



Growth Performances of Black Soldier Fly Larvae Reared on the Varying Ratios of Fermented Waste

Akbar Aditya Trihendarsa¹, Faizal Andri¹, and Nurul Isnaini^{1*}

¹ Faculty of Animal Science, Universitas Brawijaya, Malang 65145, Indonesia
*nurulisna@ub.ac.id

Abstract. Black soldier fly (BSF) is increasingly recognized as a vital component of circular economy systems, facilitating organic waste recycling while producing alternative protein feed for the livestock industry. This study aimed to evaluate the growth performance of BSF larvae reared on varying ratios of fermented waste consisted of fermented coconut dregs (FCD) and fermented rumen contents (FRC). Five treatments were tested, namely T0 (100% FCD), T1 (95% FCD + 5% FRC), T2 (90% FCD + 10% FRC), T3 (85% FCD + 15% FRC), and T4 (80% FCD + 20% FRC). Larval length, width, and mass were measured at 6, 11, and 16 days. Data were analyzed using one-way analysis of variance, with significance set at $P < 0.05$. Duncan Multiple Range Test was used to differentiate treatment effects. Results showed that larvae in T0 had a higher length ($P < 0.05$) than those in T4 at 6 and 11 days. However, the larval length was not significantly differed ($P > 0.05$) among treatments at 16 days. In terms of larval width and mass, T0 consistently had a higher value ($P < 0.05$) as compared to T4 at 6, 11, and 16 days. In conclusion, 100% FCD is recommended as the optimal substrate for maximizing BSF larval growth.

Keywords: Black Soldier Fly, Circular Economy System, Coconut Dregs, Larvae Development, Rumen Ontents.

1 Introduction

The black soldier fly has gained recognition for its exceptional capability to transform organic waste into high-value biomass, positioning it as a vital organism in sustainable organic waste management practices [1,2]. One notable source of organic waste is coconut dregs, a by-product of the coconut processing industry, which presents considerable disposal challenges [3]. In addition, rumen contents from slaughterhouses represent a substantial waste stream that further complicates environmental and public health issues [4]. While coconut dregs and rumen contents are often viewed as waste, they still harbor valuable nutrients that can facilitate the growth and development of black soldier fly larvae [5]. However, when utilized in their raw forms, these substrates are not fully effective for rearing purposes. The elevated fiber content found in coconut dregs and rumen contents can restrict the larvae's ability to digest and utilize nutrients [6]. Additionally, these substrates may possess anti-nutritional factors or exhibit nutrient imbalances that could impede larval growth and overall biomass pro-

duction [7]. Consequently, pre-treatment is essential to optimize these organic wastes for black soldier fly cultivation.

One promising approach to enhance the nutritional profile and reduce anti-nutritional factors in these substrates is fermentation technology [8]. Through fermentation, complex fibers can be decomposed, improving nutrient bioavailability [9] and thus supporting the optimal development of black soldier fly larvae. Currently, there is limited information regarding the use of fermented coconut dregs (FCD) and fermented rumen contents (FRC) as combined substrates for black soldier fly rearing. Therefore, this study investigated the effects of a varying ratios of FCD and FRC on growth performances of black soldier fly larvae.

2 Materials and Methods

Coconut dregs and rumen contents were firstly pre-treated with EM-4 fermentation for 7 days. After that FCD and FRC were mixed with varying ratio as treatment medium, including T0: 100% FCD, T1: 95% FCD + 5% FRC, T2: 90% FCD + 10% FRC, T3: 85% FCD + 15% FRC, and T4: 80% FCD + 20% FRC. A total of 0.5 grams of black soldier fly eggs were placed on hatching medium consisted of 250 g rice bran and 250 g of milk waste. The eggs were allowed to hatch over 3-4 days under room temperature. On day 7, the larvae were transferred to rearing container consisted of two kg substrates according to the treatments.

Evaluation of growth performance of larvae were conducted 6, 11, and 16 days of rearing period after being transferred to the treatment medium. The evaluation including length, width, and mass of larvae. The length and width were measured using digital calipers, while the weight was evaluated using digital balance. Data were then analyzed using way analysis of variance. A Duncan Multiple Range Test was further used to evaluate the different among treatments.

3 Results and Discussion

The results in Table 1 show the larval length of black soldier flies reared on different ratios of FCD and FRC across three growth stages: 6 days (LL6), 11 days (LL11), and 16 days (LL16). At 6 days, larvae in the T0 had the highest average length, which was significantly greater ($P < 0.05$) than those in T4. T1 and T3 did not significantly differed ($P > 0.05$) as compared to T0. At 11 days, T0 larvae maintained higher length ($P < 0.05$) compared to T4. T1, T2, and T3 had comparable results ($P > 0.05$) as compared to T0. However, by 16 days, the larval length was not significantly differed ($P > 0.05$) among treatments. These findings suggest that higher proportions of FCD in the substrate yield longer larval lengths, while increasing FRC content appears to limit growth.

