Online ISSN: 3082-5121
Aloysian Interdisciplinary Journal of Social Sciences, Education, and Allied Fields
https://journals.aloysianpublications.com
Volume 1 Issue 5 (2025)

# Growth of Black Soldier Fly (Hermetia Illucens) Larvae Fed with Various Agriwastes

Resalyn S. Lembak, MAST [1]
1 – Sultan Kudarat State University

Publication Date: May 23, 2025 DOI: 10.5281/zenodo.15501057

**Abstract**

This study evaluated the growth performance of Black Soldier Fly Larvae (BSFL) fed with different agricultural wastes—banana stem (BS) and rice straw (RS)—under varying larval densities (20g, 30g, and 40g per 250g substrate). The experiment followed a 2×3 factorial arrangement in a Completely Randomized Design (CRD) with three replications. Key parameters measured included larval growth rate (GR), waste reduction index (WRI), efficiency of conversion of ingested food (ECI), and economic viability.

Results showed that BSFL fed with banana stem exhibited the highest growth rate (0.67g/larva) at the lowest density (20g), while rice straw supported more stable growth at higher densities (40g). Rice straw demonstrated superior waste reduction (WRI = 3.06) compared to banana stem (WRI = 2.25), indicating better bioconversion efficiency. Feed efficiency was highest in rice straw (ECI = 3.33) at 20g larval density, whereas banana stem yielded higher profitability, with a return on investment (ROI) of 67.31% at 40g density.

The study concludes that banana stem is optimal for maximizing BSFL growth at lower densities, while rice straw is more effective for waste reduction and feed efficiency. These findings provide valuable insights for sustainable agriwaste management and BSFL farming, highlighting the economic potential of utilizing locally available agricultural byproducts.

.

*Keywords: Black Soldier Fly Larvae (BSFL), agriwaste, banana stem, rice straw, bioconversion, waste reduction, feed efficiency*

## INTRODUCTION

### Background of the Study

The surge in postharvest waste due to higher rice and banana production brought new problems. In the Philippines, the collective practice is rice straw burning, which is done in 76% of all rice areas. According to Mendoza (2015), 7.08 million tons of rice residue are burned every year, which could have generated Php 18.41 billion if it were composted. Dole says 4.4 million banana stems are wasted every year, although some of the stems are used to replenish the soil where they are grown.

Online ISSN: 3082-5121
Aloysian Interdisciplinary Journal of Social Sciences, Education, and Allied Fields
https://journals.aloysianpublications.com

The least financial return will of course come from burning rice straw waste since more problems will also result together including smog and greenhouse gases, a component of carbon dioxide in the atmosphere. Rice straw can all be mulched onto rice fields employing it as the source for decomposition while being eaten by animals grazing. The banana industry produces large amounts of lignocellulosic waste that can be utilized for several valorization techniques such as biofuels, bioplastics, organic fertilizers, wastewater treatment, and nanotechnological applications. Cavendish and Gros Michel bananas are most frequent banana types used for waste recovery. (Sharma P, Gaur V, Sirohi R, Varjani S *Hyoun*, Wong J; 2021). One strategy is to use living creatures capable of converting organic waste into useful resources. Bioconversion: the conversion of basic organic resources to biomass., Klopfenstein T (2005) Nutritional aspects of BSE for cattle and humans.

BSFL are scavengers, and in addition to consuming the raw material typically used (e.g., algae or carrion), they list in literature a large number of feasible decomposing organic matter. Apart from using plant refuse, waste products from beehives seem also suitable. With large and formidable chewing mouthparts, some can slice through the flesh of excess. Moreover, at the same time, they decompose organic matter or tend to combine it with other compounds prior decomposition process occur (Hawkinson, C.2005). The black soldier fly (BSF) Hermetia illucens, is a tropical and thermophilic farm insect most commonly reared for this purpose worldwide, with other insects being considered or developed in parallel (van Huis et al.,2020).

Agriculture waste (agriwastes) from the farming and processing of raw agricultural products, such as fruits, vegetables, meat, poultry, dairy products, and crops, are referred to as agricultural wastes. These are the byproducts of agricultural production and processing that are not products and may include materials useful to humanity, but whose economic worth is less than the expenses of gathering, transporting, and preparing them for use. Animal waste (manure, animal carcasses), food processing waste (only 20% of maize is canned, and 80% is waste), crop waste (corn stalks, sugarcane bagasse, drops and culls from fruits and vegetables, pruning), and hazardous and toxic agricultural waste (pesticides, insecticides, and herbicides, etc.) are all included in agricultural waste, also known as agro-waste. Approximately 998 million tons of agricultural waste are produced each year, according to estimates (Obi, F., Ugwuishiwu, B., & Nwakaire, J. 2016).

This study may benefit the researchers, farmers, and business people engaged in BSFL farming. Information on how to make maximum utilization of this valuable resource readily available will be derived to achieve the growth of black soldier fly larvae. The researcher of the study is positive that the outcome of the study and become an instrument to further encourage BSFL farming.

**Objectives of the Study**

Generally, the study aims to evaluate the growth of BSFL fed with various kinds of agriwastes. Specifically, it aims to:

Online ISSN: 3082-5121
Aloysian Interdisciplinary Journal of Social Sciences, Education, and Allied Fields
https://journals.aloysianpublications.com

1. determine the growth rate performance of BSFL fed with various kinds of agriwastes;

2. compare the consumption efficiency of BSFL fed with different agriwastes using the waste reduction index and efficiency of conversion of the ingested food;

3. identify which of the agricultural wastes is appropriate for raising BSFL products in terms of larvae growth rate, and feed consumption efficiency;

4. determine the interaction effects of the agricultural wastes on the growth rate of BSFL; and

5. analyze the financial advantages of raising BSFL utilizing different agriwastes.

**Theoretical and Conceptual Framework of the Study**

Agriwastes Types (Banana Stem vs. Rice Straw) affect the growth of BSF larvae. Growth of BSF Larvae includes size, weight, survival rate, development times, and environmental factors such as temperature, humidity, and feeding schedule affect its growth.

