

The Effect Of Substrate Differences On The Biomass And Yield Of Black Soldier Fly (BSF) Larvae In Supporting Sustainable Fisheries

Yolla Tifa¹, Yusra^{2*}, Reni Desmiarti³

¹ Master's Program in Utilization of Aquatic Resources, Coastal, and Marine Areas, Bung Hatta University. Jl. Sumatera Ulak Karang, Padang 25133, West Sumatra, Indonesia

^{2*} Department of Fisheries Resource Utilization, Faculty of Fisheries and Marine Sciences, Bung Hatta University. Jl. Sumatera Ulak Karang, Padang 25133, West Sumatra, Indonesia.

³ Department of Chemical Engineering, Faculty of Industrial Technology, Bung Hatta University. Jl. Gajah Mada No. 19 Olo Nanggalo, Padang 25143, West Sumatra, Indonesia.

Corresponding Author: Yusra. Tel./fax.: +62-751-7055475, E-mail: yusra@bunghatta.ac.id



Abstract: *Black Soldier Fly (Hermetia illucens)* larvae are an alternative protein source that has the potential to support sustainable fisheries development through the utilization of organic waste. This study aimed to analyze the effect of different substrate types on the biomass and meal yield of *Black Soldier Fly (BSF)* larvae. The method used was an experiment with three substrate treatments: household waste, fruit waste, and vegetable waste, which were maintained for 14 days until the prepupal phase. Parameters observed included wet weight, dry weight, and larval meal yield after a drying process at 65°C for 6 hours. The results showed that the household waste substrate produced the highest biomass with a wet weight of 2200 g, a dry weight of 720 g, and a yield of 32.73%. Fruit waste produced a wet weight of 1750 g, a dry weight of 300 g, and a yield of 17.14%. Vegetable waste produced a wet weight of 1195 g, a dry weight of 275 g, and a yield of 23.01%.

Keywords: Black Soldier Fly, Substrate, Biomass, Yield, Flour

INTRODUCTION

The fisheries sector in Indonesia plays a strategic role in supporting food security, providing employment, and improving the national economy. As an archipelagic nation with vast potential for aquatic resources, Indonesia offers significant opportunities for developing both capture fisheries and aquaculture ^[1]. In recent years, the aquaculture subsector has shown significant growth in line with increasing demand for fish consumption domestically and in the export market. However, this growth has also been accompanied by challenges in providing sustainable and affordable quality feed for fish farmers ^[2]. The increasing demand for animal protein, particularly in the aquaculture sector, poses a significant challenge in realizing a sustainable production system. Feed is the largest cost component in fish farming, and most fisheries still rely on fish meal as the primary protein source. This dependence creates ecological problems because the exploitation of captured fish resources for feed can threaten the balance of the marine ecosystem ^[3]. Therefore, alternative protein sources that are more environmentally friendly, sustainable, and can be produced efficiently are needed.

One alternative currently being widely developed is the use of *Black Soldier Fly (Hermetia illucens)* larvae as a feed ingredient. *Black Soldier Fly (BSF)* larvae have a relatively high protein and fat content and the ability to convert organic waste into economically valuable biomass. Furthermore, their relatively short life cycle and simple cultivation techniques make them potentially suitable for both household and industrial scale development. Utilizing *Black Soldier Fly (BSF)* not only provides an alternative protein source but also contributes to sustainable organic waste management^[4]. In *Black Soldier Fly (BSF)* cultivation systems, the substrate, or feeding medium, is the primary factor influencing larval growth and biomass production. Commonly used substrates are derived from organic waste such as household waste, fruit waste, and vegetable waste. Each type of substrate has a different nutritional content, including protein, carbohydrates, fat, and water content. These differences in nutrient composition can affect growth rate, feed conversion efficiency, and the final weight of the larvae produced^[5].

Black Soldier Fly (Hermetia illucens) larval meal is increasingly being researched as a substitute for fish meal in aquaculture feed formulations due to its high protein content, ranging from 35–45% in dry powder form, and its relatively complete essential amino acid profile. Several studies have shown that *Black Soldier Fly (BSF)* meal can partially or even to a certain extent replace fish meal without compromising the growth performance of farmed fish. [3] explained that the use of insect protein in aquaculture feed can maintain feed conversion efficiency (FCR) and specific growth rate (SGR) in various freshwater and marine fish species^[6]. In addition, [7] stated that the fat and lauric acid content in *Black Soldier Fly (BSF)* larvae have potential as natural antimicrobial agents that can support fish health^[7].