Table 1. Larval length of black soldier fly reared on the different ratio of fermented coconut dregs (FCD) and fermented rumen contents (FRC).

Treatments	LL6 (mm)	LL11 (mm)	LL16 (mm)
T0	16.06 ± 0.47 ^c	17.13 ± 0.42 ^b	17.79 ± 0.36
T1	15.83 ± 0.31 ^{bc}	16.87 ± 0.42 ^{ab}	17.69 ± 0.38
T2	15.50 ± 0.25 ^{ab}	16.76 ± 0.30 ^{ab}	17.57 ± 0.13
T3	15.73 ± 0.34 ^{bc}	16.85 ± 0.26 ^{ab}	17.53 ± 0.38
T4	15.17 ± 0.45 ^a	16.41 ± 0.24 ^a	17.48 ± 0.22

^{a-c} Different superscripts indicate a significant different ($P < 0.05$)

LL6: Larval Length at 6 days, LL11: Larval Length at 11 days, LL16: Larval Length at 16 days
 T0: 100% FCD, T1: 95% FCD + 5% FRC, T2: 90% FCD + 10% FRC, T3: 85% FCD + 15% FRC, and T4: 80% FCD + 20% FRC.

The results in Table 2 present the larval width of black soldier flies reared on varying ratios of FCD and FRC at 6 days (LW6), 11 days (LW11), and 16 days (LW16). At 6 days, larvae in T0 exhibited the greatest average width, which was significantly higher ($P < 0.05$) than those in T4 treatment. By 11 days, T2 had the highest average width, though T0, T1, and T3 were statistically comparable ($P > 0.05$). However, T4 continued to display the lowest width. At 16 days, larvae in T0 retained a relatively high width, with T4 again showing the smallest width. This pattern suggests that higher FCD proportions contribute to wider larval growth, whereas increasing FRC content in the substrate may reduce larval width. This complements the findings on larval length, further supporting the beneficial role of higher FCD ratios for larval development.

Table 2. Larval width of black soldier fly reared on the different ratio of fermented coconut dregs (FCD) and fermented rumen contents (FRC).

Treatments	LW6 (mm)	LW11 (mm)	LW16 (mm)
T0	4.31 ± 0.18 ^c	4.87 ± 0.14 ^b	5.39 ± 0.06 ^b
T1	4.16 ± 0.07 ^{bc}	4.77 ± 0.16 ^{ab}	5.34 ± 0.07 ^b
T2	4.01 ± 0.08 ^b	4.89 ± 0.09 ^b	5.29 ± 0.10 ^{ab}
T3	4.25 ± 0.29 ^{bc}	4.87 ± 0.18 ^b	5.30 ± 0.09 ^b
T4	3.71 ± 0.18 ^a	4.60 ± 0.11 ^a	5.19 ± 0.07 ^a

^{a-c} Different superscripts indicate a significant different ($P < 0.05$)

LW6: Larval Width at 6 days, LW11: Larval Width at 11 days, LW16: Larval Width at 16 days
 T0: 100% FCD, T1: 95% FCD + 5% FRC, T2: 90% FCD + 10% FRC, T3: 85% FCD + 15% FRC, and T4: 80% FCD + 20% FRC.

The results in Table 3 illustrate the larval mass of black soldier flies reared on different ratios of FCD and FRC at 6 days (LM6), 11 days (LM11), and 16 days (LM16). At 6 days, larvae in T0 displayed the highest average mass, which was significantly greater ($P < 0.05$) than T2, T3, and T4 treatments, with T4 showing the lowest mass. At

11 days, T0 again had the greatest mass, while T4 exhibited the lowest. By 16 days, T0 maintained the highest mass, followed by T1, whereas T4 continued to have one of the lowest masses. These results align with previous findings on larval length and width, indicating that a higher proportion of FCD promotes greater larval mass, while increased FRC content appears to reduce growth performance. This reinforces the positive impact of higher FCD levels on larval development in terms of mass, suggesting its potential as an optimal rearing substrate.

Table 3. Larval mass of black soldier fly reared on the different ratio of fermented coconut dregs (FCD) and fermented rumen contents (FRC).