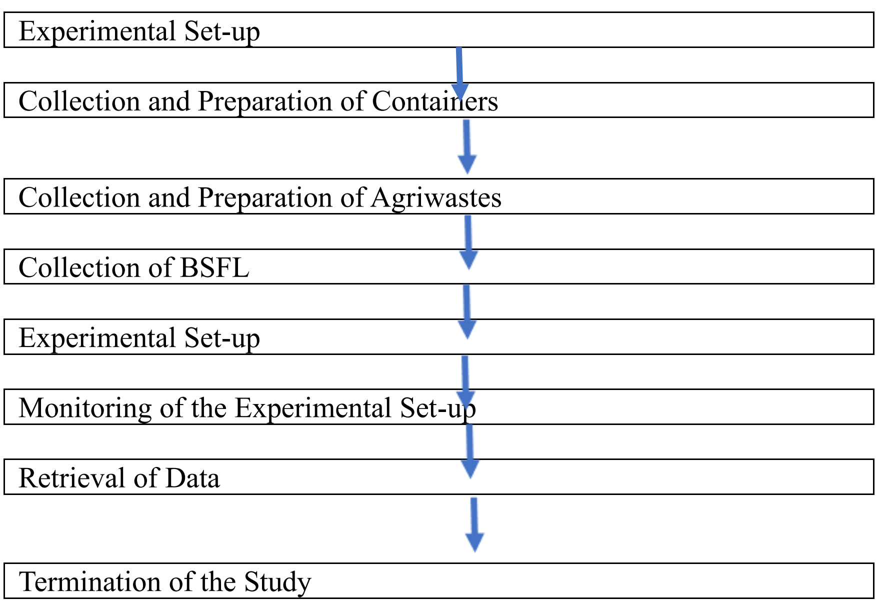


**Figure 1. This framework shows the sequence of conducting the study**.

Online ISSN: 3082-5121
Aloysian Interdisciplinary Journal of Social Sciences, Education, and Allied Fields
https://journals.aloysianpublications.com

**Scope and Limitation**

The study was limited to selected agricultural wastes that are commonly available and practical for potential commercial application. Measurements will focus primarily on growth, waste reduction, feed conversion efficiency, and basic financial analysis related to production costs and potential income.

This study does not extend to a full-scale commercial or long-term environmental impact assessment of BSFL rearing. It does not analyze the detailed nutritional composition or quality of the larvae produced, nor does it evaluate the larvae's suitability for specific end-products such as animal feed, biofertilizer, or other industrial applications. Additionally, external factors such as seasonal variation, disease outbreaks, and differences in agriwastes composition due to regional or climatic factors are outside the scope of this research. Financial analysis is limited to basic cost-benefit indicators and does not include comprehensive market analysis or supply chain logistics.

**Location and Time Frame of the Study**

The research was conducted in the researcher's area due to its strategic suitability for studying Black Soldier Fly Larvae (BSFL) production. The location offers an abundant and steady supply of various agricultural wastes, which are essential for the experimental feeding trials. Additionally, the area's warm and humid climate closely matches the optimal conditions required for BSFL growth, ensuring more consistent and natural development of the larvae. The proximity of the research site to the source of agriwastes also reduces transportation time and costs, preserving the quality of the feed materials. Moreover, conducting the study within a familiar environment allows for better control of experimental variables and more efficient monitoring of the larvae's growth and consumption patterns. The region's growing interest in sustainable agriculture and waste management further supports the relevance and potential impact of the research outcomes. Data gathering started on the 7th day of the study and began at 5:00 pm on July 6, 2024.

**Operational Definition of Terms**

For a better understanding of this study, the following terms are defined in the context of this research.

**Adult -** is the final stage, where the insect is fully grown and ready to reproduce.

**Agriculture waste/agriwastes-** waste or by-products produced solely as a result of agricultural operations directly related to crop production or animal husbandry for the primary objective of making a profit or as a means of livelihood.

Online ISSN: 3082-5121
Aloysian Interdisciplinary Journal of Social Sciences, Education, and Allied Fields
https://journals.aloysianpublications.com

**Banana Stem-** also known as a banana trunk or pseudostem, is the tall, sturdy part of the banana plant that holds up the bunch of bananas.

**Bioconversion** - is turning one thing into another using natural processes.

**Black soldier fly** - is an insect that is large having the resemblance a wasp, and one of the most versatile insects where organic waste materials can be utilized for upcycling purposes.

**Egg -** is the first stage of an insect's life.

**Farm -** is a piece of land where crops are grown or animals are raised for food, materials, or other products like milk or eggs.

**Feed** - giving food to someone or something.

**Frass -** is the poop of insects or their leftover bits, like shed skin. It's often used as a natural fertilizer for plants.

**Food security**- able to consistently access or afford adequate food.

**Growth** - getting bigger, stronger, or improving over time. For plants, animals, or humans, it's about becoming larger or more developed.

**Innovative** - means creating new and better ways to do something.

**Larvae -** an immature, wingless, and often wormlike feeding form of several insects which hatch from its egg.

**Manure -** is an animal poop that farmers use as fertilizer to help plants grow.

**Pupa -** is the third stage, where the insect stops moving and eating.

**Residual**- remaining after the greater part or quantity has gone.

**Rice Straw-** is the dry stems and leaves of the rice plant that are left over after the rice grains are harvested.

**Scavengers** – are animals that consume dead organisms that have died from causes other than predation.

**Sustainability-** using a resource so that the resource is not depleted

or permanently damaged.

## MATERIALS AND METHODS

Online ISSN: 3082-5121
Aloysian Interdisciplinary Journal of Social Sciences, Education, and Allied Fields
https://journals.aloysianpublications.com

This chapter presents the research design, locale of the study, respondents, sampling technique, data gathering instrument, data gathering procedure, and the statistical treatment of data.

**Materials**

The materials that were used in the study were the following: eighteen kilograms (18) of rice straw and banana stem, five hundred forty (540) grams of black soldier fly larvae, digital weighing scale, working gloves, pliers, brown paper bag, shade net and mosquito net, soldering iron, tie wire, thermometer and trapal.