From a sustainability perspective, utilizing *Black Soldier Fly (BSF)* meal as a substitute for fishmeal can reduce pressure on capture fisheries, which have been the primary source of global fish meal raw materials. Fishmeal production relies on the exploitation of small pelagic fish, which, if not properly managed, can disrupt the balance of marine ecosystems. [8] emphasized that a bioconversion system using *Black Soldier Fly (BSF)* larvae can convert organic waste into high-value biomass with high conversion efficiency, thus creating a circular economy model^[8]. Therefore, developing *Black Soldier Fly (BSF)* meal is not only an alternative feed ingredient solution but also an integrative strategy to support a more environmentally friendly, efficient, and sustainable fisheries system.

High larval biomass is an indicator of successful *Black Soldier Fly (BSF)* cultivation, especially when intended as a raw material for fish feed. In addition to wet weight, another important parameter is the dry weight or meal yield produced after the drying process. The meal yield reflects production efficiency and determines the economic value of the final product. The higher the flour yield, the more optimal the substrate utilization in producing a product ready for use as a feed ingredient^[9]. In sustainable fisheries, the use of *Black Soldier Fly (BSF)* larval meal has the potential to reduce dependence on conventional fishmeal. The concept of sustainability emphasizes not only production aspects but also resource efficiency and reduced environmental impact. The use of organic waste as a substrate for *Black Soldier Fly (BSF)* cultivation represents an integration of waste management and alternative feed production, creating a more circular and environmentally friendly system^[10].

Although various studies have reported the potential of *Black Soldier Fly (BSF)* as an alternative protein source, further studies on the effect of different substrate types on biomass and flour yield are still needed, particularly in the context of its application to sustainable fisheries. Each region has different organic waste characteristics, so research is needed that can provide recommendations for the best substrate based on biomass production and flour processing efficiency. Based on this background, this study aims to analyze the effect of different substrates on *Black Soldier Fly (BSF)* larval biomass and flour yield in supporting sustainable fisheries. The results of this study are expected to provide scientific information regarding the optimization of *Black Soldier Fly (BSF)* flour production as an alternative feed raw material, as well as become the basis for developing a more efficient and sustainable cultivation system in the future.

MATERIALS AND METHODS

2.1 Location and Time

The research was conducted at the Fisheries Product Processing Technology Laboratory (TPHP), Faculty of Fisheries and Marine Sciences, Bung Hatta University, and the Chemical Engineering Laboratory. The research was conducted in April 2025.

2.2 Materials and Equipment

The primary sample used in this study were *Black Soldier Fly (BSF)* juveniles, cultivated for 14 days and fed with different substrates: household waste, fruit waste, and vegetable waste.

The equipment used in this study included a biopond, digital scale, sieve, oven, blender, spoon, plastic wrap, tray, and 1000 ml thinwall food container.

2.3 Experimental Design

The method used was an experiment to determine the effect of different substrate types (A: Household Waste, B: Fruit Waste, and C: Vegetable Waste) on biomass and starch yield.

2.4 Maintenance Procedures

Prepare a biopond with controlled environmental conditions, including a temperature range of 27–30°C and humidity of 60–70% to support optimal growth of *Black Soldier Fly (BSF)* larvae. The baby maggots are then divided into three treatment groups based on the type of feed provided: Group A fed household waste, Group B fed fruit waste, and Group C fed vegetable waste. Feeding is carried out continuously for 14 days until the maggots reach the prepupa stage ^[11].

2.5 Drying and Flour Making Process

After the rearing period is complete, the maggots are harvested and washed with clean water. The washed larvae are weighed to determine their wet weight. They are then oven-dried at 65°C for 6 hours. During the drying process, the maggots are stirred every 30 minutes to ensure even drying. The dried larvae are ground into flour and weighed to determine their dry weight.

2.6 Flour Yield (AOAC, 2016)

Flour yield is calculated by comparing the dry weight to the wet weight of the larvae before drying using the formula:

$$\text{Rendement (\%)} = \frac{(\text{Dry Weight (gr)})}{(\text{Wet Weight (gr)})} \times 100 \%$$

RESULT AND DISCUSSION

3.1 Black Soldier Fly Cultivation

The cultivation of *Hermetia illucens (Black Soldier Fly/BSF)* larvae is a rapidly developing organic waste bioconversion technology that supports sustainable fisheries systems. The *Black Soldier Fly (BSF)* cultivation substrate is shown in Figure 1.

