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The Use of Fermented Coconut Waste and Layer Manure as Rearing Substrates for Black Soldier Fly: Effects on Egg Production, Egg Size, and Hatchability

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Abstract. Black Soldier Fly (BSF) has emerged as a key species in sustainable waste management and alternative feed production systems. Reproductive performance of BSF determined by rearing substrate composition. This study aimed to evaluate the effects of fermented coconut waste (FCW) and layer manure (FLM) as rearing substrates on egg production, size, and hatchability of BSF. Five rearing substrates with varying ratios of FCW and FLM were tested, namely T0 (100% FCW), T1 (95% FCW + 5% FLM), T2 (90% FCW + 10% FLM), T3 (85% FCW + 15% FLM), and T4 (80% FCW + 20% FLM). Variables observed were egg production, size (length and width), and hatchability. Data were analyzed using one-way analysis of variance, followed with Duncan post-hoc test. Results showed that BSF reared on T0 did not produce any egg, indicating unsuitability of rearing substrate for black soldier fly productivity. Egg production in T2 and T3 were higher (P<0.05) as compared to T1 and T4. However, egg length and width were not affected (P>0.05) by rearing substrates. The highest hatchability was observed in T2, followed by T1, while T3 and T4 showed lower hatchability (P < 0.05). In conclusion, the use of 90% FCW + 10% FLM is recommended as rearing substrate to optimize egg production and hatchability of BSF.

Keywords: black soldier fly, coconut waste, egg production, hatchability, layer manure.

1 Introduction

Black Soldier Fly (BSF) has emerged as a key species in sustainable waste management and alternative feed production systems. This insect has gained attention due to its remarkable ability to convert a wide range of organic wastes into valuable biomass, which is rich in protein and fat [1,2]. BSF larvae efficiently break down organic waste, contributing to the reduction of waste volumes while producing high-quality feed ingredients [3,4]. The adult flies of BSF do not act as pests, as they neither feed nor transmit diseases, further enhancing the environmental safety of BSF farming systems [5]. These unique attributes make the BSF an ideal candidate for circular bioeconomy applica-

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tions, where waste streams are upcycled into useful products [6]. As a result, BSF farming is being explored globally as a sustainable solution to both waste management challenges and the need for alternative protein sources.

Optimizing BSF production systems is essential to fully realize their potential in waste management and alternative feed production. Substrate formulation serves as a critical determinant in the success of BSF rearing. The quality of the substrate directly influences larval growth performance, survival rates, and overall biomass yield [1]. Furthermore, substrate composition significantly impacts adult reproductive traits, such as egg production, size, and hatchability [7,8]. High-quality substrates improve nutrient availability for growth and reproductive performance of BSF. Enhancing substrate quality is therefore key to improving the efficiency and sustainability of BSF production systems.

Fermentation has been identified as a promising method to enhance the quality of substrates used in BSF production systems. Fermentation process alters the nutritional profile of organic materials, breaking down complex compounds, and reducing antinutritional factors that may hinder larval growth or reproduction [9,10]. Fermentation can transform low-value agricultural waste into more suitable substrates for BSF rearing [11,12]. Coconut waste and layer manure are two abundant materials generated by agriculture and animal production activities in Indonesia. However, coconut waste and layer manure are often underutilized and can pose waste management challenges. Fermenting organic materials such as coconut waste and layer manure offers a potential solution, as it can improve their digestibility and reduce the presence of pathogens or inhibitory compounds [13,14]. Fermented coconut waste (FCW) and layer manure (FLM) have potential as promising candidates for BSF rearing substrates, as they combine improved nutritional profiles with reduced environmental risks.

Despite the potential of FCW and FLW as rearing substrate, the specific effects of FCW and FLM on key reproductive parameters of BSF such as egg production, egg size, and hatchability have not been thoroughly investigated. Understanding these effects is crucial for optimizing BSF production systems. Therefore, this study aimed to evaluate the potential of FCW and FLM as rearing substrates for BSF, with a particular focus on their influence on reproductive performance, including egg production, size, and hatchability.

2 Materials and Methods

2.1 Experimental design and rearing substrates

A total of 0.5 grams of BSF eggs were placed on a hatching medium consisting of 250 g of rice bran and 250 g of milk waste. The eggs were incubated under room temperature for 3–4 days to facilitate hatching. Upon hatching, the larvae were reared on the same medium for an additional seven days before being transferred to rearing containers containing 2 kg of substrates formulated according to the experimental treatments.

The rearing substrates were prepared using varying proportions of FCW and FLM. The FCW and FLM were each fermented for seven days using an EM-4 solution prior to use. The nutrient compositions of the FCW and FLM substrates are summarized in Table 1. Five substrate formulations were tested including T0: 100% FCW, T1: 95% FCW + 5% FLM, T2: 90% FCW + 10% FLM, T3: 85% FCW + 15% FLM, T4: 80% FCW + 20% FLM. All substrate mixtures were prepared based on weight ratios. Each treatment was conducted in triplicate. The average temperature and relative humidity during the BSF rearing were 28.40±0.37oC and 75.75±3.77%, respectively.