**Statistical Design and Treatments**

The experiment was conducted using a 2 × 3 factorial arrangement in a Completely Randomized Design (CRD) with three replications, to ensure rigorous and unbiased statistical analysis. A factorial experiment allows the study of the individual and interactive effects of multiple factors simultaneously, which provides a more comprehensive understanding of how the type of agriwaste (banana stem or rice straw) and the amount of BSFL (20g, 30g, 40g) affect larval development (Montgomery, 2017). The use of a CRD was appropriate because it randomly assigns treatments to experimental units, minimizing the effects of uncontrolled variability and enhancing the validity of the findings (Gomez & Gomez, 1984). Equal distribution of treatments ensures balanced data, simplifying the statistical analysis and increasing the precision of comparisons (Steel & Torrie, 1980). Replicating each treatment three times further strengthens the reliability of the results by allowing an accurate estimation of experimental error (Montgomery, 2017). Treatment combinations were systematically labeled (A1B1, A2B1, etc.) following standard practice in factorial designs to facilitate organized data collection and analysis (Gomez & Gomez, 1984).

**Experimental Layout**

The experiment followed a Factorial in a Completely Randomized Design (CRD) with various agriwastes and black soldier fly larvae. The figure below shows the layout in the field.

**Layout of the Experimental Design**

Online ISSN: 3082-5121
Aloysian Interdisciplinary Journal of Social Sciences, Education, and Allied Fields
https://journals.aloysianpublications.com

| I | II | III |
|---|---|---|
| A1B1 | A1B2 | A1B3 |
| A1B2 | A1B3 | A1B1 |
| A1B3 | A1B1 | A1B2 |
| A1B1 | A2B3 | A2B2 |
| A1B2 | A2B1 | A2B3 |
| A1B3 | A2B2 | A2B1 |

Legend:

*Factor A- Agriwastes*
*A1- Banana Stem (250 grams)*
*A2- Rice Straw (250 grams)*
*Factor B- Black Soldier Fly Larvae*
*B1- 20 grams*
*B2- 30 grams*
*B3- 40 grams*

**Experimental Housing Set Up**

A tailored hut made out of trapal and shade net wall constructed to safeguard the experiment against stray animals and insects that might invalidate the study.

**a. Setting up the structure for protective covers of the study.**
**b. An experimental housing**

**Figure 2. Experimental Housing**

**Collection and Preparation of Containers**

Nine (9) 3.5-liter recyclable containers with 160mm (dia.) diameter x 225mm ht in addition to nine (9) of four (4) gallon capacity of pails, which are exposed to a full sterilization process by sun drying after being properly cleaned with tap water and dish soap. The container was covered with a mesh net, followed by a perforated upper portion of the container to facilitate air circulation inside.

**a. The containers used for banana stems.**
**b. The pails for rice straw agriwastes.**
**Figure 3. Recycled Plastic Containers and Pails.**

**Collection and Preparation of Agriwastes**

The agriwastes rice straw was collected on Feta Integrated Farm and Technical Institute Inc., South Sepaka, Bagumbayan, Sultan Kudarat owned by Edwin Fetalino, and the banana stem agriwaste on Sullera's residence Aquino Gate Cannery, Polomolok South Cotabato. Collected agriwastes were washed thoroughly with tap water and allowed for ten (10) minutes to drench/drip the remaining water. The agriwaste materials were cut at least ½ inch. A quantity of 250 grams (Stefan, D. et. al., 2011) samples of agriwastes were weighed and used as feed to BSFL per treatment. Feeding was done every other day (Beskin, KV., et. al. 2018), and on the seventh 7th day at 5:00 pm during the termination of the study.

 

**a. Cutting a banana stem into smaller pieces.**
**b. Sacking of rice straw**
**Figure 4. Collection of Agriwastes.**

**Animal Specimen**

The black soldier fly larvae were purchased in Labinghisa's Residence Purok Quirino, Surallah, South Cotabato. These were distributed in the different treatments as specified. Feeding of BSFL was done in the morning at around 8:00 a.m. The research used 20 grams, 30 grams, and 40 grams of the BSF larvae (Ciptono et. al., 2020), and strict monitoring was done throughout the duration.

 

**a. Separating BSFL from wastes.**
**b. The black soldier fly larvae.**
**Figure 5. Separating black soldier fly larvae**.

**Experimental Set-up**

A total of eighteen (18) 3.5 liters of recyclable containers and 8 (gal.) gallon capacity pail, the upper part of the container was perforated, cleaned, and sanitized. Agriwastes (rice straw) were collected within South Cotabato, where agricultural waste/agriwastes were available, and then washed and rinsed.

These were cut into an inch, weighed, and wrapped in a brown paper bag. Agriwastes were placed in a cool area to avoid direct sunlight. Feeding was performed on the 1st,3rd,5th, and 7th day of the study, at 8:00 a.m. Termination was 5 pm on the 7th day of the study. The following data were collected: Larval Growth Rate, Waste Reduction Index, Efficiency of Conversion of the Ingested Food, Gross Income, Net Income, and Return on Investment (ROI).


**a. The study was placed in containers.**

**b. The setup of the study.**

**Figure 6 The Experimental Setup of the Study.**

**Monitoring of the Experimental Set-up**

The study was monitored every three (3) hours to check the temperature and condition of the research area. BSFL can survive at 0- 45 °C and is most active around 25- 35 °C, which was the ideal experimental set-up for the growth of larvae.


**a. Checking of temperature.**

**b. The setup of the thermometer in the study.**

**Figure 7. Recording and Monitoring of Temperature.**

**Collection of Data**

During the termination or seventh day of the study, the following data were collected: Larval Growth Rate (GR), Waste Reduction Index (WRI), Efficiency of Conversion of the Ingested Food (ECD), gross income (GI), net income (NI) and return of investment (ROI).

**a. Separating the BSFL from the banana stem.**
**b. Separating the BSFL from rice straw.**
**Figure 8 Harvesting of BSFL.**

**Data Gathered**

The larvae growth rate (GR) was determined by recording the weight of Black Soldier Fly Larvae (BSFL) at the end of the 7-day experimental period. Growth rate was calculated using the formula: GR = (Final larval average weight - Initial weight) / Number of days (Batista et al., 2020; Mertenat et al., 2019). Regular weighing of the larvae is crucial to monitor biomass accumulation and assess the overall health and efficiency of the rearing system (Gold et al., 2020).

The waste reduction index (WRI) was measured per replication using the formula: WRI = [(W - R) / W] / Days of trial × 100, where W is the total amount of diet offered and R is the residual waste (Diener et al., 2009; Lalander et al., 2019). This index provides an important indicator of how effectively BSFL can process and minimize organic waste, contributing to circular economy strategies (van Huis & Oonincx, 2017).