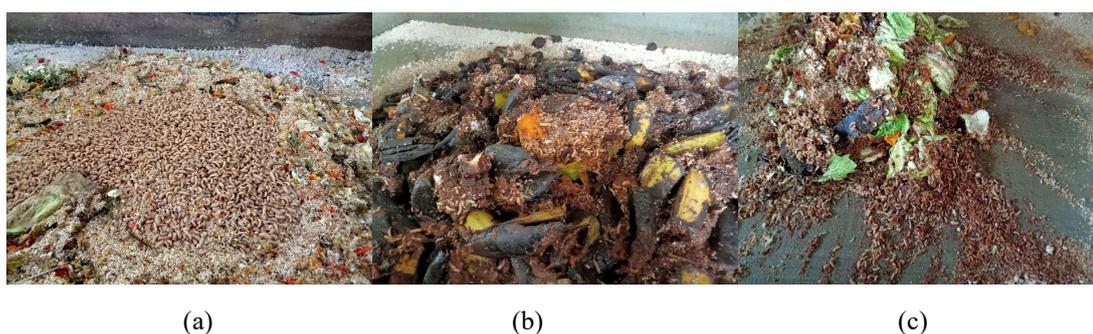


Figure 1. *Black Soldier Fly (BSF)* Cultivation Substrate: (a) Household Waste; (b) Fruit Waste; (c) Vegetable Waste

In general, previous research has shown that the success of *Black Soldier Fly (BSF)* cultivation is greatly influenced by substrate quality, larval density, and environmental conditions such as temperature and humidity. [8] explained that the efficiency of *Black Soldier Fly (BSF)* larvae's bioconversion of organic waste is highly dependent on the macronutrient content of the

substrate, particularly available protein and energy. Meanwhile, [7] emphasized in their study that nutrient balance in the feeding medium plays a crucial role in determining growth rate, survival rate, and body chemical composition of larvae. Compared with these previous studies, this study shows a similar pattern, where substrates with a more complete nutrient composition result in better growth performance. Therefore, these results reinforce previous findings that substrate optimization is key to an efficient *Black Soldier Fly (BSF)* cultivation system.

Technically, *Black Soldier Fly (BSF)* cultivation requires controlled environmental management to ensure optimal growth. The ideal temperature ranges between 27–30°C and relative humidity of 60–70%, as reported by [12], who stated that temperature deviations that are too low or too high can slow metabolism and reduce substrate conversion efficiency. In this study, rearing was carried out at an optimal temperature range so that larval growth lasted optimally until the prepupal phase for 14 days [12]. When compared to the study by [13], a rearing duration of 12–15 days under optimal conditions generally produced maximum biomass before larvae entered the metamorphosis phase. This indicates that harvest timing management is also an important factor in cultivation, as late harvesting can reduce nutrient content due to the use of energy reserves for the phase change process [13].

In addition to environmental factors, feed management and substrate characteristics are key determinants of aquaculture productivity. Research by [14] reported that mixed organic waste substrates provided higher nitrogen conversion and retention efficiency than single substrates, thus directly impacting the increase in larval dry biomass [14]. These findings align with the results of this study, where household waste as a mixed substrate yielded the highest growth performance compared to fruit and vegetable waste. This indicates that in the *Black Soldier Fly (BSF)* cultivation system, a diversity of nutrient sources in the substrate can support optimal protein synthesis. In other words, *Black Soldier Fly (BSF)* cultivation depends not only on feed quantity but also on the quality and balance of its nutritional composition.

In sustainable fisheries, *Black Soldier Fly (BSF)* cultivation has advantages because it can integrate waste management and alternative feed raw material production within a single circular system. [6] stated that utilizing insect protein as a partial substitute for fishmeal can reduce pressure on global capture fisheries resources. In line with the findings of [10], who confirmed that the *Black Soldier Fly (BSF)*-based production system contributes to emission reductions and increased resource efficiency. Compared to conventional approaches relying on fishmeal, *Black Soldier Fly (BSF)* cultivation offers a more environmentally friendly, locally adaptable, and economically viable production model. Therefore, the results of this study are not only technically relevant in increasing biomass and yield but also have strategic implications in supporting the transformation of feed systems towards more sustainable fisheries.

