:

D : Total feed reduction

T : Total time larvae consumed feed (days)

W : Total feed amount (g)

R : Amount of feed remaining after a certain time (g)

WRI : Waste Reduction Index

3. Results and Discussion

3.1 Results

Variation of feed substrate on maggot fresh weight

Based on the results of weighing maggot fresh production in each growth media treatment used, namely vegetable waste (P1), corn dregs (P2), and tofu dregs (P3). The P3 treatment (tofu dregs) showed the highest average fresh production, which was (23.5) grams.

Table 1. Maggot fresh weight calculation results

Treatment	Replication									Average
	1	2	3	4	5	6	7	8	9	
P1	9.4	11.6	12.1	11.9	10.8	11.1	11	11.3	13.2	11.4 ± 1.10 ^b
P2	10.7	10.1	10.1	11.6	10.3	11.6	10.8	10.7	9.5	10.6 ± 0.71 ^b
P3	23.2	23.6	22.9	24.5	23.1	22.6	24.8	24.4	23.7	23.5 ± 0.70 ^a

Description: P1 = Vegetable waste, P2 = Corn dregs, P3 = Tofu dregs

The results of the one-way analysis of variance (ANOVA) test on the maggot fresh weight variable, obtained a calculated F value of 669.323 with a significance value (Sig.) of 0.000. Because the significance value is smaller than 0.05 ($p < 0.05$), there is a statistically significant difference between treatment groups.

Table 2. One Way ANOVA test results maggot fresh weight

	Sum Of Square	df	Mean Square	F	Sig.
Between Groups	963.701	2	481.850	669.323	.000
Within Groups	17.278	24	.720		
Total	980.979	26			

Variation of feed substrate on maggot dry weight

Based on the results of dry weight measurements showed the highest value in the P3 treatment of 9.38 g significantly different ($P < 0.01$) with the value of P1 and P2 which is 3.00 g and 2.64 g although the value of P1 and P2 is also different but still in the same level.

Table 3. Maggot dry weight calculation result

Treatment	Replication									Average
	1	2	3	4	5	6	7	8	9	
P1	2.7	2.9	3.0	3.1	2.6	3.1	3.5	2.9	3.4	3.00 ± 0.62^a
P2	2.2	2.7	2.8	2.9	2.6	2.6	2.8	2.8	2.4	2.64 ± 0.62^a
P3	9.4	8.7	9.3	10.4	7.3	9.2	10.3	10.3	9.6	9.38 ± 0.62^b

Description: P1 = Vegetable waste, P2 = Corn dregs, P3 = Tofu dregs

Based on the results of the One Way ANOVA test analysis on the maggot dry weight variable in Table 2, the calculated F value is 362.279 with a significance value (Sig.) of 0.000.

Table 4. One Way ANOVA test results maggot dry weight

	Sum Of Square	df	Mean Square	F	Sig.
Between Groups	257.621	2	128.810	362.279	.000
Within Groups	8.533	24	.356		
Total	266.154	26			

The role of maggot as an agent of bioconversion of organic waste

Based on the results of waste reduction for 14 days, the digested feed efficiency value was 2.5-5.80 g/day. The highest compost reduction was achieved in treatment C at 5.80 g/day followed by treatment A at 5.67 g/day.

Table 5. Recapitulation of Waste Reduction Index (WRI) during the study

Treatment	Initial	Final	T	Average (g/day)
P1	180 grams	33 grams	14	5.67
P2	180 grams	40 grams	14	2.74
P3	180 grams	98 grams	14	5.80