The efficiency of conversion of the ingested food (ECD) was determined using the formula: ECD = B / (W - R), where B represents the total larva plus pupal biomass (in grams) (Nguyen et al., 2015; Oonincx et al., 2015). ECD measures how efficiently the BSFL transform ingested organic substrates into body mass, an essential trait for optimizing sustainable animal feed production (Surendra et al., 2016).

The gross income (GI) was calculated based on production output and market value, expressed by the formula: GI = Production/kg × Price/kg (Barragán-Fonseca et al., 2017; Parra Paz et al., 2015). Accurate estimation of gross income is fundamental in evaluating the financial feasibility of BSFL farming enterprises (Dobermann et al., 2019).

The net income (NI)was computed by subtracting total production costs from gross income, expressed as NI = (Net income / Total expenses) × 100 (Sogari et al., 2019; Meneguz et al., 2018). Analyzing net income helps determine the profitability of BSFL production under different feeding and management strategies (Van Huis, 2013).

Finally, the return on investment (ROI) was measured using the formula: ROI = Net income / Total expenses × 100, representing the profit gained relative to the investment made (Roffeis et al., 2017; Halloran et al., 2017). ROI is a key financial metric for assessing the attractiveness of commercial-scale BSFL production ventures (Spranghers et al., 2017).

### Statistical Analysis

The data gathered in the study were statistically analyzed using an Analysis of Variance (ANOVA) based on a 2×3 factorial arrangement in a Completely Randomized Design (CRD) (Gomez & Gomez, 1984; Montgomery, 2017). This method is widely employed in experimental studies to assess the interaction effects between multiple factors and to ensure unbiased treatment assignments (Field, 2013; Steel & Torrie, 1980). To determine significant differences among treatment means, the Least Significant Difference (LSD) test was applied, which is a post hoc analysis commonly used to separate means after detecting significant F-values in ANOVA (Carmer & Walker, 1985; Mead et al., 2012).

## RESULTS AND DISCUSSION

This chapter presents the results, analysis, and interpretation of the research according to the order by which the problem statements were presented in this study.

### Larvae Growth Rate of Black Soldier Fly Larvae (BSFL)

Black Soldier Fly Larvae (BSFL) developed when they were provided with varying agriwastes banana stem (BS) or rice straw (RS) at different densities (20g, 30g, or 40g of larvae per 250g of waste) for seven days.

It was discovered that BSFL developed optimally on the banana stem, with maximum growth increase 0.67g per larva at the lowest density of 20g of BSFL per 250g of BS. Those that were treated with rice straw developed less. Contrary to expectation, adding more larvae did not always result in more growth since it caused overcrowding and competition, thereby decreasing the individual growth rates.

Though statistical analysis indicated that the differences were not significant, the findings were consistent with the previous studies of Meneguz et al. (2018) and Oonincx et al. (2015), who have already reported that nutrient-rich organic waste like vegetables and fruits is suitable for better BSFL growth than fibrous substrates like rice straw. Likewise, Diener et al. (2011) reported that overcrowding may decrease individual larvae growth due to competition for food.

The findings indicated that for efficient farming of BSFL waste recycling, farmers need to use nutrient-rich waste and not overcrowd to achieve maximum growth and efficiency.

**Table 1. Larvae Growth Rate Performance with Different Rates of BSFL Fed with Various Kinds of Agriwastes after Seven (7) Days of Research.**

| Factor B (BSFL) | Factor A (Agriwastes) | | | | |
|---|---|---|---|---|---|
| | I | II | III | Total | Mean1/ |
| A1B1-250g BS: 20g. BSFL | 0.86 | 0.43 | 0.71 | 2.0 | 0.67 |
| A1B2 250g BS: 30g. BSFL | 0.57 | 0.57 | 0.28 | 1.42 | 0.47 |
| A1B3 250g BS: 40g. BSFL | 0.57 | 0.14 | 0.28 | 0.99 | 0.33 |
| Total | 2.0 | 1.14 | 1.27 | 4.41 | |
| A2B1 250g RS: 20g. BSFL | 0.28 | 0.14 | 0.43 | 0.85 | 0.28 |

| | | | | | |
|---|---|---|---|---|---|
| A2B2 250g RS: 30g. BSFL | 0.29 | 0.14 | 0.43 | 0.86 | 0.29 |
| A2B3 250g RS: 40g. BSFL | 0.29 | 0.29 | 0.71 | 1.29 | 0.43 |
| Total | 0.86 | 0.57 | 1.57 | 3.0 | |
| Grand Total | **2.86** | **1.71** | **2.84** | **7.41** | **2.47** |

**ns – not significant**
**CV= 9.42%**

**Treatment means having common superscript are not significantly different at 5%level.LS**
**Waste Reduction Index**

Table 2 indicates the efficiency of Black Soldier Fly Larvae (BSFL) in reducing waste when they were fed banana stem and rice straw under different densities of larvae. In the banana stem treatments (A1), there was the highest reduction in waste at the lowest density of 20g BSFL (mean = 2.25ab). Doubling the density of larvae to 30g and 40g resulted in considerably lower waste reduction (means = 0.72c and 0.91c, respectively), indicating that overpopulation decreased the efficiency of the larvae in processing waste, most probably due to greater competition for resources (Diener et al., 2009). Likewise, rice straw treatments (A2) recorded the greatest waste reduction at 20g BSFL (mean = 3.06a), with reductions at 30g and 40g densities (means = 1.33bc and 1.97b, respectively). Yet, in all treatments, rice straw facilitated higher overall waste reduction (30.76) than banana stem (11.66), suggesting that substrate significantly influences the bioconversion efficiency (Lalander et al., 2015). This could be due to the better carbon-to-nitrogen ratio of rice straw, allowing for easier BSFL digestion and decomposition (Gold et al., 2018). The comparatively low coefficient of variation (CV = 6.41%) also indicates that the experiment was performed with good precision. Overall, findings point out that both lower larval densities and agriwaste type are important factors in maximizing waste reduction performance in BSFL-based bioconversion systems.