Treatments	LM6 (mm)	LM11 (mm)	LM16 (mm)
T0	133.70 ± 2.93 ^b	145.50 ± 4.69 ^b	173.50 ± 3.44 ^b
T1	129.00 ± 3.72 ^{ab}	138.10 ± 5.82 ^{ab}	169.90 ± 6.77 ^{ab}
T2	126.10 ± 5.31 ^a	137.00 ± 10.00 ^{ab}	165.70 ± 3.55 ^a
T3	125.70 ± 5.75 ^a	131.70 ± 4.31 ^a	163.70 ± 4.38 ^a
T4	122.20 ± 6.68 ^a	131.10 ± 3.73 ^a	165.20 ± 3.95 ^a

^{a-b} Different superscripts indicate a significant different ($P < 0.05$)

LM6: Larval Mass at 6 days, LM11: Larval Mass at 11 days, LM16: Larval Mass at 16 days

T0: 100% FCD, T1: 95% FCD + 5% FRC, T2: 90% FCD + 10% FRC, T3: 85% FCD + 15% FRC, and T4: 80% FCD + 20% FRC

The results of this study demonstrate that higher proportions of fermented coconut dregs (FCD) in the rearing substrate promote better growth performance in black soldier fly larvae in terms of length, width, and mass, particularly when compared to treatments with higher fermented rumen content (FRC). This difference in growth can be explained by the distinct crude fiber content of the two substrates. In this study, FRC has a notably higher crude fiber content (33.16%) compared to FCD (14.82%), which could limit the larval growth and nutrient absorption in treatments with higher FRC ratios.

Black soldier fly larvae are known to thrive on substrates with moderate fiber levels, as excessively high fiber can be difficult for larvae to digest and absorb, leading to reduced growth efficiency. The higher crude fiber in FRC likely increases the indigestible fraction of the substrate, making it challenging for larvae to obtain adequate nutrients to support their development [10]. In contrast, the lower fiber content of FCD provides a more accessible nutrient profile, allowing for better nutrient utilization and resulting in enhanced growth metrics across length, width, and mass in the T0 (100% FCD) treatment.

4 Conclusion

In conclusion, 100% FCD is recommended as the optimal substrate for maximizing BSF larval growth.

Acknowledgments. The authors acknowledge financial support from Directorate of Research and Community Services Universitas Brawijaya through “Hibah Penguatan Ekosistem Riset Guru Besar 2024”.

Disclosure of Interests. The authors have no competing interests to declare that are relevant to the content of this article.

References

1. Isnaini, N., Amertaningtyas, D., Sulisty, H.E., Yekti, A.P.A, and Andri, F. 2023. Reproduction and production traits of eggier of black soldier fly reared in different enriched media and its potential as poultry feed. *Advances in Animal and Veterinary Sciences*, 11, 1905-1910.
2. Mahmood, S., Zurbrugg, C., Tabinda, A. B., Ali, A., and Ashraf, A. 2021. Sustainable waste management at household level with black soldier fly larvae (*Hermetia illucens*). *Sustainability*, 13(17): 9722.
3. Basri, N.E.A., Azman, N.A., Ahmad, I.K., Suja, F., Jalil, N.A.A., and Partonoor, M.A.M. 2022. Comparison of black soldier fly larvae (BSFL) growth and frass production fed with fermented food waste, coconut dregs and cow manure. *Mathematical Statistician and Engineering Applications*, 71, 1201-1209.
4. Wiyoso, S.A., Sulisty, H.E., Andri, F., and Isnaini, N. 2023. Effect of fermented laying hen manure and starter feed as growing media on black soldier fly larvae development. *BIO Web of Conferences*, 81, p. 00021.
5. Khaekratoke, K., Laksanawimol, P., and Thancharoen, A. 2022. Use of fermented spent coffee grounds as a substrate supplement for rearing black soldier fly larvae, *Hermetia illucens* (L),(Diptera: Stratiomyidae). *PeerJ*, 10, e14340.
6. Hatta, U., Mozin, S., Adjis, A., and Sundu, B. 2020. Fermentation of selenium-added coconut dregs improve chicken egg production and slow down the deterioration of egg quality during 28 days storage. *Livestock Research for Rural Development*, 32, p. 196.
7. Murtius, W.S., Argo, B.D., Nurika, I., and Sukardi, S. 2024. Identification of availability and lignocellulosic properties in coconut dregs waste. *Journal of Applied Agricultural Science and Technology*, 8, 92-105.
8. Fasha, F.R., Andri, F., and Isnaini, N. 2024. Morphometric traits of Black Soldier Fly larvae in slaughterhouse waste and rice bran growing medium. *BIO Web of Conferences*, 88, p. 00035.
9. Bai, X., Grassino, M., and Jensen, P.D. 2023. Effect of alkaline pre-treatment on hydrolysis rate and methane production during anaerobic digestion of paunch solid waste. *Waste Management*, 171, 303-312.
10. Palma, L., Fernandez-Bayo, J., Niemeier, D., Pitesky, M., and VanderGheynst, J.S. 2019. Managing high fiber food waste for the cultivation of black soldier fly larvae. *NPJ Science of Food*, 3, p. 15.

Open Access This chapter is licensed under the terms of the Creative Commons Attribution-NonCommercial 4.0 International License (<http://creativecommons.org/licenses/by-nc/4.0/>), which permits any noncommercial use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license and indicate if changes were made.

The images or other third party material in this chapter are included in the chapter's Creative Commons license, unless indicated otherwise in a credit line to the material. If material is not included in the chapter's Creative Commons license and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder.