Description: P1 = Vegetable waste, P2 = Corn dregs, P3 = Tofu dregs

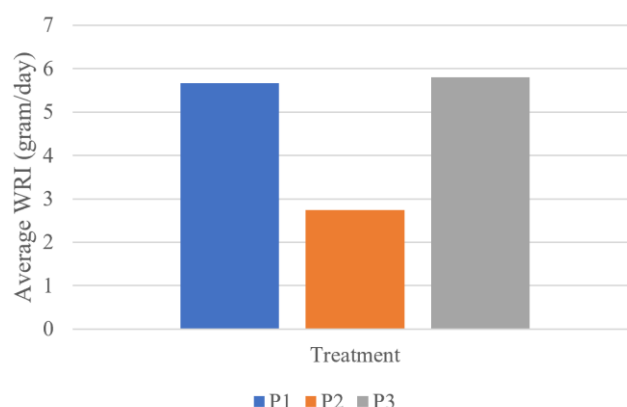


Figure 1. Waste Reduction Index (WRI) per treatment (P1: Vegetable waste, P2: Corn dregs, P3: Tofu dregs)

3.2 Discussion

Variation of feed substrate on maggot fresh weight

Based on Table 4.1, there is a statistically significant difference between the treatment groups, indicating that variations in growth media with different nutritional qualities have a direct effect on the fresh weight production of larvae. A comparison of the nutritional composition of each medium shows that tofu dregs is most suitable for the standard nutritional requirements of *H. illucens*, which are 15-20% protein, 40-50% Nitrogen-Free Extract Material (BETN), 10-15% fat, and low to moderate crude fiber, thus better supporting optimal larval growth [8]. Tofu dregs has a protein content of 18.29%, Nitrogen-Free Extract Material (BETN) of 47.19%, fat of 10.66%, and fiber of 17.57% [9], all of which are within the ideal range to support larval metabolism and development. On the other hand, vegetable media generally have very low protein content, high fiber, and limited energy, making them less capable of meeting the nutritional needs of larvae [10]. Ground corn does have a high Nitrogen-Free Extract Material (BETN) content as an energy source, but its low protein content prevents larvae from achieving optimal growth [11]. It is estimated that these differences in nutritional quality cause variations in the larval biomass produced in each treatment.

The high protein content in tofu dregs media plays an important role in supporting the formation of larval body tissues, including enzyme synthesis, muscle development, hemolymph, and other morphological structures, thereby increasing the rate of growth and biomass accumulation. Meanwhile, the high Nitrogen-Free Extract Material (BETN) provides rapidly digestible energy that larvae need to support metabolic activity, digestion, and biosynthesis of body molecules. The combination of sufficient protein as a growth substrate and high Nitrogen-Free Extract Material (BETN) as an energy source enables larvae to maximize anabolic processes, resulting in greater biomass production [12]. When energy is available in sufficient quantities, protein is not used as an energy source but is focused on tissue growth, which ultimately increases fresh harvest weight. This is in line with the statement [13] that substrates with good nutritional quality increase larval productivity because they are able to meet optimal growth requirements. Additionally, [14] emphasizes that the quality and quantity of the growth medium not only determine the growth rate but also affect the duration of development, mortality rate, and physiological condition of the larvae. Therefore, the high fresh production in the P3 treatment occurred because the tofu dregs medium provided the most suitable nutritional balance for the physiological requirements of *H. illucens*, resulting in maximum growth and biomass accumulation.

Variation of feed substrate on maggot dry weight

The results of dry weight measurements in Table 4 show very significant differences statistically between treatment groups, this indicates that the type of feed substrate given has a significant effect on maggot dry weight. This difference occurs due to media nutrition and the amount of consumption of feed substrate in each treatment which ultimately affects the availability of nutrients for the formation of body tissues and has an impact on differences in production weight [15]. Tofu dregs media contains nutrients consisting of crude protein, fat, and non-fiber carbohydrates that are easily digested by maggots. According to Dewayani et al. [16], tofu dregs contains 45.44% Nitrogen-Free Extract Material (BETN), 8.36% crude protein, 7.06% crude fiber, and 5.52% fat. This composition makes tofu dregs the media with the most balanced nutritional content among the three treatments. This content allows maggots to absorb more nutrients that are used in the process of forming body tissues, so that they can significantly increase their dry weight.