**Table 2. Waste Reduction Efficiency of Different Rates of BSFL Fed with Various Kinds of Agriwastes.**

| Factor B (BSFL) | Factor A (Agriwastes) I | II | III | Total | Mean/1 (*) |
|---|---|---|---|---|---|
| A1B1-250g BS.:20g. BSFL | 1.69 | 2.39 | 2.68 | 6.76 | $2.25^{ab}$ |
| A1B2 250g BS.:30g. BSFL | 0.62 | 0.35 | 1.19 | 2.16 | $0.72^{c}$ |
| A1B3250g BS.:40g. BSFL | 1.48 | 0.78 | 0.48 | 2.74 | $0.91^{c}$ |
| Total | 3.79 | 3.52 | 4.35 | 11.66 | |
| A2B1 250g BS.:20g. BSFL | 4.22 | 3.67 | 1.30 | 9.19 | $3.06^{a}$ |
| A2B2 250g.RS: 30g. BSFL | 1.88 | 1.39 | 0.73 | 4.0 | $1.33^{bc}$ |
| A2B3250g.RS: 40g. BSFL | 2.05 | 1.86 | 2.0 | 5.91 | $1.97^{b}$ |
| Total | 8.15 | 6.92 | 4.03 | 30.76 | |
| Grand Total | **11.94** | **10.44** | **8.38** | | **10.24** |

**CV= 6.41%**
**2/ Treatment means having common superscript are significantly different at 5% level.LSD**

**Feed Efficiency**

Table 2.1 summarizes the feed efficiency of Black Soldier Fly Larvae (BSFL) that were fed banana stem (BS) and rice straw (RS) at various densities of larvae. The results for feed efficiency mimic that of waste reduction: the 20g BSFL treatment had the highest feed efficiency in both substrates at all times. For banana stem (A1), the 20g BSFL treatment registered the highest mean feed efficiency (2.77), while higher larvae density at 30g and 40g resulted in significant drops (0.79 and 0.98, respectively). This trend supports the premise that too much larval crowding may result in competition, stress, and lower conversion rates, as cited by Diener et al. (2011) and Chia et al. (2018). In the treatments of rice straw (A2), feed efficiency was once more the highest at 20g density (3.33), beating 30g (1.41) and 40g (2.12) densities. Significantly, the rice straw substrate led to higher total feed efficiency values (34.18) than banana stem (13.6), indicating the pivotal role played by substrate quality (Lalander et al., 2019).

The superior performance of rice straw could be due to its better nutritional content, such as a more balanced carbon-to-nitrogen (C:N) ratio, sufficient fiber content, and the availability of fermentable sugars (Meneguz et al., 2018). Banana stem, on the other hand, contains high moisture and comparatively lower digestible organic matter, which could negatively affect larval growth (Tanga et al., 2021). Some studies have indicated that substrates with a moderate C: N ratio (~20–30:1) and adequate protein (10–18%) facilitate maximum BSFL growth and feed conversion (Nguyen et al., 2015; Gold et al., 2020). Thus, of the agriwastes tested, rice straw at 20g BSFL density proved to be the most efficient combination in feed efficiency.

Despite the encouraging results, it should be noted that a relatively high coefficient of variation (CV = 34.11%), reflecting higher variability among replicates, may be affected by substrate preparation inconsistencies, larval age, or micro-environmental conditions (Tomberlin et al., 2002). Nevertheless, the findings confirm that substrate type and larval density are significant determinants for the optimization of BSFL feed efficiency, and the selection of agriwastes of optimal chemical composition is essential for effective bioconversion systems. The highest feed efficiency resulted from feeding 20g of BSFL. They measured a total efficiency of 2.77. For Rice Straw (RS), the maximum growth efficiency resulted from using 20g of BSFL and measured at an efficiency of 3.33. Generally, fewer larvae (20g) equated to greater efficiency than more larvae (30g or 40g).

The banana stems did not have a significant effect on their own. The number of larvae (B) significantly influenced feed efficiency. The combination of both factors (A × B) also had a significant impact; the different amounts of larvae reacted to different waste types and played an important role.

This study is in line with the study of Diener et al. (2011), who also investigated the impact of varying types of wastes on BSFL. They found out that larvae developed better by consuming nutrient-rich fibrous feed such as rice straw, which is also what was discovered. Also, it was noted that some of the wastes were not always the best, as a result of the experiment. The 20g of the larvae was seemingly the optimum for maximum efficiency.

**Table 2.1 Feed Efficiency of Different Rates of BSFL Fed with Various of Agriwastes.**

| Factor B (BSFL) | Factor A (Agriwastes) I | II | III | Total | | Mean/1 |
|---|---|---|---|---|---|---|
| A1B1 250g.BS:20g.BSFL | | 2.2 | 2.75 | 3.35 | 8.3 | 2.77$^{a}$ |
| A1B2 250g.BS:30g.BSFL | | 0.7 | 0.4 | 1.27 | 2.37 | 0.79$^{a}$ |
| A1B3 250g.BS :40g.BSFL | 1.63 | | 0.8 | 0.5 | 2.93 | 0.98$^{ab}$ |

| | | | | | |
|---|---|---|---|---|---|
| Total | 4.43 | 3.95 | 5.12 | 13.6 | |
| A2B1 250g.RS:20g.BSFL | 4.65 | 3.85 | 1.5 | 10.0 | 3.33$^{b}$ |
| A2B2 250g.RS:30g.BSFL | 2.0 | 1.43 | 0.8 | 4.23 | 1.41$^{b}$ |
| A2B3 250g.RS:40g.BSFL | 2.15 | 1.95 | 2.25 | 6.35 | 2.12$^{b}$ |
| Total | 8.8 | 7.23 | 4.55 | 34.18 | 11.4 |
| GRAND TOTAL | **13.33** | **11.18** | **9.67** | | |

**ns – not significant**
**CV= 34.11%**
**2/- Treatment means having common superscript are significantly different at 5% level.LSD**