3.2 Wet Weight

The wet weight results of *Black Soldier Fly (BSF)* larvae can be seen in Figure 2.

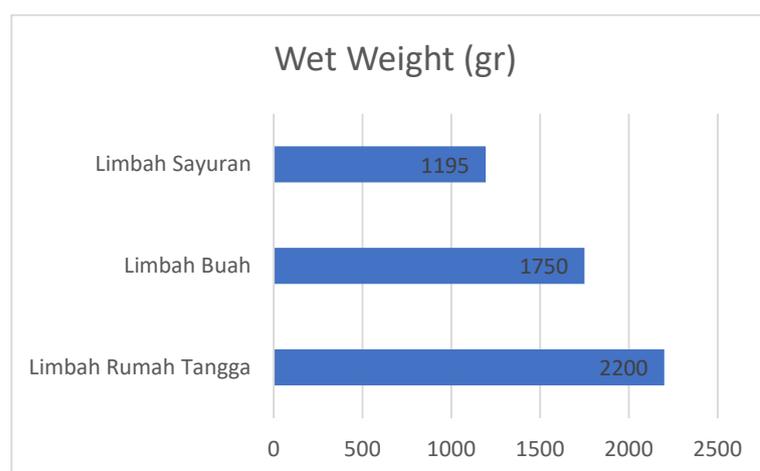


Figure 2. Wet Weight of *Black Soldier Fly (BSF)* Larvae

Figure 2 shows that the household waste substrate treatment produced the highest wet weight of larvae at 2200 grams, followed by fruit waste at 1750 grams and vegetable waste at 1195 grams. This difference indicates that substrate type significantly influences the growth and biomass of *Black Soldier Fly (BSF)* larvae. Household waste generally has a more complex and diverse composition, containing a mixture of carbohydrates, proteins, and fats from leftover rice, side dishes, and other organic materials. Research by [7] revealed that a more complete nutrient content supports optimal larval growth rates and increases biomass accumulation. Furthermore, the balanced C/N (carbon/nitrogen) ratio in mixed waste is usually more ideal for larval metabolism. [8] found that mixed food waste (household food waste) produces higher biomass and substrate reduction efficiency than single wastes such as vegetables alone. Energy and protein content are the main factors in increasing larval production. Thus, this study aligns with these findings, where household waste, which has a more complete nutritional composition, produces the highest larvae yield compared to fruit and vegetable waste.

Conversely, fruit waste tends to have a high water and simple sugar content but relatively low protein. While the sugar content provides energy for larvae, a lack of protein can limit tissue synthesis, resulting in lower biomass production compared to nutrient-rich waste. This aligns with the findings of [15] who found that fruit waste substrates generally support high larval survival rates (often exceeding 85%), but larval weight and developmental rates can differ from nutrient-rich substrates due to variations in protein and carbohydrate content [15].

Vegetable waste produced the lowest wet weight, at 1195 grams. This is due to its higher crude fiber content (cellulose and lignin), making it more difficult for larvae to digest. Furthermore, vegetables generally contain lower protein than mixed household waste. This study is consistent with the findings of [16], who reported that substrates with high fiber content, such as vegetable waste, produce lower growth than nutrient-rich mixed waste [16]. High crude fiber content reduces larval digestive efficiency. So it can be concluded that substrates with more balanced nutritional content and higher protein tend to produce greater biomass production of *Black Soldier Fly (BSF)* larvae.

3.3 Dry Weight

The results of the dry weight of *Black Soldier Fly (BSF)* larvae can be seen in Figure 3.