Table 1. Nutrient contents of fermented coconut waste (FCW) and fermented layer manure (FLM)

Nutrient contents	FCW	FLM
Dry matter (%)	25.70	36.79
Ash (%)*	1.90	47.12
Crude protein (%)*	6.04	13.18
Crude fiber (%)*	14.82	22.02
Ether extract (%)*	59.16	0.81

*as 100% dry matter

2.2 Data Collection

The measured variables included egg production, egg length, egg width, and hatchability. Egg production was quantified by weighing the collected eggs using a precision analytical balance (Joanlab FA2004, Joanlab Equipment Co. Ltd., China). Egg length and width were determined using image analysis software (OLYMPUS cellSens Dimension, Olympus Corporation, Tokyo, Japan) in conjunction with a compound microscope (Olympus CX-23, Olympus Corporation, Tokyo, Japan). Hatchability was assessed by counting the number of larvae emerging from eggs. The measurement of egg length and width, and evaluation of hatchability of BSF is illustrated in Fig. 1.

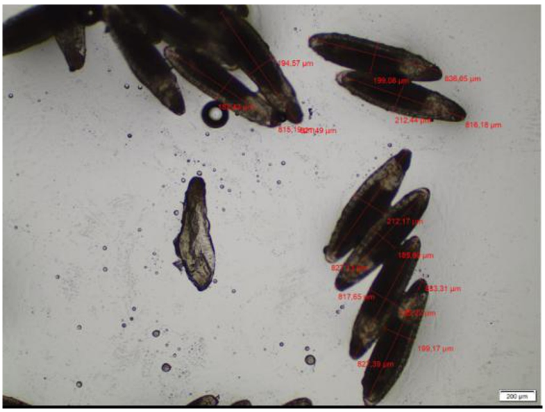

Fig. 1. The measurement of egg length (A) and width (B), and evaluation of hatchability of BSF (C)

2.3 Statistical analysis

Data were analyzed using one-way analysis of variance, with a significance level set at P < 0.05. Where significant differences were detected, means were further separated using Duncan's multiple range test. All statistical analyses were performed using IBM SPSS Statistics version 25 (IBM Corp., Armonk, NY, USA).

3 Results and Discussion

The effects of varying ratios of fermented coconut waste (FCW) and fermented layer manure (FLM) as rearing substrates on the reproductive performance of BSF are summarized in Table 2. Substrate composition significantly influenced (P < 0.05) egg production and hatchability, but not (P > 0.05) egg length and width. Egg production was significantly higher (P < 0.05) in T2 and T3 compared to T1 and T4. The highest hatchability was observed in T2, followed by T1, while T3 and T4 showed lower hatchability (P < 0.05).

Table 2. Effects of fermented coconut waste (FCW) and layer manure (FLM) with varying ratios as rearing substrate on egg production, egg length, egg width, and hatchability of black soldier fly

Variables	T0	T1	T2	T3	T4	SEM	P value
Egg production (mg)	-	49.00^{a}	648.33^{b}	606.00^{b}	47.67^{a}	93.33	0.001
Egg length (μm)	-	859.12	811.47	800.94	914.84	20.11	0.160
Egg width (μm)	-	199.83	183.12	193.44	218.68	5.84	0.171
Hatchability (%)	-	91.67^{bc}	94.33^{c}	83.67^{ab}	81.67^{a}	1.99	0.033

^{ab}different superscript within the same row indicate a significant different (P<0.05)
T0 (100% FCW), T1 (95% FCW + 5% FLM), T2 (90% FCW + 10% FLM), T3 (85% FCW + 15% FLM), and T4 (80% FCW + 20% FLM)

The differences in reproductive performance observed across substrate treatments can be closely attributed to the nutrient profiles of FCW and FLM. The high ether extract content in FCW likely provided a substantial energy source for BSF development but was insufficient alone to support reproduction, as shown by the complete absence of egg production in T0. Grossule et al. [15] noted that lipids offer high energy density and are essential for BSF development, serving as crucial energy reserves for adult flies to survive and reproduce. Since adult BSF do not feed after emergence, larvae must accumulate sufficient fat reserves to ensure successful reproduction [16]. However, excessive fat in the diet can have detrimental effects on BSF development, potentially leading to metabolic imbalances and reduced performance [17].

Protein-rich substrates such as FLM provide essential support for the reproductive success of BSF. Dietary protein plays a critical role in supporting the growth and reproductive performance of BSF, where high-protein diets accelerate development, increase larval weight, and enhance egg production, while protein deficiencies limit these processes [18,19]. Yet, the higher ash and crude fiber contents in FLM may reduce digestibility and limit nutrient absorption when included in excess [14,20]. This study suggests that incorporating moderate proportions of FLM, particularly at 10%, into FCW substrates can provide a favorable nutrient balance that supports egg production without introducing excessive ash or crude fiber that could impair reproductive performance. This nutrient synergy likely explains the superior egg production and hatchability observed in T2. These results underscore the importance of carefully formulating rearing substrates that combine the high-energy content of FCW with the protein richness of FLM to meet the nutritional requirements for BSF performance.

4 Conclusion

These findings highlight the importance of determining the optimal ratio of FCW and FLM to enhance the reproductive performance of BSF. Based on the results of this study, the use of a rearing substrate composed of 90% FCW and 10% FLM is recommended to optimize egg production and hatchability. However, further research is required to evaluate the economic feasibility and scalability of these substrates under practical production conditions.

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

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