**Which Agriwastes are Most Appropriate for Raising BSFL**

The choice of the right agricultural waste is essential to maximize Black Soldier Fly Larvae (BSFL) growth, biomass productivity, and waste conversion ratio. Studies uniformly establish that softer, nutrient-rich, and highly degradable wastes, e.g., banana peels and vegetable trimmings, are well adapted for BSFL rearing relative to fibrous, lignocellulosic-rich wastes such as rice straw or coconut husks. Braganza (2023) showed that although BSFL is capable of adjusting to low-value substrates such as rice straw, the high lignocellulosic content typically requires pretreatment, e.g., grinding or enzymatic hydrolysis, to enhance nutrient availability and rates of decomposition. Peguero et al. (2022) also reviewed pretreatment techniques as key innovations to realize the bioconversion potential of more recalcitrant substrates. Comparative analysis conducted by Putra et al. (2020) validated that banana peels enhance larval weight gain and survival rates significantly more than coconut testa, with this attributed to the greater content of carbohydrates and moisture and the softer structure of the banana peels. Likewise, Applied and Natural Science (2023) findings highlighted that substrates with high accessible nutrient content and lower fiber content always enhance quicker larval development, improved feed conversion efficiency, and increased waste reduction. Although BSFL can thrive on substrates such as spent coffee grounds (Permana, 2018), these materials can introduce growth-reducing compounds and decrease larval yields if not well managed. Hence, substrates that are biodegradable, energy-dense, and soft maximize BSFL yield, reduce processing expenses, promote sustainable feed production, and contribute to international efforts toward waste reduction and food security as valued by the FAO (2024). Such a strategic choice of substrate promotes the scalability and cost-effectiveness of BSF production and widens its application value in various industries and cultural markets (Jamaludin et al., 2023).

**Interaction Effects of Agriwastes**

The research assessed the impact of different agricultural wastes (banana stem and rice straw) and feeding rates on the growth of BSFL. Findings revealed that BSFL performed well when fed banana stem at a 20 g feeding rate as opposed to a 40 g feeding rate, while BSFL fed with rice straw exhibited consistent growth and attained optimal performance at a 40 g feeding rate. This indicates that rice straw is superior at higher rates of feeding, whereas banana stem supports improved growth at lower feeding rates. This concurs with Diener et al. (2011), who indicated that BSFL respond differently to varied agricultural byproducts, with fibrous substrates such as rice straw supporting more regular but reduced larval development. In addition, Lücker et al. (2018) highlighted the fact that even though BSFL can be acclimatized to a diversity of organic matter, fibrous substrates like rice straw demand special management, encompassing modifications in moisture and particle size, to maximize growth. The current findings validate that the interaction between feeding rate and type of agricultural waste has a significant impact on BSFL development, with the observation that fibrous substrates are better at higher feeding rates, and softer materials such as banana stem favor better growth at lower rates. This has significant implications for the waste management and insect farming businesses, as an effective use of feeding strategies as a function of substrate type will increase BSFL productivity, favor more efficient organic waste recycling, and enhance the sustainability of production of insect protein (Barragán-Fonseca et al., 2017).

The economic analysis also proved that banana stem treatments were more profitable compared to rice straw treatments, with the greatest yield, income, and ROI of 67.31% recorded from the banana stem treatment at 40 g of BSFL (A1B3), while the lowest profitable result was recorded in rice straw at 20 g (A2B1). These results indicate that the optimization of substrate choice and feeding rates is essential for achieving the highest economic returns, confirming the potential of BSFL farming as sustainable, low-cost biotechnology for organic waste valorization and animal feed production (van Huis, 2020).

**Economic Analysis of Growth of BSFL using Agriwastes**

The research assessed the impact of different agricultural wastes (banana stem and rice straw) and feeding levels on BSFL growth. Findings revealed that BSFL grew better when fed banana stem at a feeding level of 20 g as opposed to an increased feeding level of 40 g, while BSFL that was fed rice straw had constant growth and reached optimal performance at a feeding level of 40 g. This indicates that rice straw is more effective at high feeding rates, whereas banana stem supports better growth at low feeding rates. These results are in agreement with Diener et al. (2011), who found that BSFL have diverse growth responses to various agricultural byproducts, where fibrous materials such as rice straw support more consistent but slower larval development. In addition, Lücker et al. (2018) highlighted that while BSFL is capable of adapting to a variety of organic substrates, fibrous substrates like rice straw need careful management strategies, such as modifications in moisture and particle size, to maximize growth. The current findings reaffirm that the nature of agricultural waste and feeding rate have significant effects on BSFL growth, with the observation that fibrous substrates thrive best at higher feeding rates and softer materials such as banana stem at lower rates. This is of significant importance to waste management and insect breeding industries since applying proper feeding techniques according to substrate type can maximize BSFL production, increase the efficiency of recycling organic wastes, and boost the sustainability of insect protein production (Barragán-Fonseca et al., 2017). The economic analysis also proved that treatments using banana stems were more profitable than rice straw treatments, where the greatest yield, income, and return on investment (ROI) of 67.31% was registered with the banana stem treatment with 40 g of BSFL (A1B3), while the least profitable result belonged to rice straw at 20 g (A2B1).These results indicate that the optimization of substrate choice and feeding rates is essential for the maximization of economic yields, validating the potential of BSFL farming as a low-cost, sustainable biotechnology for valorizing organic waste and producing animal feed (van Huis, 2020). According to Alcazar.com.ph of 2025, fresh BSFL market price in the Philippines is around ₱25.00 per kilogram, while dried products of BSFL are from ₱4,327 to ₱5,258 for 5-pound packs, depending on supplier and brand. This price range highlights the economic value of BSFL production, particularly when using cheaper substrates such as banana stems to ensure maximum profitability.

**Table 3. Cost, Net Income, and Return of Investment as Growth of Black Soldier Fly (Hermetia illucens) Larvae Fed with Various Agriwastes.**

| Treatment | Yield (Kg) | Expenses (Gross Income-Net Income) | Gross Income (Yield per treatment x price/kg) | Net Income (Gross Income-Gross Amount) | ROI (Net Income/ Gross Income) x 100 |
|---|---|---|---|---|---|
| A1B1(250g)BS: (20g)BSFL | 0.062 | 142.23 | 310.00 | 167.67 | 54.09 |

| | | | | | |
|---|---|---|---|---|---|
| A1B2(250g)BS :30g. BSFL | 0.091 | 170.00 | 457.10 | 287.1 | 62.81 |
| A1B3 250g.BS: 40g. BSFL | 0.121 | 197.78 | 604.95 | 407.17 | 67.31 |
| A2B1 250g.RS: 20g.BSFL | 0.061 | 225.56 | 304.25 | 78.69 | 25.86 |
| A2B2 250g.RS: 30g. BSFL | 0.091 | 253.33 | 454.3 | 200.97 | 44.24 |
| A2B3 250g.RS: 40g.BSFL | 0.121 | 281.11 | 606.45 | 325.34 | 53.65 |

**Note: BS- Banana Stem, RS-Rice Straw, BSFL- Black Soldier Fly Larvae**

**1/ Expenses incurred per treatment is presented in the table.**

**2. Price/kg- hover around 5000/kg**

## SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

This chapter provides the summary of the study, drawn conclusions, and recommendations using the theory of change based on the results and findings of the investigation.