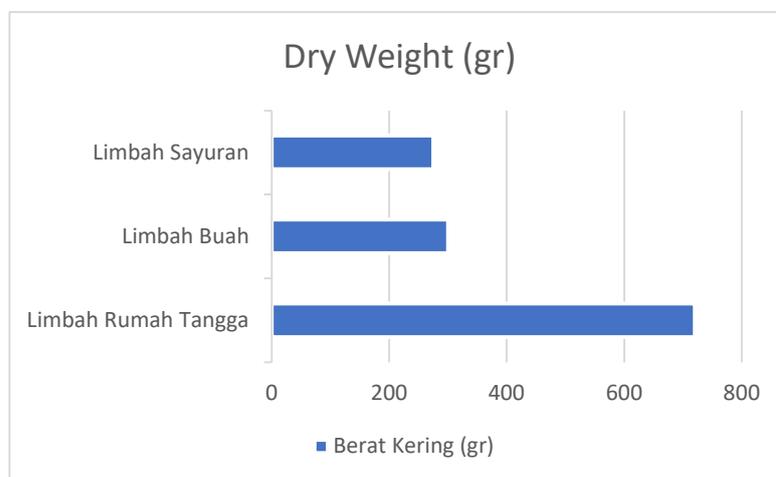


Figure 3. Dry Weight of *Black Soldier Fly (BSF)* Larvae

According to Figure 3, the dry weight of *Black Soldier Fly (BSF)* larval meal shows significant differences between treatments. Household waste produced the highest dry weight at 720 g, followed by fruit waste at 300 g, and vegetable waste at 275 g. This difference indicates that the type of substrate used during larval rearing significantly influences dry matter accumulation after the drying and flouring processes. Dry weight reflects the content of solid nutrients such as protein, fat, and minerals stored in the larvae's bodies. Therefore, the higher the dry weight, the greater the potential nutritional and economic value as a feed ingredient.

The higher dry weight in the household waste treatment is likely due to its more diverse and balanced nutritional composition. Household waste generally consists of a mixture of leftover rice, side dishes, vegetables, and other organic materials containing protein, carbohydrates, and fat in relatively complete proportions. Adequate protein content will increase larval tissue synthesis, while fat and carbohydrates serve as energy sources for growth. The balance of the carbon and nitrogen (C/N) ratio in mixed substrates also supports the efficiency of larval metabolism, so that the conversion of organic matter into dry biomass is more optimal than with single substrates. The results of this study are consistent with the findings of [14] who compared mixed organic waste substrates (kitchen waste) with larval production. The results showed that mixed kitchen waste substrates provided the highest dry weight of *Black Soldier Fly (BSF)* larvae compared to single vegetable or fruit-based substrates. [14] emphasized that variations in substrate composition affect nitrogen retention in the larval body, which contributes directly to the increase in dry weight of flour.

In contrast, the dry weight of fruit waste (300 g) and vegetable waste (275 g) was relatively lower. Fruit waste generally has a high water and simple sugar content, so although it can provide quick energy, its protein content is relatively low to support optimal tissue formation. This is in line with the findings of [13], who evaluated fruit waste as a substrate for *Black Soldier Fly (BSF)* larvae. The results showed that although fruit waste can support larval growth, the resulting dry weight is relatively lower than that of mixed substrates (kitchen waste) due to its limited protein content. Numerically, the dry weight of fruit waste ranged from 280–350 g. These results are in the same range as the present study, indicating that fruit waste provides moderate flour productivity for *Black Soldier Fly (BSF)* larvae, but not as optimal as more nutrient-rich substrates such as household waste.

Meanwhile, vegetable waste tends to have a higher crude fiber content and lower protein content. Difficult-to-digest fiber can reduce the efficiency of digestion and nutrient absorption by larvae, resulting in lower dry matter accumulation. [14] reported that vegetable waste substrates produced lower dry matter or dry weight of larvae than mixed waste, due to coarse fiber inhibiting nutrient digestion efficiency. The figures reported by these findings indicate that the dry weight of larvae in vegetable waste ranged from 250–320 g. This finding suggests that vegetable waste tends to produce the lowest yield of *Black Soldier Fly (BSF)* larval meal due to limited nutrients and high levels of indigestible fiber.

The results of this study demonstrate that substrates with more complete and balanced nutritional content produce higher dry weight of larval meal. This research reinforces the concept that *Black Soldier Fly (BSF)* larval meal production is strongly influenced by feed quality during the growth phase. From an application perspective, the use of household waste as a substrate has the potential to be more effective in producing high-value larval meal for livestock or fish feed. Therefore, optimizing substrate composition is a crucial factor in sustainably increasing production efficiency and the quality of *Black Soldier Fly (BSF)* larval meal.

3.4 Yield

The yield of *Black Soldier Fly (BSF)* larval meal can be seen in Figure 4.