Treatment A (vegetable waste) and B (corn husks) showed significantly lower dry weight results and were not significantly different from each other. Corn husks had the lowest average dry weight value. It is known that corn husks contain 13.22% crude protein, 5.8% crude fat, 2.92% crude fiber, and a high dry matter (DM) content of 87.27%, indicating that this material is rich in nutrients in dry form [11]. The high dry matter content in corn husks indicates that this medium has low moisture, which is less than optimal for larvae. Larvae require sufficient medium moisture to support biological activities such as movement, digestion, and nutrient absorption [17].

The ideal moisture content for fly larvae cultivation media is around 70-80%, which can maintain optimal moisture to support larval activity and increase the efficiency of feed conversion into biomass [17]. According to Amini & Rohayat [6], fly larvae can have difficulty digesting and absorbing nutrients if the medium used is too dry, thereby reducing growth efficiency and biomass conversion. Substrates that are too dry can also significantly inhibit larval development. This is in line with [18] research, which found that excessively low moisture content causes the substrate to become too dry for

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Table 5 shows that the level of waste reduction over 14 days had a digestible feed efficiency value of 2.5–5.80 g/day. The highest compost reduction was achieved in treatment C at 5.80 g/day, followed by treatment A at 5.67 g/day, while the lowest WRI value was recorded in treatment B at 2.74 g/day. The WRI value in the tofu dregs medium (5.80 g/day) was within the same range as the results reported by [19], who reported a WRI value of 4.10–6.20 g/day using high-protein substrates. This indicates that the results of this study are in the high category for tofu dregs media. The WRI value in vegetable waste media (5.67 g/day) is also comparable to the findings of [20], who found that fresh vegetable waste produces high reduction efficiency due to its low water and fiber content. The high feed consumption value reflects the effectiveness of both as easily degradable substrates. The high feed consumption of *H. illucens* larvae on tofu dregs and vegetable waste media is due to the easily digestible nutrients and texture suitable for larval growth [21]. Tofu dregs has a high protein content and soft texture, which greatly supports the metabolic process and growth of larvae [22]. Meanwhile, vegetable waste, especially from fresh vegetables such as mustard greens, spinach, or kale, has a high water content and lower fiber content compared to lignocellulosic waste such as corn husks, making it easier for larvae to consume [20].

The lowest WRI value in corn husks (2.74 g/day) is consistent with the findings of [23], who obtained WRI values of 2.50–3.00 g/day in waste with high lignocellulose content.

Corn husks contain high crude fiber, mainly in the form of lignocellulose, which is a combination of lignin, cellulose, and hemicellulose [24]. This content is complex and difficult to break down by larval digestive enzymes, thereby inhibiting feed consumption efficiency. A low WRI value indicates that fly larvae are unable to break down and consume corn husks optimally [23]. Rohmanna et al. [25] stated that *Hillucens* larvae cannot digest lignin as well as cellulose and hemicellulose. This is supported by research by Razid et al. [26], which shows that in the digestive tract of *H. illucens* larvae, there are lignin-digesting microorganisms that convert lignin into cellulose as an energy source for the larvae. The crude fiber contained in the culture medium cannot be digested by the larvae because they do not have enzymes capable of digesting crude fiber into simple compounds so that their digestive tract can absorb and digest them [27]. The high lignin and coarse fiber content requires additional processing, such as microbial fermentation, the addition of cellulase enzymes, or heating to improve digestibility [26].

4. Conclusion

The results of the study indicate that variations in feed media significantly affect maggot growth and waste bioconversion efficiency, with tofu pulp being the most optimal medium due to its balanced protein content, high Nitrogen-Free Extract Material (BETN), and easily digestible texture, enabling it to produce the highest fresh and dry larval weight. Conversely, vegetable waste provides lower biomass growth but still shows high waste reduction efficiency thanks to its water content and easily decomposable texture, even though its nutrients do not fully meet the metabolic needs of the larvae. Corn pulp media provided the lowest performance due to its high lignocellulose and low water content, which inhibited digestion and nutrient absorption, thereby reducing feed consumption and bioconversion efficiency. Overall, this study confirms that the balance of nutrients and physical characteristics of feed media are determining factors for maggot growth success and waste decomposition effectiveness, making the selection of appropriate media crucial for optimizing biomass production and bioconversion performance.

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