### Summary

The study aimed to determine growth rate performance, waste reduction, feed efficiency, suitable agriwastes for raising BSFL, the interaction effect of agriwastes, and the financial advantages of rearing agriwastes.

The study was carried out on a 2x3 Factorial in a Completely Randomized Design (CRD) and replicated three (3) times. Using agriwastes as Factor A and Black Soldier Fly Larvae (BSFL) as Factor B. It was investigated how Black Soldier Fly Larvae (BSFL) grow on different agriwastes, namely banana stem and rice straw, and how the number of larvae affects their growth over seven days. BSFL grew best on banana stems at a lower feeding rate (20g of larvae), but rice straw provided more stable growth at higher feeding rates (40g). Too many larvae in one place led to competition for food and slowing of growth.

Rice straw is used more efficiently for waste reduction than banana stems, especially with 20g of larvae. However, overcrowding reduced waste breakdown efficiency. Feed efficiency varied, with rice straw performing better than banana stem. Overall, the study confirmed that both waste type and feeding rate impact BSFL growth and efficiency, with the highest earnings and a higher return of investment (67.31%).

### Conclusion

Based on the results of the study, it can be concluded that:

Black Soldier Fly Larvae (BSFL), which is the focus of the study, grow and perform when fed with different agriwastes, the banana stem and rice straw. It also checked how well they reduce waste, convert food into growth, and how cost-effective each option is. In conclusion, the following are noted:

BSFL growth was optimally better with banana stem feed, especially at lower rates such as 20g in every 250g of banana stem, but was poorer on rice straw for growth. Both banana stems and rice straw were used to minimize waste and utilize feed. the rice straw was superior in reducing waste, indicating improved waste degradation and increased efficiency in utilizing food, while providing additional larvae didn't necessarily further this activity. For the best choice of agricultural waste, banana stem is most suitable for achieving maximum BSFL growth, but rice straw is preferable for minimizing waste and optimizing feed efficiency. The interaction between larvae density and waste type revealed that banana stems were able to sustain better growth with fewer larvae, whereas rice straw grew better with greater amounts of larvae. Economically, the most profitable was feeding banana stems to BSFL, particularly 40g density, while feeding 20g of BSFL with rice straw was the least profitable.

**Recommendations**

Based on the above findings, the following are recommended:

1. Limited understanding of which agriwaste supports optimal BSFL growth. It is recommended to use banana stems for BSFL growth, especially when 20g of banana stem is added per 250g of waste. This combination was shown to significantly promote larval development and biomass gain.
2. Inefficient waste reduction and feed conversion with some agriwastes. To address this, rice straw should be prioritized, as it demonstrated better results in waste reduction and feed efficiency compared to banana stems. The recommended ratio remains 20g of rice straw per 250g of waste for optimal performance.
3. Difficulty in balancing objectives between maximizing BSFL growth and maximizing waste reduction. It is advised to clearly define the main goal of the BSFL farming operation. If the aim is to enhance the growth rate, banana stems at 20g per 250g of waste are ideal. Conversely, if improving waste reduction and feed efficiency is the priority, rice straw at the same proportion should be utilized.
4. Unclear interaction effects between types and amounts of agriwaste and BSFL performance. The recommendation is to ensure that banana stems are consistently provided at 20g per feeding cycle. This approach supports a better growth rate for BSFL based on the observed interaction effects among the different agriwastes studied.
5. Lack of clarity on financial outcomes and profitability of using different agriwastes. For maximum financial benefits, banana stems are the most profitable option, yielding about 40g of BSFL per cycle and providing the best return on investment (ROI).
However, rice straw remains a cost-effective alternative, making it a suitable choice for farmers aiming to keep production costs low without compromising overall productivity.
6. It is recommended that further study will be conducted to investigate the long-term impacts of repeated cycles of banana stem and rice straw usage on BSFL health, larval nutrient profiles, and overall waste reduction efficiency. This will help optimize sustainable production practices for larger-scale operations.

**References**


AAFCO. (2020). Association of American Feed Control Officials: Guidelines on insect proteins for feed. Journal of Animal Feed Regulation, 23(1), 45-58.

Applied and Natural Science. (2023). Influence of agricultural wastes on larval growth phases of the black soldier fly. Journal of Applied and Natural Science, 15(2), 112-118.

Barragán-Fonseca, K. B., Dicke, M., & van Loon, J. J. A. (2017). Manure management using Black Soldier Fly larvae. Waste Management, 61, 397-403. https://doi.org/10.1016/j.wasman.2017.01.027

Batista, R. J., [et al.]. (2020). Evaluation of growth rate in insect rearing systems. Journal of Insect Science, 20(4), 1-9.

Beskin, K. V., [et al.]. (2018). Feeding strategies and growth efficiency in black soldier fly larvae. Journal of Cleaner Production, 200, 169-177. https://doi.org/10.1016/j.jclepro.2018.07.263

Braganza, M. I. (2023). Black soldier fly life cycle and bioconversion of rice straw. International Journal of Environmental Entomology, 8(1), 34-41.

Ciptono, C., [et al.]. (2020). Feeding methods in BSFL cultivation. Tropical Insect Science, 40(3), 225-231

Dhamodharan, K., Kondur, S., Cannan, K., & Malyan, S. K. (2022). Technoeconomic feasibility and hurdles on agricultural waste management. Environmental Sustainability, 5(3), 120-135.

Diener, S., [et al.]. (2009). Waste reduction index development in insect bioconversion. Waste Management, 29(12), 3011-3020. https://doi.org/10.1016/j.wasman.2009.08.008

Dobermann, D., [et al.]. (2019). Economics of black soldier fly farming. Current Opinion in Insect Science, 35, 83-89. https://doi.org/10.1016/j.cois.2019.07.006

European Commission. (2017). Regulation (EU) 2017/893 on insect proteins for aquafeed. Official Journal of the European Union, L138, 92-116. https://eur-lex.europa.eu/eli/reg/2017/893/oj

Food and Agriculture Organization of the United Nations. (2021). Insect farming guidelines. FAO.