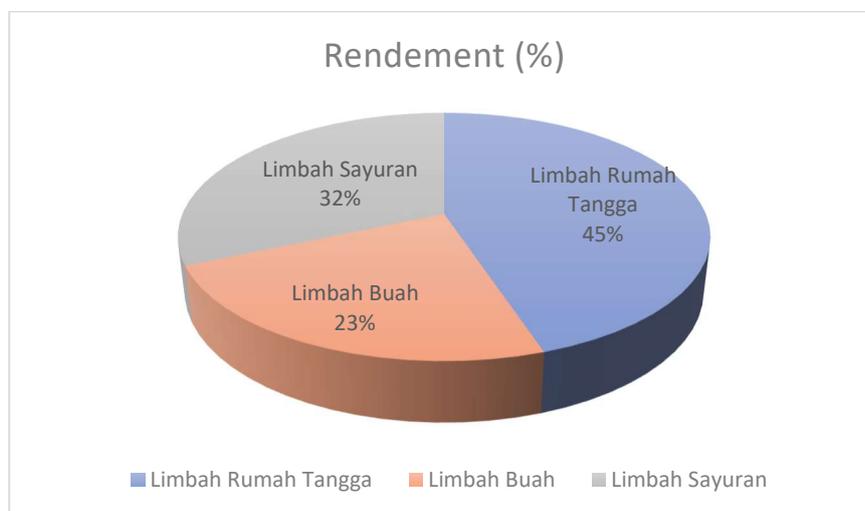


Figure 4. Black Soldier Fly (BSF) Larvae Meal Yield

According to Figure 4, the yield of *Hermetia illucens* larval meal shows quite clear variation between substrate treatments. Household waste produced the highest yield at 32.73%, followed by vegetable waste at 23.01%, and fruit waste at 17.14%. This yield indicates the percentage conversion of fresh larval biomass into dry meal after the drying and milling process. The higher the yield, the greater the efficiency of larval meal production from the initial biomass. This difference confirms that substrate quality and composition significantly determine dry matter accumulation in *Black Soldier Fly (BSF)* larvae.

The high yield of household waste (32.73%) indicates that this substrate is capable of producing biomass with a higher solid matter content (protein and fat). Household waste generally contains a mixture of food waste rich in protein and energy, thus supporting optimal larval tissue synthesis. A more complete nutrient content allows larvae to convert substrate into biomass with greater efficiency. These results align with research by [8], which reported that mixed food waste yielded higher conversion efficiency and larval dry matter yield than single substrates. Furthermore, research by [12] also found that substrates with a good protein-energy balance significantly increased larval meal yield.

The yield of vegetable waste, at 23.01%, is in the middle range. Although its dry weight is lower than that of household waste, the yield of vegetable waste is relatively higher than that of fruit waste. This is likely due to the structure of vegetable tissue, which, despite its fibrous nature, still provides solid components that can be converted into larval biomass. Research by [13] showed that vegetable waste produces moderate dry matter yields because its fiber content limits digestion efficiency, but it still produces stable biomass. A recent study by [17] also confirmed that plant substrates with a balanced nutrient composition can still produce fairly good dry matter conversion results, although not as high as mixed waste [17].

Meanwhile, the lowest yield of fruit waste (17.14%) indicates that the high water and simple sugar content in fruit is not fully converted into dry biomass. Energy from sugars is used more for metabolism than for the formation of solid body tissue, resulting in relatively lower protein and fat accumulation. Research by [7] explains that low-protein substrates tend to produce lower dry matter content for larvae. Overall, these results are consistent with previous studies that suggest that substrates with a more complete nutritional composition and a balanced C/N ratio produce higher yields of *Black Soldier Fly (BSF)* larval meal, making household waste the most potential substrate for efficient and sustainable larval meal production.

CONCLUSION

Based on the research results, it can be concluded that different substrate types significantly influence the biomass and meal yield of *Black Soldier Fly (Hermetia illucens)* larvae. Household waste performed best, with a wet weight of 2200 g, a dry weight of 720 g, and a yield of 32.73%, compared to fruit and vegetable waste. The high yields of household waste indicate that a more complete and balanced nutrient composition can increase the efficiency of converting organic matter into biomass and dry matter for larvae. Fruit waste produced relatively high biomass but the lowest yield due to its highwater content and relatively low protein content, while vegetable waste produced the lowest biomass due to its high crude fiber content, which limits larval digestion efficiency. Optimizing substrate quality is a key factor in increasing the productivity of *Black Soldier Fly* meal as an alternative protein source that has the potential to reduce dependence on fishmeal and support a more sustainable fisheries system.

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