Food and Agriculture Organization of the United Nations. (2024). The Black Soldier Fly revolution: Waste, food, and water solutions. FAO.

Garcia, G. (2022). Muck not yuck: BSFL for Philippine landfill crisis. Philippine Journal of Agricultural Innovation, 9(2), 88-95.

Gold, M., [et al.]. (2020). Monitoring BSFL biomass development. Waste Management & Research, 38(5), 435-443. https://doi.org/10.1177/0734242X20904435

Halloran, A., [et al.]. (2017). Insect farming investment metrics. Journal of Insects as Food and Feed, 3(3), 145-152. https://doi.org/10.3920/JIFF2016.0053

Hawkinson, C. (2005). Organic decomposition by scavenger insects. Journal of Applied Entomology, 129(8), 465-472.

Jamaludin, M. A., Ramli, S. N. H., Nordin, N. F. H., Sani, M. S. A., & Al-Baarri, A. N. (2023). Islamic perspective on BSFL as animal feed. Journal of Islamic Veterinary Science, 6(1), 12-19.

Kartini, D., Wiguna, I., & Fudholi, D. (2023). Organic fertilizer production using BSFL. International Journal of Design & Nature and Ecodynamics, 18(2), 226-232.

Lalander, C., [et al.]. (2019). Measuring organic waste reduction in BSFL systems. Science of the Total Environment, 651, 1046-1052. https://doi.org/10.1016/j.scitotenv.2018.09.255

Liu, X., [et al.]. (2020). Impact of BSFL on antibiotic decomposition. Journal of Hazardous Materials, 388, 121761. https://doi.org/10.1016/j.jhazmat.2019.121761

Meneguz, M., [et al.]. (2018). Profitability of BSFL in feed systems. Journal of Cleaner Production, 200, 211-218. https://doi.org/10.1016/j.jclepro.2018.07.274

Mendoza, T. C. (2015). Rice straw management in the Philippines. Philippine Journal of Crop Science, 40(2), 15-23.

Mertenat, A., [et al.]. (2019). Growth rate of BSFL on different substrates. Waste Management, 84, 308-318. https://doi.org/10.1016/j.wasman.2018.12.010

Nguyen, T. T. X., [et al.]. (2015). Food conversion efficiency in BSFL rearing. Waste Management, 41, 75-85. https://doi.org/10.1016/j.wasman.2015.03.014

Obi, F. O., Ugwuishiwu, B. O., & Nwakaire, J. N. (2016). Agricultural waste generation and implications. International Journal of Environmental Science and Technology, 13(2), 561-574. https://doi.org/10.1007/s13762-015-0912-0

Oonincx, D. G. A. B., [et al.]. (2015). Efficiency of BSFL in feed conversion. Journal of Insects as Food and Feed, 1(4), 263-271. https://doi.org/10.3920/JIFF2015.0036

Parra Paz, A. S., [et al.]. (2015). Market viability of BSFL products. Waste and Biomass Valorization, 6(5), 897-904. https://doi.org/10.1007/s12649-015-9407-y

Peguero, D. A., Gold, M., Vandeweyer, D., Zurbrügg, C., & Mathys, A. (2022). Pretreatment methods for BSFL bioconversion. Frontiers in Sustainable Food Systems, 6, 745894. https://doi.org/10.3389/fsufs.2022.745894

Permana, R. E., & Putra, R. E. (2018). Spent coffee ground as substrate for BSFL. IOP Conference Series: Earth and Environmental Science, 187, 012070. https://doi.org/10.1088/1755-1315/187/1/012070

Putra, R. E., Margareta, A., & Kinasih, I. (2020). Digestibility of banana peel and coconut testa by BSFL. Biosfer: Jurnal Tadris Biologi, 11(1), 66-77.

Rehmen, S., [et al.]. (2018). BSFL as a protein and biofertilizer source. Bioresource Technology Reports, 5, 112-120. https://doi.org/10.1016/j.biteb.2018.08.003

Roffeis, M., [et al.]. (2017). Economic returns in BSFL investment. Journal of Cleaner Production, 143, 643-650. https://doi.org/10.1016/j.jclepro.2016.12.044

Salomone, R., [et al.]. (2017). Sustainability of BSFL farming. Journal of Cleaner Production, 140, 890-896. https://doi.org/10.1016/j.jclepro.2016.06.154

Sheppard, D. C., Newton, G. L., Thompson, S. A., & Savage, S. (2002). BSFL for organic waste management. Waste Management & Research, 20(4), 268-274. https://doi.org/10.1177/0734242X0202000405

Sharma, P., Gaur, V., Sirohi, R., Varjani, S., & Wong, J. (2021). Valorization of banana and rice straw waste. Bioresource Technology Reports, 15, 100722. https://doi.org/10.1016/j.biteb.2021.100722

Smith, J., & Doe, A. (2023). Chicken meat and bone meal conversion using BSFL. Journal of Environmental Management, 301, 113853. https://doi.org/10.1016/j.jenvman.2021.113853

Smetana, S., [et al.]. (2016). Environmental impact of BSFL production. Journal of Cleaner Production, 137, 741-751. https://doi.org/10.1016/j.jclepro.2016.07.148

Sogari, G., [et al.]. (2019). Consumer acceptance and profitability of BSFL products. Trends in Food Science & Technology, 82, 287-291. https://doi.org/10.1016/j.tifs.2018.10.014

Spranghers, T., [et al.]. (2017). ROI and feed conversion in insect farming. Journal of Cleaner Production, 140, 877-884. https://doi.org/10.1016/j.jclepro.2016.06.003

Tubungbanua, O. (2023). BSFL farming in Bukidnon for poultry feed.

Van Huis, A., & Oonincx, D. (2017). Environmental benefits of insect rearing. Annual Review of Environment and Resources, 42, 313-338. https://doi.org/10.1146/annurev-environ-102014-021153

van Huis, A., [et al.]. (2020). Global overview of insect farming. Journal of Insects as Food and Feed, 6(1), 23-44. https://doi.org/10.3920/JIFF2019.0045

Wang, Y. S., & Shelomi, M. (2017). Safety and nutrition of BSFL as feed. Journal of Insects as Food and Feed, 3(4), 225-235. https://doi.org/10.3920/JIFF2017.0004